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Optimization and reduction of industrial load in a wastewater basin

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ABSTRACT

In this study, a method for specification and reduction of industrial wastewater load has been determined in a wastewater basin. The operation of industrial pre-treatment plants is not very efficient in the basin and causes operational problems both in sewer and central treatment plants. Also, heavy metals from anthropogenic activities are among the most widespread pollutants. However, there is a few research for the heavy metals reaching the treatment plants from the urban sewer. In the study, a comprehensive survey and analysis study was carried out for 20 parameters of the industries with the highest load. These parameters were found to have a burden on the municipal wastewater treatment plant at rates ranging from 85% to 99%. By the proposed load reduction method, approximately 99% of the industrial wastewater could be treated and discharged at the legislation limits in the study basin. The reduction in the pollutant load was also examined in detail by two parameters and it was calculated that the organic load will be decreased to 6,331 kgCOD/d (chemical oxygen demand) as 85% and, Zn to 6.8 kg/d with a 94% decrease. The findings of the study clearly indicated that the removal of a higher amount of pollutants is achieved with the use of fewer industrial wastewater pre-treatment plants and the protection of the environment is ensured.

Keywords: Basin; Characterization; Industrial; Optimization; Pollutant; Wastewater

1. Introduction

The use of water and the generation of wastewater production has increased after industrial development. Collection and treating industrial wastewater are necessary to protect public health and prevent pollution of water resources [1,2]. Industrial wastewater is highly polluted and should be treated before released into the environment [3,4]. The content of industrial wastewater differs according to the product type, amount of water used and other factors [5–8].

Heavy metals from anthropogenic activities are among the most widespread pollutants. However, there are a few research for the heavy metals reaching the treatment plants from urban sewer and/or watersheds [9]. In a study conducted in the Seine River (Paris), 7.9 kg/d Cu and 13 kg/d Ni could be discharged into the river even after the wastewater treatment plant and around half this load is in the labile metal form [10]. For that reason, metal fluxes of the river increased, especially during low-flow periods. Similarly, the distribution of heavy metals in the wastewater treatment effluent and sludge was studied in Thessaloniki city and found that more than half of Cd, Cr, Pb, Fe, Ni and Zn metals are kept in the treated effluent [11].

Istanbul, with its 14 million inhabitants as Turkey's most populous city, corresponds to approximately 18% of the country's population and are also contained about 31% of the country's industry. Rapid, uncontrolled and illegal urbanization in the last decades accompanied by insufficient infrastructure has caused a chaotic city type including many industries within the city. It is also the most intensive city

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in the country in terms of industry. Production processes of 6,321 industries operating in Istanbul are the main source of industrial wastewater [12]. Dense population and economic activities in a limited area and chaotic urbanization cause increasing pressure on the natural resources of the city.

In the city, the main urban wastewater consisting of domestic and industrial wastewater and also rainwater is collected by the sewerage system. However, in the areas where the infrastructure system is not available or inadequate, the receiving water media is used to discharge (lakes, streams, etc.). Moreover, in Istanbul, 86% of the industrial wastewater-producing industries are scattered in the city but not inside an organized industrial zone (OIZ). For example, only 107 industries were in the OIZ of the studied basin. In addition to large-scale industrial plants, the number of small-scale plants is quite abundant in the city. Based on the amount of wastewater originating, the daily wastewater of 643 facilities is below 5 m^3. This figure corresponds to 77% of the total industrial installations [12,13].

In the industries that built a treatment plant according to the current legislation in Istanbul, monitoring of treatment efficiency is not easy if generated daily wastewater flow is very low or the discharges are not given hourly but over a long period of time. Moreover, the operation of these plants is not very efficient. Then, these types of industrial discharges and wastewater content cause operational problems both in the sewerage line and in the central municipal treatment plants. Furthermore, there is a risk that these pollutants will migrate to the receiving medium if there is no collector system in the location of the factory or if there are floods in infrastructure systems in rainy weather. For this reason, effective and feasible methods to ensure full control of industrial wastewater pollution are needed to be investigated. The established wastewater pre-treatment plants (WTPs) can be controlled by only periodic inspections but not frequently. In that case, while the WTPs can be observed by a momentary status at the time of inspection, the operation remains out of control at other times and is not controlled by water administration.

