TREATMENT PROCESS SIMULATION OF WASTEWATER FROM A DAIRY PLANT USING COMPUTER SOFTWARE PACKAGE

Stefania Iordache[1] , Maria Iordan[1], Cezarina Necula[1]
[1]Faculty of Environmental Engineering and Biotechnology,
Valahia University of Târgovişte, Regele Carol I, nr 2,130024, Târgovişte, Romania
E-mail: stefania.iordache@yahoo.com

Abstract
The dairy industry involves processing raw milk into products such as consumer milk, butter, cheese, yogurt, condensed milk, dried milk (milk power), and ice cream, using a lot of specific processes. Dairy effluents contain dissolved sugars and proteins, fats, and possible residues of additives.. Cream, butter, cheese, and whey production are major sources of BOD in wastewater. Because of its high levels of protein and lactose, discharging wastewater from a dairy plant directly into the waterway could cause a severe pollution problem, most of all because of whey.
The paper presents computer simulation scheme for aerobic treatment of wastewater from dairy processing plants that generate an average of 525 m^3 of wastewater daily. The primary aim of simulation was to reduce the 5-d biochemical oxygen demand (BOD5) of the wastewater so that the effluent could be discharged to the municipal sewage.
It was simulated an aerobic treatment of wastewater from a dairy processing plant in two variants: using both a three-stage and a two-stage activated sludge plant. The simulation was realized using BioWIN 3.0, a simulator software package in which the user can define and analyze behavior of complex treatment plant configurations with single or multiple wastewater inputs. The simulation allowed to obtain some data regarding parameters of treatment process in order to increase the efficiency in operation.

Key words: process simulation, aerobic treatment, dairy wastewater.

1. INTRODUCTION

The dairy industry involves processing raw milk into products such as consumer milk, butter, cheese, yogurt, condensed milk, dried milk (milk powder), and ice cream, using different processes. Dairy effluents contain dissolved sugars and proteins, fats, and possible residues of additives. The key parameters that are important for wastewater treatment of dairy effluents, are biochemical oxygen demand (BOD) chemical oxygen demand (COD) (normally about 1.5 times BOD level), total suspended solids, phosphorus and nitrogen.
The volume of residual water from a milk processing plant depending on the type of milk product, processing capacity, technological water recirculation percent, etc. Table 1 presents average of key indicators for characterization of wastewater from dairy industry [1].
Cream, butter, cheese, and whey production are major sources of BOD in wastewater. The potential pollution problem regarding dairy effluents is much more increased because still exists some producers who decide to haul away the whey [2,6]. Because of its high levels of protein and lactose, discharging whey directly into the waterway could cause a severe pollution problem. Pretreatment of effluents consists of screening, flow equalization, neutralization, and air flotation (to remove fats and solids); this process is normally followed by biological treatment.
According with European regulation, pretreated

Table 1. Key parameters for wastewater treatment of dairy effluents

Type of Milk Processing Plant	Average of wastewater key indicators						
	Flow m^3 ww/ m^3 milk	COD [mg/l]	BOD_5 [mg/l]	TSS [mg/l]	Ammonia [mg/l]	Phosphor [mg/l]	Clor [mg/l]
Whole Milk	15	8000	4200	2600	180	120	400
Butter	15,7	15100	6500	5200	300	70	680
Cheese	41,0	62500	30200	31400	1600	650	14700

dairy effluents can be discharged to a municipal sewerage system, if the values of specific indicators are less than that are presented in table 2.

Table 2. Effluents requirements for direct discharge in surface water

Parameter	Units	Maximum value
pH	-	6,5-8,5
BOD	mg/L	300
COD	mg/L	450
TSS	mg/L	300
Total Nitrogen	mg/L	30
Total Phosphorus	mg/L	5
Temperature	° C	<40

The diary effluents levels presented in Table 3 should be achieved, if the effluents are discharged directly in surface water.

Table 3. Effluents requirements for direct discharge in surface water

Parameter	Units	Maximum value
pH	-	6 - 9
BOD5	mg/L	25
COD	mg/L	37,5
TSS	mg/L	50
Ammonia $NH4^+$	mg/L	10
Total Phosphorus	mg/L	1
Temperature	° C	<35

Aerobic treatment, such as activated sludge process, has been commonly used for wastewater from food industry, having in view its high levels of organic loads [2,4,5].
This paper presents a simulation scheme for the treatment of wastewater from a milk processing plant, having a production capacity by 35000 liter daily, that generated an average of 525 m3 of wastewater daily.
The primary aim was to develop a simple biological process to reduce the 5-d biochemical oxygen demand (BOD_5) of the wastewater so that the effluent could be discharged to the municipal sewage.
The secondary aim was to make a comparison between two treatment scheme: aerobic treatment with activated sludge, using three and two stages.

