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Performance evaluation of the wastewater treatment plant of Pelareh Dairy Industry, Iran

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Original Article

Abstract

Pelareh Dairy Industry (PDI) is located in the west of Iran. The aim of the present study was to assess the quality and quantity of PDI wastewater and compare the results with the regulations. PDI has a wastewater treatment plant that consists of sewage collection system, screening system, equalization tank, clarification tank, anaerobic system for pretreatment, activated sludge processing, disinfection, and solids drying beds. In this research, seven quality parameters, including chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD_5), nitrate (NO_3), total suspended solids (TSS), phosphate (PO_4), temperature (T°c), and pH, were measured as qualitative variables. Thus, 20 samples were collected from influent and effluent zones. Wastewater samples were collected using random grab sampling during peak hours. Based on the results, the average (SD) COD concentration of the raw wastewater in wet season and dry season was 2152.22 (1384.00) and 1813.38 (518.33) mg/l, respectively. The results revealed that the removal efficiency of BOD_5, COD, and TSS at the studied plant was 89.22%, 88.79%, and 71.72%, respectively. Based on achieved results, the pollution load of PDI effluent wastewater was determined and presented. Based on the obtained results, the pollution load based on BOD_5 variable was 15.71 kg/day. The obtained results indicate that the treatment plant was not efficient enough to be considered as a treatment process for the removal of suspended solids and organic matter.

KEYWORDS: Environment, Industrial wastewater, Pollution, Wastewater

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Introduction

Food processing is one of the most intensive water user industries and the volume of its wastewater is relatively high and dependent on the process details.[1] In the dairy industry, raw milk is processed into different products such as consumer milk, condensed milk, dried milk (milk powder), cheese, butter, yogurt, and ice cream. Unit operations in dairy industries that generate wastewater include disinfection and washing of equipment such as tanks, pipes, pasteurizers, centrifuges, homogenizers, pails, and etc. Depending on the capacity and type of the industry, raw industrial wastewater is highly polluted and contains high concentrations of organic matter such as carbohydrates, proteins, oil and grease, suspended solids, nitrogen, and a level of phosphorus. In addition, all of these substances contribute greatly towards the high values of five-day biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD).[2-8] It also has an unpleasant odor due to decomposition of some compounds such as casein which may have unsatisfactory effects.[5,9,10]

It is necessary to remember that almost all organic constituents of dairy waste are highly biodegradable.[11] In recent decades, many

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researchers have tried to determine the quantity of dairy wastewater generated by different industries. Based on the latest available information, total quantity of effluent produced in the industry is found to vary widely from company to company, and depends on the processing mode and its conditions.[10]

Kyrychuk et al. estimated that the amount of effluent wastewater generated by the dairy industry is in the range of 0.2 to 10 l of effluent per liter of pasteurized milk with the mean of about 2.5 l of wastewater per liter of pasteurized milk.[11] Karthikeyan et al. reported that the amount of wastewater produced annually by the mentioned industries was between 3.74 and 11.22 million cubic meters of wastewater per year, which means approximately one to three times the volume of milk processed.[12] Gulyas et al. confirmed that the volume of effluent wastewater produced for each cubic meter of processed milk is in the range of three to four cubic meters.[13]

Regarding the priority of environmental issues, it is necessary to adopt a positive approach to sustainable management of water, soil, and other finite resources and monitor industrial wastewater including dairy wastewater. On this basis, the aim of the present study was to investigate the quality and quantity of wastewater of Pelareh Dairy Industry (PDI) and also estimate the pollution load as part of environmental management policies in Iran.

Materials and Methods

PDI is located in Hamadan Province (Malayer Township) in the west of Iran, covering 2 hectares with three working shifts a day. The nominal capacity of the plant is approximately 55 tons of dairy product per day. These products are pasteurized milk, cheese, pizza cheese, and some types of yogurt. PDI has approximately 100 employees as permanent workers and workers' normal shifts are 8 hours a day, 7 days a week. The said factory has a wastewater treatment plant that consists of sewage collection system, screening system, equalization tank, clarification tank, anaerobic system for pretreatment, activated sludge processing, disinfection, and solids drying beds. Figure 1 provides a schematic flow diagram of PDI wastewater treatment facility.

This research project was conducted during 2014-2015. First, the general features of the study area and PDI were assessed using library and field visits. In this section, initial planning or pre-test was performed to assess the feasibility of the study, identify the site, investigate the problem, and determine the minimum sample size necessary to achieve a desired level of significance.

