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BOD/COD a Measure of Dairy Waste Treatment Efficiency- A Case Study

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Abstract: *Our environment gets polluted day by day due to the disposal of sewage and industrial waste without proper treatment in a totally unscientific way. Environmental Engineering is concerned with all types of pollution and Industrial waste treatment is the core area under the present study. Dairy industry is one among the highly offensive waste generating areas which increases the pollution rate of the total environment. Dairy industry requires 2.5 to 4litres of water per litre of milk process which comes out as waste water. Various studies revealed that dairy waste water treatment is a complicated one. Waste water from dairy processing units contains dissolved sugars, proteins and fats which are organic in nature and biodegradable which liberates gases, causes taste and odour, and creates color and turbidity. So treatment of dairy waste has great importance and care should be taken before disposing to environment. This work is an assessment of the performance of few dairies based on BOD, COD, and BOD/COD ratio and further scope of research area has been identified.*

Keywords: *Biochemical Oxygen Demand, Chemical Oxygen Demand, dairy, Efficiency, Effluent Treatment Plant*

I. Introduction

The dairy industry consists of multitude of milk products and therefore different production sectors. Every dairy plant has at least one or two production lines or all of them like pasteurized milk, cheese, butter, yogurt, condensed milk, flavoured milk, milk powder and ice cream. For the manufacture of the products, a series of operations such as collecting, storing, processing of raw materials, packing and storing of products and other secondary operations are involved. The initial operations are common for all dairies such as Homogenization, standardization, clarification, separation, and pasteurization. Large centrifuges which are specially designed is generally used for the clarification and separation. According to the type of products the processes like drying and condensing are also used. The type and size of processing units of one dairy is different from the other depending on the raw material inputs and the products manufactured. The milk and milk products are susceptible to microbial attack, for this reason the whole operations are facilitated with hygiene conditions. Modern dairy plants use closed systems operated continuously for 24 hours unlike older dairy plants.

The dairy industry is one among the most water consuming industry and highest producers of effluent per unit production. In addition they generate bulk volume of sludge during biological treatment. Majority of waste water released from dairy industry is from cleaning operations like cleaning of silos, homogenizers, tanks, pipe sand, heat exchangers and other equipment and it contains high organic load. Milk is the main constituent of this organic load, so the resulting effluent will have high levels of COD, BOD and Oil & Grease. Flow rates of the dairy effluents change significantly due to its intermittent generation.

This research paper deals with an evaluation study of various dairy waste treatment plants. Its performance was evaluated based on the removal efficiency of various characteristics such as Biochemical Oxygen Demand, Chemical Oxygen Demand, Oil & Grease and also taken the BOD/COD ratio as a tool for checking the biodegradability of effluent.

II. Need of Dairy Industry

In our everyday life milk has become one of the most important commodity as it is one of the unavoidable food product. As milk is highly perishable, utmost care should be given to provide milk of good quality, pure and free from pathogenic bacteria while considering the basic public health and economic aspects. In view of these considerations the quality standard shall be maintained for which quality control operations are to be performed at all the stages of production of milk. Attention shall also be given to maintain the sanitary conditions at milking place, storage, transportation and handling the milk at reception docks, processing and packing etc. till the milk is delivered to consumer. It was noticed that the milk production is mostly from the rural areas and the urban areas are acting as the collection centers and the milk processing plants and product manufacturing factories. Due to the rapid industrialization taking place all over the country, it resulted in sharp

rising in number of dairies and allied industries. Depending on the modernity and life style new varieties of milk products are generated and has become a part of our daily life.

2.1 Dairy Technology

Milk treatment is a series of operations from the collection point of raw milk to the final stage of the required product. The treatment of milk is always carried out in the specially prepared room with the arrangements of the processing units. The treatment of milk is always with an orientation of further activity based on the products to be produced. The dairy industry is characterized by the multitude of products and therefore production techniques also varies. Many dairies are not promoting themselves bottling pasteurized milk and making ghee from scoured milk. However, in India the production of skimmed and toned milk and cheese making is seen increasing due to the increased demand [3].

