Dairy Industry Wastewater Treatment: Methods and Challenges

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ABSTRACT
This research to get the optimal solution for the treatment of wastewater for Labanita dairy factory, which lies in Noubariya City, Behira Governorate, Egypt.

A pilot lab scale was erected in the Labanita dairy factory laboratory. The pilot consisted from feeding tank followed by DAF unit followed by SBR unit. Different operation scenarios had been applied to determine the optimal operation procedure and the best removal efficiency.

Samples were taken continuously for 3 months from the inlet, outlet and between the units of treatment to determine the parameters (COD, TSS, TDS and pH), in order to get the removal efficiency for each unit as well as the overall efficiency.

The study illustrated the need of aeration system to be continuous that improved the dissolved oxygen stability in the SBR and improves the tank COD removal efficiency. The decreasing of chemical dose for soda or acid to 10% its used value not affected the DAF removal efficiency but improved the plant removal efficiency for COD & TDS and decrease the running cost for the minimization of chemical’s needs. The increasing of inflow after the fixation of the previous items achieved the required efficiency with 150% of the startup flow due to known design criteria. The decrease of aeration period in the SBR unit to 5 hours instead of 6 hours had achieved the higher removal efficiency for COD, TSS & TDS.

KEYWORDS: Industrial Wastewater Treatment, Dairy industrial wastewater. DAF, SBR.

INTRODUCTION
Milk production began as early as 6,000 years ago during the “Agricultural Revolution.” This was also the period in which ancient man learned to domesticate animals and recognized the nutritive value of their milk. From the early years until now, milk is a source of both energy and necessary nutrients for growth, and it is the only food of a young mammal in its first period of life. Milk also contains antibodies that are responsible to protect the young mammal against infection and diseases [1].

The dairy industry is a major enterprise in Egypt, occupying a significant place in food supply. This industry has been identified as an important contributor to the pollution of waterways especially when large industrial establishments are involved.

Dairy industries have shown tremendous growth in size and number in most countries of the world, it considered to be the largest source of processing wastewater in many countries. These industries discharge wastewater which is characterized by high chemical oxygen demand, biological oxygen demand, nutrients, organic and inorganic contents. Such wastewaters, if discharged without proper treatment, severely pollute receiving water bodies. The dairy industry is characterized by the multitude of products and therefore production lines. Plants can have as few as one or two production lines or all of them (pasteurized milk, cheese, butter, etc.) [2].
The organic components of the wastewater from dairy processing operations can be classified as proteins, lactose and fat. The organic components in dairy processing wastewater are highly biodegradable. These will affect the environment in different ways depending on their biodegradability and their solubility **[3]**.

As evident from the low COD: BOD ratio the dairy wastes can be treated efficiently by biological processes. Moreover, these wastes contain sufficient nutrients for bacterial growth. Both high rates tricking filters and activated sludge plants can be employed very effectively for complete treatment of dairy waste. But these conventional methods involve much skilled persons and special type of equipments. Also, the low cost treatment method like oxidation ditches is applied. **[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. **Nesla factory** industrial wastewater treatment plant used SBR which achieved COD removal efficiency 87% with organic loading rate 7.5 gm COD/L. day and retention time 5 days. **Milky land factory** in 10th of Ramadan city used conventional activated sludge process improved by second stage Dual Flow Aerated Bio-filters (DBAF) unit after increasing hydraulic capacity of the factory and reuse the effluent in irrigation of green area instead damping it into city sewerage system **[5]**. **Beyti factory** in Noubariya used equalization tank followed by dissolved air floatation and then SBR unit **[6]**. Two stages conventional activated sludge are used in **Masr for dairy** factory in Damietta. Dissolved air floatation followed by roughing filter and finally conventional activated sludge are used in **El Masryeen** dairy factory in Giza. **EL Salahaya** factory used oxidation ditch. Most of the medium and small dairy factories used septic tanks followed by disposal cesspool that caused several problems to environment **[5]**. This lead to a need to solve this problem by using a treatment achieves minimum area with higher efficiency which may achieved by SBR or DBAF techniques. This study will investigate the SBR technique.