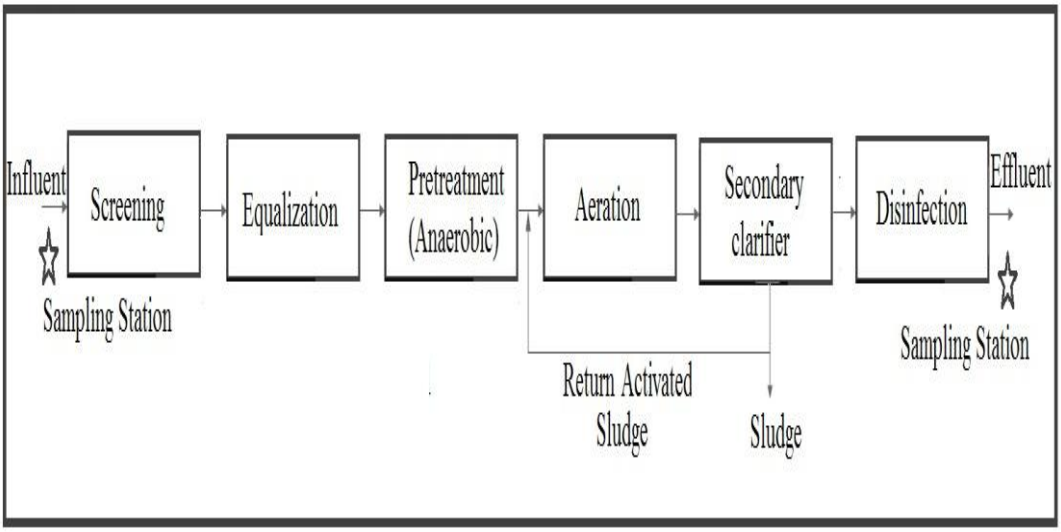

Figure 1. Flow diagram of Pelareh Dairy Industry wastewater treatment plant

Based on the water consumption rate, production volume, and number of workers, the total amount of wastewater, such as municipal wastewater and industrial wastewater, of the factory was obtained. Wastewater sampling was performed in two seasons (wet and dry). A computer random number generator was used to select 5 days in each season. During each sampling session, 20 samples were collected from influent and effluent zones. Wastewater samples were collected using random grab sampling during peak hours of activity and analysis was carried out as recommended by standard methods.[14]

In this research, 7 quality parameters, including COD, BOD_5, nitrate (NO_3), total suspended solids (TSS), phosphate (PO_4), temperature (T°c), and pH, were measured as qualitative variables to evaluate the quality of wastewater and pollution load. The efficiency of the wastewater treatment plant of the factory in terms of each parameter was determined in the following sections. The average concentration of each parameter was measured and compared against the standard. Microsoft Excel and SPSS software (version 19.0, SPSS Inc., Chicago, IL, USA) were used for data analysis. Kolmogorov-Smirnov test was used for testing the distribution normality. The significance of all differences was tested using the one sample t-test.

Results and Discussion

The information obtained from PDI revealed that the amount of water consumed in the factory was 180 cubic meters per day. About 2% to 3% of this amount is related to municipal or human wastewater of the factory. A certain percentage of supplied water was commonly used for irrigation of the factory's green space. Based on the results achieved, the milk processing capacity of this factory was 70 cubic meters per day and the volume of wastewater generated by the industry was about 140 cubic meters per day. Under these circumstances, the amount of effluent wastewater generated by the industry was about 2 l of effluent per liter of pasteurized milk.

Kolmogorov-Smirnov test was applied to test the normality of distribution. The results of the Kolmogorov-Smirnov test indicated that the distribution of data was normal.

The quality of raw and treated wastewater of PDI in different seasons are presented in table 1. In many cases, the results were very similar in the wet season and dry season. Based on the said results, the average (SD) concentration of COD in the raw wastewater collected in the wet season and dry season was 2152.22 (1384.00) and 1813.38 (518.33) mg/l, respectively.

