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Physical properties of influent and effluent samples collected from dairy industry effluent treatment plant

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Abstract

The dairy industries are an impudend bread and butter piece of many nations due to their resourceful products. Physical properties of dairy industrial effluent was varies with the different treatment methods, sampling sessions and months. The samples were characterized based on physical properties such as TSS, TDS, pH, EC and turbidity. Total seven samples were collected at sampling points of dairy effluent treatment system for further analysis. Results from the study revealed that, dairy effluent is slightly alkaline in nature, and TSS, TDS, pH and turbidity values obtained during the analysis of dairy effluent indicate the presence of heavy load of organic substances. Physical properties of effluent samples obtained after dead-end filtration system were more than the permissible limits of Environmental Protection Rule. Hence, it is very important that proper effluent treatment systems should be installed for the protection of the environmental health and for the ecological balance.

Keywords: Physical properties, effluent, dairy industry, sampling points, seasons and months

Introduction

Dairy industry is one of the major food industries in India. India ranks first among the milk producing nations and Karnataka ranks 11th among milk producing states of the country. The total milk production in India was 163.73 million tonnes and per capita availability of milk was 352 g/day. The annual growth rate of milk production in India is between 5-6 per cent, against the world's one per cent (Garg *et al.*, 2017) [9].

The dairy industry leads to water pollution at large scale, not only in terms of the volume of effluent generated, but also in terms of its characteristics as well. It generates about 2-10 litres of effluent per litre of processed milk with an average generation of about 2.5 litre of wastewater per litre of the milk processed (Shete and Shinkar, 2013a) [20]. Water management in dairy industry is well documented but effluent production and disposal remains a problematic issue for dairy industry (Shete and Shinkar, 2013b) [21]. Among all industrial sectors, dairy industry is major contributor of effluent generation (Verma and Singh, 2017) [25]. Different types of milk based products are produced and consequently waste streams may vary on a daily basis thereby, reflecting a change in physico-chemical parameters. Dairy industry is growing at a substantial rate in India and it generates enormous volumes of effluents through its different operations like pasteurization, bottling, whey generation, cleaning, sanitization, heating, cooling, washing of floor and utensils etc (Sharma *et al.*, 2013) [18].

To comply with the discharge standards, the dairy industries in India are practicing an elaborate effluent treatment protocol. The main objective of treating dairy effluent is reduction of organic load. This organic load may be reduced to a considerable level, so that an eco-friendly effluent could be generated (Sarkar *et al.*, 2006) [16]. The effluent of dairy industry contains large quantities of milk constituents such as casein, lactose, fat inorganic salt, besides detergents and sanitizers used for washing. As per different research findings carried out at national and international levels, a typical untreated dairy effluent is characterized by high organic loads such as Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, Electrical Conductivity (EC), Turbidity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oil, grease, phosphate, sulphate, nitrate, ammonical-nitrigen, chloride and whey (Arora *et al.*, 2005) [2].

All of these require specialized treatments to prevent environmental problems. Dairy effluent is characterized by wide fluctuations in flow rates, related to discontinuity in the production cycles of different products (Britz *et al.*, 1992) [5]. The variable nature of dairy effluent in terms of volume, flow rates, pH and suspended solids (SS) makes it difficult to choose an effective effluent treatment regime (Demirel *et al*., 2005) [7]. To comply with new discharge standards, the dairy industries have adopted an elaborate effluent treatment protocol. This is affecting the overall economy of the plant and increasing the costs of conventional treatment systems.

Materials and Methods

Collection of sample

The effluent samples required for the experiments were collected from dairy plant of Karnataka Milk Federation (KMF-Nandini), Bellary, Karnataka (India). The plant situated at 1512 feet above mean sea level, 15.09° latitude and 76.54° longitude. The plant has 150.90 km distance from department of Processing and Food Engineering. The plant process one lakh litres of milk per day. The dairy plant processes and sells the double toned milk under the brand name of “SHUBHAM” along with other dairy products like curd, ghee, Mysore pak and peda.

