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Comparison between Two Techniques for Dairy Industrial Wastewater Treatment Plant

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Abstract*—The dairy industry is a major enterprise in Egypt occupying a significant place in food supply. Its wastewater is a huge environmental problem that needs a special treatment. Our study covers a comparison between two techniques for wastewater treatment for one of JUHAYNA factories in 6th of October city, with a very small land availability and the high removal required for reuse effluent for landscape purposes.*

A pilot had been used consisted from two parallel lines. First line simulated the DBAF system plant and the second line simulated the DAF + SBR plant and operated for a period of three months.

From the study results it can be seen that the applied DBAF system that proposed to be made give the ability to meet the design flow and loads with high effluent criteria for BOD, COD, TDS, pH & TSS parameters. Also, it can be seen that the applied DAF + SBR system that applied gives the ability to meet the design flow and loads with high effluent criteria for BOD, COD, TDS, pH & TSS parameters.

In general all effluent results with DBAF system are more than enough for the drainage to the city sewerage system and meet the legal requirements for reuse for irrigation for landscape green areas due to the Egyptian environmental laws [1]. Also the system takes very small area and fit inside the available area inside the factory with no erection, operation or maintenance problems due to the shortage of area.

Also, all effluent results with DAF+SBR system are more than enough for the drainage to the city sewerage system and meet the legal requirements for reuse for irrigation for Jungle trees due to the Egyptian environmental laws [1]. In the other hand the system takes a small area but not fit inside the available area inside the factory that may cause erection, operation or maintenance problems due to the shortage of area.

***Keywords*—** *Industrial wastewater, Dairy industries waste water, Treatment of Wastewater, Biological treatment.*

I. INTRODUCTION

Dairy industries have huge growth in most countries of the world. The dairy industry is a major enterprise in Egypt occupying a significant place in food supply. Water is used throughout all steps of the dairy industry including cleaning, sanitization, heating, cooling and floor washing. Naturally the requirement of water is huge which, if not treated, could lead to increased disposal and several pollution problems. All steps in the dairy chain, including production, processing, packaging, transportation, storage, distribution, and marketing, impact the environment [1].

Normally biological treatment preceded by pretreatment units consists of screening, flow equalization, neutralization, and air flotation were applied in USA & Europe since 1910 with good results for the effluent to be disposed in stream bodies [2]. If space is available, land treatment or pond systems are potential treatment methods and applied in different countries around the world successfully to produce sufficient effluent for disposal in agricultural drain or reused in irrigation needs [3].

Other possible aerobic biological treatment systems include trickling filters, rotating biological contactors, and activated sludge treatment were used for dairy industrial wastewater treatment producing high removals for all pollutants [4].

Currently the government is taking serious steps towards protection the environment from pollution. The investigation of dairy factories in Egypt shows several treatments had been applied most of them achieved successfully results.

Beyti factory in Noubariya used neutralization tank followed by DAF unit that feeds SBR unit. This system achieved removal efficiencies for COD ranged from 98.87% to 94.72 %. The BOD removal range value that fluctuates between 99.6% and 98% with average 99%. TSS removal is between 98 % and 88% with average 93%. TDS removal is between 91 % and 57% [5].

The applying of SBR system in treating industrial wastewater of Nestla factory achieved COD removal efficiency 87% with organic loading rate 7.5 gm COD/L/day with retention time 5 days [6].

Two stages conventional activated sludge are used in Mesr for dairy factory in Damietta, with removal efficiencies varied between 89% and 94 % for COD, TSS and BOD and 82% for TDS [6].

Dissolved air floatation followed by roughing filter and finally conventional activated sludge are used in El Masryeen dairy factory in Giza producing effluent meets the limits for disposal to agricultural drains as environment laws limits [6].

EL Salehaya factory used oxidation ditchs and drain its effluent to irrigation system for the landscape of the factory and its surrounding street green areas [6].

Milky land factory in 10th of Ramadan city applied conventional activated sludge process and dispose its effluent to the city sewerage system safely [6].