In the existing wastewater management model, it is inevitable that the burden of industrial pollution on the central municipal treatment plants and the receiving environment is inevitable because of the exemptions from WTP installation and insufficient control of the operation of the established WTPs. It has also been found that WTPs installed for very low wastewater sources have no operational practice and it is difficult to control the unintentional and/or illegal discharge of these wastewaters. Because of all these reasons, there is a need to develop a wastewater control method that will ensure that the majority of industrial wastewater sources, which are scattered in the area, should be controlled. In order to meet this need, in this study, an industrial load reduction method (LRM) has been used to ensure reducing the loads by local detection of industrial pollutant sources in the Ambarli Wastewater Catchment Basin (AWCB) in Istanbul. This basin is one of the biggest and most important industrial areas in the city.

Effective and feasible methods to ensure full control of industrial wastewater pollution are needed to be investigated. Especially, heavy metals from anthropogenic activities are among the most widespread pollutants. However, there are only a few research for those pollutants reaching the treatment plants from the urban sewer. In this study, the amount of the industrial pollutant load that may affect the central wastewater treatment plant is calculated to lower the targeted pollutant loads in the basin in 2016. Thus; energy, time and economic savings can be achieved by controlling the sewer system with a lower number of industrial wastewater treatment plants and also lower the pollutant load (organic and metals) in the basin area. Moreover, operating fewer industrial treatment plants by planning a waste LRM is another useful output.

2. Materials and methods

2.1. Study area and the existing industries

This research was conducted in the AWCB, with an area of approximately 438 km^2, which covered Beylikduzu, Esenyurt and Arnavutkoy districts and a major part of the Avcilar and Basaksehir districts. Sazlidere Dam, as the aquatic area which provides drinking water, and a major part of the catchment basin of the Kucukcekmece Lake and a part of the Alibeykoy catchment basin is also within the boundaries of the AWCB basin. Fig. 1 gives the location of the Basin.

The AWCB is a sensitive basin because of the intensity of industrial facilities and the water catchment basins it covers. In the study, it was determined that there are 832 facilities releasing industrial wastewater and a total of 6,967 m^3 wastewater is released daily [12,13]. In the AWCB, there are various production sectors, mainly the industries that produce metal, textile and food stand out both with respect to the number of facilities and various amount of wastewater released. Three power plants and eight petroleum products storage facilities were among the other important facilities in the basin. Some industrial facilities (258 of them) are at the same time in the water catchment basin. In the study basin, there is one OIZ, including 107 industries; but other industries were scattered in the area. There are 2 treatment plants in the OIZ and the untreated process wastewater or pre-treatment output from some industries and domestic wastewater are treated here. For the 725 industries outside the OIZ, a treatment plant, required as in the legislation, must be installed and these plants must be periodically controlled. The existing state of the industries in the basin is given in Table 1. In the AWCB, there is Ambarli Advanced Biological Wastewater Treatment Plant (ABWTP), which is designed according to the average wastewater flow rate of 400,000 m^3/d. According to the data from the Istanbul Water and Sewerage Administration (ISKI) (abbreviated as ISKI in Turkish), the amount of urban wastewater treated in the plant was 201,905 m^3 in 2015 [12]. In Istanbul, the total industrial wastewater amount and daily treated municipal wastewater (biological and pre-treatment systems) in 2015 were 55,898 and 3,170,432 m^3, respectively [12].

The industries in the coastal region of the basin and the industries in the Arnavutkoy district, except for the animal husbandry establishments, are connected to the sewage line. Accordingly, of the 832 industries in the basin, 766 is subject to the Sewage Usage and Discharge Regulation, in Turkish and the rest is subject to the Water Pollution Control Regulation, in Turkish.



Fig. 1. Location of the Ambarli Wastewater Catchment Basin.

2.2. Classification of wastewater

In the study, some facilities, such as hotels, hospitals, schools, restaurants, were excluded and the data were produced by investigating the processes and wastewater from industrial facilities. Each industrial facility identified was coded by letters and numbers (e.g., T_1, T_2, …, T_n). In order to determine the pollutant load of the basin, pollution properties and loads of each industrial facility were identified. All data including wastewater analysis and waste load values from industries entered into a Microsoft-Excel file and used for calculation. Although the industrial classification approach firstly based on pollution characteristics [14], new industrial categories were established since the industrial variation in the AWCB is high. With this aim, the number of sub-categories was increased and made more specific. During categorization, it was determined that some facilities did not belong to a single category/sub-category with respect to their activities but belong to more than one category/sub-category. The categorization of such facilities was based on the main production activity. As the main part of the study, an industrial waste LRM was adopted in the categories considered as important pollutants based on the characteristics.

