CONCEPTUAL APPROACH FOR THE DETERMINATION OF POINT SOURCES IN MELEN WATERSHED

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ABSTRACT

Many settlement areas, fertilized agricultural lands, industrial plants and solid waste dumping areas are present in Melen Watershed, causing substantial pollution problems. The aim of the *Integrated Protection and Water Management in Melen Watershed Project* is to control the pollution of Melen Watershed with an integrated approach using Master Planning and Feasibility Study. In this respect, Integrated Protection and Water Management project is of vital importance since it will protect one of the main drinking water resources of İstanbul. The project will be conducted in parallel to the construction of planned water works. This paper present a part of a comprehensive survey conducted for the determination of point sources in Melen Watershed, based on the reports of İTÜ Wastewater Management Group, working on the Integrated Protection and Water Management in Melen Watershed Project.

Keywords: Point source, Melen Watershed, Wastewater, Industrial, Domestic

1. INTRODUCTION

Melen Watershed should be regarded as a "*sensitive area*" in accordance with the European Union (EU) Urban Wastewater Treatment Directive, since Büyük Melen River will be used as a potable water source in the near future. To protect the watershed, the Integrated Protection and Water Management in Melen Watershed project has been initiated on behalf of State Hydraulic Works (DSİ) under the joint venture of MELEN Engineering and Consultancy Services Group and İstanbul Technical University, Environmental Engineering Department on June 6th, 2006. The project is the sub-component of Great İstanbul Water Supply, 2nd Stage Melen System that aims to fulfill the drinking water requirements of İstanbul after 2010. The project mainly covers the items of water quality protection, rehabilitation-sustainable watershed protection, water and waste management within a master planning program. The construction of Great Istanbul Water Supply, 2nd Stage Melen System project is still going on and 1st Construction Stage of the project is planned to be completed by 2010. After the completion of this project, İstanbul will receive an additional 8.5 m^3/s of water that will meet the drinking water requirement of İstanbul until 2040. State Hydraulic Works (DSİ) organizes the water supply project with the aid of international financial institutions.

The data presented in this paper are based on the reports of İTÜ Wastewater Management Group, working on the Integrated Protection and Water Management in Melen Watershed Project [Öztürk *et al*., 2006a; Öztürk *et al*., 2007a]. Although diffuse pollution may be an important factor in total pollutant loads, this paper comprises of point sources of pollution dealt with up to now in this ongoing project.

2. PROJECT AREA

Melen Watershed located at the western part of the Black Sea Region (latitudes 41° 5′ 00″ N to 40° 40′ 00″ N and longitudes 30° 50′ 00″ E to 31° 40′ 00″ E) covers a total area of 2,317 km^2. The location of the planned Melen Reservoir is at the downstream where the Büyük Melen River and the Lahana Stream join prior to discharging to the Black Sea [DSİ, 2005]. The total drainage area of the two flowing water bodies constitutes the total area of the Melen Watershed. Since approximately 80% of Melen Watershed is in the Düzce Province while the rest is distributed among the neighboring provinces of Bolu (7%), Sakarya (12%) and Zonguldak (0.3%), the study will concern not only Düzce Province but also the other areas of the Melen Watershed that belong to the neighboring provinces. The districts of Düzce Province are Düzce Provincial Center, Akçakoca, Cumayeri, Çilimli, Gölyaka, Gümüşova, Kaynaşlı and Yığılca. The subdistricts in Düzce Province are Beyköy, Boğaziçi and Konu-

ralp. The only subdistrict in Sakarya Province is Ortaköy. There are 235 villages that are in Düzce Province and 40 villages that reside in Sakarya Province.

3. POPULATION

Total population in Düzce Province is 285,068 according to the results of the 2000 census [http://www.yerelnet.org.tr/). The population distribution between urban and rural areas corresponds to 105,072 (37%) and 179996 (63%), respectively. The population that reside in Melen Watershed but outside of Düzce Province comprise approximately 5% of the population in Düzce Province, although these areas correspond to approximately 20% of the Melen Watershed. Since there is no settlement in the parts of Bolu and Zonguldak that belong to Melen Watershed, only the population in Sakarya is taken into consideration as rural population. There is one subdistrict (Ortaköy) and a total of 40 villages under two districts, namely Kocaali and Hendek in Melen Watershed. The total village population in Düzce Province decreases except in villages affiliated with Düzce Provincial Center.