Table 1. Comparison of characteristics of raw and treated wastewater samples collected from Pelareh Dairy Industry in different seasons

Wastewater	Variable	Wet season			Dry season			P
		n	Mean	SD	n	Mean	SD	
Raw	COD	5	2152.22	1384.00	5	1813.38	518.33	0.62
	BOD_5	5	1128.00	714.22	5	954.00	281.74	0.63
	TSS	5	922.00	344.99	5	782.00	78.23	0.40
	NO_3	5	2.16	3.90	5	9.80	21.91	0.46
	PO_4	5	49.20	15.22	5	89.80	32.03	0.03*
	pH	5	6.26	2.67	5	6.08	2.59	0.91
	T	5	30.10	0.74	5	31.40	2.96	0.39
Treated	COD	5	210.18	64.04	5	234.14	129.19	0.72
	BOD_5	5	114.60	34.36	5	109.80	67.57	0.89
	TSS	5	328.00	38.34	5	154.00	49.79	0.01*
	NO_3	5	12.08	11.05	5	1.42	1.94	0.10
	PO_4	5	38.60	10.45	5	29.40	5.31	0.12
	pH	5	7.47	0.33	5	7.38	0.19	0.61
	T	5	28.60	1.29	5	30.30	0.67	0.04*

* Significant; $P < 0.05$; COD: chemical oxygen demand; BOD_5: Five-day biochemical oxygen demand; NO_3: Nitrate; TSS: Total suspended solids; PO_4: Phosphate; T°C: Temperature

Table 2. Quality of raw and treated wastewater samples collected from Pelareh Dairy Industry

Wastewater	Variable	n	Mean	SD	Minimum	Maximum
Raw	COD	10	1982.80	1001.31	1218.50	4592.90
	BOD_5	10	1041.00	520.00	720.00	2400.00
	TSS	10	852.00	247.11	660.00	1500.00
	NO_3	10	5.98	15.37	0.00	49.00
	PO_4	10	69.50	31.89	31.00	145.00
	pH	10	6.171	2.48	4.20	10.71
	T	10	30.75	2.15	28.50	35.50
Treated	COD	10	222.16	96.95	139.30	460.60
	BOD_5	10	112.20	50.60	57.00	228.00
	TSS	10	241.00	100.82	110.00	380.00
	NO_3	10	6.75	9.36	0.00	28.00
	PO_4	10	34.00	9.20	22.00	51.00
	pH	10	7.42	0.26	6.90	7.75
	T	10	29.45	1.32	27.00	31.00

COD: chemical oxygen demand; BOD_5: five-day biochemical oxygen demand; NO_3: nitrate; TSS: total suspended solids; PO_4: phosphate; T°C: temperature

Since the concentrations of variables in the raw and treated wastewater in different seasons were similar, the data were reanalyzed without regard for the season and is presented in table 2. Based on the reanalyzed data, the average (SD) concentration of COD of raw and treated wastewater was 1982.80 (1001.31) and 222.16 (96.95) mg/l, respectively.

Regarding the purpose of the study, it was necessary to compare the results with the reference standard. Therefore, average values of several variables were compared to the approved standard for wastewater reuse in agricultural irrigation, artificial recharge, and disposal into rivers.

The results showed that there was a highly significant difference ($P < 0.05$) in mean pH level among the test groups, which was in the normal range, compared to the Iranian maximum permissible limits (Table 3). In terms of pH, the treated wastewater of PDI can be reused in agricultural irrigation or be disposed in surface water. Moreover, there was a highly significant difference ($P < 0.05$) in mean TSS level among the test groups, which was higher than the maximum permissible limits in Iran (Table 3). In terms of TSS concentration, the treated wastewater of the mentioned factory cannot be reused in agricultural irrigation or disposed in surface water and groundwater.

Table 3. Comparison of average wastewater quality parameters of Pelareh Dairy Industry effluent wastewater and Iranian Department of Environment standards

Effluent use	Factor	n	Mean	SD	Standard value	t	P
Agriculture	BOD_5 (mg/l)	10	112.20	50.60	100	0.76	0.465
	COD (mg/l)	10	222.16	96.95	200	0.72	0.488
	TSS (mg/l)	10	241.00	100.82	100	4.42	0.002*
	PH	10	7.42	0.26	(6-8.5)	11.36	0.001*
Artificial recharge	BOD_5 (mg/l)	10	112.20	50.60	30	5.14	0.001*
	COD (mg/l)	10	222.16	96.95	60	5.29	0.001*
	NO_3 (mg/l)	10	6.75	9.36	10	1.10	0.301*
	PO_4 (mg/l)	10	34.00	9.20	6	9.62	0.001*
	PH	10	7.42	0.26	(5-9)	29.54	0.001*
Discharge into surface waters	BOD_5 (mg/l)	10	112.20	50.60	30	5.14	0.001*
	COD (mg/l)	10	222.16	96.95	60	5.29	0.001*
	TSS (mg/l)	10	241.00	100.82	40	6.30	0.001*
	NO_3 (mg/l)	10	6.75	9.36	50	14.62	0.001*
	PO_4 (mg/l)	10	34.00	9.20	6	9.62	0.001*
	PH	10	7.42	0.26	(6.5-8.5)	11.27	0.001*