Most of the medium and small dairy factories used septic tanks followed by disposal cesspool that caused several problems to environment specially the groundwater [6]

Several problems faced the applications of dairy industry wastewater treatment as the production increase, the change of loads, the variations in disposal points, the reuse needs, the change of laws limits the application of new procedure for no

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waste or cleaner industry and or the increase in the effluent quantities.

There are a lot of systems used all over the world to upgrade the existing industrial plants which need to increase production and flow with or without available land because of development in industrial, furthermore some factory used another line of production and increase in inlet flow they need for modification of existing plants and increase efficiency and quality of effluent wastewater before disposal into different location. The different methods will illustrated after to explain the application of dairy industry treatment in the world.

In 1995 *Monroy* [7] upgraded an existing wastewater treatment system of a cheese manufacturing industry in Mexico, The old treatment system was not effective enough to reduce the BOD, COD, TSS, and FOG to acceptable levels, although the final pH of 7.5 was within the recommended range. So, FOG tank of four sections is constructed (the first section is mechanical and emulsification then the second and third sections are floatation, the last section is gravity separation), then modified anaerobic pond followed by aerobic pond and finally water hyacinth pond. The modified wastewater treatment process resulted in an overall removal efficiency of 98% BOD, 96% COD, 98% TSS, and 99.8% FOG. The modifications ultimately resulted in a total operating cost increase of 0.4% at the factory

Pascod, presents that with land availability, land treatment or pond systems are potential treatment methods [2].

Pretreatment of effluent consists of screening, flow equalization, neutralization and air flotation to remove fats and solids followed by biological treatment was successfully applied by Macrino [3].

Other possible aerobic biological treatment systems include trickling filters, rotating biological contactors, and activated sludge treatment [3].

El Tokhy, et al., prove in their study the suitability of applying of DAF unit followed by SBR unit for treating the dairy factory effluent wastewater to meet the disposal limits to agricultural drain [5].

El Sergany, et al., determine the optimal operating limits for the DAF followed by SBR unit application for dairy factory to achieve the irrigation limits for effluent [8].

El Nadi, et al, improve a dairy industry conventional activated sludge process by pre DBAF unit to improve the plant quality to meet irrigation needs with minimum piping & area [9].

Rusten improved a Norwegian cheese factory to meet the wastewater treatment demands set by large increases in production. The process description after modification first is Equalization tank followed by two moving bed biofilm reactors then intermediate settling tank, chemical flocculation then final sedimentation tank and finally sludge storage chamber. So, the average removal efficiency of 98% for both the total COD and the total phosphorous content. Extreme pH values in the incoming wastewater were also efficiently neutralized in the equalization tank, resulting in a 7.0–8.0 pH range in the reactors [10].

In 10th of Ramadan city the improve the existing wastewater treatment plant in Milky land dairy factory to change its effluent quality to meet the needs for its reuse for irrigation of green areas in and surrounding the factory was done using pretreatment by DBAF unit that also make it deal with the increase in inflow by 100m3/day with the reality of no space for any extension [9].

Our study covers a comparison between two techniques for wastewater treatment for one of *JUHAYNA* factories in 6th of October city, with a very small land availability and the high removal required for reuse effluent for landscape purposes.

The factory consisted from two production lines in two buildings and the administration building and the wastewater treatment plant site which has an area about 10m x 20m. The factory is operated seven days a week for twenty-four hours per day on three shifts a day. About 30 labors works per shift.

The daily wastewater flow is about 400 m3 including both industrial and domestic wastewater. The required target is to use the effluent for landscape irrigation by spry system or drop system with fitting the plant in the available area in the factory.

II. Materials & Methods

A pilot had been used consisted from two parallel lines. First line simulated the DBAF system plant as presented by figure 1.

The second line simulated the DAF + SBR plant as presented by figure 2.

The DBAF pilot takes 30% of the DAF+SBR pilot area also it cost less by 40%.

The pilot operated for a period of three months. The operation program was applied on the laboratory scale pilot units according to several runs for the both lines with 1m3/d inflow for each line to determine the performance, efficiency and suitability of each system to be applied and chosen the best one of them whom covered all the requirements technically, environmentally and economically. The measured parameters BOD, COD, TSS, pH value & Temperature were made on weekly samples for the influent and effluent of each unit for each line.