2.2 Milk Processes

Various operations involving receiving and storing of raw materials, processing of raw materials into finished products, packaging and storing of finished products, and a group of other ancillary operations including heat transfer and cleaning are some of the great variety of operations performed in the dairy industries. The operations including homogenization, standardization, clarification, separation, and pasteurization are common to most plants as its initial operations. Specially designed large centrifuges are generally used for the operations such as clarification and separation. The processes like drying and condensing are also used for the production of various products in diary industries [1].

2.3 Water Consumption, Sources and Generation of Waste Water

Basically, the range of heat treatments in a dairy determines the microbiological quality of milk. It affects the usage of cooling water in heat exchangers and the consumption of cleaning water [7].

Dairy factories discharged huge amount of effluent from various processing units and cleaning, and the ratio varies according to the particular products. The effluent discharge was often noticed that 85 – 90% of the consumed water in the case of pasteurized milk, 90 – 95% for butter and cheese, for milk powder and condensed milk it was more than 100%. Dairy waste contains milk solids enter from almost all of the operations in dilute condition with varying concentration. Generally, the wastes generated from dairy industry are as follows:

- The washing and cleaning out of product remaining in equipments like tank, trucks and cans. 2. Spill out is produced due to overflow, leaks, boiling over, freezing-on and careless handling.
- Losses during milk processing are (1) Sludge discharge from settling tank, (2) Discharges from bottles and washers and (3) Splashing and container breakage in automatic packaging equipment.
- Detergents and other compounds are used in the washing and sanitizing solution [3], [5], [2].

2.4 Characteristics of the Effluent

The effluent characteristics of dairy industry can be determined by the parameters such as color, temperature, DO, pH, COD, BOD, suspended solids, dissolved solids, sulphate, chlorides, oil and grease. These parameters largely depend on the quantity of milk and milk products. Dairy wastes are usually white in color. It is slightly alkaline in nature, but due to the fermentation of milk it becomes acidic and they have high BOD level in all liquids. Due to the curd content in cheese waste there is significant quantity of suspended matter found in dairy waste. High oxygen demand is arising due to the dairy waste pollution. As a result of the decomposition of casein heavy black sludge and strong butyric acid odours are formed [9], [1].

2.5 Methods of Treatment and Disposal

Proper management of dairy wastes has an important role in protecting, preserving and improving the quality of surface and ground waters. The best management practices can prevent direct discharge of wastewater and can enhance the operational efficiency of the dairy unit. The dairy waste can also be used for beneficial purposes such as fertilizer, compost or bedding. Agricultural Utilization Systems of treatment and disposal effluents of dairy industry is one of the pioneer methods which include (a) Ridge and furrow system, (b) Flood irrigation and (c) Spray irrigation.

All over the world various treatment methods and technologies have developed in the sector. The treatment of dairy effluents in India consists of Preliminary, Primary and Secondary treatment of effluents which became the conventional treatment units. Preliminary treatment involves removal of oil, grease and coarse solids, Primary treatment involves dilution with water and anaerobic lagooning or aerated lagooning for a shorter period unlike settling and digesting the sludge in usual waste treatment practice and the secondary treatment consists of Oxidation ditch/ Aerated lagoon/ Anaerobic lagoon followed by stabilization pond [4] (IS 8682- 1977).

2.6 Effects of effluents

The waste water generated from dairy industry contains huge amount of milk constituents like inorganic salts, caseins, along with sanitizers and detergents used for washing. All these components will make increase the BOD and COD levels higher than the specified limits in BIS for industrial effluent discharge. So disposal of these wastes to river or land, without prior treatment causes serious problems to the environment [3], [1].