Population projections for Melen Watershed is based on the method of the United Nations [UN, 2006], which suggests a decrease in rural and an increase in urban population (Table 1).

Table 1. Population projections for Melen Watershed

Districts and subdistricts	Census		Projection	
	2000		2006	
	Urban	Rural	Urban	Rural
Düzce Province				
Provincial Center	56,649	103,041	90,917	75,412
Cumayeri	7,434	5,914	8,454	5,877
Çilimli	7,147	9,702	8,128	9,641
Gölyaka	8,572	11,040	9,748	10,970
Gümüşova	12,103	5,940	13,764	5,903
Kaynaşlı	9,439	12,200	10,734	12,123
Yığılca	3,728	17,462	4,240	17,352
Konuralp	8,499	-	8,445	-
Beyköy	3,239	-	3,219	-
Boğazici	2,959	-	2,940	-
Total	***119,769***	***165,299***	***160,589***	***137,278***
Sakarya Province				
Ortaköy	-	2,073	-	2,060
Villages	-	15,340	-	15,243

4. WASTEWATER GENERATION

4.1. INDUSTRIAL WASTEWATER GENERATION

There are approximately 250 individual industries registered to the Chamber of Commerce and Industry, Düzce Branch in different sizes in 2005 [DPDMoEF, 2004b]. The industries are mainly located nearby the Düzce Provincial Center. The locations of the all industries are illustrated in Figure 1[DPDMoEF, 2004b].

Industrial and domestic wastewater flowrates originating from Düzce 1st OID and individual industries in Melen Watershed are obtained through the following tools:

- Questionnaires
- On-site surveys
- Comparative evaluation with the literature data

Several facilities were selected to represent the size of the facilities and the spectrum of the sectors present in Melen Watershed and a questionnaire was sent to these facilities. Reported data in the questionnaires were assumed to be correct except in cases where a large deviation from the literature data was found in the reported flowrates or where the amount of abstracted water and the wastewater produced were too different. In case of inconsistency, larger figures were used for the calculation of the flowrate to err on the cautious site. For facilities which reported their annual production, flowrates were calculated using the flowrate per unit production, provided that it was available from the literature. When there was no data about the production capacity or the production data was not in a form which could be used in flowrate calculations, then one of the two following approaches was used.

- If the industry generates process wastewater according to the literature survey, then the wastewater flowrate of the facility in question was estimated using the wastewater flowrate of a facility which was similar in production and size.

- When the sector or the specific subcategory does not generate any process wastewater according to the literature survey, the industrial process water flowrate was assumed to be zero.

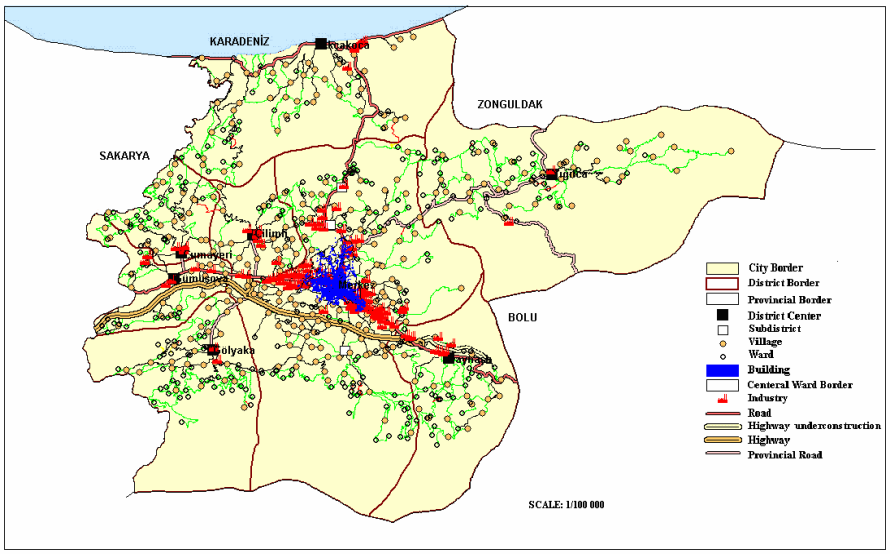


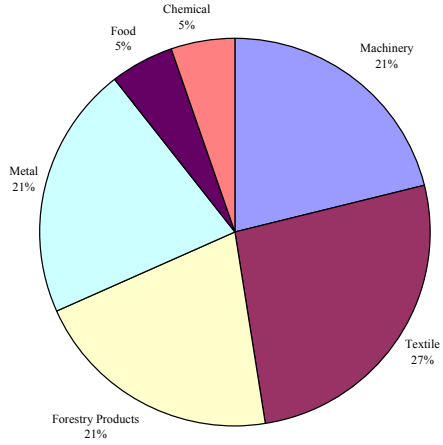
Figure 1. Locations of the industries in Düzce Province