MATERIALS & METHODS

The work was applied on a lab scale pilot unit that was erected at **Labanita dairy factory** lab. The system is a bench scale continuous flow system and consists of three plastic tanks, feeding tank with volume 25 L it contains a float valve to adjust the head on the effluent, then it was followed by DAF unit with volume 2.8 L, the water enters from the bottom of the tank and chemicals were added (Acid or Soda to adjust pH value, Alum & polymer to help fats & G & suspended solids to float at tank surface), this tank is provided with a continuous air supply. Finally the SBR tank with volume 19 L, it is provided with system of aeration in the bottom of the tank, there was a gate move to the top water level and the bottom water level for decanting, SBR operated 3 cycles per day each cycle operates 8 hrs, 6 hrs aeration, 1 hr settle and 1 hr decanting.

The influent wastewater was taken from **Labanita dairy factory** raw sewage pump station wet well. **Figure (1)** shows the schematic flow diagram for the constructed pilot system and **figure (2)** shows the pilot photo. Also, **table (1)** shows the typical dimensions for the study pilot.

Table (1) Specification of the Study Pilot Unit

Unit	Diam. cm	Height cm	Water depth cm	Surface Area cm^2	water Volume Lit.	Ret. time min.	Inflow rate l / hr
Feeding tank	40	45	20	1256	25		1.0 for I&II scenarios 1.5 for scenario III
DAF	12	30	25	113	2.8	20	
SBR	35	40	20	961	19	480	

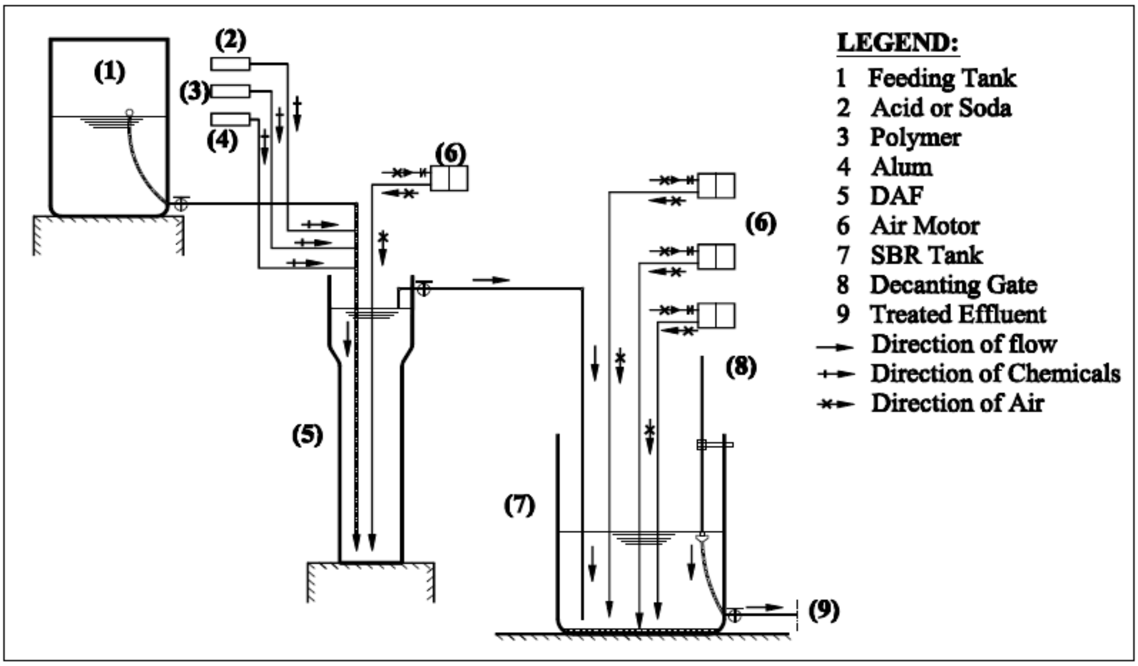

Figure (1) Flow Diagram for Pilot System

During the experimental work the first sample was taken from the feeding tank effluent that fed from the factory raw wastewater from raw sewage pump station wet well, the second sample was taken from DAF effluent and the third from SBR effluent. The analyses performed on these samples are pH–value, chemical oxygen demand (COD), total suspended solids (TSS) and total dissolved solids (TDS). The proposed samples locations at the plant are the feeding tank effluent, the DAF effluent and the SBR effluent and made their analysis at **Labanita dairy factory** lab.

Three operation scenarios had been applied, to determine the best operation loads and conditions suits with the sewage criteria and effluent properties. Table (2) illustrated the conditions of each scenario.

