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Dairy wastewater treatment plant in removal of organic pollution: a case study in Sanandaj, Iran

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Abstract
Background: Wastewater produced by a dairy in Sanandaj is a major source of environmental pollution threatening the city. The dairy uses activated sludge treatment to remove organic pollution from the wastewater. The present study evaluated the performance of this process and its compliance with national requirements for chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total suspended solids (TSS) remaining in the plant effluent.
Methods: A total of 48 samples were obtained from the dairy inflow and outflow. The COD, BOD, and TSS were measured for each sample. The statistical sign test was used to assess the standards.
Results: The results showed that the average BOD, COD and TSS in the input wastewater was 292.25, 422.92, and 198.33 mg/l, respectively. The ratio of BOD/COD was 0.69, which indicates the capacity of biological treatment was high. The BOD decreased to 64.22 mg/l (92% removal), COD to 33.74 mg/l (92% removal), and TSS to 43.11 mg/l (94% removal) in the effluent, indicating significant removal of water contaminants. The statistical sign test showed that TSS ($P<0.0001$) and BOD ($P=0.031$) were incompliance with national standards, but COD exceeded standard threshold ($P=0.076$).
Conclusion: Activated sludge treatment showed a good performance for TSS removal, but was not reliable for removal of BOD and COD pollutants.
Keywords: Activated sludge system, Dairy wastewater, Sanandaj, Wastewater treatment, BOD, COD, TSS
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Introduction

Urbanization has increased industrial activity and the discharge of industrial wastewater into surface water. Water pollution decreases the quality of water for agricultural purposes and limits potable water supplies (1,2). Wastewater is water that has been contaminated and cannot be used for consumption. Sewage is waste transported by water from residential, office, commercial and industrial areas. Depending on the conditions, it is possible for groundwater, surface water and flood to be mixed (3). If untreated wastewater accumulates, partially decomposed organic materials can produce large quantities of malodorous gases (4).
Industrial wastewater treatment is one step necessary for elimination of environmental impacts (5). Physical, chemical and biological processes can be used for wastewater treatment. Biological processes are used extensively for treatment of wastewater with high organic loads. The oldest and most common biological process for sewage treatment is activated sludge (6,7). Activated sludge system is used in slaughterhouses and the dairy industry because it offers simple technology and high efficiency for removal of organic materials (8).
Milk and dairy industry wastewater usually contains ammonium (from amino acids) and phosphate (from casein) and is an eutrophication factor in the environment. Wastewater treatment facilities are expected to control these resources at in accordance with national standards. The parameters used to evaluate the performance of treatment plants are biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS) in the effluent (9,10).
Several studies have examined the performance of activated sludge system and have arrived at different con-

clusions about the effectiveness of this system. Zazouli et al (11) evaluated the performance of an activated sludge wastewater treatment system in Golestan province. The efficiency of this system for removal of BOD, COD and TSS from effluent reported to be 97%. They stated that effluent quality of 3 contaminants was in accordance with standards at most times of year; however, they did not report the standards and they did not apply statistical tests to support their claim.

Faizi et al (12) examined the performance of activated sludge for treatment of wastewater from the Sanandaj slaughterhouse and showed very weak performance of the system. They found that the mean level of all contaminants in the effluent was unexpectedly far above national standards. They reported that the mean level of BOD was 517.5 mg/l (487.5 mg/l greater than BOD standard of 30 mg/l) and of COD was 671.71 mg/l (227.35 mg/l greater than COD standard of 60 mg/l). The main source of industrial wastewater in the city of Sanandaj is a dairy that employs an activated sludge system. The present study investigated the performance of this system and its compliance with national standards.

Methods

In this study, 48 wastewater samples from treatment system inflow (24 samples) and outflow (24 samples) were collected. Figure 1 shows the Sanandaj dairy that uses activated sludge in its wastewater treatment plant. This plant comprises a screen for the influent, a primary settling chamber, an aeration basin, a secondary settling chamber, and a disinfection method that uses chlorine as a disinfectant. The sampling plan was collection of 2 samples per week (one from influent and another from effluent) over 6 months.