Domestic wastewater produced at the facilities is calculated using a unit flowrate of 50 L/ca.day [Kerestecioğlu *et al.*, 2004] and the total wastewater flowrate generated by the industrial facilities is calculated by the sum of industrial process wastewater and domestic wastewater.

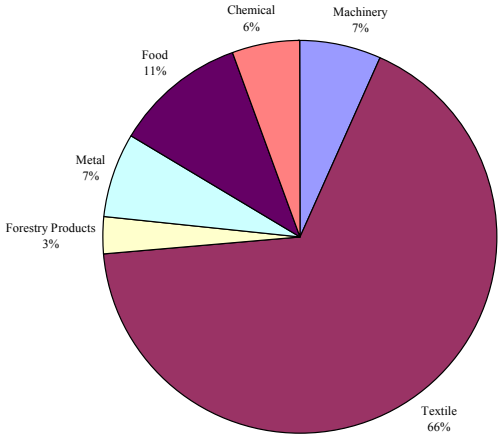
4.1.1. Organized Industrial Districts (OIDs)

There are 2 OIDs in Melen Watershed. Düzce 1st OID located in Beyköy Subdistrict in Düzce Provincial Center. The capacity of the 1st OID is 48 industrial facilities and 8230 persons are expected to be employed in these industries. The second OID was planned to be established on a 150 ha area and it has not been occupied yet. The industrial facilities in Düzce 1st OID can be divided into 6 main categories, with a total number of 24 facilities. The majority of the industrial facilities (27 %) belong to textile industry, followed by machinery, metal and forestry products categories (21 % each, Figure 2a).

Textile industry accounts for 66 % of the total wastewater flowrate in Düzce 1st OID, followed by the food industry (11%). The other four categories each account for less than 10% of the total wastewater flow (Figure 2b)



(a) Industrial categories



(b) Wastewater flowrates

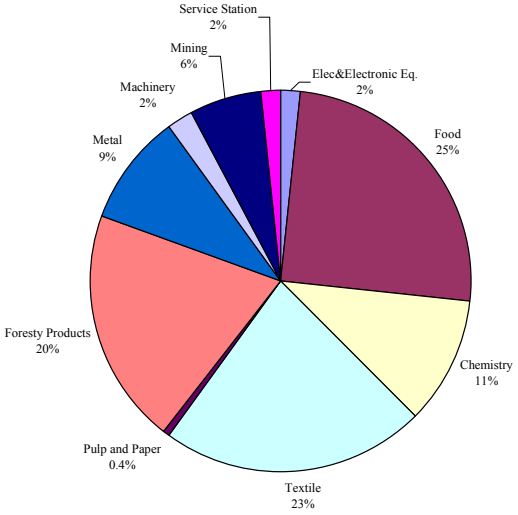
Figure 2. Distribution of industrial categories and wastewater flowrates in Düzce 1st OID

Among the industrial facilities located in Düzce 1st OID, facilities that belong to three categories, namely, machinery, forestry products and metal generate relatively less process wastewater and their total wastewater flowrate is dominated by domestic wastewater. On the other hand, the textile, food and chemicals industries generate more process wastewater than domestic wastewater.

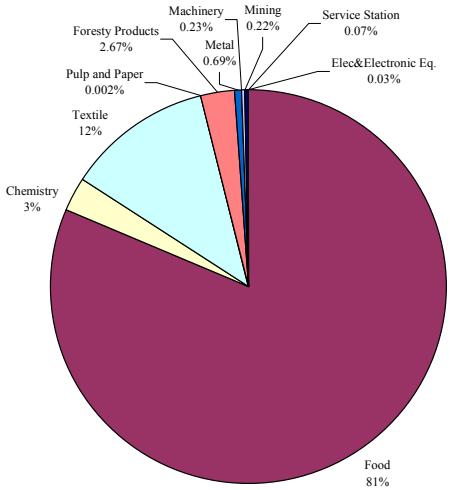
The production types of the industries established in the Düzce 1st OID is quite similar to industries in Tokat OID. Therefore, the unit flowrate of the Düzce 1st OID is estimated to be equal to the unit flowrate of Tokat OID, 13.8 m^3/day.ha, resulting in a wastewater flowrate of 1380 m^3/day.