The measurements were taken according to the American Standard Methods for Examinations of Water & Wastewater [11].

III. Results & Discussions

This step was made by operating the pilot plant for three months period to determine the best solution in performance, efficiency and operation. This was done by measuring the parameters of the weekly samples of the influent and effluent of each unit for each line. The results for both lines and the calculations for removal ratios for each step in each treatment line for COD, BOD and TSS are presented in tables from I to III as follows:

Table I shows COD results and table II shows the removal ratios for COD for each unit from each treatment line and for the whole plant for both tested lines during the study period.

According to tables I & II it can be seen that the removal efficiency for COD after primary plate settler tank for DBAF plant was between 18.31% & 31.67% and was between 30.00% & 52.00% after DAF unit for DAF+SBR system. That

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means for this primary treatment the removal efficiency for DAF is better than the removal efficiency for plate settler. This may be due to the dairy wastewater characteristics that filled with fats oily and colloidal matters that were suitable to be removed by floatation than settling.

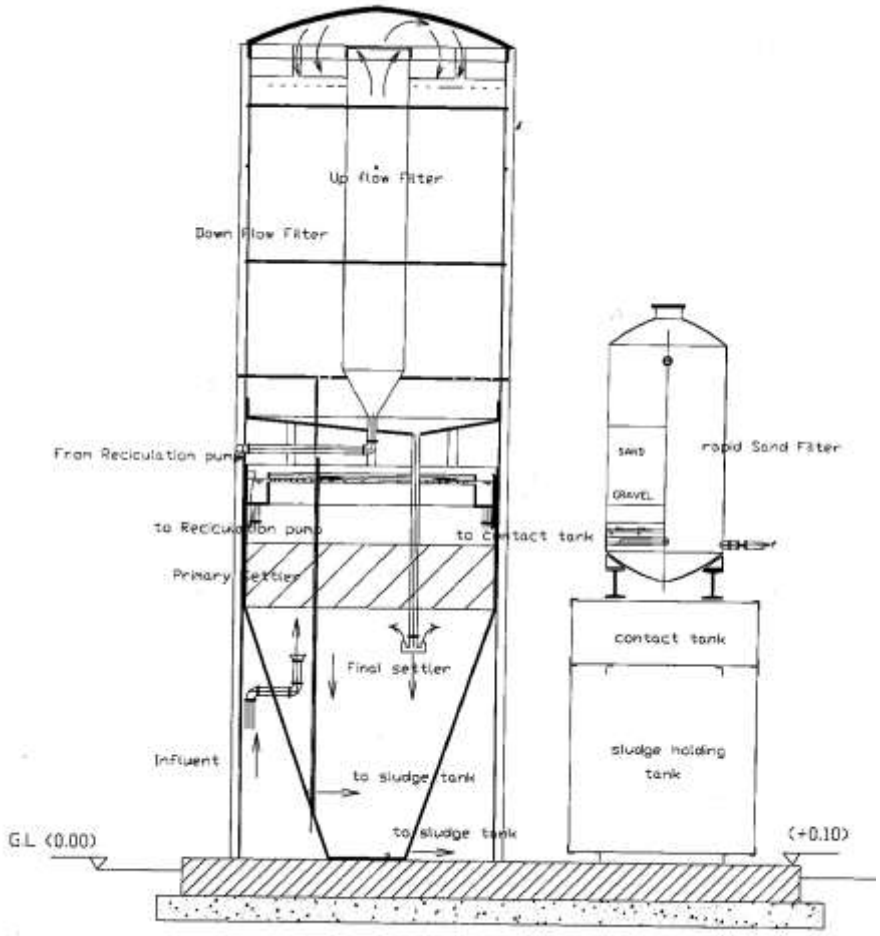

Fig. 1. First pilot line for DBAF system.