The KMF dairy plant has an effluent treatment plant (ETP) suitable for processing capacity of two lakh liters per day. The ETP has seven sampling points *viz.*, effluent collection tank (P_1), equalization tank (P_2), primary aeration tank (P_3), primary clarifier (P_4), secondary aeration tank (P_5), secondary clarifier (P_6) and sand and carbon filter (P_7). For the present experiment, the effluent samples were collected at the end of each sample collection point. The process flow chart of dairy ETP with sampling points is depicted in Fig. 1. The effluent samples were collected during rainy season (September, 2016 (M_1) and October, 2016 (M_2)), winter season (November, 2016 (M_3) and December, 2016 (M_4)) and summer season (March, 2017 (M_5) and April, 2017(M_6)). The two months in each season the effluent samples were collected in one litre capacity high density polyethylene (HDPE) bottles. Before filling, the bottles were rinsed two times and labeled. The effluent samples were collected in the respective sample points and transported immediately to the laboratory for further analysis and stored at 4 °C (Noorjahan *et al.*, 2004) [14]. Effluent samples collected from dairy industry ETP at different sampling points are given in Fig. 2.

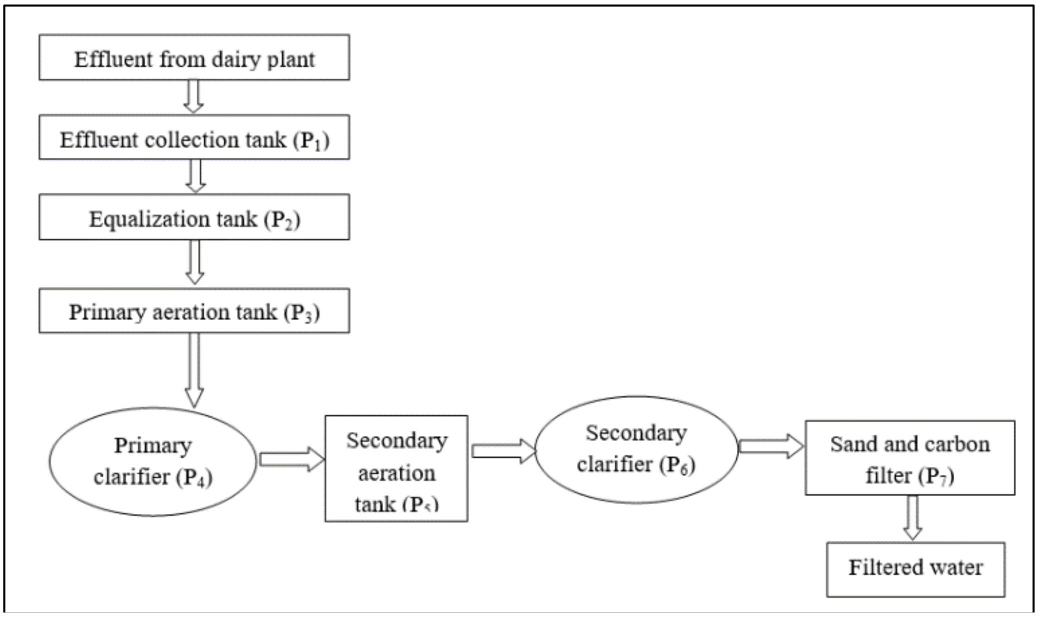


Fig 1: Flow diagram of existing dairy ETP with sampling points

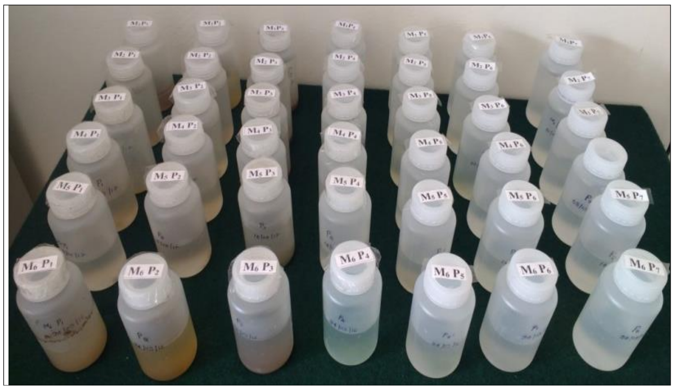


Fig 2: Effluent samples collected from dairy plant ETP at different sampling points

Chemicals and standards used

The chemicals used throughout the experiment were procured from M/s. Sigma Aldrich Chemicals, Bengaluru and standards were procured from M/s. Himedia Chemical Co. Bengaluru.

Physical properties

The effluent collected from different collection points of dairy industrial ETP were analyzed for physical properties *viz.*, TDS, TSS, pH, EC and turbidity. The data obtained were compared with the standards laid down by Environmental Protection Rule (EPR, 1993) [8].