4.1.2. Individual Industrial Facilities

Individual facilities located in Melen Watershed can be divided into 10 categories, with a total number of approximately 245 facilities. The majority of the individual facilities (25%) belong to food industry, followed by textile and forestry products industries (23 and 20%) respectively,



(a) Industrial categories



(b) Wastewater flowrates

Figure 3. Distribution of individual industrial facilities and wastewater flowrates in Melen Watershed

Food industry sector also has the highest total wastewater flowrate among the industries, accounting for almost 81% of the total wastewater flowrate (Figure 3b). Wastewater flowrate of the food industry is approximately 8,125 m^3/day and most of this flowrate originates from a yeast production facility. Process wastewater accounts for most of the total industrial wastewater in food, chemistry, textile and forestry products industries, whereas domestic wastewater generated in the other sectors accounts for most of the total industrial wastewater.

4.2. DOMESTIC WASTEWATER GENERATION

Daily domestic wastewater flowrates are calculated using the daily per capita water consumptions calculated for different districts. The fraction of water consumption that is used for garden irrigation is assumed not to reach the sewer system and hence not to contribute to the amount of domestic wastewater. Therefore, a conversion factor of 80% is assumed between domestic water consumption and wastewater generation. The calculated wastewater flowrates for Düzce Province are given in Table 2. Total domestic wastewater flowrate in Düzce Province is 16,681 m^3/day; the provincial center accounts for 57% of the domestic wastewater generation.

Table 2. Wastewater generation in districts and subdistricts in 2006

Districts and subdistricts	Wastewater generation (m^3/day)
Provincial Center	17,078*
Cumayeri	954
Çilimli	650
Gölyaka	780
Gümüşova	1,101
Kaynaşlı	1,391
Yığılca	339
Beyköy	977
Boğaziçi	291
Konuralp	416
Total	23,977

*the wastewater flowrate is based on actual measurements rather than calculated values

4.3. DOMESTIC WASTEWATER IN RURAL AREAS/CESSPOOLS

The mountainous geography of the region leads to detached settlements. Moreover, the difference in altitudes within an even small settlement makes the construction and use of sewer systems difficult. Therefore, domestic wastewater in rural areas is collected in cesspools which allow infiltration of wastewater to the soil. These cesspools act as both physical and biological treatment systems, leading to a decrease in COD, BOD and TSS concentrations up to 90%. Since the pollution load from cesspools is considered to be a diffuse source, they will not be further discussed in this paper.

4.4. INFILTRATION RATE

The calculation of the infiltration flowrates in the Provincial Center were based on the actual measurements conducted by the İTÜ team at the WWTP effluent and the two bypass channels. All sewer systems except for the permanent residences were assumed to have the same ratio of wastewater generation and infiltration, hence infiltration rate calculated for the old sewer system of Provincial Center (31%) was used to calculate the infiltration flowrate for the other districts and subdistricts. For the sewer system that serves the permanent residences, the infiltration flowrate was calculated as the difference between the measured flowrate and the calculated domestic wastewater flowrate generated in the residences (84%). The high infiltration flowrate in this sewer system can be explained by the reported damage in conduits which carry wastewater from the permanent residences to the WWTP and the high water table in the area as well as improper connections within the passages of streams and creeks.

4.5 ROADSIDE REST AREAS

Since Düzce Province is located between two big cities, İstanbul and Ankara, on two main highways (E5 and D-100) there are several roadside rest areas in the Melen Watershed. 12 of these facilities are located in Kaynaşlı district on D-100 highway. The total number of visitor per day is assumed to be between 30,000 and 40,000 people and there are approximately 1500 employees, leading to a total wastewater flowrate of 600 m^3/day. The generated wastewater is assumed to have a strong domestic wastewater characterization.

5. CURRENT SITUATION OF WASTEWATER TREATMENT PLANTS

There is only one domestic wastewater treatment plant in Melen Watershed which is located in Düzce Provincial Center. The wastewater treatment plant is on the west side of Düzce Province, near Küçük Melen River and has a design flowrate of 875 m^3/h [DMTWD, 2006].

