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Evaluation of efficiency analysis of waste water treatment plants and applications in Denizli

Mahmud Güngör[a,*], Sibel Yildiz[b], Engin Demýrcý[b]

[a]*Denizli Municipality, Deputy Mayor, Denizli, Turkey*
Tel. +90 258 2652137; email: mgungor@pau.edu.tr
[b]*Denizli Municipality, Water and Sewerage Department, Central Waste Water Treatment Plant, Denizli, Turkey*

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ABSTRACT

The aim of this study was to identify and analyze operational performance of Denizli waste water treatment plant (DWWTP). This plant treats mostly domestic-industrial waste water received from residential and industrial areas in Denizli. DWWTP has an active sludge unit. At intake and outflow; pH, temperature, conductivity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen and total phosphate are analyzed on a routine basis. Besides, measurements of dissolved ox ygen, suspended solids (SS) and active sludge volume index (SVI) are carried out. At the outflow of the plant, BOD and COD concentration values can change in the intervals of 45–100 mg/l and 5–15 mg/l respectively and these values comply with the limit values stated in water pollution controlling regulations (WPCR). SVI average value is approximately 200 ml/g in the aeration tank. 'Using the output water for irrigation' was planned during the project period, therefore the efficiency analysis must be conducted accurately and in conjuntion with this, the outflow water quality must be controlled regularly.

Keywords: Waste water treatment; Efficiency of treatment plant; Outflow parameters; Irrigation water criteria

1. Introduction

At the present day, establishment and operation of waste water treatment plants to preserve the environment is not sufficient. The pollution parameters belonging to the output water must be below the limit value given by the regulations while running the plant properly. The most common method in the world and Turkey for domestic and industrial waste water treatment is the activated sludge process [1,2]. Activated sludge process was developed in 1914 by Ardern and Lockett. Recently, many versions of this process are used, but basically all versions are similar. Performance of an urban WWTP including activated sludge process depends on many parameters so predicting the plant performance is rather difficult [1–3]. Fluctuations of waste water flow rates and compositions entering the plant in high amounts, continuous changing of environmental conditions in the plant and problems encountered in the facility may be considered as the most important reasons [4–5].

Waste water treatment processes are established as a result of design, construction and assembly operations. Howsoever they are designed to environmental technologies principles, built within the desired technical features, of which all mechanical, electrification—automatic control and remote systems are installed according to the standards; a treatment process that is not functioning properly can not operate and ensure the receiver environment standards. The first three operations are performed once only and they don't provide continuity. Operational process has the continuity feature and it is extremely important in terms of ensuring the receiver environment standards.

*Corresponding author.

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The following principles should be considered for a proper operation:

- A proper operation and maintenance program
- Training and experience of operational staff
- Control of the process by visual and physical control systems such as laboratory analysis
- Recording accurate and current data containing process trend
- Evaluation of operational data and laboratory data together
- ''Adjustment'' of process with the data obtained
- Interventions on time in case of possible process failures

When activated sludge system is operated properly, there is no reason not to ensure the required treatment efficiency. The operational way of the process will determine the treatment costs of all the plant . The important thing is to keep the discharged water at a high quality by obtaining optimum efficiency with optimum costs [9].

With this study, operation performance and efficiency analysis of Denizli Central WWTP a decent example of activated sludge process—have been tried to be evaluated.

Table 1
Parameters that are essential to the project

	2005	2025
Population	380,000 persons	703,000 persons
Project flow	1692 l/sec	2806 l/sec
Max. flow	2120 l/sec	3600 l/sec
Min. flow	1330 l/sec	2130 l/sec
Organic load (BOD)	240 mg/l	233 mg/l

Fig. 1. The aerial view of Denizli WWTP.

2. Denizli waste water treatment plant

Denizli WWTP was tendered by the Provincial Bank in 1995 and in 1996 construction of the plant had begun. Project of the plant was prepared as a two-tier according to years 2005 and 2025. Project flow is 1692 l/sec for the year 2005 and 2806 l/sec for the year 2025. Project population is assumed as 378,353 for the year 2005 and 703,838 for the year 2025. While calculating the domestic and industrial pollution loads coming to Denizli WWTP, unit values predicted by the Provincial Bank are taken as the basic values. According to this; 54 g/person.day of BOD_5 load, 10 g/person.day of the total nitrogen load, 2 g/person.day of total phosphorus load and 140 g/person.day of SS load are expected to come to the plant based on the project. Besides, by taking into consideration flow and pollution load from industry, the basic flow and pollution loads of the project were obtained [9]. Parameters that are essential to the project are given in Table 1.