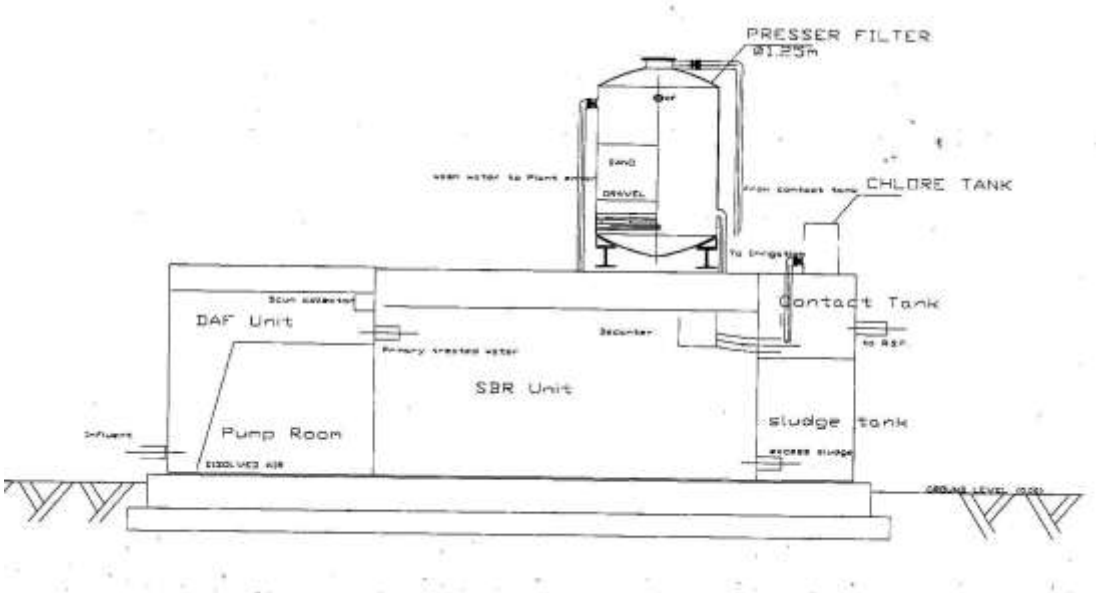

Fig. 2. Second pilot line for DAF + SBR plant.

El Nadi, M.H.; El Hefny, Z.A.M.; and El Hosseiny, O.M., "Comparison between two techniques for dairy industrial wastewater treatment plant," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 1, pp. 75-80, 2019.

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TABLE I. COD results at the DBAF & DAF+ SBR systems lines.

Sample		Raw WW	After Primary Treatment		After Biological Treatment		After Rapid Sand Filter		Law Limits for Irrig.
No.	Date		Line1	Line 2	Line1	Line 2	Line1	Line 2	
1	06/2/2018	4250	2960	2040	60	60	30	30	40
2	13/2/2018	4300	3090	2795	70	70	35	35	40
3	20/2/2018	4130	2990	2685	70	70	34	35	40
4	27/2/2018	4330	2950	2555	70	70	34	35	40
5	03/3/2018	3550	2900	2485	74	70	37	36	40
6	10/3/2018	3800	2900	2508	72	70	35	36	40
7	17/3/2018	3730	2980	2574	75	71	36	36	40
8	24/3/2018	4000	2980	2560	71	71	33	36	40
9	31/3/2018	4030	3000	2620	71	71	34	36	40
10	07/4/2018	3970	3010	2620	72	70	35	35	40
11	14/4/2018	3990	3000	2514	71	71	35	35	40
12	21/4/2018	4090	2990	2495	71	71	35	35	40
13	28/4/2018	4140	2980	2484	71	71	34	35	40

TABLE II. COD removal ratios at the DBAF & DAF+ SBR systems lines.