Table (2) Conditions of Operation Scenarios

Scenario Number	In flow l/hr	pH adjustable type & dose mg/l	Alum dose mg/l	Polymar dose mg/l	Air rate in SBR litair/litw/hr	SBR aeration period hr
I	**1.00**	**Sulfuric acid 375**	**250**	**8**	**6.7**	**6**
II	**1.00**	**Soda ash 37.5**	**250**	**8**	**10**	**6**
III-a	**1.50**	**Soda ash 37.5**	**250**	**8**	**10**	**6**
III-b	**1.50**	**Soda ash 37.5**	**250**	**8**	**10**	**5**
III-c	**1.50**	**Soda ash 37.5**	**250**	**8**	**10**	**4**

RESULTS & DISCUSSIONS

The applied three operation scenarios were made during the study period on three weeks for each of first and second scenarios and six weeks for third scenario which divided to three steps two weeks for each step.

FIRST SCENARIO

The first scenario operated for three weeks operation with biweekly sampling measurement. **Table (3)** shows the results of all measurements of the first scenario.

Table (3) Results at different pilot units in first scenario

Sample location	date	COD mg/l	TDS mg/l	TSS mg/l	pH
After feeding tank	04/12/2014	**2260**	**2420**	**630**	**6.50**
	07/12/2014	**2260**	**2420**	**630**	**6.50**
	11/12/2014	**2260**	**2420**	**630**	**6.50**
	14/12/2014	**2260**	**2420**	**630**	**6.50**
	18/12/2014	**2260**	**2420**	**630**	**6.50**
	21/12/2014	**2260**	**2420**	**630**	**6.50**
After DAF Unit	04/12/2014	**1931**	**4100**	**160**	**6.30**
	07/12/2014	**1915**	**4060**	**158**	**6.28**
	11/12/2014	**1890**	**4030**	**156**	**6.26**
	14/12/2014	**1877**	**3944**	**152**	**6.26**
	18/12/2014	**1860**	**3900**	**150**	**6.25**
	21/12/2014	**1850**	**3890**	**149**	**6.25**
After SBR Unit	04/12/2014	**1224**	**2040**	**60**	**6.10**
	07/12/2014	**210**	**1980**	**44**	**6.10**
	11/12/2014	**180**	**1930**	**36**	**6.11**
	14/12/2014	**130**	**1910**	**34**	**6.10**
	18/12/2014	**110**	**1900**	**30**	**6.09**
	21/12/2014	**106**	**1895**	**29**	**6.10**

Table (3) illustrated that the overall efficiency for COD removal varied from 46% at first week, then enters stability by 92%at second week up to 95.1% at the last week. DAF tank removal efficiency increased from 14.6 to 16.4 then 17.7 % and SBR removal efficiency increased from 36.6 to 90.5 then 94.1 %. Almost the pilot stabilized and achieved good results for COD parameter. But compared with litrature **[4&5]** for such system this values should be improved.

The TDS overall removal efficiency improved with time from 15.7% to 20.2% upto 21.5% at the third week. TDS removal efficiency for DAF unit appeared with negative values due to adding chemicals before DAF which increased amount of soluble organic matter. With respect to SBR tank the removal efficiency increased with time from 50.2 % to 51.3% at the third week.

The results illustrated the TSS overall removal efficiency increased from 90.5 %, 94.3% to reach 95.2 at third week. For DAF unit the removal efficiency improved from 74.6%, 75.2% to 76.2% at the last week. With respect to SBR tank the removal efficiency increased from 62.5% to 76.9% then 80%. Almost the pilot has stabilized and achieved results for TSS parameter with acceptable variation.

The pH values show the increase of acidity in the wastewater through the pilot that raise the change of adding acid to be alkaline.

SECOND SCENARIO

The aim of this step is to solve operational problems appeared in the first scenario in order to increase SBR efficiency as well as DAF efficiency. In this scenario six sets of samples had taken in three weeks two samples each week. Two modifications had been made one by change acid dose to alkaline dose with 0.1 its value and the second by increase added air to SBR by 1.5 of its value. **Table (4)** shows the results of all measurements of the second scenario.