*Significant; $P < 0.05$; COD: chemical oxygen demand; BOD_5: five-day biochemical oxygen demand; NO_3: nitrate; TSS: total suspended solids; PO_4: phosphate; T°C: temperature; SD: Standard deviation

Table 4. Removal efficiency of important variables in Pelareh Dairy Industry wastewater treatment plant

Variable	Raw (influent) wastewater	Treated (effluent) wastewater	Removal efficiency$^{\Psi}$(%)
COD (mg/l)	1982.80	222.16	88.79
BOD_5 (mg/l)	1041.00	112.20	89.22
TSS (mg/l)	852.00	241.00	71.72
NO_3 (mg/l)	5.98	6.75	-12.87
PO_4 (mg/l)	69.50	34.00	51.08
pH	6.17	7.425	-20.32
T	30.75	29.45	4.23

$^{\Psi}$Removal efficiency: [initial concentration - final concentration]/initial concentration; *100%; COD: Chemical oxygen demand; BOD_5: Five-day biochemical oxygen demand; NO_3: Nitrate; TSS: Total suspended solids; PO_4: Phosphate; T°C: Temperature

Based on the results, there was a significant and nonsignificant difference in terms of mean BOD_5 and COD concentrations, respectively, among the test groups compared to the maximum permissible limits in Iran (Table 3). Under these circumstances, disposal of treated wastewater of PDI into the ground or surface water is not permitted.

In addition, there was a highly significant difference ($P < 0.05$) between the test groups in terms of mean PO_4 level; its concentration was higher than the maximum permissible limits in Iran (Table 3).

The mentioned wastewater may not be appropriate for disposal into surface water or groundwater, because the concentration of PO_4 was higher than the Iranian maximum permissible limits.

It should also be noted that there was a significant or nonsignificant difference in mean NO_3 concentration level among the test groups, compared to the maximum permissible limits in Iran (Table 3). In terms of NO_3 concentration in the treated wastewater of PDI, the discharging of the treated wastewater of PDI into the ground or surface water is permitted.

The average amount of some variables in influent wastewater and effluent at PDI wastewater treatment plant, and the removal efficiency are summarized in table 4. The results revealed that the removal efficiency of BOD_5, COD, and TSS at the studied plant was 89.22%, 88.79%, and 71.72%, respectively.

Due to the importance of pollution load assessment of industrial wastewater, this value was calculated in the present study. Based on the obtained results, the pollution load of COD, BOD_5, TSS, NO_3, and PO_4 was 31.10, 15.71, 33.74, 0.94, and 4.76 kg/day, respectively.

The present study was successfully conducted to evaluate the quantity and quality of PDI wastewater and also to determine the treatment efficiency of this wastewater treatment plant.

Analysis of wastewater quantity

The obtained results confirmed that the quantity of PDI wastewater was about 140 cubic meters per day. Indeed, the quantity of wastewater generated by PDI was about 2 l of effluent per liter of processed milk.

Few studies have been carried out on the quantity of dairy wastewater. Comparable results were obtained by Mahendraperumal Guruvaiah et al.[15] Their study investigated the quality and quantity of dairy industry wastewater and concluded that the mentioned industry generates 0.2-10 l of wastewater per litre of milk processed.[15] Another study performed by Briaoi and Granhen Tavares suggested that dairy industry wastewater generates up to 10 l of wastewater per litre of milk processed.[16] Furthermore, Gulyas et al. reported that the volume of effluent wastewater produced for each cubic meter of processed milk is in the range of 3 to 4 cubic meters.[13] It is therefore concluded that the amount of water used in the dairy factory is less than the amount used in similar plants.

Analysis of the wastewater quality

Some different parameters and results were analyzed and the findings are explained in

the following sections.