Sample		Raw WW	After Primary Treatment		After Biological Treatment		After Rapid Sand Filter		Total RR	
No.	Date		Line1	Line 2	Line1	Line 2	Line1	Line 2	Line1	Line 2
1	06/2/2018	4250	30.35	52%	97.97	96%	20.00	38%	98%	99%
2	13/2/2018	4300	28.14	35%	96.37	97%	20.00	33%	98%	99%
3	20/2/2018	4130	27.60	35%	96.50	97%	26.27	33%	98%	99%
4	27/2/2018	4330	31.87	41%	96.93	97%	17.89	33%	98%	99%
5	03/3/2018	3550	18.31	30%	96.56	97%	12.00	26%	98%	98%
6	10/3/2018	3800	23.68	34%	96.96	97%	12.22	27%	98%	98%
7	17/3/2018	3730	20.11	31%	96.67	97%	22.33	28%	98%	98%
8	24/3/2018	4000	25.50	36%	95.65	97%	30.77	24%	98%	98%
9	31/3/2018	4030	25.56	35%	95.97	97%	24.37	24%	98%	98%
10	07/4/2018	3970	24.18	34%	96.34	97%	20.75	27%	98%	98%
11	14/4/2018	3990	24.81	37%	96.21	96%	16.36	33%	98%	98%
12	21/4/2018	4090	26.89	39%	96.31	97%	17.27	29%	98%	99%
13	28/4/2018	4140	28.02	40%	96.68	97%	21.21	29%	98%	99%

The removal efficiency for COD after DBAF unit and final sedimentation tank was between 95.65% & 97.97% and was between 96 & 97% for SBR that shows a lower quality for the SBR unit compared with DBAF unit. This may be for the most of COD are undegradable for aeration action. Or may be for the additional anaerobic action that takes place in the biological filter system and do not appear in the activated sludge systems that destruct some of undegradable COD.

The total removal efficiency for COD for DBAF plant after rapid sand filter was between 12.22% & 30.77 % and for DAF + SBR plant was between 24% & 38% for all measured samples, which is good and high for such treatment type.

Effluent COD results are between 30 & 35 mg/l, for both plants which is more than enough for the drainage to the city sewerage system or to be drained to agricultural drains also for reuse for irrigation even for Jungle trees due to the Egyptian environmental laws [1].

The BOD results for both lines and the calculations for removal ratios for each step in each treatment line for BOD are presented in tables III & IV.

Table III shows BOD results and table IV shows the removal ratios for BOD for each unit from each treatment line and for the whole plant for both tested lines during the study period.

According to tables III and IV it can be seen that the removal efficiency for BOD after primary plate settler for DBAF plant was between 30.05% & 44.72% and was between 31.46% & 48.39% for SBR plant that shows for this treatment unit the BOD removal efficiency for both types are almost the same with some increase for Daf than the plate settler.

TABLE III. BOD results at the DBAF & DAF+ SBR systems lines.

Sample		Raw WW	After Primary Treatment		After Biological Treatment		After Rapid Sand Filter		Law Limits for Irrig.
No.	Date		Line1	Line 2	Line1	Line 2	Line1	Line 2	
1	06/2/2018	2250	1460	1420	39	40	20	20	30
2	13/2/2018	2300	1590	1550	40	43	21	22	30
3	20/2/2018	2130	1490	1460	40	50	21	25	30
4	27/2/2018	2330	1450	1420	40	49	22	25	30
5	03/3/2018	2550	1600	1560	44	46	23	23	30
6	10/3/2018	2800	1500	1460	38	40	19	21	30
7	17/3/2018	2730	1780	1750	36	40	18	21	30
8	24/3/2018	2000	1280	1250	38	39	19	20	30
9	31/3/2018	2030	1300	1270	32	40	17	20	30
10	07/4/2018	1970	1310	1280	32	47	16	24	30
11	14/4/2018	1990	1100	1080	34	42	17	22	30
12	21/4/2018	2090	1290	1260	35	47	18	25	30
13	28/4/2018	2140	1380	1350	30	40	16	20	30

El Nadi, M.H.; El Hefny, Z.A.M.; and El Hosseiny, O.M., "Comparison between two techniques for dairy industrial wastewater treatment plant," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 1, pp. 75-80, 2019.

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TABLE IV. BOD removal ratios at the DBAF & DAF+ SBR systems lines.