Plant units (Fig. 1) are listed below:

- Input Collector with diameter 1600 mm
- Manuel cleaned Coarse Screen and mechanically cleaned Fine Screens
- Aerated Grit Chamber
- 8 rectangular primary settling tanks with dimensions $47 \times 10 \times 3$ m
- 11 rectangular aeration tanks with dimensions $47 \times 15 \times 3.5$ m
- 17 rectangular final settling tanks with dimensions $47 \times 10 \times 3.5$ m
- Chlorination unit
- 2 sludge thickening tanks with a diameter 18 m and a height 4.5 m
- 2 sludge digestion tanks for the first tier with a diameter 20 m and a height 18 m
- 2 sludge digestion tanks for the second tier with a diameter 20 m and a height 16 m
- 3 Beltfilter press units [9]

3. Denizli waste water treatment plant operations

3.1. Biological treatment processes

Denizli WWTP, which was come into operations in 2007, collects the waste water within the municipal boundaries as well as domestic and industrial waste water gathered from some surrounding municipalities and treats the waste water biologically according to activated sludge system. In Denizli WWTP, 'Fully mixed-short aerated activated sludge system' has been selected as the method of biological treatment. In activated sludge process; waste water is taken into aeration tanks where microorganisms bulks (active sludge) are developed, organic substances within are broken down by microorganisms, used in cell growth and turned into carbon dioxide. Essential nutrient for microorganisms is supplied from pollution load in the water and oxygen is supplied by the surface aerators. The aeration tank contains mixed liquid. The bio-mass defined as mixed liquor suspended solids concentration (MLSS), is composed of microorganisms, inert suspended materials and suspended solid materials that can not be decomposed biologically.

The mixed liquor taken from aeration tank, is passed through a filter defined as sedimentation tank, in here suspended solids are separated from the treated water. Settled solids in concentrated form at the bottom of sedimentation tanks, are transferred back to the beginning of the process to keep the concentration of microorganisms in the aeration tank at a certain level.

In the process, since continuous growth of microorganisms occurs, excess biomass must be removed from the system periodically. Depending on the design and operation of the process, sludge production is likely to be increased or decreased [9–11].

Activated Sludge Process have various components which are interrelated and listed below:

- Aeration Tank where biological reactions occur
- An aerator for biological treatment and holding of suspended mixture in order to supply the necessary oxygen
- Sedimentation tanks which enable the seperation of active sludge from treated water
- The system which realizes gathering of sludge in the sedimentation tank and turning back to the aeration tank
- System which removes excessive active sludge from the process.

From microbiological point of view, dominant microorganism type depends on features of waste water, environmental conditions, process design and process running method. The success of an activated sludge plant depends on adaptation of biological community to the waste water to be treated. This biological commuity consumes organic material, gathers in bulks, settles to form concentrated sludge for turning back and provides clear output water [9–11].

3.2. Process control and SCADA systems

Supervisory control and data acquisition (SCADA) and Automation systems are also currently used at the Denizli Central WWTP for running the plant. 18 programmable logic controller (PLC) and the local automation system were developed by seperating the plant into sections within the frame of plant operation flow diagram. These sections were merged through a network system, thus SCADA system was designed.

In Figs. 2–4, flow diagrams of Denizli WWTP are displayed.

In Fig. 2; input structure, coarse screen, fine screens, grit chamber, distribution structure and primary settling tanks are displayed.

In Fig. 3; aeration tanks and final settling tanks are displayed.

In Fig. 4; sludge thickening, sludge digestion tanks and belt presses are displayed.

1. Waste water
2. Primary settling sludge
3. Treated water

These sections in the system are run automatically in PLC control by forming a logic in accordance with plant flow diagram with controlled equipment. In principle, running the process properly and controlling the system in every point are aimed.

The facility is continuosly controlled through SCADA and automation systems designed according to the needs of Denizli WWTP. With the assistance of this system:

- Data collection
- Enabling remote monitoring and controlling from a center
- Instant malfunction localization and malfunction analysis
- Keeping archives
- Reporting are enabled.