2. MATERIALS AND METHODS

In this study, an aerobic treatment with activated sludge was tested for the treatment of wastewater from a milk processing plant.
It was realized a simulation for an aerobic treatment using both a three stages and a two stages of biological scheme using the software package BioWIN 3.0, a simulator software package in which the user can define and analyze behavior of complex treatment plant configurations with single or multiple wastewater inputs.
In the simulation environment was designed the biological step for a milk processing plant which generates an average of 525 m3 of wastewater daily.
In the beginning, it was designed the biological step of wastewater treatment using a three-stage activated sludge aerobic treatment.
The 525 m3 biological step of wastewater treatment plant is composed of three stages of activated sludge treatment. The wastewater was treated sequentially for 1 hours in Stage 1 and 1.7 hours each in Stages 2 and 3. Effluent from Stage 3 overflowed to a 22 m3 circular settling tank. Part of the settled sludge (35%) was recycled to Stage 2 in order to maintain a mixed liquor volatile suspended solids (MLVSS) at a proper level. A part (14%) of settled sludge was discharged. The aeration system is used for maintaining the dissolved oxygen at a constant level by 2 mgO/L. Fine bubble diffusers were used for simulating the aeration. The dissolved oxygen level in each stage was kept at about 2 mg/L.
The scheme using three-stage activated sludge treatment is presented in figure 1.
In the second part of this study it was simulated the biological step of wastewater treatment using a two-stages of activated sludge treatment.
The wastewater was treated sequentially for 1 hours in Stage 1 and 1.7 hours in Stages 2. Effluent from Stage 2 overflowed to a 25 m^3 circular settling tank. Like in the primary scheme, a part of the settled sludge (35%) was recycled to Stage 2 in order to maintain a mixed liquor volatile suspended solids

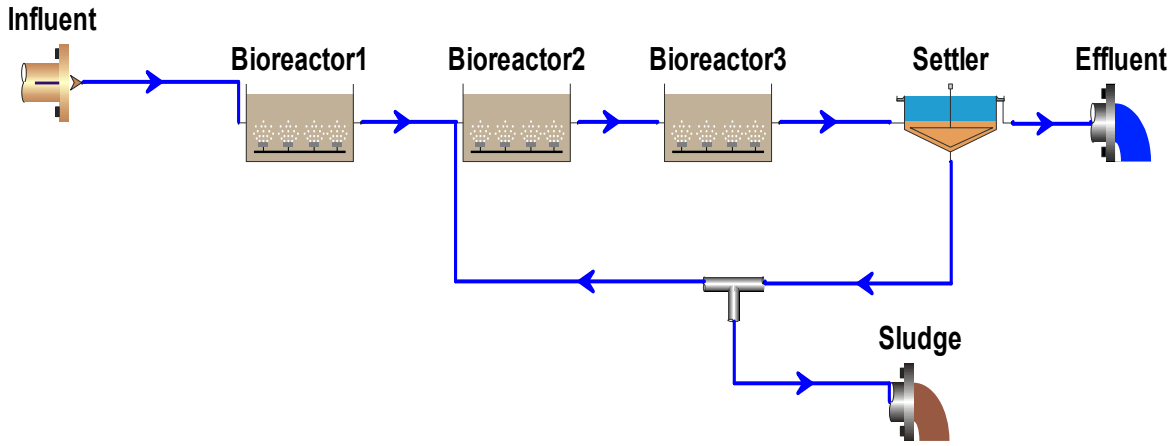

Figure 1 Simulation scheme for aerobic treatment using three stage activated sludge

(MLVSS) at a proper level. The dissolved oxygen concentration in each stage was maintained at a constant level by 2 mgO/L. Table 4 presents the dimension of bioreactors used for simulation.

Table 4. Bioreactors dimensions for aerobic treatment using three stages

Element name	Volume [m3]	Area [m2]	Depth [m]
Bioreactor1	22	7.33	3.0
Bioreactor2	55	12.22	4.5
Bioreactor3	55	12.22	4.5

3. RESULTS AND DISCUSSION

The computer simulation was realized having in view two situations:

- Aerobic treatment using three-stages activated sludge
- Aerobic treatment using two-stages activated sludge

For the first simulation treatment scheme (three-stages activated sludge) it was considered two variants, having in view the fact that pollutant levels in the wastewater from dairy industry fluctuated considerably.