Sample		Raw WW	After Primary Treatment		After biological Treatment		After Rapid Sand Filter		Total RR	
No.	Date		Line1	Line 2	Line1	Line 2	Line1	Line 2	Line1	Line 2
1	06/2/2018	2250	35.11	36.89	97.33	97.18	48.72	50.00	99.11	99.11
2	13/2/2018	2300	30.87	48.39	97.84	97.23	47.50	48.84	99.09	99.04
3	20/2/2018	2130	30.05	31.46	97.32	96.58	47.50	50.00	99.01	98.83
4	27/2/2018	2330	37.77	39.06	97.24	96.55	45.00	48.98	99.06	98.93
5	03/3/2018	2550	37.25	38.82	97.25	97.05	47.73	50.00	99.10	99.10
6	10/3/2018	2800	46.43	47.86	97.47	97.26	50.00	47.50	99.32	99.25
7	17/3/2018	2730	34.80	35.90	97.98	97.71	50.00	47.50	99.34	99.23
8	24/3/2018	2000	36.00	37.50	97.03	96.88	50.00	48.72	99.05	99.00
9	31/3/2018	2030	35.96	37.44	97.54	96.85	46.88	50.00	99.16	99.01
10	07/4/2018	1970	33.50	35.03	97.56	96.33	50.00	48.94	99.19	98.78
11	14/4/2018	1990	44.72	45.73	96.91	96.11	50.00	47.62	99.15	98.89
12	21/4/2018	2090	38.28	39.71	97.29	96.27	48.57	46.81	99.14	98.80
13	28/4/2018	2140	35.51	36.92	97.83	97.04	46.67	50.00	99.25	99.07

The removal efficiency for BOD after DBAF unit was between 96.91% & 97.98% fit with previous studies [12], while it was between 96.11% & 97.71% for SBR unit that illustrates a lower quality for the SBR unit compared with DBAF unit. This may be for the most of BOD are degradable for aeration action.

The removal efficiency for BOD for DBAF plant after rapid sand filter was between 45.00% & 50.00 % while, for DAF + SBR plant it was between 46.81% & 50.00% for all measured samples, which is good and high for such treatment type.

The total removal efficiency for BOD for DBAF plant in the effluent was between 99.01% & 99.34% while it was between 98.83%&99.25% for DAF+SBR plant for all measured samples which shows the stability of DBAF plant in its effluent and also its higher BOD removal efficiency compared with DAF+SBR system.

Effluent BOD results are between 16 & 23 mg/l, for DBAF plant while was for DAF+SBR plant between 20 & 25 mg/l which is more than enough for the drainage to the city sewerage system or to be drained to agricultural drains also for reuse for irrigation even for Jungle trees due to the Egyptian environmental laws [1].

Tables V & VI show results & removal ratios for TSS for each unit from the existing plant and modified existing plant during the study period.

TABLE V. TSS results at the DBAF & DAF+ SBR systems lines.

Sample		Raw WW	After Primary Treatment		After Biological Treatment		After Rapid Sand Filter		Law Limits for Irrig.
No.	Date		Line1	Line 2	Line1	Line 2	Line1	Line 2	
1	06/2/2018	550	350	320	36	40	18	20	30
2	13/2/2018	500	350	300	34	40	17	20	30
3	20/2/2018	630	430	400	35	40	17	19	30
4	27/2/2018	530	330	300	30	36	15	18	30
5	03/3/2018	550	350	330	33	41	15	20	30
6	10/3/2018	500	350	320	34	43	16	21	30
7	17/3/2018	430	300	270	35	42	16	21	30
8	24/3/2018	500	350	310	34	40	16	20	30
9	31/3/2018	430	300	260	35	35	16	17	30
10	07/4/2018	470	320	290	30	39	15	19	30
11	14/4/2018	490	340	310	30	36	15	18	30
12	21/4/2018	390	270	240	30	37	15	18	30
13	28/4/2018	440	290	260	30	38	15	19	30

TABLE VI. TSS removal ratios at the DBAF & DAF+ SBR systems lines.