As an indicator of wastewater pollution, the COD, BOD, and TSS were measured in all samples. The open reflux method was applied to COD measurement and aqualytic BOD meter (model AL606, Germany) was used for measurement of BOD. TSS was measured by the gravimetric method. Potassium dichromate, mercury sulfate, silver sulfate, sulfuric acid, ferrous ammonium sulfate and Freon manufactured by Merck (Germany) used for COD measurement. Experimentation was conducted in accordance with standard methods (13). The national standards for each pollutant were obtained from the United States Environmental Protection Agency (EPA) (14). R statistical software was used to analyze the data (15).

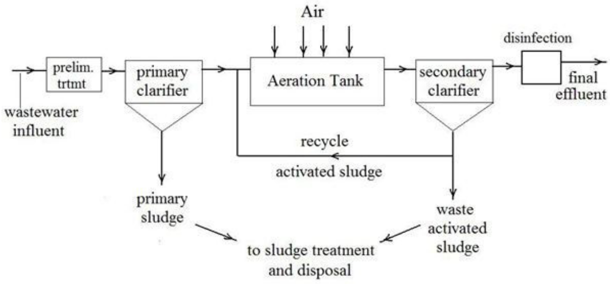

Figure 1. Flow diagram of wastewater treatment plant at Sanandaj dairy.

Results

Table 1 shows the preliminary results of analysis. The mean and standard deviation for COD for treatment inflow was estimated to be 422.92 and 19.89 mg/l, respectively (411.92 ±19.89 mg/l). The COD was the highest in September and at a minimum in October. The mean COD for treatment outflow decreased to just 33.74 mg/l, which indicates 92% removal from the effluent.

Comparison of the inflow and outflow rates for BOD and TSS showed 92% and 94% removal of contaminants respectively. Figure 2 shows the overall level of contaminants in the effluent. The horizontal axis represents the treatment inflow and the vertical axis represents treatment outflow. TSS showed less variation for both inflow and outflow and higher variation was recorded for BOD, especially for treatment outflow. The COD in the effluent is shown to be above the national standard for some periods of the year.

Figure 3 shows the level of wastewater contaminant for each month of the study period. The boxplot measures

Table 1. Mean BOD, COD and TSS from Sanandaj dairy treatment effluent

	TSS[a]		COD[a]		BOD[a]	
	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow
July	8.50	192.12	72.00	224.32	11.90	237.60
August	15.0	190.00	24.34	435.00	35.00	264.30
September	10.0	198.88	30.00	450.00	14.00	300.00
October	12.98	198.00	42.25	430.22	16.00	280.00
November	14.80	200.00	40.56	390.00	28.96	321.11
December	7.50	211.00	61.10	420.00	30.00	350.53
Mean	11.46	198.33	33.74	422.92	22.64	292.25
SD	3.24	7.37	20.17	19.89	94.9	40.44

Abbreviations: COD, chemical oxygen demand; BOD, biochemical oxygen demand; TSS, total suspended solids.

[a] Each the average is the result of 4 measurements at 4 weeks of the month.

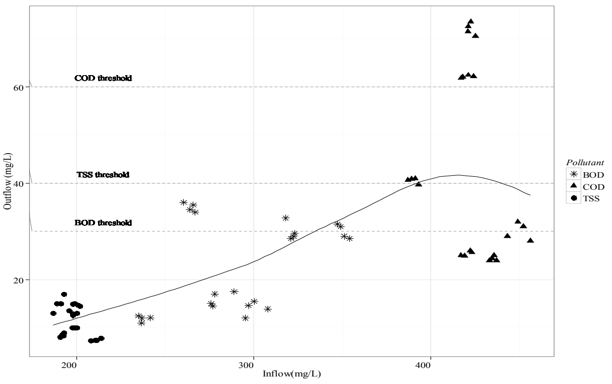

Figure 2. BOD, COD and TSS in Sanandaj in dairy wastewater. The dashed lines denote standard thresholds for each contaminant.