The high degrees of fluctuation in the pollutant levels have been reported as a common phenomenon in dairy effluent. Pollutant levels in the wastewater fluctuated considerably. The high degrees of fluctuation in the pollutant levels have been reported as a common phenomenon in dairy effluent [3,8,].

The standard deviations of wastewater in the dairy processing plant could be around 50% to 70% of the averages for TOC, COD, and BOD_5, and 70% or more for Total Kjeldahl Nitrogen, Total N, TSS, and VSS [1, 9]

Table 5 summarizes the characteristics of the influent used for computer simulation foar aerobic treatment with three-stages activated sludge.

Table 5 – Characteristics of Influent

Element name	Influent Characterstics (Variant 1)	Influent Characterstics (Variant 2)
Flow	525	525
Total Carbonaceous BOD [mgBOD/L]	4200.00	900.00
Volatile suspended solids [mgVSS/L]	1872.00	350.00
Total suspended solids [mgTSS/L]	2600.00	500.00
Total Kjeldahl Nitrogen [mgN/L]	180.00	70.00
Total P [mgP/L]	110.00	27.00
Nitrate N [mgN/L]	12.00	12.00
pH	7.80	7.80

Table 6. Characteristics of effluents and efficiency of treatment scheme

Parameters	Variant 1(BOD=4200)			Variant 2 (BOD=900)		
	Influent Conc. [mg/L]	Effluent Conc. [mg/L]	Reduction of pollutant level [%]	Influent Conc. [mg/L]	Effluent Conc. [mg/L]	Reduction of pollutant level [%]
Total Carbonaceous BOD	4200.44	31.70	99.25	900.09	10.19	98.87
Total suspended solids	2600.68	47.19	98.19	500.14	13.49	97.30
Volatile suspended solids	1872.00	39.31	97.90	350.00	10.97	96.87
Total COD	7856.70	460.11	94.14	1659.43	103.80	93.74
Particulate COD	2994.30	61.03	97.96	559.81	16.69	97.02
Filtered COD	4862.40	399.08	91.79	1099.62	87.11	92.08
Soluble PO4-P	55.00	29.12	47.05	13.50	7.95	41.11
Total P	110.00	29.90	72.82	27.00	8.22	69.56
Filtered TKN	133.08	8.88	93.33	54.97	18.29	66.73
Particulate TKN	46.92	1.70	96.38	15.03	0.72	95.21
Total Kjeldahl Nitrogen	180.00	10.57	94.13	70.00	19.01	72.84
Filtered Carbonaceous BOD	3156.96	4.40	99.86	718.08	2.92	99.59
Nitrite + Nitrate	12.00	5.61	53.25	12.00	10.04	16.33
Total N	192.00	16.18	91.57	82.00	29.04	64.59
Total inorganic N	130.80	10.44	92.02	58.20	25.94	55.43
pH	7.80	5.64	27.69	7.80	6.91	11.41
Total inorganic suspended solids	728.68	7.88	98.92	150.14	2.52	98.32
Ammonia N	118.80	4.84	95.93	46.20	15.90	65.58

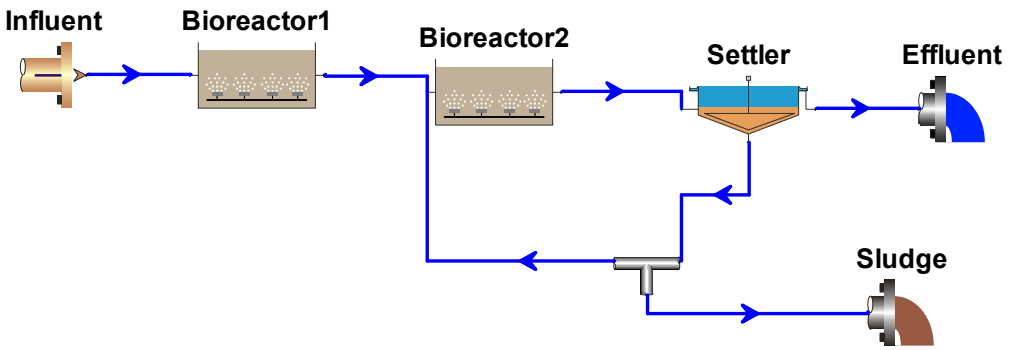

Figure 2. Simulation scheme for aerobic treatment using two-stage activated sludge

Results of computer simulation for the two variants taken into consideration are presented in Table 6.
It can be observed that it can be obtained good results for reducing of pollutants level in both variants, except the concentration of phosphorus that violates the regulation.
Having in view that aerobic treatment using three-stages activated sludge can lead to increasing of costs, it was simulated an aerobic treatment using twoe-stages activated sludge for the variant in which wastewater has a greater level of pollution (BOD5 = 4200 mg/L). The results are presented in table 7.