3.2.1. Data collection

Variables required for running the plant in optimum level are collected by PLCs in the field and this process enables monitoring on SCADA system. Data such as input flow, output flow, reverse cycle flow, balance chlorine value of output water, ph and temperature value of sludge, produced-consumed amounts of gas flow, and pressure value of constituted gas, etc., are collected and tracked on SCADA system.

3.2.2. Enabling remote monitoring and controlling from a center

This feature provides monitoring states of all the controlled equipment which exist in the units of SCADA system and provides manual or automatic control. Besides, by calculating working times of equipment, it creates work condition in equal operation time to extend the life span of equipment and pumps through operation system.

3.2.3. Instant malfunction localization and malfunction analysis

At the equipment tracked by SCADA system, if a malfunction is caused by any reason, alarm system will automatically determine where, when and in which equipment malfunction is. In this way, without wasting time for the malfunction search, quick and local solutions can be found in dealing with the malfunctions occurred in the plant [13].

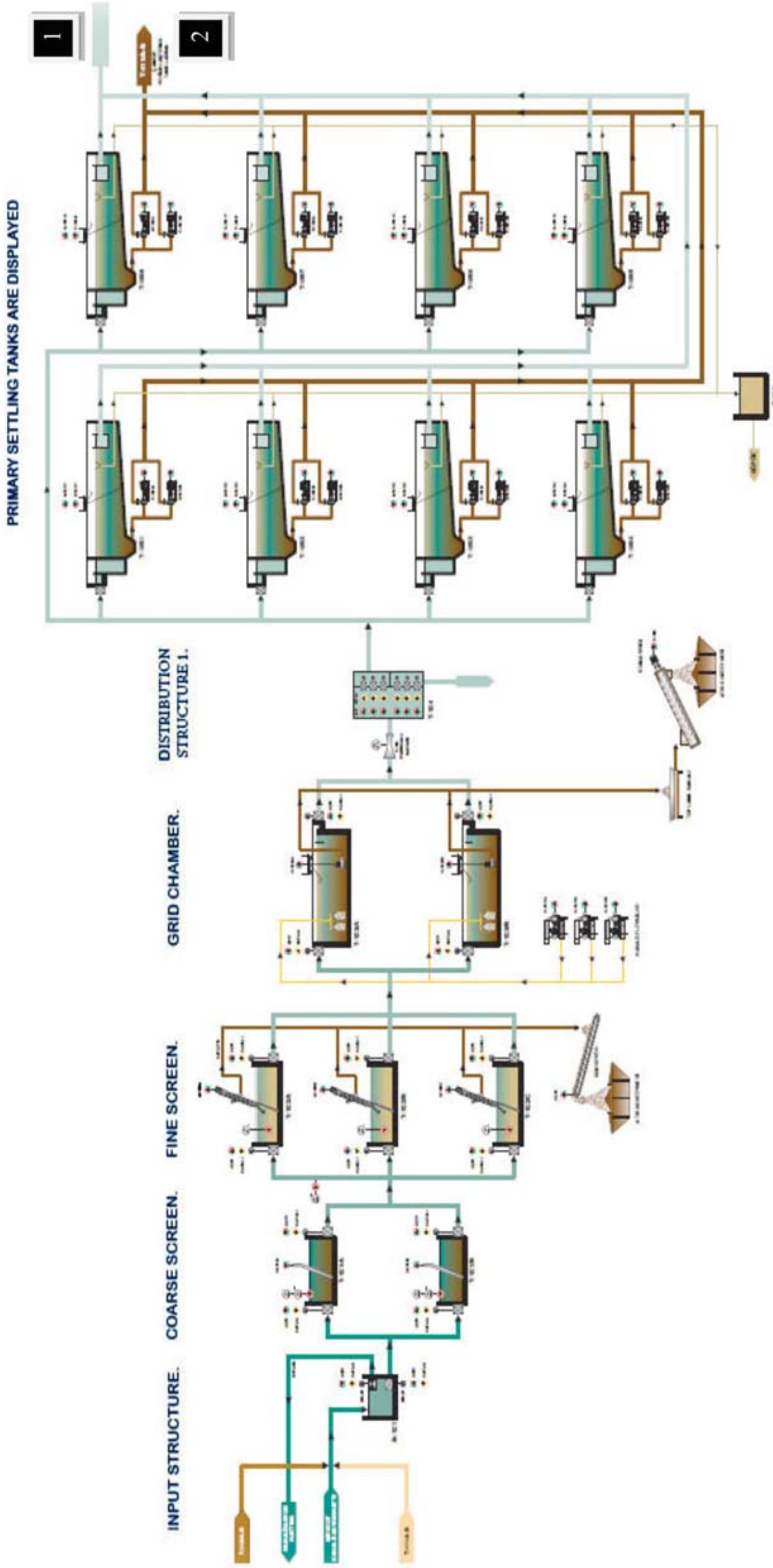

Fig. 2. Flow diagram of input structure, coarse screen, fine screens, grit chamber, distribution structure and primary settling tanks are displayed.