The flowrate of the wastewater was measured to be higher than 3,300 m^3/h by Technical Works Department of Düzce in 2005. Since the flowrate is much higher than the design flowrate of the wastewater treatment plant, only 600-800 m^3/h of total collected wastewater is transferred to the WWTP and hence is subjected to treatment. The remainder, approximately 2,600 m^3/h is bypassed and discharged to Küçük Melen River without any treatment [DMTWD, 2006]. The inadequate capacity of the wastewater treatment plant is indicated by the two bypasses from the WWTP to Küçük Melen River. Bypass # 1 consists of raw wastewater that can not be taken to and treated in the WWTP due to the less than enough capacity of the WWTP. The

second bypass (referred to as bypass # 2) consists of wastewater that originates from the permanent residences which is diluted due to the high infiltration rates to the sewer system.

Although COD and BOD parameters have been measured in the influent and effluent of the WWTP between July, 1994 and October, 2006, there are less data between 2000 and 2004 due to the damage of the 1999 earthquakes in Düzce. To represent the recent trends and the exiting situation, the data collected in 2006 are evaluated. The mean influent and effluent COD concentration for the data collected in 2006 are 518 and 58 mg/L, respectively (Figure 4). The BOD to COD ratio of the influent wastewater ranges between 0.49 and 0.66 with a decreasing trend.

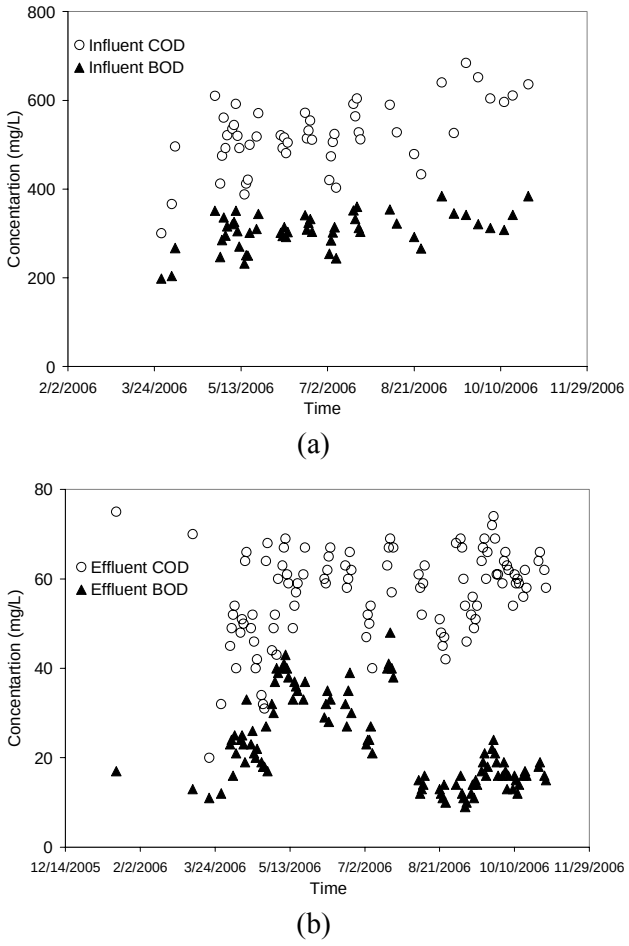


Figure 4. COD and BOD_5 concentrations in the influent (a) and the effluent (b) of WWTP

On two recent trips to Düzce, samples from WWTP were collected by the İTÜ team, which were subsequently analyzed in İTÜ Environmental Engineering Laboratory. Samples from influent, effluent and bypass #1 were collected on November 29, 2006. On December 15, 2006, samples from bypass #2 were also collected in addition to the aforementioned three samples (Table 3) and (Table 4). The samples were collected at approximately 12 pm when the wastewater characterization is thought to be strongest.