Table 7. Characteristics of effluents for two stages activated sludge treatment scheme

Parameters	Influent [mg/L]	Effluent [mg/L]	Reduction of pollutant level [%]
Total Carbonaceous BOD	4200	95.31	97.73
VSS	1872	88.26	95.29
TSS	2600.68	104.41	95.99
Particulate COD	2994.3	137.48	95.41
Filtered COD	4862.4	439.3	90.97
Total COD	7856.7	576.78	92.66
Soluble PO4-P	55	30.71	44.16
Total P	110	32.34	70.60
Filtered TKN	133.08	20.01	84.96
Particulate TKN	46.92	3.39	92.77
Total Kjeldahl Nitrogen	180	23.4	87.00
Nitrite + Nitrate	12	4.63	61.42
Total N	192	28.03	85.40
Total inorganic N	130.8	20.38	84.42
pH	7.8	6.24	20.00
Total inorganic suspended solids	728.68	16.15	97.78
Ammonia N	118.8	15.75	86.74

4. CONCLUSIONS

Because of its high levels of protein and lactose, discharging wastewater from a dairy plant directly into the waterway could cause a severe pollution problem.
The paper presents computer simulation scheme for aerobic treatment of wastewater from milk processing plants that generate an average of 525 m^3 of wastewater daily. The aim of simulation was to obtain some data regarding parameters of treatment process in order to increase the efficiency in operation, so that the effluent could be discharged to the municipal sewage
This study has demonstrated that wastewater from milk processing plant could be effectively treated aerobically. Computer simulation demonstrated that the BOD_5 of wastewater can be reduced by an activated sludge treatment having three or two stages.
The percent of reducing of BOD_5 is important in both situations that were simulated.
The results demonstrated that wastewater analyzed treated aerobically using a scheme with three-stages activated sludge is efficient from the point of view of reducing of pollutans level. It were obtained a reducing of BOD_5 by 99.25% in the variant1 and 98,87% in the variant2. It can be observed that all requirements imposed to the quality indicators of effluents were in the allowed levels, with a single exception: concentration of phosphorus in the treated effluent.
Even in terms of using biological step in two stages, reduction of level of pollutants allows compliance with quality indicators required, with the same exception, phosphorus concentration.

5. REFERENCES

[1] Banu C. s.a. Manualul Inginerului de industrie alimentara, Ed Tehnica, Bucharest, 1988, p.163-164.
[2] Herbert H. ,P. Fang - Treatment of Wastewater from a Whey Using Activated Sludge and Anaerobic Processing Plant Processes – Journal of dairy Science, vol 74 p2015-2019, 1991.

[3]Fang H.H.P. Anaerobic treatment of agricultural and industrial wastewater. Hong Kong Eng.17(2):9, 1989.

[4] Gilde L. and O. M. Aly - Water pollution control in the food industry. Page 5.1 in Industrial wastewater management handbook H. S. Azad, McGraw - Hill ed. 1976.

[5]-Landine, R C. Anaerobic treatment of dairy wastewater. Page 701 in Proc. 42nd Industrial Waste. Conference, Purdue Univ. West Lafayette,1988**.**

[6].Marshall,K.R,andW.J.Harper..'The treatment of wastes from dairy industry. *Page* 296 *in* Survey in industrial wastewater treatment. Part 1. D. Barns, C. F.Forster and S.E.Hmdey,ed. Pinan, Marshfield MA. l984

[7] J.-C. Frigon a, J. Breton a, T. Bruneau b, R. Moletta c, S.R. Guiot - The treatment of cheese whey wastewater by sequential anaerobic and aerobic steps in a single digester at pilot scale, Journal of Bioresource Technology 100 (2009) 4156–4163

[8] M Negulescu s.a,. Epurarea Apelor Uzate Industriale "Industrial Wastewater Treatment". Published by Ed Technica , Bucharest, 1989

[9] Vasso Oreopoulou, Winfried Russ - Utilization of By-Products and Treatment of Waste in the Food Industry, Springer; 1 edition, 2006

[10] Lawrence K. Wang, Yung-Tse Hung - Waste Treatment in the Food Processing Industry, CRC Press, 2006