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Low Cost Developing for an Existing Dairy Industrial Wastewater Treatment Plant to Meet Additional Flows and Loads

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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 problem occurs from the increase in its wastewater flow from 300 to 650 m3/d, with unavailable land for new extension required for the existing WWTP.

A pilot had been used consisted from two parallel lines. First line simulated the existing plant and operated on design flow. The second line simulated the modifications in the existing plant and operated on double of the design flow of the existing for a period of three months.

From the study results it can be seen that the applied modifications that proposed to be made on the existing plant by use the plate settlers in both primary and final sedimentation tanks and modifying the entrance of the aeration tank to make it stepped aeration unit instead of conventional one give the ability to meet the additional flow and loads with the same or better criteria for the effluent specially for BOD, COD, TDS, pH & TSS parameters.

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.

Keywords- *Dairy Industry, Wastewater, Environmental*

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].

Nestla factory industrial wastewater treatment plant used SBR which achieved COD removal efficiency 87% with organic loading rate 7.5 gm COD/L/day with retention time 5 days [6].

In Masr for dairy factory in Damietta, two stages conventional activated sludge are used 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 10^{th} 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 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 problem occurs from the increase in its wastewater from existing 300 m3/d to 650 m3/d with unavailable land for new extension required for the existing WWTP. The factory consisted from the old production line building and the new production line building, the administration building and the wastewater treatment plant which lies underground in the front of the new production line. The factory is operated seven days a week for twenty four hours per day on three shifts a day. About 50 labors works per shift.

The existing wastewater treatment plant of conventional activated sludge system was built under the ground since 12 years ago. The existing inlet flow to the plant is $300m^3$/day including both industrial and domestic wastewater. In case of emergency and over flow conditions, a by Pass is used to direct the over flow to the city sewerage system.

The plant is consisted from four following units, primary sedimentation tank followed by aeration tank that is using surface aerator rotor then final sedimentation tank with under pipe for returned sludge from it to aeration tank and a sludge holding tank for sludge collection that disposed biweekly by evacuating car.

II. MATERIALS & METHODS

A pilot had been used consisted from two parallel lines. First line simulated the existing plant as presented by figure (1). The second line simulated the modifications in the existing plant to meet the total loads by applying plate settlers in both sedimentation tanks and use the step feed system in aeration tank with diffused air piping instead of surface aerator as presented by figure (2).

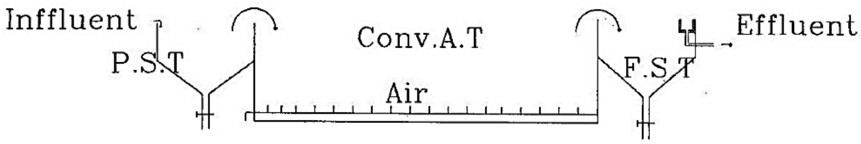

Figure 1. First Pilot Line for simulating Existing Plant

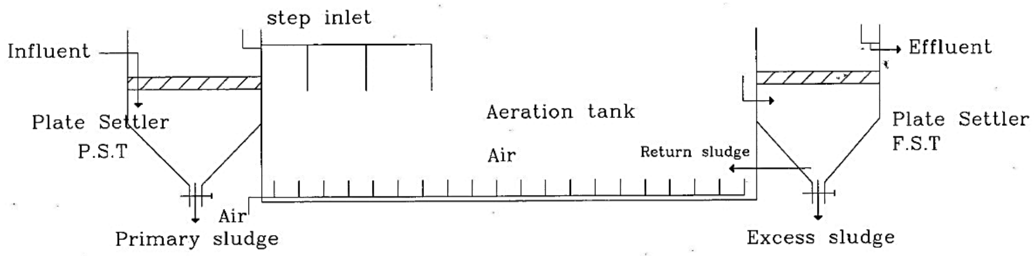

Figure 2. Second Pilot Line for Modified Existing Plant

The operation program was applied on the laboratory scale pilot units according to several runs for line one of existing plant and line two for modified of existing plant with double flow as shown in figure (3) for three months to determine the performance, efficiency and suitability of such system to be applied with measuring the parameters of biweekly samples for the influent and effluent of each unit for each line.