Analysis of physical parameters

Physical characteristics such as TDS, TSS, turbidity, pH and EC present in the dairy industrial effluent (DIE) were determined as per the method described by ISO (1984; 3025: Part 16 &17) [10], APHA (1995; Method 180.1) [1], USEPA (1993; Method 150.1) [24]. The electrical conductivity (EC) of effluent samples were determined by using digital conductivity meter and expressed in µS/cm.

Statistical analysis

All the experiments were conducted in triplicate and the mean values were reported.

A 3 × 7 × 2 spilt plot design was taken and statistical analysis was done by using SPSS (Statistical Package for Social Sciences, version 16.0) software (Montgomery, 2001). Selected split plot design include three factors *viz.*, seasons (levels: rainy (S_1), winter (S_2) and summer (S_3)), sample collection points (levels: P_1, P_2, P_3, P_4, P_5, P_6 and P_7) and months (levels: M_1 and M_2). After proper analysis, data were accommodated in the tables as per the needs of objective for interpretation of results.

Results and Discussion

Effect of sampling seasons, months and sampling points on total dissolved solids of DIE

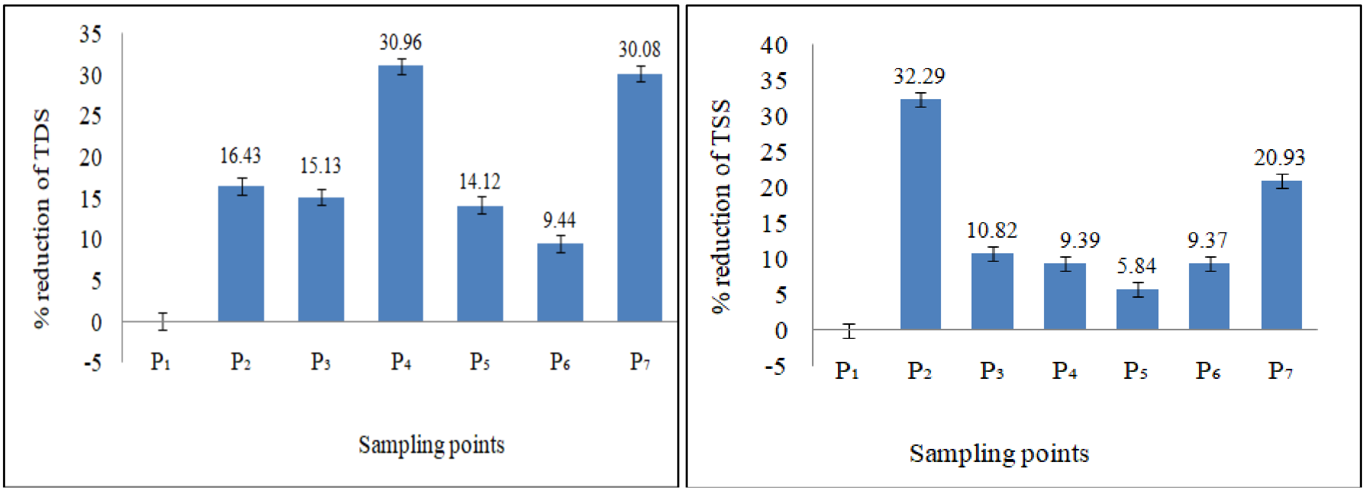
From the Table 1 it is noticed that, TDS of effluent in the different sampling points decreased from P_1 to P_7. This might be due to physico-chemical treatment process in the dairy effluent treatment plant which affected the rate of flocculation of colloidal particles. Similar trend was reported by Chavda and Rana (2014) [6] for performance evaluation of effluent treatment plant of dairy industry. Concentration of TDS in the effluent sample decreased from rainy to summer season. This decreased trend might due to higher temperature during summer season which probably affected the flocculation and sedimentation of the TDS in the effluent. Similar trend was reported by Sahithya and Lakshmi (2016) [15] for performance evaluation of effluent treatment plant in pharmaceutical industry.