III. Materials and Methods

3.1 Study Area

The study was conducted in 4 dairies in south India with processing capacity of 700000, 100000, **125000 and** 50000 litres per day in each dairy named as Dairy-A, Dairy-B, Dairy-C, Dairy-D. As instructed by the Dairy authorities and as directed by the experts, it is unable to provide the name of the Dairies along with the data. The study was carried out during the period of January – December in the year 2014.

3.2 Methodology

Sampling was done as per standard methods prior to the treatment and after treatment of waste water [APHA][10]. Analysis for BOD, COD and Oil & Grease were carried out in all samples in accordance with standard procedures and BOD_5/COD ratio was determined. This includes determination of ranges and mean values of biodegradability indices in an attempt to make a kind of zoning for the BOD/COD ratio (biodegradability index) [6].

The test results were tabulated for detailed analysis and interpretations.

IV. Results and Discussions

The initial studies were conducted in the four Dairies which are mentioned above. Table 1 describes the four dairies about its processing capacity, water consumption, waste water generated and capacity of ETP.

Table 1 Detail of Water Consumption And Waste Water Generation In Litres

Sl No	Name of Dairy	Capacity of Dairy	Water Consumption	Waste water generated	Capacity of ETP
1	Dairy - A	700000	1540000	1447600	1500000
2	Dairy - B	125000	312500	296875	300000
3	Dairy - C	100000	220000	208032	200000
4	Dairy - D	50000	125000	116250	100000

4.1 General Processing units of Dairies

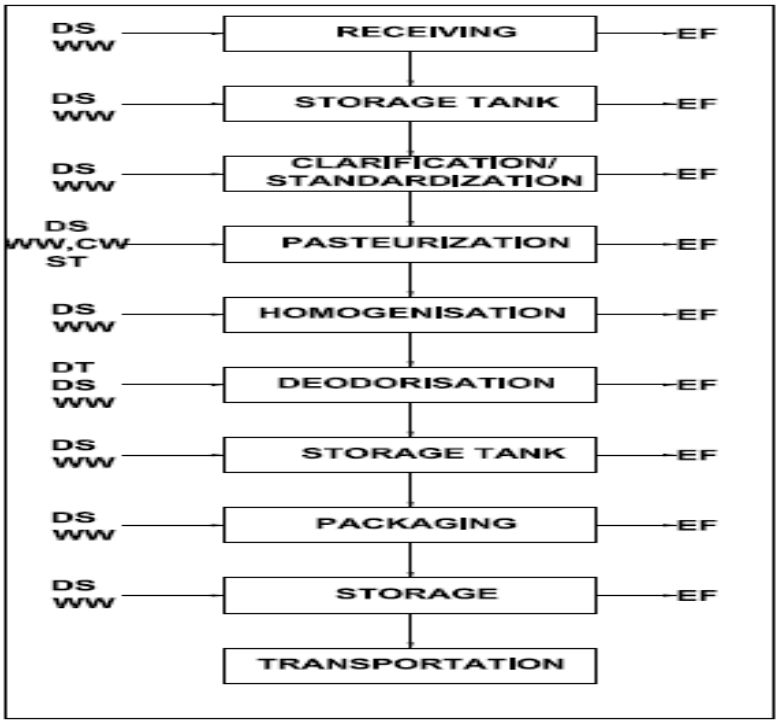

Fig.1 Process diagram of a Dairy

Figure 1 describes typical general processing units of a dairy. But the units are always varying depending on the products of the dairy. Characteristics of waste water varies according to the products manufactured in the dairy, it implies the generation of various waste water streams. Hence the units of the ETP's of the dairies may also be varied.

The characteristics of influent and effluent from dairy –A is depicted through Table 3. According to the environmental protection rules maximum allowable value for BOD of effluent discharge is 30mg/L and 100mg/L for water bodies and for land respectively. Here, the value of BOD is seen in between 300-400mg/L in the year. It is much higher than the permissible value and further treatment is essential to match with standard effluent discharge standards. The value of COD is seen very much higher than the maximum allowable value 250mg/L, to discharging to the water bodies and COD should be zero for disposing to the land. As this reason, the effluent requires further treatment to make it to the permissible level. The maximum value of Oil & Grease content of effluent discharge is 10mg/L for discharging to both water and land. In Dairy –A, it is greater than the permissible value in standard, so this require further treatment.