Samples were collected at inlet and outlet of each unit in all pilot lines and existing plant to evaluate and determine the performance and efficiency for each line and make the comparison between each system to obtain the optimal solution.

The water samples were analyzed for measuring BOD, COD, TSS, TDS, VSS, pH value & Temperature because these are the parameters mainly used for measuring waste water pollution. The measurements were taken according to the American Standard Methods for Examinations of Water & Wastewater [11].

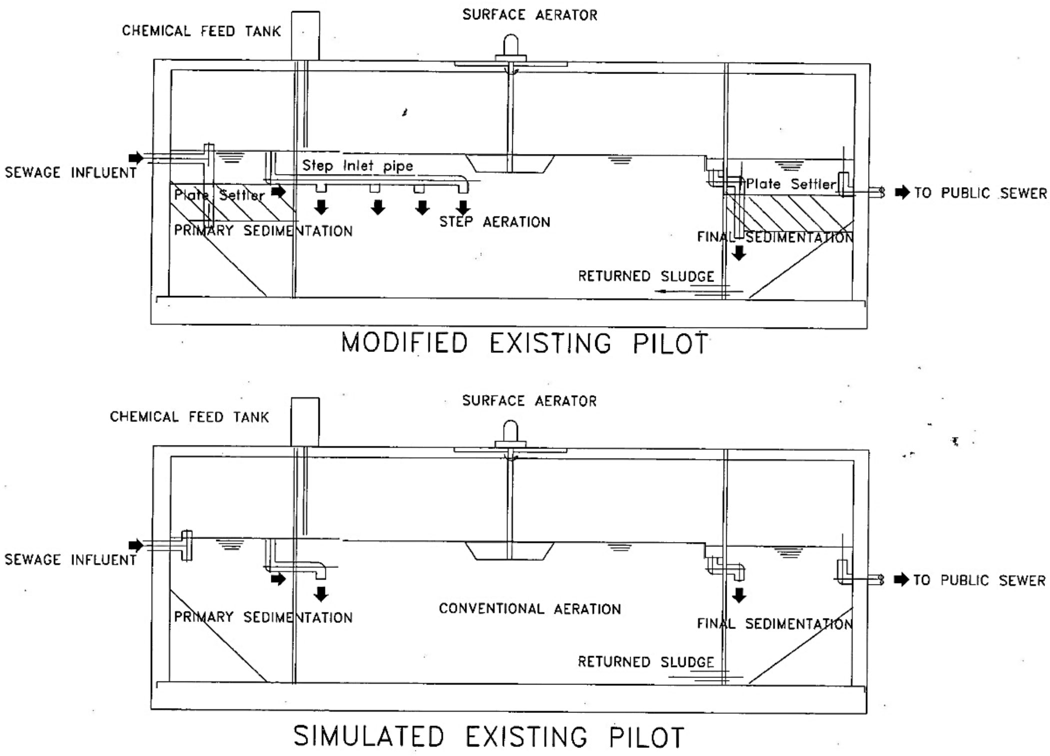

Figure 3. Operation of Modified with Existing pilot

III. RESULTS & DISCUSIONS

This step was made by operating the pilot plant for line one simulates the existing plant with design flow and line two that presents the modified existing plant with double of design flow. This was done for three months period to determine the best solution in performance, efficiency and operation. This was done by measuring the parameters of the biweekly 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, TDS and TSS are presented in tables from (1) to (5) and Figures from (4) to (6) as follows:

A. COD

Table (1) and Figure (4) show removal ratios for COD for each unit from each treatment line and also for the whole plant for the existing plant and the modified existing plant during the study period.