Table 1: Effect of sampling seasons, months and sampling points on TDS of DIE

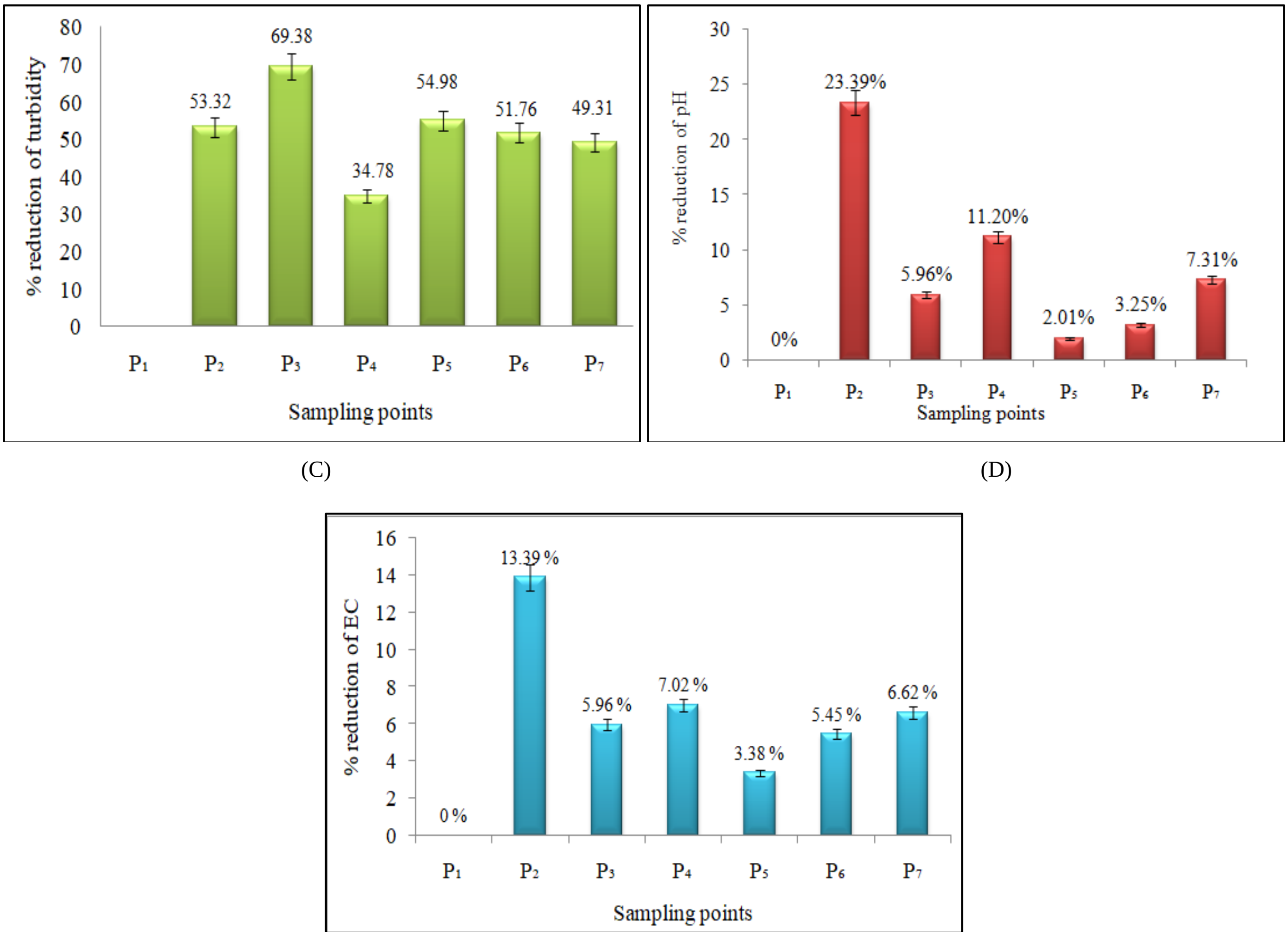
Sampling seasons (S)	Sampling months (M)	Sampling points (P)						
		P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainy	M_1	2626.77	2119.25	1814.90	1286.20	1154.31	1056.46	735.23
	M_2	2716.84	2205.06	1864.75	1323.34	1137.60	1023.01	695.45
	Mean (M)	2671.80	2162.15	1839.82	1304.77	1145.95	1039.73	715.34
Winter	M_1	2575.94	2162.15	1726.25	1230.05	1051.97	1015.40	680.02
	M_2	2479.07	2170.21	1876.84	1275.55	1062.10	1006.24	650.15
	Mean (M)	2527.50	2158.22	1801.54	1252.80	1057.03	1010.82	665.08
Summer	M_1	2455.05	2046.65	1730.47	1190.05	986.68	854.90	636.66
	M_2	2345.45	2013.32	1765.00	1135.01	996.57	829.98	647.98
	Mean (M)	2400.25	2029.98	1747.73	1162.53	991.625	842.44	642.32
Mean (S)		2533.18	2116.78	1796.36	1240.03	1064.87	964.33	674.24