The wastewaters of the industries in the study basin were monitored in a total of 20 pollutant parameters, considering the conventional parameters as chemical oxygen demand (COD), oil and grease, total suspended solids (TSS), phenol, total-N, total-P, total-S, Cu, total-Cr, Zn, Ni, Pb, As, Cd, Ag, Sn, Hg, F, total-CN and detergent. Averages of wastewater characterization values were determined for each parameter using local analysis data and partially from literature data [13].

2.3. Determination of the categories and LRM

In determining the category and LRM, the data from wastewater samples from the industries in the study basin and in general in Istanbul, the average pollutant concentration values of the categories were produced using the data from characterization sample analyses of at least 3, but in general 6–10 samples [13].

Table 1
Existing wastewater treatment situation of industrial plants

Industrial groups	Industry	Number of existing WTP	Non-WTP	Treated wastewater quantity (m^3/d)	Non-treated wastewater (m^3/d)
Metal	187	116	71	1,016	66
Chemistry and related	144	50	94	379	83
Paper and related	23	8	15	17	4
Textile	142	99	43	3,154	278
Leather	1	1	–	–	–
Oil and related	134	18	116	296	101
Solid waste	1	–	1	–	3
Mineral	71	8	63	27	201
Food and related	129	21	108	1,145	198
Total	832	321	511	6,034	934

As the first stage of method determination for load reduction, which is the essential part of the study, principal polluting sources were identified and the following approaches were considered in the LRM (i) all industrial plants with wastewater flow greater than 5 m^3/d must establish (pre-) treatment plants according to the regulation of ISKI. For that reason, the study was based on this regulation. In the facilities with a wastewater flow of less than 5 m^3/d, the treatment plant was determined on the basis of the pollution load. In these cases, principal wastewater sources were identified (those containing significant pollutants and/or high pollutant load). Generally, it was determined with the highest COD (as organic matter load) and/or the highest heavy metal parameter. Industrial facilities with less than 5 m^3/d correspond to 77% of the total installations in the city and 641 of the 832 industries in the AWCB, (ii) wastewater categories containing heavy metal, CN and phenol parameters and/or high acidity and alkalinity were also considered principal pollutant sources, (iii) COD parameter load was applied in two ways: Food production categories, car overwashing and carpet washing plants with a load of more than 1.5 kg of COD/d are considered as significant sources. Outside of these categories and, other product categories with the potential of toxic or resistant organic matter, the industries with a COD load of more than 0.1 kg/d are considered to be principal sources and wastewater is transported to a planned common treatment plant, (iv) plastic processing industry wastewaters have been considered important pollutants. The reason for this is assumed that these plants create a significant amount of pollution as a result of the use of water in cycles, (v) the wastewater of the facilities with low wastewater volume will be transported to a common treatment plant, (vi) treatment plants of high wastewater flow industries will also be monitored by remote sensing system, (vii) no wastewater management is envisaged for categories providing discharge limits regardless of the amount of wastewater, (viii) wastewater of animal feeding areas is planned to be transported and treated in a separate common treatment plant in the nearest area, (ix) marble, soil products and concrete production industries are not principal because they do not use wastewater treatment but have recycled system.

After analysis of all industrial wastewater, all pollution load of industries was calculated and compared by Microsoft-Excel tables and LRM was applied for Ambarli Basin.

3. Results and discussion

In the study, the wastewater that is used in pollutant load calculations were identified as process wastewater and other sources than processes (i.e., equipment maintenance and emission wastewater). The daily average of the total industrial wastewater generated in the AWCB was calculated as 6,967 m^3, and it was determined that the 6,674 m^3/d of this amount came from 766 facilities that had an effect on ABWTP and the 293 m^3/d came from 66 facilities affecting the receiving medium (river, lake, etc).