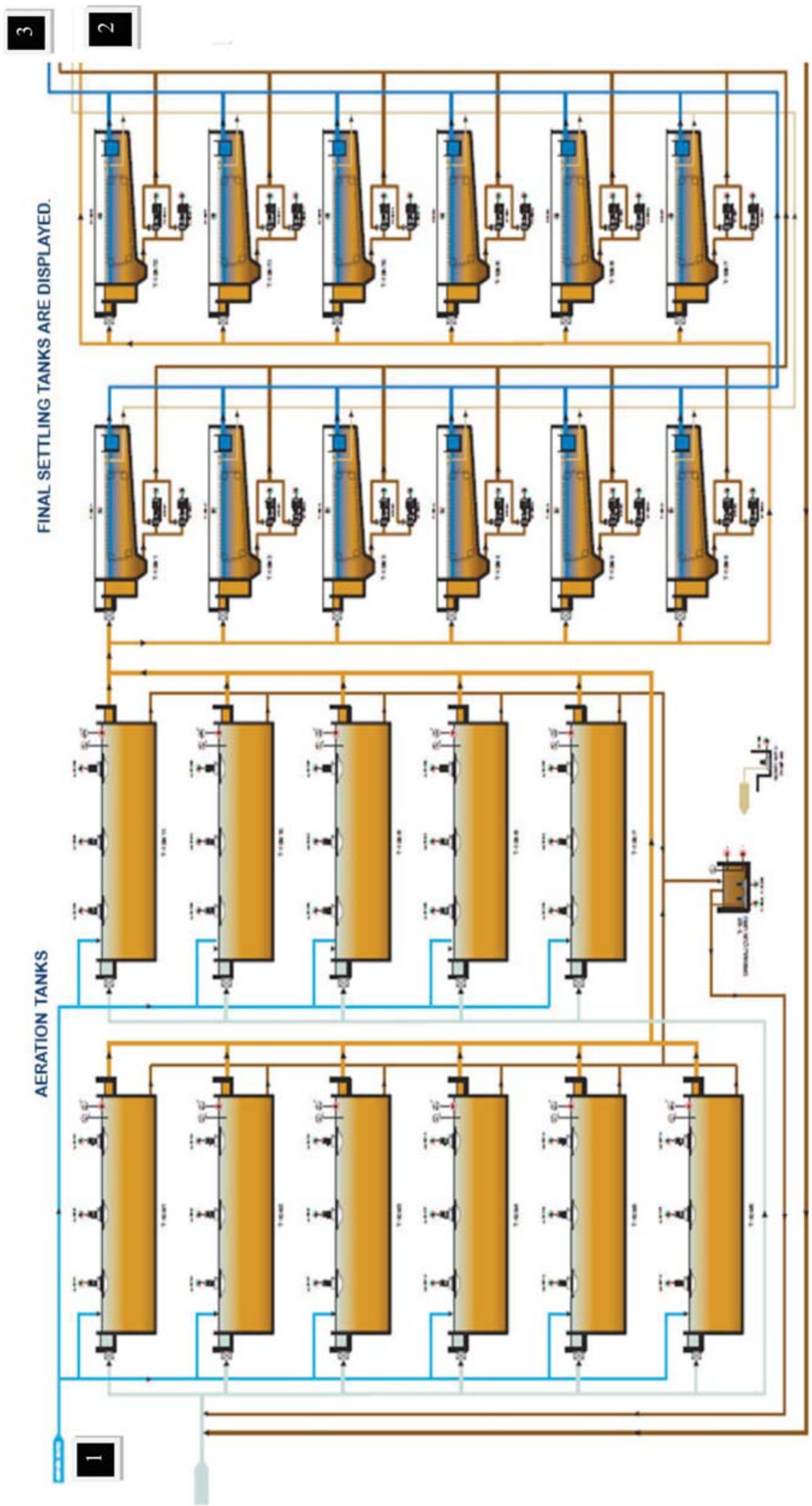

Fig. 3. Flow diagram of aeration tanks and final settling tanks are displayed.