TABLE I. COD REMOVAL RATIOS AT THE EXISTING & MODIFIED EXISTING LINES

Sample		Raw WW	After PST		After AT		After FST		TOTAL RR	
No.	Date		RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	After Ex	After Mod
1	06/12/2016	4250	30.35	52%	96.67	96%	20.00	38%	98%	99%
2	13/12/2016	4300	28.14	35%	96.37	97%	20.00	33%	98%	99%
3	20/12/2016	4130	27.60	35%	96.50	97%	26.27	33%	98%	99%
4	27/12/2016	4330	31.87	41%	96.93	97%	17.89	33%	98%	99%
5	03/01/2017	3550	18.31	30%	96.56	97%	12.00	26%	98%	98%
6	10/01/2017	3800	23.68	34%	96.96	97%	12.22	27%	98%	98%
7	17/01/2017	3730	20.11	31%	96.67	97%	22.33	28%	98%	98%
8	24/01/2017	4000	25.50	36%	95.65	97%	30.77	24%	98%	98%
9	31/01/2017	4030	25.56	35%	95.97	97%	24.37	24%	98%	98%
10	07/02/2017	3970	24.18	34%	96.34	97%	20.75	27%	98%	98%
11	14/02/2017	3990	24.81	37%	96.21	96%	16.36	33%	98%	98%
12	21/02/2017	4090	26.89	39%	96.31	97%	17.27	29%	98%	99%
13	28/02/2017	4140	28.02	40%	96.68	97%	21.21	29%	98%	99%

According to table (1) and Figure (4) it can be seen that the removal efficiency for COD after primary sedimentation tank for existing plant was between 18% & 30% and was between 30% &52 for modified that means for this treatment unit the removal efficiency for modified better than the removal efficiency for existing. This may be due to the ability of plate settlers to remove the colloidal COD which was not able to be removed by normal sedimentation tank.

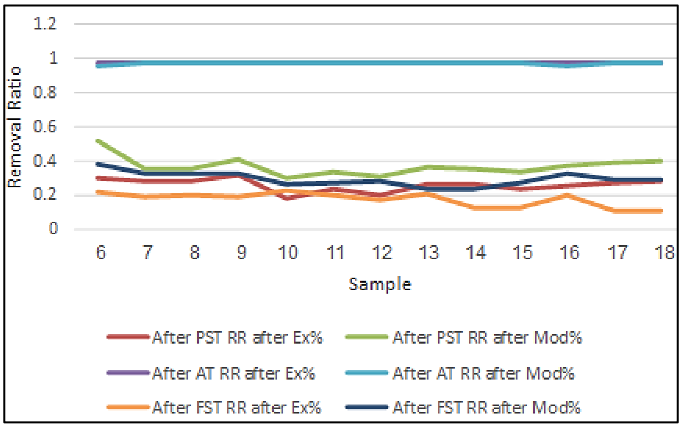

Figure 4. COD Removal Ratios at the Existing & Modified existing lines

The removal efficiency for COD after conventional aeration tank for existing plant was between 11% & 23% and was between 24% &33 for modified that means a low quality for the unit compared with a similar type of treatment units may for the most of COD are undegradable for aeration action. The removal efficiency for COD after final sedimentation tan for existing plant was 97% and was between 96 &97 for modified this treatment unit with low high quality for COD removal but actually it is normal for such tank type.

The total removal efficiency for COD for this existing plant in the factory was between 95% & 98% for existing plant and was between 98% & 99% for modified units all measured samples which is good and high for such treatment type.

Effluent COD results are between 70 & 80 mg/l, for existing plant and are for modified between 50 & 68 mg/l which is 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 if there is a need for reuse for irrigation.

B. BOD

Table (2) and Figure (5) show removal ratios for BOD for each unit from the existing plant and modified existing plant during the study period.

According to table (2) and figure (5) it can be seen that the removal efficiency for BOD after primary sedimentation tank for existing plant was between 30% & 46% and was between 30% & 46% for modified that means for this treatment unit the removal efficiency for modified have the same result the removal efficiency for existing.

The removal efficiency for BOD after conventional aeration tank for existing plant was between 97% & 96% and was between 97% & 96% for modified that means a high quality for the unit compared with a similar type of treatment units may for the most of BOD are degradable for aeration action. The removal efficiency for BOD after final sedimentation tan for existing plant was 25% to 2% and was between 47% &32% for modified this treatment unit with low quality for BOD removal but actually it is normal for such tank type.