Table 2 Effluents Discharge Standards

Sl No	Parameters	ISI Standards	
		Water Body	Land
1	pH	5.5-9.0	5.5-9.0
2	BOD mg/L	30	100
3	COD mg/L	250	--
4	TSS mg/L	100	200
5	O & G mg/L	10	10

Table 3 Influent – Effluent Characteristics of Dairy- A

Characteristics of Dairy-A						
Date	BOD (mg/L)		COD (mg/L)		O & G (mg/L)	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Jan-14	1560	350	3368	747	236	41
Feb-14	1511	340	3400	800	240	42
Mar-14	1571	342	3406	788	245	45
Apr-14	1567	353	3401	789	250	46
May-14	1516	311	3398	752	249	43
Jun-14	1561	349	3393	728	241	43
Jul-14	1546	309	3361	733	240	40
Aug-14	1552	352	3370	738	238	35
Sep-14	1548	311	3381	724	232	32
Oct-14	1597	356	3396	773	240	42
Nov-14	1560	353	3432	755	241	43
Dec-14	1564	355	3440	762	249	40

Table 4 Influent – Effluent Characteristics Of Dairy- B

Characteristics of Dairy-B						
	BOD (mg/L)		COD (mg/L)		O & G (mg/L)	
Date	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Jan-14	1857	526	5253	1317	404	155
Feb-14	1788	482	5307	1417	413	127
Mar-14	1872	469	5316	1382	425	117
Apr-14	1867	530	5309	1428	435	165
May-14	1794	470	5303	1366	433	160
Jun-14	1858	495	5295	1297	414	128
Jul-14	1837	424	5242	1249	413	107
Aug-14	1845	528	5257	1301	408	140
Sep-14	1839	470	5275	1321	396	134
Oct-14	1909	505	5301	1330	414	126
Nov-14	1856	485	5360	1284	416	113
Dec-14	1862	532	5373	1341	433	153

Regarding dairy –B, the characteristic of influent and effluent tabulated in Table 4. In the case of BOD the maximum allowable value of effluent discharge is 30mg/L and 100mg/L for inland surface water and land irrigation respectively. The effluent from dairy – B it is seen that BOD value is in between 400-550mg/L in every month and the effluent has to be treated more for making the BOD level of the effluent to the permissible level. The value of COD is found near 1000mg/L for every month and it is very much greater than the allowable value. So it cannot be discharged to environment without further treatment. In Dairy –B value of Oil & Grease content is greater than the standard value (10 mg/L) of effluent discharge to the environment, so this require further treatment.

The characteristic of influent and effluent from Dairy – C is depicted through Table 5. Here, effluent from dairy – C, value of BOD is found much greater than the permissible value in every month in the year and further treatment is required for making the BOD level in the effluent to the permissible level. In the effluent from dairy –C also the value of COD is found near 1000mg/L for every month and it is very much greater than the limited value. For this reason, it cannot be discharged to environment without further treatment. The value of Oil & Grease content of effluent discharge from this dairy is in the range of hundreds which is greater than maximum allowable value 10mg/L, so this require further treatment for discharging to both water and land.