TDS concentration of effluent samples decreased from rainy season to summer season, which might be due to the efficient working capability of mechanical parts of ETP during summer months. Moreover, feasible temperature in summer months might have brought about the inactivation of microbes. The reverse was the case in winter months as variation in climatic conditions might be reduced the efficiency of machine parts and thus will reduce efficiency rate. The temperature plays an important role in working capability of effluent treatment plant (Wani *et al.*, 2013) [27].

From Fig. 3(a) it is depicted that, not much variation in the effluent TDS was found in between the sampling months. Therefore, the effect of sampling months and seasons on total TDS of dairy plant effluent was non-significantly different at $p>0.01$ (0.742). But greater difference in the values of TDS was found between the sampling seasons. These variations in the dairy processing effluents were generated in an intermittent way and the flow rates of these effluents changed significantly. The volume, concentration and composition of the effluents arising in dairy industry were dependent on the type of product being processed, production program, operating methods, design of processing plant, the degree of water management being applied and subsequently the amount of water being conserved (Shete and Shankar, 2013a) [20]. Maximum per cent reduction of TDS was found at sampling point P_4 (30.96%) followed by P_7 (30.08%) and P_2 (16.43%). This might be due to most of the bio-solids were separated by means of primary clarifier, sand and carbon filter and equalization tanks in the ETP (Mittal, 2011) [13].



(A) (B)



(C) (D)

(E)

Fig 3: Effect of sampling points on per cent variation of (a) TDS, (b) TSS, (c) Turbidity, (b) pH, (e) EC of dairy industrial effluent

Effect of sampling seasons, months and sampling points on TSS solids of DIE

The mean values of TSS of ETP sampling points (P_1 to P_7) during rainy season vary from 662.92 to 1778.28 in the months of Sep, 2016 and Oct, 2016. Similarly, during the winter season (Dec, 2016 and for Jan, 2017) the TSS was found in the range of 649.45 to 1693.05 mg/L and summer season (March, 2017 and Apr, 2017) the collected samples obtained TSS values varied from 1538.96 to 536.68 mg/L and is shown in Table 2.

Table 2: Effect of sampling seasons, months and sampling points on total suspended solids of DIE

Sampling seasons (S)	Sampling months (M)	Sampling points (P)						
		P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainy	M_1	1836.91	1246.67	1006.62	972.08	884.60	846.15	698.05
	M_2	1719.66	1166.58	1087.37	1010.66	912.19	861.13	627.80
	Mean (M)	1778.28	1166.58	1046.99	991.37	898.39	853.64	662.92
Winter	M_1	1628.05	1160.06	1012.69	975.63	921.04	812.35	689.41
	M_2	1758.05	1120.67	991.33	882.01	849.25	695.69	609.50
	Mean (M)	1693.05	1140.36	1002.01	928.82	885.14	754.02	649.45
Summer	M_1	1553.88	1015.99	967.92	788.69	761.25	694.09	510.05
	M_2	1524.04	1074.05	984.04	852.61	833.05	767.94	563.31
	Mean (M)	1538.96	1045.02	975.98	820.65	797.15	731.01	536.68
Mean (S)		1670.09	1117.32	1008.32	913.61	860.23	779.55	616.35

Considering all the sampling seasons and sampling months, the mean value of TSS were found to be 1670.09 mg/L at P_1, 1117.32 mg/L at P_2, 1008.32 mg/L at P_3, 913.61 mg/L at P_4, 860.23 mg/L at P_5, 779.55 mg/L at P_6 and 616.35 mg/L at P_7, respectively.

From the Fig. 3(b) it could be analyzed that, during rainy season, per cent reduction of TSS was found to be the highest at P_2 (32.14%) followed by P_7 (22.34%) and P_3 (13.22%), respectively. Similarly, during winter season, the maximum per cent reduction was found at P_2 (32.64%) followed by P_7 (16.95%) and P_3 (12.13%), respectively. Effluent samples collected during summer season were found to be mean values of highest per cent reduction of TSS at P_2 (32.09%) followed by P_7 (26.58%) and P_4 (15.91%), respectively. The mean values of sampling seasons resulted the highest per cent reduction of TSS (32.29%) at P_2. The effluent samples obtained from ETP was found the TSS values were more than the EPR (1993) standard permissible limit (<200 mg/L).