Table 3 Results for samples collected on November 29, 2006

PARAMETER	Unit	Results		
		Influent	Effluent	Bypass #1
Total Kjeldahl Nitrogen	mg/L	68	6.3	59
Ammonium Nitrogen	mg/L	41	3.4	34
Total Phosphorus	mg/L	11.7	6.8	6.8
BOD_5	mg/L	500	10	380
COD	mg/L	1085	45	825
pH		6.7	7.4	6.9
TSS	mg/L	455	12	350
VSS	mg/L	395	7	295

The BOD to COD ratio for influent samples collected on both days are 0.46; the ratio in bypass #1 samples were 0.46 and 0.42, for the samples collected on November 29, 2006 and December 15, 2006, respectively. The BOD to COD ratio of the bypass #2 sample collected on December 15, 2006 was 0.32. The COD to TKN ratios for influent samples collected on November 29, 2006 and December 15, 2006, were 16 and 13, respectively. The COD to TP ratios for influent samples collected on November 29, 2006 and December 15, 2006, were 93 and 77, respectively (Table 4).

Table 4. Results for samples collected on December 15, 2006

PARAMETER	Unit	Results			
		Influent	Effluent	Bypass #1	Bypass #2
Total Kjeldahl Nitrogen	mg/L	72	3.4	97	27
Ammonium Nitrogen	mg/L	40	0.8	58	20
Total Phosphorus	mg/L	12.4	5.2	14	4.2
BOD_5	mg/L	443	10	460	50
COD	mg/L	956	43	1083	156
Soluble COD	mg/L	271	-	-	63
pH	-	7	7.35	7.15	7.25
TSS	mg/L	395	15	450	70
VSS	mg/L	355	<10	390	<10
Nitrate	mg/L	0.2	11.5	0.27	0.14
Nitrite	mg/L	-	1.2	-	-
Phosphate	mg/L	6.3	3.6	7.83	3.1

6. WASTEWATER LOADS

6.1. DOMESTIC WASTEWATER LOADS

Domestic loads are calculated using the unit loads and the population and are given in Table 5.

Table 5.Selected values of unit loads for the calculation of domestic pollutant loads in Provincial Center

Parameter	Unit load (g/ca.day)	
	Provincial Center*	Other Districts & subdistricts**
COD	120	90
BOD_5	60	45
TSS	65	55
TKN	11	8
TP	1.8	1.3

*Source: ATV131, 2000, ** Erdoğan, 2004

6.2. INDUSTRIAL WASTEWATER LOADS

The methodologies used and the assumptions made for the calculation of pollutant loads from industrial sources are explained below:

- Industrial pollutant load: Industrial pollutant load was calculated as the sum of the pollutant load from the process wastewater and the domestic wastewater generated by the employees/workers in the facility.
  - For the industries where a unit load per production was reported in the questionnaires or was available in the literature, along with the capacity of the industrial facility, the pollutant load was calculated by multiplying the unit load by the annual production.
  - When the characteristics of the wastewater originating from the industry was available either from the questionnaires submitted by the facilities or the literature, along with the wastewater flowrate, the pollutant load was calculated by multiplying the concentrations with the wastewater flowrate (
  - Table 6).
  - For the industries in which the process wastewater is reported to have similar characteristics to domestic wastewater, the process wastewater was assumed to be of medium or strong domestic wastewater characteristics, [Tchobanoglous *et al.*, 2003] in case no wastewater characteristics or a unit load per production was available.
  - In case the industrial facility does not have a process wastewater, the process wastewater pollutant load is assumed to be zero, and the total

pollutant load is taken to be equal to the domestic wastewater load generated by the workers.

Table 6. Average wastewater characterization for industries

		Concentration (mg/L)					
Sector	Industry	COD	BOD_5	TSS	TKN	TP	Reference
Food	Yeast*	1,000	300	100	200	30	Melen Questionnaires, 2006
Food	Dairy	1,745	1,070	400	75	9.1	Cokgor *et al.*, 1997
Food	Catering **	1,000	400	350	85	15	Tchobanoglous *et al.*,2003
Food	Tobacco	1,180	530	335	0	0	Bejankiwar, 2002
Food	Slaughterhouse	7,230	3,180	910	690	3.3	Del Pozo *et al.*, 2003
Food	Beverage	2,355	1,240	200	7	7.6	Haun and Rosenwinkel, 1997
Tourism	Roadside Rest	1000	400	350	85	15	Tchobanoglous *et al.*,2003
Chemistry	Pharmaceutical	700	500	350	100	0	İnanç *et al.*, 2002
Textile	Fiber	1,300	460	0	35	0	EC, 2003
Textile	Carpet	1900	52	30	25	41	Yildiz, 2005
Forestry Products	Plywood	1,400	400	1,000	250	8.5	Andreottola *et al.*, 2001
Forestry Products	Fiberboard ***	500	220	220	40	8	Tchobanoglous *et al.*,2003
Düzce 1st OID****	-	990	525	130	54	7.9	Orhon *et al*, 2002
Düzce 2nd OID****	-	990	525	130	54	7.9	Orhon *et al*, 2002