Table (4) Results at different pilot units in second scenario

Sample location	date	COD mg/l	TDS mg/l	TSS mg/l	pH
After feeding tank	**24/12/2014**	2200	2380	650	6.50
	27/12/2014	2200	2380	650	6.50
	31/12/2014	2200	2380	650	6.50
	02/01/2015	2200	2380	650	6.50
	05/01/2015	2200	2380	650	6.50
	09/01/2015	2200	2380	650	6.50
After DAF Unit	**24/12/2014**	1800	2980	170	7.30
	27/12/2014	1740	3010	165	7.26
	31/12/2014	1720	3030	160	7.25
	02/01/2015	1710	3035	156	7.24
	05/01/2015	1700	3040	140	7.23
	09/01/2015	1700	3040	130	7.23
After SBR Unit	**24/12/2014**	194	1950	60	7.10
	27/12/2014	170	1930	35	7.09
	31/12/2014	160	1800	30	7.08
	02/01/2015	160	1800	28	7.05
	05/01/2015	100	1790	23	7.03
	09/01/2015	90	1770	20	7.00

Compared with first scenario it can be seen that the COD overall removal efficiency enhanced from 95.1% to 95.9 %, and DAF removal efficiency improved from 17.7% to 22.7%, as well as SBR removal efficiency increased from 94.1% to 94.7%. This shows that the two modifications improved the plant performance with decreasing chemicals addition.

The COD overall efficiency improved gradually with chemicals addition decrease due to the decrease in the amount of soluble inorganic fraction decreased. DAF COD removal efficiency increased after the chemicals addition decrease due to all chemicals added consumed in pH adjustment. SBR unit COD removal efficiency increased with chemicals addition decrease because adding chemicals affected bacterial activity it causes distribution for organic soluble matter structure in SBR unit which affected the removal efficiency. Also, the air increased in aeration period increased COD removal efficiency due to the continuation of aeration system that stabilized the DO inside the tank in good concentration (4-5ppm) which achieved high bacterial activity. Finally at the last day the pilot effluent comply with the environmental law 48/82 **[7]**.

Compared with first scenario it can be seen that the TDS overall removal efficiency increased from 21.5% to 25.6 %, and DAF removal efficiency improved from -61.2% to -27.7%, but SBR removal efficiency decreased from

51.3% to 41.8%. The decreasing amount of soda and acid increased the TDS overall removal efficiency to 24.4% at the first period then continuity of aeration system in SBR unit increased it to reach 25.6% at the second period. DAF removal efficiency decreased after the first modification from -25.2% at the first day to -27.7% at the last day .The negative values might be due to amount of soluble matter increased after adding chemicals. All SBR effluent comply the environmental law 48/82 **[7]**.

The pervious **table (4)** presented that TSS overall removal efficiency increased after decreasing soda and acid doses to 95.4% then it increased again after continuity of aeration system in SBR to 96.9%. Also, DAF removal eff. enhanced to 80 % instead of 76.2% in first scenario. As well as, SBR removal eff. increased to achieve 84.6 %. SBR effluent has improved.

In general decreasing the amount of soda or acid added before DAF unit improved the overall removal efficiency of the pilot for COD and TDS, In addition to enhance aeration system in SBR unit increased removal efficiency for COD and TSS as well as enhanced the pilot effluent to obey environmental law 48/82 **[7]** because amount of DO inside the tank increased so the activity of bacteria will improved.

THIRD SCENARIO

The aim of this step is to increase the working capacity of the existing plant by increasing the hydraulic load and decrease aeration time of SBR from six hours to five and four hours and show the optimum aeration time. In these step nine sets of samples had taken in six weeks two samples each week.

Three modifications were done one each two weeks the first was increase the inflow 50% of its main value as well as excess sludge withdrawal every day after decanting time, operate the pilot with this case for two weeks, the second decrease the aeration time to 5 hrs instead of 6 hrs with the new bigger flow for two weeks operation period and the third decrease the aeration time to 4 hrs with the new bigger flow also for two weeks. **Tables (5), (6) & (7)** presented COD, TSS and pH results for all pilot units during each phase of the scenario.