Effect of sampling seasons, months and sampling points on turbidity of DIE

Turbidity is not generally considered a primary pollutant since it is not deemed to be associated with health hazards. It is used as an indication of aesthetic characteristics of water and as an aggregate indicator of the presence of a broad array of contaminants

(Kavitha *et al.*, 2013) [12]. From Table 3 it could be analyzed that, turbidity of effluents in different samples and sampling points decreased from P_1 to P_7. This might be due to physico-chemical treatment process in the dairy plant when affected the rate of flocculation of colloidal particles (Chavda and Rana, 2014) [6]. Turbidity decreased from rainy season to summer season. This might be due to stagnation of suspended solids in the effluent samples. In summer season most vegetation was decaying, and hence the amount of dissolved solids was more and were settled in the effluent (Verma *et al.*, 2012) [26].

Table 3: Effect of samples collection seasons, months and sampling points on turbidity of DIE

Sampling seasons (S)	Sampling months (M)	Sampling points (P)						
		P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainy	M_1	795.96	366.28	126.26	60.97	33.56	10.93	5.75
	M_2	747.08	313.32	152.61	92.43	33.90	35.72	14.01
	Mean (M)	771.52	339.80	139.43	76.70	33.73	23.32	9.88
Winter	M_1	793.47	386.78	54.64	78.06	25.88	7.03	5.79
	M_2	731.67	338.61	133.48	58.56	40.04	17.11	9.17
	Mean (M)	762.57	362.69	94.06	68.31	32.96	12.07	7.48
Summer	M_1	729.87	335.05	84.35	39.03	13.13	12.87	7.74
	M_2	774.83	394.37	102.11	97.08	45.32	8.87	4.44
	Mean (M)	752.35	364.71	93.23	68.05	29.22	10.87	6.09
Mean (S)		762.14	355.73	108.90	71.02	31.97	15.42	7.81

The turbidity of effluent samples decreased from rainy season to summer season in M_1 samples and M_2 samples. The variation in trends of turbidity might be due to many environmental factors which influenced ETP operation and its performance, such as temperature, pH, solar radiation and salinity of the water (Bhutiani *et al.*, 2015 [3] and Birima *et al.*, 2015 [4]).

The effect of sampling points on turbidity was highly significant. This might be due to efficiency of both physico-chemical and biological treatments including the aeration tank and activated carbon filter for removing biological matter and suspended materials from the dairy effluent (Shammari *et al.*, 2015) [17].

Maximum per cent reduction of turbidity was found in P_3 (69.38%) followed by P_5 (54.98%) and P_2 (53.32%). These variations might be due to clarification of effluent water was more prominent in clarification and aeration process (Mittal, 2011) [13] and is shown in Fig. 3(c).

Effect of sampling seasons, months and sampling points on pH of DIE

From the Table 4 it was noticed that, pH of the effluent samples increased from P_1 (5.28) to P_7 (8.67). This increased trend might be due to the wide variation in the pH values of effluent which affected the rate of biological reaction and survival of various microorganisms. The presence or absence of various ionic substances can affect pH of the effluent. The pH of effluent before treatment indicated the acidic nature in most of the months. This might be due to break down of milk lactose into lactic acid (Tikariha and Sahu, 2014) [23]. Effect of sampling seasons on pH of the effluent had shown non-significant difference and not much variation in the pH values between the seasons.

The pH of the effluent samples decreased from summer to rainy season in M_1 samples and in M_2 samples. The pH initially increased from summer to winter season and then it decreased during rainy season as shown in Fig. 3(d). The variation in trends of pH might be because of many sanitary chemicals were used in dairy plant clean in place process which led to variations of acidity and alkalinity in the effluent (Sharma, 2008) [19].

From the figure it could be analyzed that, non-significant difference of effluent pH between the months, but grater difference in the values of pH in the effluent samples analyzed between the sampling points. This might due to higher efficiency of both physico-chemical and the biological treatment processes involved in ETP. Organic and inorganic ionic substances were removed during the ETP operation (Shammari *et al.*, 2015) [17]. The maximum per cent variation of pH was found in P_2 (23.39%) followed by P_4 (11.20%) and P_7 (7.31%). These variations might be due to clarification of ionic substances in effluent water was more prominent in clarification and aeration process (Shete and Shinkar, 2013a) [21].