Sample		Raw WW	After Primary Treatment		After Biological Treatment		After Rapid Sand Filter		Total RR	
No.	Date		Line1	Line 2	Line1	Line 2	Line1	Line 2	Line1	Line 2
1	06/2/2018	550	36.36	41.82	89.71	87.50	50.00	50.00	96.73	96.36
2	13/2/2018	500	30.00	40.00	90.29	86.67	50.00	50.00	96.60	96.00
3	20/2/2018	630	31.74	36.51	91.86	90.00	51.43	52.50	97.30	96.98
4	27/2/2018	530	37.73	43.40	90.91	88.00	50.00	50.00	97.17	96.60
5	03/3/2018	550	36.36	40.00	90.57	87.58	54.55	51.22	97.27	96.36
6	10/3/2018	500	30.00	36.00	90.29	86.56	52.94	51.16	96.80	95.80
7	17/3/2018	430	30.23	37.21	88.33	84.44	54.29	50.00	96.28	95.12
8	24/3/2018	500	36.36	38.00	90.29	87.10	52.94	50.00	96.80	96.00
9	31/3/2018	430	30.23	39.54	88.33	86.54	54.29	51.43	96.28	96.05
10	07/4/2018	470	31.91	38.30	90.63	86.55	50.00	51.28	96.81	95.96
11	14/4/2018	490	30.61	36.73	91.18	88.39	50.00	50.00	96.94	96.33
12	21/4/2018	390	30.77	38.46	88.89	84.58	50.00	51.35	96.15	95.38
13	28/4/2018	440	34.09	40.91	89.66	85.38	50.00	50.00	96.59	95.68

From tables V & VI it can be illustrated that the removal efficiency for TSS after plate settler was between 30.00% & 37.73% for DBAF plant w and after DAF between 36.00% & 43.40% for DAF+ SBR plant. This treatment unit has low

El Nadi, M.H.; El Hefny, Z.A.M.; and El Hosseiny, O.M., "Comparison between two techniques for dairy industrial wastewater treatment plant," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 1, pp. 75-80, 2019.

quality compared with such tank type in similar treatment and this may be due to that the a lot of suspended solids are not settle able or colloidal types also a huge values of fats and O&G which make the DAF unit higher in its removal efficiency compared with sedimentation tank.

The removal efficiency for TSS after biological unit for DBAF system were varied between 88.33% & 91.86% while for SBR unit it was between 84.44% & 90% . This complies with normal cases for such types of treatment due to a biological action happened for soluble organic matters which increased the suspended colloidal matters. This raised the suitability of DBAF system to have better results than SBR one as illustrated by El Hefny in her M.Sc. Thesis [13].

The removal efficiency for TSS after rapid sand filter was between 50.00% & 54.55%, for DBAF plant and between 50.00% & 52.50% for DAF+SBR plant which is for this treatment unit with low quality for TSS removal due to the rest SS are the very fine colloidal matters that easy to escape from the sand filter.

The total removal efficiency for TSS for the DBAF plant was ranged from 96.15 % to 97.30 % while it was between 95.12% &96.98% for DAF+SBR plant for all measured samples which shows the high removal of the DBAF line than the DAF+SBR for such wastewater type.

Effluent TSS results are from 15 to 18 mg/l in DBAF plant and from 17 to 21 mg/l, in DAF+SBR plant which is more than enough for the drainage to the city sewerage system or to be drained to agricultural drains also for reuse for irrigation even for Jungle trees due to the Egyptian environmental laws [1].

IV. CONCLUSIONS

From previous work and results it can be seen that the application of both types of treatment were very successful to produce high quality effluent easy to disposed to environment by drainage in any water body or by reuse for irrigation for landscape inside the factory or for the city streets landscape.

In general all effluent results are more than enough for the drainage to the city sewerage system but it is above the legal requirements for reuse for irrigation even for Jungle trees due to the Egyptian environmental laws [1]. This means that there is a need for additional treatment by sand filtration if there is a need for reuse for irrigation.

In general the DBAF Plant achieved better results in removal efficiency for all measured parameters with the advantages of less in construction cost and area requested.

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