*Wastewater treatment plant effluent concentrations reported by the facility

**Concentrations for selected parameters were given with the assumption of a wastewater characterization similar to "strong domestic" wastewater

***Concentrations for selected parameters were given with the assumption of a wastewater characterization similar to "medium strength domestic" wastewater

****Characterization of Düzce 1st OID wastewater is based on the characterization of Çerkezköy OID wastewater characterization.

Total pollutant loads for individual industries are provided in

Table 7. Similar to its dominance in the flowrates, food sector also dominates the total pollutant loads. The COD load of food sector, originating mostly from one single facility, accounts for 81% of the total COD load. The effect of food sector is even higher (95%) for phosphorus load. In addition to the high pollutant load, the location of that particular food sector facility seems to present a problem for the Melen Watershed since it is relatively close to the possible future location of water

extraction, Cumayeri). The current total wastewater generation in Melen Watershed is 56,941 m3/day (

Table 8). Infiltration flowrate is approximately the same as the domestic wastewater flowrate.

Table 7. Pollutant loads originating from individual industrial facilities in Melen Watershed

Category	COD	BOD_5	TSS	TN	TP
	Loads (kg/day)				
Elec&Electronic Eq.	4	2	2	0.4	0.1
Food	8,543	2,801	1,311	1,468	220
Chemistry	176	87	102	18	3
Textile	2,040	252	190	54	37
Pulp and Paper	0.33	0.15	0.20	0.03	0.01
Forestry Products	354	126	229	50	4
Metal	91	42	55	9	1
Machinery	31	14	18	3	0.5
Mining	29	14	18	3	0.5
Service Station	9	4	5	1	0.1
Total	11,278	3,342	1,930	1,607	266

Table 8. Projection of daily wastewater generation from domestic, industrial sources and infiltration

Wastewater Source	Flowrate (m^3/day)	Load (kg/day)				
		COD	BOD_5	TSS	TN	TP
1. Domestic wastewater (including infiltration)	44,783	19,952	9,976	11,257	1,811	296
2. Industrial activities						
2.1. Düzce 1st OID	*1,380*	*1,366*	*725*	*180*	*75*	*11*
2.2. Individual Industrial Facilities	*10,178*	*11,259*	*3,335*	*1,918*	*1,604*	*266*
3. Other Wastewater Sources						

3.1 Roadside Rest Areas	*600*	*600*	*240*	*210*	*51*	*9*
*3.2 Landfill (old&new) Leachate**	*0*					
TOTAL	56,941	33,177	14,276	13,565	3,541	582

* leachate not collected [Source: Öztürk *et al.*, 2006b]

7. CONCLUSIONS

Since Büyük Melen River will be used as a potable water source for İstanbul in the near future, great attention should be paid to the pollution sources in the watershed. Total nitrogen and phosphorus loads from domestic wastewater account for approximately half of the total pollutant loads, with the individual industrial facilities accounting for almost the other half, although the total flowrate of domestic wastewater is more than four times of the total industrial wastewater flowrate. The differences in pollutant loads between domestic and industrial sources are even more pronounced for BOD_5 and TSS parameters, where domestic loads are approximately three and ten times higher than the industrial loads, respectively. The difference in BOD_5 loads is due to the fact that the food industries which account for a high percentage of total industrial wastewater and total industrial load in the watershed, have low BOD_5 to COD ratios.

In addition to the pollution load of individual industries, their locations play an important role in the Integrated Protection and Water Management in Melen Watershed. Therefore, the locations of the industrial facilities, together with their wastewater flowrates and pollutant loads will be evaluated during the selection of treatment and site alternatives in the final feasibility studies of this project.

The pollutant loads from point sources alone are not enough for the evaluation of the pollution in Melen Watershed. The preliminary results for diffuse pollution loads indicate that the point sources account for 35% and 40% of the total nitrogen and phosphorus loads, respectively [Öztürk et al., 2007b]. Although the diffuse sources seem to be more important in the pollution loads, due the problems related to the management and control of diffuse pollution, treatment and hence the control of point sources may provide a better or at least a faster solution to the pollution problem in Melen Watershed.

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