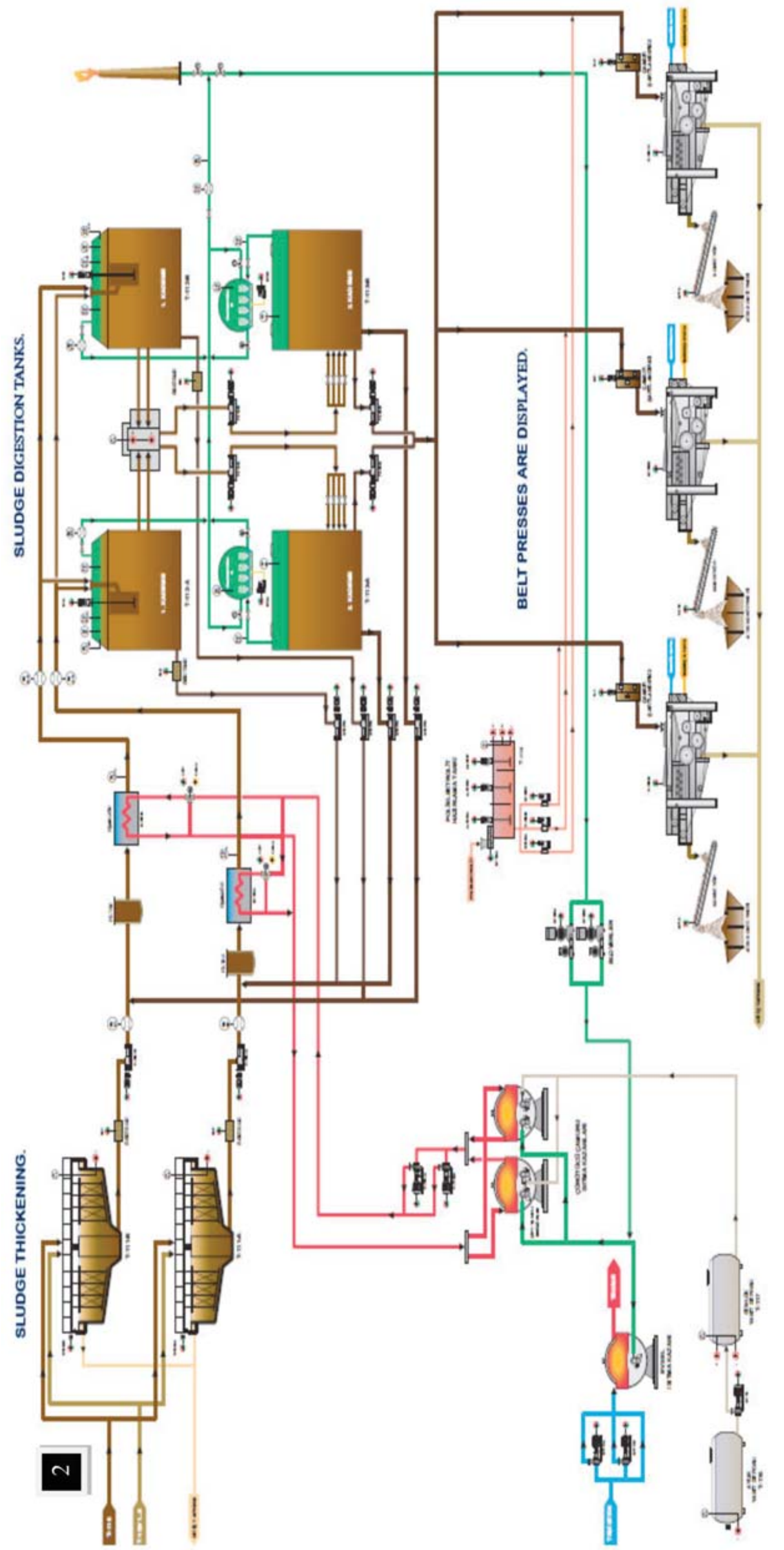

Fig. 4. Flow diagram of sludge thickening, sludge digestion tanks and belt presses are displayed.

3.2.4. Keeping archives

While the plant is being run, in SCADA system, some required variables are archived of which graphs drawn momentarily such as input flow, output flow, reverse cycle flow, oxygen values of aeration tanks, produced gas flow, consumed gas flow, etc. In addition, total values of some daily variables are stored in tables. Therefore, by obtaining values like the amount of treated water and the amount of produced-consumed gas, data collection for the plant engineer and running the process in optimum are achieved [13–14].