TABLE II. BOD REMOVAL RATIOS AT THE EXISTING & MODIFIED EXISTING LINES

Sample		Raw WW	After PST		After AT		After FST		TOTAL RR	
No.	Date		RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	After Ex	After Mod
1	06/12/2016	2250	35%	35%	97%	97%	2%	42%	98%	99%
2	13/12/2016	2300	31%	31%	97%	97%	25%	45%	98%	99%
3	20/12/2016	2130	30%	30%	96%	97%	33%	40%	98%	99%
4	27/12/2016	2330	38%	38%	96%	96%	32%	44%	98%	99%
5	03/01/2017	2550	37%	37%	97%	97%	21%	37%	98%	99%
6	10/01/2017	2800	46%	46%	97%	97%	-5%	36%	99%	99%
7	17/01/2017	2730	35%	35%	97%	97%	18%	38%	98%	99%
8	24/01/2017	2000	36%	36%	96%	96%	22%	35%	98%	98%
9	31/01/2017	2030	34%	34%	96%	96%	21%	40%	98%	98%
10	07/02/2017	1970	45%	45%	96%	95%	15%	32%	98%	98%
11	14/02/2017	1990	38%	38%	97%	96%	13%	33%	98%	98%
12	21/02/2017	2090	36%	36%	97%	97%	25%	38%	98%	98%
13	28/02/2017	2140	35.5	35.5	97.1	96.5	25%	47.37	98.6	98.6

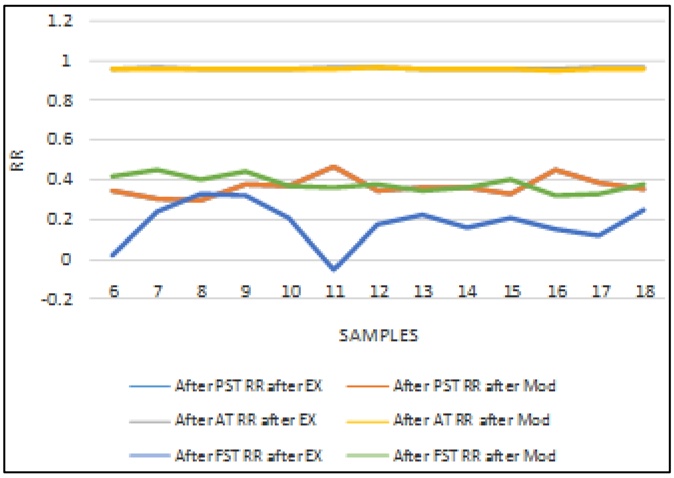

Figure 5. BOD Removal Ratios at the Existing & Modified existing lines

The total removal efficiency for BOD for this existing plant in the factory was between 98% & 99% for existing plant and was between 98%&99% for modified units all measured samples which is good and high for such treatment type.

Effluent BOD results are between 30 & 80 49mg/l, for existing plant and was for modified 29 & 34 mg/l which is more than enough for the drainage to the city sewerage system but it is above 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 if there is a need for reuse for irrigation.

C. TDS

Table (3) shows removal ratios for TDS for each unit from the existing plant and modified existing plant during the study period.

From table (3) the treatment plant overall efficiency for TDS removal was varied between 49% to 57% for existing plant and 49% to 56% for modified plant with average 50%. Influent varies from 1970 mg/l to 2250mg/l for existing plant and 1970 mg/l to 2250mg/l for modified plant also the same influent with average 2110 mg/l. Effluent varies from 890 mg/l to 1400 mg/l for existing plant and890 mg/l to 1400 mg/l for modified plant with average 1110 mg/l.

Effluent TDS is higher than influent after the aeration tank unit due to the biological action happened for soluble or suspended organic matter which increased the dissolved fractions inside the aeration tank that made the removal ratios with negative sign for existing plant, but in modified plant all the numbers in positive sign that means Effluent TDS is lower than influent after the aeration tank that means the modified plant have good quality in removal TDS than existing plant.

The TDS removal improved slightly at the final sedimentation due to the role of bacteria on the soluble fractions and the chemical reactions that may appeared due to the destruction of the organics with the other chemicals in wastewater.