Table 5 Influent – Effluent Characteristics of Dairy- C

Characteristics of Dairy-C						
Date	BOD (mg/L)		COD (mg/L)		O & G (mg/L)	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Jan-14	1755	484	4210	1055	364	154
Feb-14	1700	458	4250	1138	369	140
Mar-14	1768	433	4257	1096	378	117
Apr-14	1763	460	4252	1111	385	133
May-14	1705	440	4248	1092	383	157
Jun-14	1756	468	4241	1048	370	141
Jul-14	1739	396	4202	996	369	110
Aug-14	1746	458	4213	1016	366	116
Sep-14	1741	440	4226	1058	358	140
Oct-14	1797	476	4246	1073	370	139
Nov-14	1755	446	4290	1023	371	114
Dec-14	1759	461	4300	1046	384	125

Table 6 Influent – Effluent Characteristics of Dairy- D

Characteristics of Dairy-C						
Date	BOD (mg/L)		COD (mg/L)		O & G (mg/L)	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Jan-14	1791	466	4296	1048	372	129
Feb-14	1735	439	4337	1133	377	115
Mar-14	1805	419	4344	1096	386	97
Apr-14	1799	446	4339	1110	393	112
May-14	1740	409	4335	1074	391	120
Jun-14	1792	465	4328	1056	378	131
Jul-14	1775	404	4288	1016	377	112
Aug-14	1782	431	4299	1000	374	82
Sep-14	1777	397	4313	1027	366	91
Oct-14	1834	461	4333	1070	378	117
Nov-14	1791	446	4378	1034	379	107
Dec-14	1795	459	4388	1056	392	116

In Table 6, the characteristic of influent and effluent from Dairy – D is tabulated. While taking the parameter BOD, in dairy- D, its value is greater than 400mg/L in most of the months and that is much greater than the permissible values for discharging to environment. Regarding the COD, the value is found much greater than the permissible limit insisted by the Environmental Protection rules 1986. For this reason, it cannot be discharged to environment without further treatment. The value of Oil & Grease content of effluent discharge from the dairy -D is much greater than the maximum allowable value 10mg/L. In view of this, it requires further treatment for discharging to water body or to land. Further, a comparison among the four dairy ETPs based on the removal efficiency of the selected parameters has been carried out.

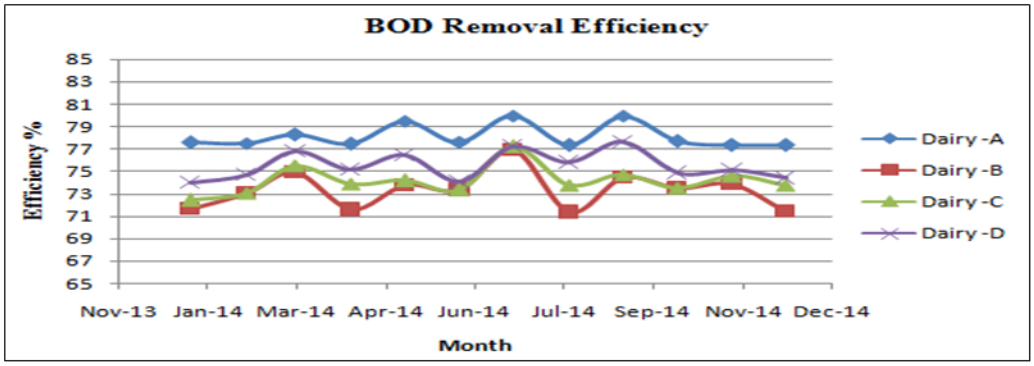

Fig. 2 Comparison of BOD Removal Efficiency

In the BOD Removal Efficiency comparison studies of the treatment plants is depicted through Figure 2. It is noticed that more than 75% of BOD removal was seen achieved through dairy A and also a consistency is seen in the performance of the ETP. Here, all the ETP's performance is seen consistent results in its own standard. No much fluctuation is seen in the efficiencies of the individual performance of the ETPs. In the month wise BOD removal comparison studies, the performance of the ETP of dairy –B seems to be inferior. This indicates that the stabilization of organic matters present in the effluent is not carried out properly. This may be due to the interference of other characters present in the effluent.