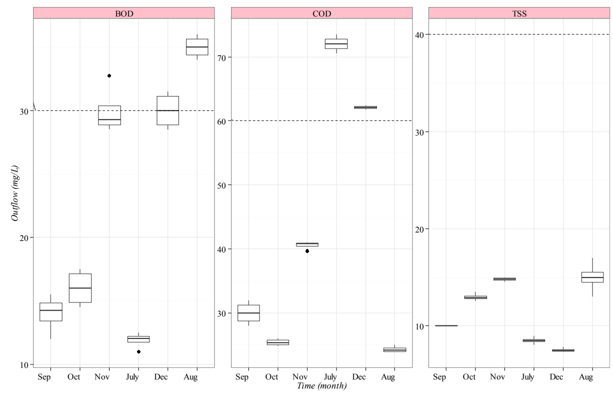

Figure 3. BOD, COD and TSS for Sanandaj dairy effluent per month. The dashed line denotes national standard.

the median and uncertainty around the median (length of box), which helps understand treatment functionality. Figure 3 shows the variation within and between samples during the study period. For example, in December, almost half of the samples were above threshold; in November, only 1 sample did not fall within the national standard range (denoted by a solid point). This sample was much different from others in this month and represented an unusual observation.

Figure 3 shows that TSS in the effluent was consistently low, which was not the case with the other pollutants. It appears that the activated sludge failed to maintain the BOD and COD at standard levels during some months. The level of COD and BOD in the wastewater treatment's outflow are displayed versus treatment's inflow in Figure 4. This Figure demonstrates how well the treatments does remove contaminations from the waste. The dotted lines in the graphs show the general trend of contaminant removal is non-linear. Note the behavior of treatment in removing COD at 420 mg/l inflow (highlighted area) where it is totally unpredictable; while the level of COD was bellow threshold in October (four bottom points in the bin) it was above the nominal allowed level on July and December (8 top points in the bin). This shows that the performance of the plant is unrelated to entrance inflow. Table 2 reports the results of the sign test for whether the treatments effluent met the national norms for each contaminant. Sign test was used since the assumption of normality was disrupted. National norms are given in the Table under the alternative hypothesis. Table 2 shows that the levels of BOD and TSS in the effluent met the norms but the level of COD did not.

Discussion

EPA guidelines recommend that COD concentration in treatment plant effluent should be least than 60 mg/l. COD removal efficiency using activated sludge was lowest in July and December and complied with the national standards during August, September, October and November. Input hydraulic shock is one possible reason for

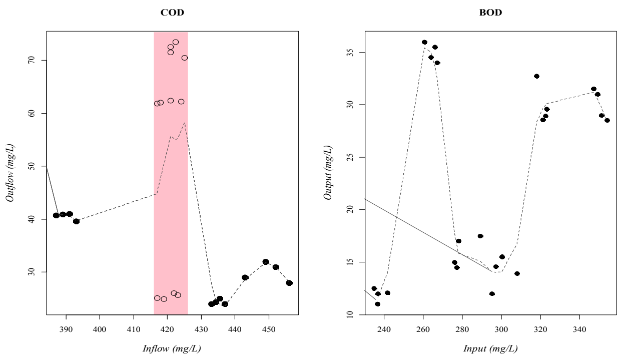

Figure 4. BOD and COD levels in Sanandaj dairy effluent. The dashed line denotes contaminant in a spline smoothing curve. The grey band in the left panel shows plant inflow.

Table 2. Comparison of non-parametric test for BOD, COD, and TSS for Sanandaj dairy treatment effluent with national norms

TSS[a]	COD[a]	BOD[a]
H_1:[b] Average is less than 40	H_1: Average is less than 60	H_1: Average is less than 30
P<0.0001	P=0.076	P= 0.031

Abbreviations: COD, chemical oxygen demand; BOD, biochemical oxygen demand; TSS, total suspended solids.
[a] Effluent from treatment plant released to surface water versus national standards.
[b] H_1 is alternative hypothesis.

the poor performance of the plant in July and December. Vasseghian et al (16) showed that use of a UV reactor can increase COD removal efficiency.