Tables (5), (6) & (7) show that COD overall removal efficiency decreased after increasing the inflow rate to reach 95.7% at the third day instead of 95.9% in the second scenario. After decreasing aeration time in SBR unit to 5 hrs the removal efficiency increased to 96.6%. But the decrease of aeration time to 4 hours decreased the COD removal efficiency to 95.8%. With respect to DAF unit the removal efficiency increased gradually with the increasing of the inflow rate from 32.9 % to 36.9% instead of 22.7% in second scenario. For SBR unit after the increasing the inflow rate the removal efficiency increased to 95.7%. The removal efficiency increased to 96.6% after decreasing the aeration time inside the tank to 5 hrs. Also, the SBR COD removal efficiency decreased to 95.3% after decreasing the aeration time inside the tank to 4 hrs. In all cases SBR effluent has obeyed the environmental law 48/82 **[7]**. **Tables (5), (6) & (7)** illustrated that after the inflow rate had increased the TSS removal efficiency decreased to 90.2% at the first phase instead of 96.9% in second scenario.

Table (5) Results at different pilot units in Third Scenario Phase 1

Sample		**COD**	**TSS**	**pH**
location	**date**	**mg/l**	**mg/l**	
After feeding tank	**11/01/2015**	3390	368	6.50
	15/01/2015	3390	368	6.50
	18/01/2015	3390	368	6.50
	22/01/2015	3390	368	6.50
After DAF Unit	**11/01/2015**	2274	170	7.30
	15/01/2015	2250	140	7.26
	18/01/2015	2200	127	7.25
	22/01/2015	2190	125	7.24
After SBR Unit	**11/01/2015**	114	50	6.80
	15/01/2015	100	40	6.80
	18/01/2015	95	36	6.80
	22/01/2015	94	33	6.80

Table (6) Results at different pilot units in Third Scenario Phase 2

Sample		COD	TSS	pH
location	**date**	**mg/l**	**mg/l**	
After feeding tank	**25/01/2015**	3390	368	6.50
	28/01/2015	3390	368	6.50
	01/02/2015	3390	368	6.50
	04/02/2015	3390	368	6.50
After DAF Unit	**25/01/2015**	1740	126	7.30
	28/01/2015	1725	120	7.26
	01/02/2015	1710	120	7.25
	04/02/2015	1700	120	7.24
After SBR Unit	**25/01/2015**	88	35	6.95
	28/01/2015	79	28	6.95
	01/02/2015	75	20	6.95
	04/02/2015	74	20	6.95

Table (7) Results at different pilot units in Third Scenario Phase 3

Sample		COD	TSS	pH
location	**date**	**mg/l**	**mg/l**	
After feeding tank	**08/02/2015**	3390	368	6.50
	11/02/2015	3390	368	6.50
	15/02/2015	3390	368	6.50
	18/02/2015	3390	368	6.50
After DAF Unit	**08/02/2015**	2260	122	7.30
	11/02/2015	2200	120	7.26
	15/02/2015	2150	120	7.25
	18/02/2015	2130	120	7.24
After SBR Unit	**08/02/2015**	106	44	6.88
	11/02/2015	99	39	6.88
	15/02/2015	93	32	6.88
	18/02/2015	91	28	6.88

In phase 2 TSS removal ratios increased gradually 90.5 %, 92.4% and 94.6% as a reason of decreasing aeration time to 5 hrs. Finally, in phase 3 the TSS overall removal efficiency decreased again to 90.5% due to decreasing the aeration time to 4 hrs.

DAF TSS removal efficiency affected with increasing the inflow rate it decreased to 67.4% instead of 80% in second scenario. Also, SBR removal efficiency had affected by increasing the inflow rate at the first phase to reach 71.7% instead of 84.6% in second scenario.

After decreasing the aeration time to 5 hrs the TSS removal efficiency increased again to 83.3%. Finally after decreasing aeration time to 4 hrs the SBR TSS removal efficiency decreased to 70.8%.

CONCLUSIONS

The lab scale pilot plant operated on several steps to cover all possible solutions by using the DAF followed by SBR. These different operation scenarios concluded the following points:

1. The modification of the aeration system to be continuous improved the dissolved oxygen stability in the SBR and improves the tank removal efficiency for COD & BOD.
2. The decreasing of chemical dose for soda or acid to 10% its used value not affected the DAF removal efficiency but improved the plant removal efficiency for COD & TDS and decrease the running cost for the minimization of chemicals needs.
3. The increasing of inflow after the fixation of the previous items achieved the required efficiency with 150% of the start up flow.
4. The decrease of aeration period in the SBR unit to 5 hours instead of 6 hours had achieved higher efficiency.

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