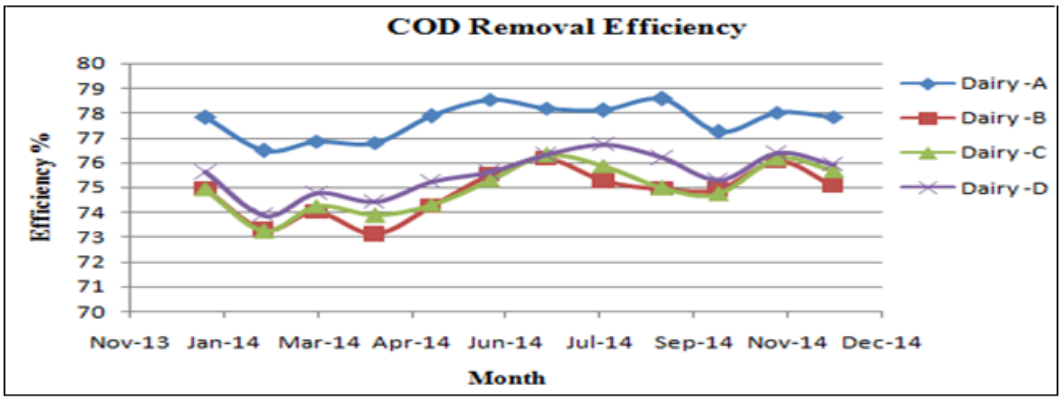

Fig. 3 Comparison of COD Removal Efficiency

In the COD Removal comparison studies of the treatment plants it is found that the performance of ETP of dairy –A ranking the first with an average value of 78%, which is depicted in Figure 3. COD removal of other ETPs is almost in the same range with an average value of 75%. In the case of COD removal also the performance of ETP of dairy –B is inferior to the performance of others.

The comparison of removal efficiency of Oil & Grease of the ETPs of dairies under study is depicted through the figure 4. The Oil & Grease removal through the ETP of dairy –A was noticed as more than 80%. It was also noticed that the removal efficiency in the other plants are seen an average of 65% only, that too with much fluctuation. This indicates that there is no uniformity of inflow in these plants.

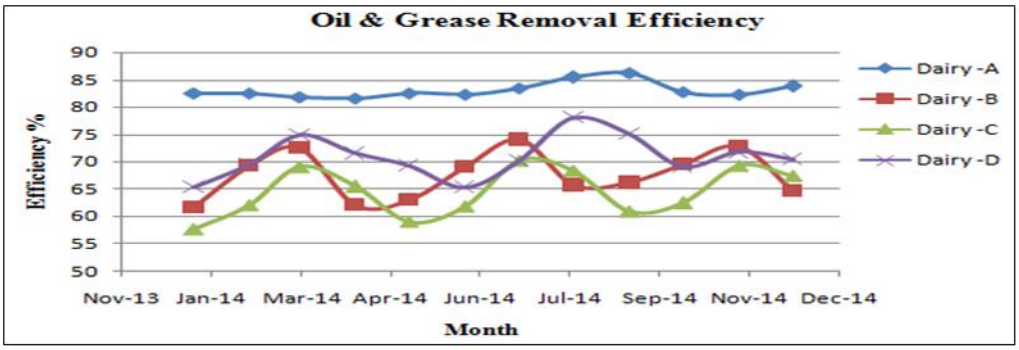

Fig. 4 Comparison of Oil & Grease Removal Efficiency

4.2 BOD/COD Ratio

The biodegradability of waste water can be decided by the BOD/COD ratio. Waste water having BOD/ COD ratio greater than 0.5 is fairly biodegradable, and can be effectively treated biologically. Seeding is required to treat the waste biologically if BOD/COD ratio is between 0.3 and 0.5, because the process will be relatively slow, as the acclimatization of the microorganisms that help in the degradation process takes time. If BOD/COD < 0.3, biodegradation will not proceed, thus it cannot be treated biologically, because the wastewater generated from these activities inhibits the metabolic activity of bacterial seed due to their toxicity or refractory properties [6], [8].