In the categorization study, the industries in the AWCB were firstly divided into 43 categories. Then, most of them were divided into sub-categories, and finally, 75 sub-categories were established. It can be seen that the petroleum products category ranked the first with 131 facilities, the finishing process of woven fabrics ranked the second with 121 facilities and the finishing processes of the metals industry ranked the third with 111 facilities. On the basis of wastewater amount, the highest was in the woven fabrics finishing processes with 3,038 m^3/d, the second was the confectionery industry category with 941 m^3/d and the third was the metal finishing processes with 586 m^3/d wastewater.

It was observed that pollutant parameters COD, TSS, oil and grease, tot-N, Zn and Cu of industrial wastewater in the AWCB were the important parameters that had higher concentrations than the other parameters. It is also found that the newly formed categories are different from the literature values because of the reasons arising from mixed regional production processes. As an example of this, the differences determined in the textile industry are given in Tables 2 and 3.

The LRM was used as (i) building a common wastewater treatment facility for industries with low flow rate (treatment of all in one plant) and (ii) treatment at the source or monitoring method with a remote sensing system for high flow rate industries. Hence, it is stated that a better system can be established by WTP installation and

Table 2
Textile industry wastewater characterization in Turkey

Category	Parameter-average concentration (mg/L)						
	COD	BOD_5	TSS	Oil and grease	Tot-Cr	Phenol	Sulfur
Wool washing	9,000	3,000	4,000	3,000	–	–	–
Fabricated production	1,200	300	200	–	–	–	–
Mesh fabric finishing	1,000	350	300	53	0.5	0.24	0.2
Stock and yarn finishing	1,200	500	40	–	5		2
Woven fabric finishing	1,200	650	300	14	0.04	0.04	3
Carpet finishing	2,000	700	100	30	0.005	0.001	0.002
Non-woven fabric	3,850	1,230	80	–	–	–	–
Jeans washing	1,000	300	300	–	–	–	–

Table 3
Textile industry characterization in AWCB

Sub-categories	Parameter-average concentration (mg/l)								
	COD	TSS	Oil and grease	Tot-Cr	Phenol	Tot-S	Tot-N	Tot-P	Surfactants
Woven fabric finishing (textile dyeing)	2,790	90	–	0.11	0.9	5	19	15	85
Woven fabric finishing (textile washing)	1,450	300	–	–	–	9	40	15	85
Woven fabric finishing (textile printing)	4,300	2,400	–	–	–	5.5	–	–	–
Non-woven fabric operations	10,150	700	–	–	–	7.9	–	–	–
Stock and yarn finishing	1,200	40	100	5	–	2	–		85
Other textile washing (carpet washing)	1,200	150	25	–	–	0.7	–	15	15
Other textile washing (textile washing)	250	80	–	–	–	0.2	–	–	15

Table 4
Distribution of COD and Zn reduction quantities in load reduction method

Categories	Number of industries	Flow rate (m^3/d)	Flow rate, %	COD (kg/d)	COD-remaining (kg/d)	COD-removal (%)	Zn-existing (kg/d)	Zn-remaining (kg/d)	Zn-removal (%)
Aluminum forming	5	14	0.2	150	12	92			
Metal tinting	22	422	6.1	329	326	1			
Metal finishing	111	586	8.4	6,577	540	92	99	3	97
Other chemicals	10	10	0.1	138	4	97			
Soap and detergent	18	35	0.5	390	29	92			
Paint and ink	13	28	0.4	162	20	87			
Plastic processing	28	69	1.0	255	65	74			
Adhesives and insulating materials	6	26	0.4	598	22	96			
Pharmaceutical	4	248	3.6	378	247	35			
Cosmetics	10	16	0.2	110	15	86			
Printing	46	19	0.3	678	10	98			
Paper	23	20	0.3	1,155	15	99			
Woven fabric finishing	121	3,038	43.6	6,941	3,002	57			
Stock and yarn finishing	9	359	5.2	431	355	18			
Power plants	3	187	2.7	1,113	75	93			
Petroleum products	131	207	3.0	592	165	72			
Animal breeding	58	33	0.5	663	16	98			
Slaughterhouses and meat products	8	125	1.8	481	124	74			
Dairy	4	52	0.8	215	51	76			
Confectionery	25	941	13.5	18,479	939	95			
Food production	20	181	2.6	404	167	59			
Total pollutant load of the 21 categories	675	6,616	95	40,239	6,199	85	99	3	97
Total AWCB pollutant load	832	6,967	100	40,693	6,331	85	105	6.8	94