3.2.5. Reporting

Automation system enables to report momentary graphics and total daily values in tables of all the variables archived as data. Also malfunctions are reported by considering time values.

In waste water treatment plants, all the flow information reaching the plant with annual reports is displayed. Thus, plant engineer can solve the issues more simply such as cost accounting of the plant and if necessary capacity increase.

Table 2
Water pollution control regulations discharge standards

Parameters	Unit	Composite samples (2 h)	Composite samples (24 h)
Biochemical oxygen demand (BOD_5)	(mg/l)	40	35
Chemical oxygen demand (COD)	(mg/l)	120	90
Suspended solids (SS)	(mg/l)	40	25
pH	–	6–9	6–9

Sector: Domestic waste water, category 4: Pollution load as raw BOD larger than 6000 Kg/d, population > 100000, Table 21.4.

Malfunction status of all equipment in the system is monitored momentarily by automation system and malfunction is being handled without wasting time. Automation system that is run according to Denizli Central WWTP, controls field equipment precisely. So, more secure working conditions are obtained in terms of occupational safety [12].

3.3. WWTP control parameters

In the laboratory of treatment plant, 2 h and 24 h composite samples obtained by composite sampling devices from input and output water are widely analyzed according to the Water Pollution Control Regulations [10].

Time-dependent performance and changes in sludge volume index values have been tried to be monitored by using the data of Denizli WWTP. In order to determine process performance, based on water pollution control regulations discharge standards (Domestic waste water, Category 4: Pollution Load as raw BOD larger than 6000 Kg/d, population > 100000) given in Table 2, efficiency analysis of discharge parameters COD, BOD, SS and pH values are carried out [6–8]. In addition, total nitrogen and phosphorus parameters which are important for irrigation are examined for input and output values although they don't exist in Water Pollution Control Regulations Discharge Standards [16].

4. Evaluations

As a result of analysis of parameters belonging to plant output like COD, BOD, SS, pH, Total Nitrogen and Total Phosphorus carried out in the laboratory; average efficiency calculations were made with max, min and mean values by using 100 d data. Average output parameter values were graphed by comparing

Table 3
Input–Output analysis of data from waste water

Parameters	Max. value	Min. value	Average value	Average yield	Regulation value
Input pH	7.91	7.43	7.67		
Output pH	8.04	7.74	7.89	–	6–9
Input SS	412	132	272		
Output SS	30	4	17	94%	40
Input COD	755	355	555		
Output COD	100	45	72.5	87 %	120
Input BOD	342	142	242		
Output BOD	15	5	10	96 %	40
Input Total Nitrogen	55	19	37		
Output Total Nitrogen	20	6	13	64 %	–
Input Total Phosphorus	12	6	9		
Output Total Phosphorus	5.1	2.5	3.8	57 %	–