All TDS effluents comply with the effluent standards of Egyptian environmental laws [1] for disposal in both sewerage systems or in irrigation for any type of agriculture. That means the existing plant in the factory has normal attitude for TDS. But the efficiency of modified is better than the efficiency of the existing plant in this parameter.

TABLE III. TDS REMOVAL RATIOS AT THE EXISTING & MODIFIED EXISTING LINES

Sample		Raw WW	After PST		After AT		After FST		TOTAL RR	
No.	Date		RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	After Ex	After Mod
1	06/12/2016	2250	18%	18%	-22%	49%	49%	49%	49%	49%
2	13/12/2016	2300	13%	13%	-15%	57%	57%	57%	57%	57%
3	20/12/2016	2130	9%	9%	-10%	52%	52%	52%	52%	52%
4	27/12/2016	2330	13%	13%	-15%	56%	56%	56%	56%	56%
5	03/01/2017	2550	16%	16%	-19%	55%	55%	55%	55%	55%
6	10/01/2017	2800	11%	11%	-13%	50%	50%	50%	50%	50%
7	17/01/2017	2730	11%	11%	-12%	51%	51%	51%	51%	51%
8	24/01/2017	2000	15%	15%	-18%	55%	55%	55%	55%	55%
9	31/01/2017	2030	15%	15%	-17%	54%	54%	54%	54%	54%
10	07/02/2017	1970	15%	15%	-18%	51%	51%	51%	51%	51%
11	14/02/2017	1990	15%	15%	-18%	55%	55%	55%	55%	55%
12	21/02/2017	2090	14%	14%	-17%	56%	56%	56%	56%	56%
13	28/02/2017	2140	14%	14%	-16%	54%	54%	54%	54%	54%

D. TSS

Table (4) and Figure (7) show removal ratios for TSS for each unit from the existing plant and modified existing plant during the study period.

From table (4) and Figure (7) it can be illustrated that the removal efficiency for TSS after primary sedimentation tank was between 30% & 38% for existing plant and the same for modified plant this treatment unit with low 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.

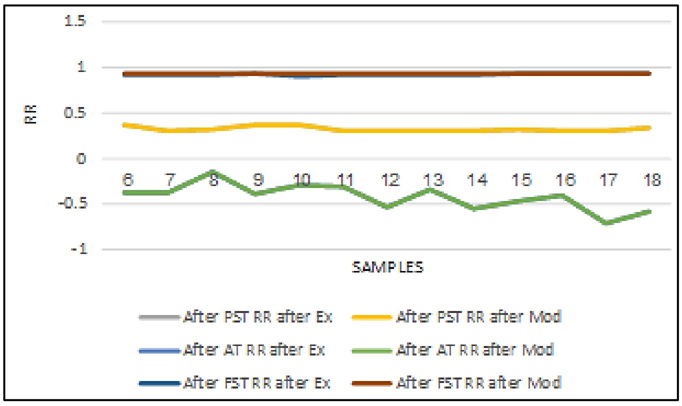

Figure 6. TSS Removal Ratios at the Existing & Modified existing lines

The removal efficiency for TSS after conventional aeration tank was with negative sign for the increase in their values due to a biological action happened for soluble organic matter which increased the suspended colloidal fractions inside aeration tank. This complies with normal cases for such type of treatment. That for both existing and modified plant

The removal efficiency for TSS after final sedimentation tank was between 94% & 90%, for both existing and modified plant this treatment unit with high quality for TSS removal but actually it is normal for such tank type. The total removal efficiency for TSS for this existing plant was ranged from 93 % to 92 % for existing plant and equal 92% &95% for modified plant with average 92 % for all measured samples which is good and high for such treatment type.

Effluent TSS results are 30 mg/l in modified plant and 40 mg/l, in existing plant which is more than enough for the drainage to the city sewerage system but it, is above 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 if there is a need for reuse for irrigation for existing plant but no need for this treatment in modified unit.

E. pH

Table (5) shows the variations in pH values through each unit from the existing plant and modified existing plant during the study period.