The average output BOD was 22.64 mg/l, which is lower than the 30 mg/l permissible limit for discharge into surface water; however, the average did not fall into the standard range in August. The average BOD was 30 mg/l in December, which suggests that the level of activated sludge was not desirable. Mohapatra et al (17) showed that other treatments, such as advanced oxidation, can be effective for consistent compound removal.

Figure 3 shows the impressively low concentration of TSS in the system effluent for all months of study. These results comply with those from a study by Zazouli et al (11). The thinness of the box in represents the very low rate of output and shows consistent TSS removal. For example, samples taken during different weeks in July ranged from 8.04 to a maximum of 9 mg/l. Some change was also seen in the effluent for COD, but this was outside standards for 2 months of the year. In other words, in 33% of cases, activated sludge was ineffective for COD removal.

Figure 3 showed that the results for activated sludge were random in nature for BOD removal. The BOD level in the effluent was in accordance with national standards in July and August, but did not meet the standard in September and was again within national standards in November and December (slightly higher or lower). The output BOD in 29% of cases was outside national standards (30 mg/l). It can be inferred from Figure 3 that there was a lack of uniform treatment for the removal of all contaminants in each month. The emission concentration of BOD fell within standard range in July. COD did not fall within the standard range in August, but BOD was outside of the standard range. Only September showed all pollutants within national range.

Hassani et al (18) showed that a fixed activated sludge system can increase the performance of persistent material compounds such as heavy metals and fat. Figure 4 shows a lack of a predictable relationship between input and output pollutants. The output concentration of COD was nonstandard for time at 390 mg/l, but was within standard range at 435 mg/l for input at 420 mg/l (highlighted by gray bar). At the same concentrations, the purification system had a dual function. In some cases, the output fell within the standard range (COD output <60 mg/l); at other times, the COD was significantly higher than standard levels. Similar oscillations were also observed for BOD removal; as input BOD increased, the output of the system fell within standard range at times and outside standard range at others.

Table 2 indicates that the performance of the Sanandaj treatment plant was within standard range for removal of TSS and BOD, but was nonstandard for COD. Note that, although the sign test determined that output BOD was within standard range, this should be interpreted with caution. That the results are within standard range. If one unit of standard value decreased and is assumed to be 29 mg/l, the result of the signal test for output BOD does not comply with the standard range ($P > 0.05$). Table 2 showed that the treatment performance for BOD removal fell at the border of standard range in many cases or at a slight distance outside the standard. Porwal et al (19) concluded that the use of some microbial isolates from activated sludge can be effective for treatment of this kind of wastewater. Brennan (20) concluded that the use of an activated sludge wastewater treatment system with a high-rate anaerobic side stream reactor increased efficiency of removal of all biodegradable contaminants.

Conclusion

The levels of BOD, COD and TSS pollutants in the effluent of dairy wastewater at a treatment plant in Sanandaj were measured to study the performance of an activated sludge system. The results showed that this system was successful for removal of TSS and adequate for removal of the other 2 pollutants. Statistical analysis detected that the BOD concentration in the effluent was accordance with national standards, but caution should be used when interpreting these results because half of the samples were recorded at threshold level or slightly outside and 29% of samples fell outside the standard range for effluent BOD for release to surface water (not statistically significant). The performance of activated sludge for COD removal was outside the standard in 33% of cases, which is statistically significant. There was no special relationship between input and output of COD. The following steps are suggested to improve treatment efficiency:

1. Build an equalizer pond in the corner of the main equalizer pond to increase wastewater retention time and improve neutralization and chock control.
2. Require the dairy to perform primary treatment of sewage using storage tanks, dilution the sewage, or use of septic tanks as pretreatment and sand filtration as tertiary treatment.
3. Return the output sludge to the aeration pond.

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Ethical issues

We certify that all data collected during the study is presented in this manuscript and no data from the study has been or will be published separately.

Competing interests

The authors declare that they have no competing interests.

Author contributions

SS conceived and designed the study. RAF and NA performed the literature search and wrote the manuscript. All authors participated in the data acquisition, analysis and interpretation. All authors critically reviewed, refined and approved the manuscript.

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