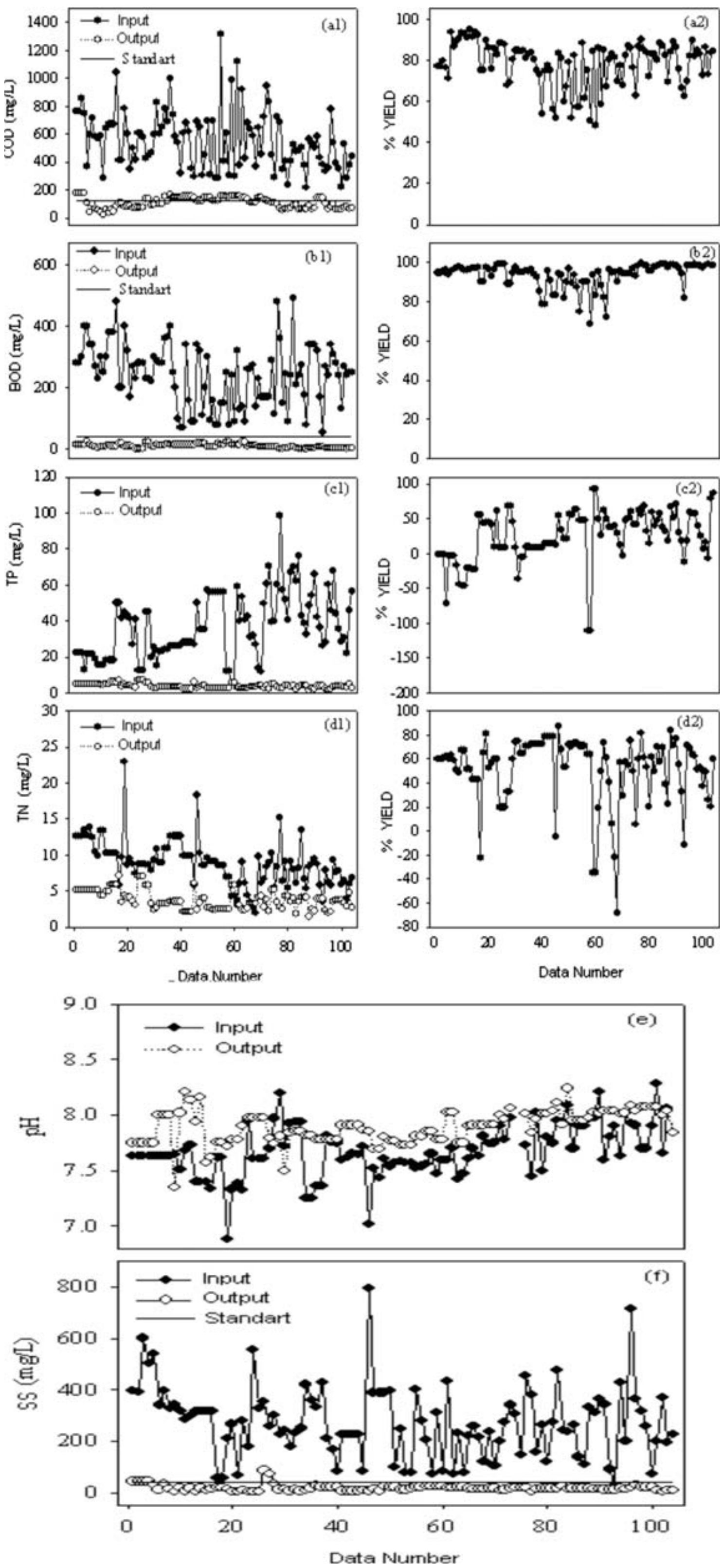

Fig. 5. COD (a1), BOD (b1), Total Nitrogen (c1) and Total Phosphorus (d1), pH (e), SS (f) are change of data; (a2), (b2), (c2), (d2) are removal efficiencies; regarding to plant input and output water.

with discharge limits given in Water Pollution Control Regulation Discharge Standards.

When the regulation values in Table 3 are examined, Denizli WWTP complies with the discharge limits continuosly. Average treatment percentages between the input and output parameters are; 94% for SS, 87% for COD and 96% for BOD, so treatment efficiency of domestic waste water treatment is quite high (Fig. 5). Besides, in active sludge aeration tank, dissolved oxygen, suspended solid matter(SS) and sludge volume index(SVI) measurements are carried out in routine. CHI values are about 200 ml/g in aeration tank. Although there is no nitrogen-phosphorus removal in the system, with the current treatment units nitrogen-phosphorus parameters are treated with a removal over 50%. Total treated nitrogen parameter is 64% and total treated phosphorus parameter is 57% in average.

5. Conclusion and recommendations

Input and output values of the parameters concerning the graphics have been made, and it is seen that biological efficiencies of Denizli Municipality WWTP (SS, COD, BOD) are rather high. Conventional activated sludge process was chosen for the system and it is observed that efficiency of nitrogen-phosphorus removal seems quite sufficient according to current system [15]. The average COD and BOD concentrations in the plant output, respectively change in the intervals of 45–100 mg/l and 5–15 mg/l, and they are within the specified limits of the Water Pollution Control Regulations. When observed as efficiency analysis assessment, the efficiency of COD, BOD, SS are 87%, 96%, 94% respectively. In total nitrogen and total phosphorus values, efficiencies are 64% and 57%. Due to the high treatment efficiency, output water can be used as irrigation water.

In Denizli Municipality WWTP, as a result of SCADA-automation applications, regular laboratory work and process follow-up performed by the plant engineers effectively; it is seen that a high efficiency is obtained for the output water values.

As in the case of Denizli, removal percentages of all the parameters analyzed in input-output water of WWTPs should be measured constantly and efficiencies of domestic WWTP should be kept under control by the operating engineers.

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