Table 4: Effect of sampling seasons, months and sampling points on pH of DIE

Sampling seasons (S)	Sampling months (M)	Sampling points (P)						
		P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainy	M_1	5.10	6.31	6.82	7.85	8.11	8.22	8.86
	M_2	5.27	6.64	6.75	7.48	7.75	7.87	8.71
	Mean (M)	5.18	6.47	6.78	7.66	7.93	8.04	8.78
Winter	M_1	5.25	6.82	6.97	7.94	8.00	8.27	8.66
	M_2	5.39	6.74	7.17	8.27	8.36	8.30	8.59
	Mean (M)	5.32	6.78	7.07	8.10	8.18	8.28	8.63
Summer	M_1	5.47	6.19	7.05	7.60	7.69	7.98	8.52
	M_2	5.20	6.39	6.66	6.92	7.08	7.88	8.73
	Mean (M)	5.33	6.29	6.85	7.26	7.38	7.93	8.62
Mean (S)		5.28	6.51	6.90	7.67	7.83	8.08	8.67

Effect of sampling seasons, months and sampling points on electrical conductivity of DIE

From the Table 5 it could be seen that, EC of the effluent samples decreased from P_1 to P_7. Electrical conductivity of effluent is a useful indicator of its salinity. The salinity content of effluent was reduced in each treatment stages of ETP (Singh *et al.*, 2012) [22]. Effect of sampling seasons on EC of the effluent increased from rainy to summer season and this might be due to higher temperature which affected the electrical conductivity of effluent (Tikariha and Sahu, 2014) [23]. Electrical conductivity of water is directly related to the concentration of dissolved ionized solids in the water. Ions from the dissolved solids in water create the ability for that water to conduct an electrical current (Iyasele and Idiata, 2015) [11].

EC of the effluent samples decreased from rainy to summer season in both M_1 and in M_2 samples. This might be because of higher efficiency of both the physico-chemical and the biological treatment process including the aeration tank and the activated carbon filter which removed biological matter and suspended materials from the dairy effluent (Shammari *et al.*, 2015) [17].

Maximum per cent variation of EC was found in P_2 (13.83%) followed by P_3 (7.33%) and P_7 (6.66%). These variations might be due to equalization tank, aeration tank, sand activated carbon filters which have able to reduce the dissolved and suspended solids in the effluent as shown in Fig. 3(e).

Table 5: Effect of sampling seasons, months and sampling points on electrical conductivity of DIE

Sampling seasons (S)	Sampling months (M)	Sampling points (P)						
		P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainy	M_1	2.56	2.46	2.36	2.23	2.13	2.03	1.88
	M_2	2.86	2.16	1.99	1.97	1.91	1.82	1.73
	Mean (M)	2.71	2.31	2.17	2.10	2.02	1.92	1.80
Winter	M_1	2.76	1.92	1.86	1.68	1.79	1.62	1.61
	M_2	2.26	2.40	2.10	2.14	1.94	1.86	1.66
	Mean (M)	2.51	2.16	1.98	1.91	1.86	1.74	1.63
Summer	M_1	2.30	1.72	1.70	1.84	1.63	1.53	1.49
	M_2	2.46	2.43	2.16	1.97	2.03	1.94	1.72
	Mean (M)	2.38	2.07	1.93	1.90	1.83	1.73	1.60
	Mean (S)	2.53	2.18	2.02	1.97	1.90	1.80	1.68

Conclusion

Mean total dissolved solids, total suspended solids, turbidity, pH and electrical conductivity values of analyzed diary industrial effluent samples were ranged from 674.24 to 2533.18 mg/L; 616.35 to 1670.09 mg/L; 7.81 to 762.14 NTU; 5.28 to 8.67 and 1.68 to 2.53 µS/cm. Based on these findings it was conclude that, the dairy industrial effluent treatment system is inevitable for the prevention of the increase of the organic loads. Hence, proper treatment methods required for protection of the environmental health and the preservation of the ecological balance. It has been determined that, first the balancing pools, then chemical treatment, subsequently treatment with proper method and conclusively the implementation of the ventilation pools and discharge would be appropriate.

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Compliance with Ethical Standards

No funding and during research there is no involvement of human participants and animals.

Conflict of Interest

No conflict of interest

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