Table 5
Number of industrial wastewater sources and sectors in Istanbul

		Industrial category								
		Petroleum	Metals	Minerals-not metal	Food	Textile	Chemical	Leather	Other	Total
Facilities with industrial wastewater	Number	2,283	1,239	619	615	863	600	15	87	6,321
	Q (m³/d)	4,826	5,722	9,038	5,656	12,435	2,745	13,354	2,122	55,898
Those with treatment facilities	Number	26	631	38	64	397	172	5	19	1,352
	Q (m³/d)	617	5,455	1,018	4,566	10,705	2,426	13,353	2,071	40,211
In-plant measures	Number	98	81	484	136	11	92	6	17	925
	Q (m³/d)	326	16	7,961	401	40	54	1	4	8,803
Transport of wastewater	Number	8	248	8	1	3	77	2	8	355
	Q (m³/d)	3	90	1	3	1	27	1	3	129
No pre-treatment requirement in the legislation	Number	1,147	218	57	361	428	248	2	41	2,502
	Q (m³/d)	3,827	125	37	582	1,223	222	1	7	6,024
Pre-treatment requirement	Number	4	61	32	53	24	11	0	2	187
	Q (m³/d)	53	34	21	104	467	14	0	0	693

Table 6
Pollutant load reduction method of controlled industries and amount of wastewater

Industrial groups	Number of industries	Removed WTP	Remaining WTP	Newly installed WTP	Total WTP	Total flow (m³/d)	No. of transfer (industries)	Transferred flowrate (m³/d)	AWCB total flow (m³/d)	Total purified wastewater (m³/d)	Number of no-WTP industries	Untreated wastewater (m³/d)
Metal	187	76	40	2	42	965	145	115.8	1,081	1,081	–	–
Chemistry and related	144	37	13	1	14	389	129	70	459.3	459.3	1	0.01
Paper and related	23	6	2	–	2	12.5	21	7.3	19.8	19.8	–	–
Textile	142	25	74	11	85	3,332	51	80.3	3,432	3,413	6	19.3
Leather	1		1		1	7.2			7.2	7.2	–	–
Oil and related	134	11	7	1	8	287	35	47.1	394.4	334.4	91	60
Solid waste	1	–	–	–	–	–	1	3	3	3	–	–
Mineral	71	7	1	(59 recycling system)	1	21	11th	6.2	228	228 (including recycling systems)	–	–
Food and related	129	1	20	5	25	1,261	90	78.2	1,342	1,339.2	14	2.8
Total	832	163	158	20	178	6,276	483	407.9	6,967	6,885	112	82.1

4. Conclusion

In this study, the pollutant loads were calculated by classifying 832 industrial facilities, and a LRM was determined based on the pollutant type and waste load. By this method, the high flow rate of the major pollutant wastewater sources is treated in the WTPs installed in the source while the low-flow wastewater resources are treated by common WTPs.

Reducing the pollutant load, in turn, reduces the pollutant load on the receiving medium, contributing to the effective operation of central treatment plants and protecting the aquatic environment from pollutant discharge. The recommended LRM in the study reduces the number of industries that must be continuously monitored and controlled by approximately 45% and ensures saving time and energy for control.

Finally, some future perspectives and recommendations for sustainable management of wastewater basins and treatment plants could be summarized as follows: (i) mapping the industrial wastewater pollutant loads of all wastewater catchment basins, (ii) revising the industrial wastewater control/discharge legislation considering the pollutant type and load to ensure the control of all important pollutants, (iii) installing remote sensing system for high-volume industrial wastewater to control easily and efficiently, (iv) assessing the transport of the food industry wastewater to some treatment inlets after investigating the nutrient needs, (v) research of the recovery of substances contained in the wastewater considering the industrial categories, (vi) establishment of specialized OIZ should be done as a recommendation to gather the industries in an area.

The study does not include an economic analysis but it is obvious that LRM will be economic from the benefits obtained such as; use of fewer industrial WTPs, less time of inspection by water administration, and also energy, time and economic savings by controlling less industrial facilities.

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