TABLE IV. TSS REMOVAL RATIOS AT THE OF EXISTING & MODIFIED EXISTING LINES

Sample		Raw WW	After PST		After AT		After FST		TOTAL RR	
No.	Date		RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	RR after Ex%	RR after Mod%	After Ex	After Mod
1	06/12/2016	550	36%	36%	-37%	-37%	92%	94%	93%	95%
2	13/12/2016	500	30%	30%	-37%	-37%	92%	94%	92%	94%
3	20/12/2016	630	32%	32%	-14%	-14%	92%	94%	94%	95%
4	27/12/2016	530	38%	38%	-39%	-39%	93%	93%	94%	94%
5	03/01/2017	550	36%	36%	-29%	-29%	91%	93%	93%	95%
6	10/01/2017	500	30%	30%	-31%	-31%	91%	93%	92%	94%
7	17/01/2017	430	30%	30%	-53%	-53%	91%	93%	91%	93%
8	24/01/2017	500	30%	30%	-34%	-34%	91%	94%	92%	94%
9	31/01/2017	430	30%	30%	-55%	-55%	92%	94%	92%	93%
10	07/02/2017	470	32%	32%	-47%	-47%	94%	94%	94%	94%
11	14/02/2017	490	31%	31%	-41%	-41%	94%	94%	94%	94%
12	21/02/2017	390	31%	31%	-70%	-70%	93%	93%	92%	92%
13	28/02/2017	440	34%	34%	-59%	-59%	93%	93%	93%	93%

TABLE V. PH RESULTS AT EXISTING & MODIFIED EXISTING LINES

Sample		Raw wastewater	After PST		After AT		After FST	
No.	Date		Ex.	Mod.	Ex.	Mod.	Ex.	Mod.
1	6/12/2016	9.45	6.42	6.42	7.50	7.50	7.50	7.50
2	13/12/2016	10.64	9.92	9.92	7.90	7.90	7.90	7.50
3	20/12/2016	10.90	9.20	9.20	7.80	7.80	7.80	7.50
4	27/12/2016	10.20	8.60	8.60	7.50	7.50	7.50	7.50
5	3/01/2017	11.70	5.13	5.13	7.70	7.70	7.70	7.50
6	10/01/2017	10.90	7.50	7.50	7.95	7.95	7.95	7.55
7	17/01/2017	6.50	6.30	6.30	7.70	7.70	7.70	7.50
8	24/01/2017	9.67	5.09	5.09	7.86	7.86	7.86	7.56
9	31/01/2017	6.89	6.04	6.04	7.17	7.17	7.17	7.57
10	07/02/2017	11.38	5.48	5.48	7.95	7.95	7.95	7.55
11	14/02/2017	10.39	8.07	8.07	8.07	8.07	8.07	7.57
12	21/02/2017	10.49	8.85	8.85	7.70	7.70	7.70	7.50
13	28/02/2017	9.45	6.42	6.42	7.50	7.50	7.50	7.50

The raw wastewater were in most cases alkaline with pH value varied between 9.45 and 11.38 but also some days it were nearby acidic with pH value 6.50 to 6.89 this due to a variation in the production line due to change the raw material source or the change of production procedure and additives or due to the production line cleaning.

In primary sedimentation tank the pH value decreased due to the settling of the suspended solids that may affect the raise of pH value but in a range between 1.0 to 3.0 units depending on the reflection of the settled matters on it and this for the both treatment lines. The aeration tank oxidation action fixed the variations of the pH values and make it about normal values between 7 & 8 units as slightly alkaline but suitable for bacterial activity for the both treatment lines. The final sedimentation tank had almost very little effect or no effect on the pH value than after aeration tank for the both treatment lines.

In general all the plant effluent pH values are inside the limits for Egyptian environmental laws [1] for disposal in city sewerage system or reuse in irrigation which is normal for both types of treatment.

IV. CONCLUSIONS

From previous work and results it can be seen that the applied modifications that proposed to be made on the existing plant by use the plate settlers in both primary and final sedimentation tanks and modifying the entrance of the aeration tank to make it stepped aeration unit instead of conventional one give the ability to meet the additional flow and loads with the same or better criteria for the effluent specially for BOD, COD, TDS, pH & TSS parameters.

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.

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