The influent values for the ratio of BOD/COD for the untreated and treated wastewater of the 4 dairies under study given in Table 7 and Table 8 are in the range from 0.34 to 0.48. The BOD/COD values indicate that the wastes from all the selected dairies are of not easily biodegradable. So, special attention and technology are to be provided to make the waste to the treatable conditions.

Table 7 BOD/COD Ratio of Untreated Waste Water

Comparison of BOD/COD Ratio of Untreated Wastewater				
Month	Dairy -A	Dairy -B	Dairy -C	Dairy -D
Jan-14	0.46	0.35	0.42	0.42
Feb-14	0.44	0.34	0.40	0.40
Mar-14	0.46	0.35	0.42	0.42
Apr-14	0.46	0.35	0.41	0.41
May-14	0.45	0.34	0.40	0.40
Jun-14	0.46	0.35	0.41	0.41
Jul-14	0.46	0.35	0.41	0.41
Aug-14	0.46	0.35	0.41	0.41
Sep-14	0.46	0.35	0.41	0.41
Oct-14	0.47	0.36	0.42	0.42
Nov-14	0.45	0.35	0.41	0.41
Dec-14	0.45	0.35	0.41	0.41

Table 8 BOD/COD Ratio of Treated Waste Water

Comparison of BOD/COD Ratio of Effluent				
Month	Dairy -A	Dairy -B	Dairy -C	Dairy -D
Jan-14	0.47	0.40	0.46	0.44
Feb-14	0.43	0.34	0.40	0.39
Mar-14	0.43	0.34	0.40	0.38
Apr-14	0.45	0.37	0.41	0.40
May-14	0.41	0.34	0.40	0.38
Jun-14	0.48	0.38	0.45	0.44
Jul-14	0.42	0.34	0.40	0.40
Aug-14	0.48	0.41	0.45	0.43
Sep-14	0.43	0.36	0.42	0.39
Oct-14	0.46	0.38	0.44	0.43
Nov-14	0.47	0.38	0.44	0.43
Dec-14	0.47	0.40	0.44	0.43

In this work, the BOD/COD of the influent of Dairy-A is in the range of 0.44 to 0.47 and that for the effluent is in the range of 0.41 to 0.48. This indicates that, even after the present treatment the effluent has not reached the disposable standards, which require further possibilities of treatments. In the case of Dairy-B, its influent is in the range of 0.34 to 0.36 and that for the effluent is in the range of 0.34 to 0.41. The results reveal that the quality of the treated effluent is poor and the present treatment facilities are totally inadequate to bring the effluent standards to a disposable status. Regarding the Dairy-C, the influent is in the range of 0.40 to 0.42 and that for the effluent is in the range of 0.40 to 0.46. Even though the treated effluent is below the range of biodegradability, much hope is seen through the results. In short, the present treatment facilities are not adequate, and needs further treatment before its final disposal. About the influent of Dairy-D is in the range of 0.40 to 0.42 and that for the effluent is in the range of 0.38 to 0.44. The ratio of the treated effluent indicates that the effluent is not reached to the permissible standards for disposal, which need further treatments.

V. Conclusions and Scope of further studies

1. Effluent Treatment Plants of Dairies C and D are seen overloaded than its installed capacities.
2. The BOD removal through the ETP of Dairy A was found as about 78% while the other Dairies performance was in the range of 70 to 77 %. In BOD removal, none of the Dairies have showed a consistent value during its monthly analysis.
3. 78% of COD removal was obtained through the Dairy A while an average value of 75% COD removal was obtained by other dairies. Compared to other dairies, Dairy A's monthly values reveal its consistency.
4. The Oil & Grease removal was about 80% for Dairy A and the other dairies removal efficiency was about 65%.
5. The BOD/COD found in all cases as less than 0.50, which indicate the poor biodegradability of the waste, need more attention in the treatment processes and to be treated before its final disposal.
6. Dairy –A was found to be more suitable for further studies.

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