BOD5 and COD

The BOD_5 and COD removal efficiency in our study was 89.22% and 88.79%, respectively (Table 4). This finding was similar to the results of other researches. For example, Gorra et al. reported a BOD_5 removal efficiencies of higher than 90% for treatment of dairy industry wastewater in a continuous flow.[17] In another study performed in the dairy industry, Harush et al. performed the aerobic biodegradation and coagulation process for the removal of COD.[18] In the mentioned research, the removal percentage of COD was up to 87.43%.[18] Other investigations of behavior of ferric sulfate as coagulant in chemical treatment for the removal of organic matter from dairy industry wastewater showed COD removal efficiency of 77.3%.[19]

Nitrate

Because of the aeration system of the wastewater treatment plant, a major part of the ammonium present in the wastewater can be removed and converted to nitrite and nitrate through the nitrification process as given below.[20]

$$NH_4^+ + 1.5O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^- + H_2O + 2H^+ \quad (1)$$

$$NO_2^- + 0.5O_2 \xrightarrow{\text{Nitrobacter}} NO_3^- \quad (2)$$

In this research, the nitrate concentration in the raw wastewater and treated wastewater was 5.98 and 6.75 mg/l, respectively, and a tenuous (12%) increase was observed in nitrate ion concentration in the effluent. This result is similar to other previous studies conducted elsewhere.[20]

Schaafsma et al. found a statistically significant increase in nitrate concentration (82%) during the treatment of dairy wastewater in a constructed wetland system.[21] Ghaly et al. reported that ammonium was oxidized into nitrite, and then, into nitrate in a hydroponic wastewater treatment system during plant growth and the concentrations were dependent on the type and quantity of seeds.[22] In the mentioned research, it was revealed that nitrite and nitrate concentrations in a hydroponic wastewater treatment system increased with time during germination period, and then, decreased during the plant growth period.[22]

TSS

TSS is a key measurement for wastewater and its treatment. In this research, TSS concentration in the effluent was on average 852 mg/l before treatment, whereas after physical and biological treatment, it was on average 241 mg/l and 71.72% reduction was observed. In the current study, however, TSS removal was relatively poor and had low contrast, but the results showed that the wastewater treatment plant of PDI has the potential to provide higher efficiency. A study in 2011 on dairy industry wastewater in Italy indicated that the removal efficiency of TSS by constructed wetland was 94.5%.[23] In a similar study, 93.85% TSS removal efficiency from dairy industry wastewater was achieved in a treatment plant consisting of screening chamber, oil and grease removal, equalization tank, neutralization tank, primary clarifier (PC), aeration tank (AT), and secondary clarifier (SC).[24] In another study, the removal efficiency of TSS from dairy industry wastewater by constructed wetland was reported to be 81%.[25]

Phosphate

In this research, phosphate removal was poor and affected by many shortage factors, such as escalation of costs of energy, materials, and labor. The results of this analysis can be compared with similar studies performed in other countries.[9,10,15,20,26-29] For example, Balamane-Zizi and Ait-Amar reported the low phosphate removal efficiency of only 41.4% for treatment of dairy industry wastewater.[26] In this research, the removal efficiency of phosphate was 25.35% after precipitation. The phosphate biologic elimination efficiency obtained in the study

by Salame et al. was 16.04% and the global elimination efficiency was 41.4%.[30]

Pollution Load

Assessment of pollution load is useful in monitoring wastewater discharge.[31] In the current study, pollution load was mainly measured in order to assess the actual impact of PDI wastewater on the environment. Similar studies have been performed on pollution load by Hosseini-Zare et al.,[32] Kaia Oras and Eda Grüner,[33] Hafizul Islam et al.,[34] and Riyahi Khoram et al.[1] among others. Frameworks, methods, and extensions used in these studies vary with the format of the survey, parameters, approaches, and resources.

Conclusion

The present study focused on the performance evaluation of PDI wastewater treatment plant and compared its effluent wastewater with permissible discharge standards in Iran. The results revealed that the treatment plant was not efficient enough to be considered as a treatment process for the removal of suspended solids and organic matter. It is clear that groundwater quality in the study area will be affected by the factory effluent. It seems that the PDI wastewater treatment plant requires technical upgrading via a complete sedimentation system and biological system before it can be used as an effective treatment plant. It is recommended that more emphasis be placed on the development, repair, and maintenance of electrical, mechanical, and process equipment. It is also recommended that more attention be paid to experiential training programs for wastewater treatment plant operators and managers to conserve energy and reduce pollution and waste.

Conflict of Interests

Authors have no conflict of interests.

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