Brazilian Journal
of Chemical
Engineering

ISSN 0104-6632
Printed in Brazil
www.abeq.org.br/bjche

Vol. 24, No. 04, pp. 487 - 497, October - December, 2007

EFFLUENT GENERATION BY THE DAIRY INDUSTRY: PREVENTIVE ATTITUDES AND OPPORTUNITIES

V. B. Brião[1]* and C. R. Granhen Tavares[2]

[1]Food Engineering Department, University of Passo Fundo, Phone: (+55) (54) 3316-8490,
Fax: (+55) (54) 3316-8455, Campus I. BR 285 km 171, Zip Code 99001-970,
PO Box 611, Passo Fundo - RS, Brazil.
E-mail: vandre@upf.br
[2]Chemical Engineering Department, University of Maringa, Phone: (+55) (44) 3261-4746,
Colombo Avenue 5790. Zip Code 87020-900, Maringá - PR, Brazil.
E-mail: celia@deq.uem.br

(Received: March 20, 2006 ; Accepted: September 2, 2007)

Abstract - Work aimed to identify the effluent is generating areas in a dairy company for the purpose of changing the concept of pollution prevention. The methodology consisted in measuring volumes and collecting samples of effluents in the production sectors. The analysis was conducted by sector, in order to identify those which generated excessive amounts of effluents. The results show that the dry products (powdered milk and powdered whey) are the greatest generators of BOD, nitrogen and phosphorus, while the products in fluid form (UHT milk, formulated UHT, pasteurized milk, pasteurized cream) and butter produced large quantities of oils and grease. Milk solids recovery, waste segregation and the water reuse can be applied with saving potential of as much R$ 28,000 ($ 11,200) per month only as in raw materials and also environmental gains in pollution prevention.
Keywords: Dairy; Pollution prevention; Wastewater; Milk.

INTRODUCTION

Of all industrial activities, the food sector has one of the highest consumptions of water and is one of the biggest producers of effluents per unit of production in addition to generating, besides to generate a large volume of sludge in biological treatment (Ramjeawon, 2000). The dairy industry is an example of this sector, in which the cleaning silos, tanks, heat exchangers, homogenizers, pipes and other equipment, engenders a large amount of effluents with a high organic load. This organic load is basically constituted by milk (raw material and dairy products), reflecting an effluent with high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), oils and grease, nitrogen and phosphorus. Moreover, the automatic cleaning system – CIP (cleaning in place) - discards rinse waters with pHs varying between 1.0 and 13.0, further complicating the question of treatment (Brião, 2000). BOD is directly related to milk wastes (90% to 94% of the effluent BOD), and in some cases losses can reach 2% of the volume processed by the industry (UNIDO, 1999a).

In order to reduce the effects of industrial sector pollutants, the end-of-pipe treatment techniques have been improved, at the same time prevention measures are being implemented in order to minimize the production of residues (Metcalf & Eddy, 1991).

End-of-pipe control captures wastewater after its generation, enabling its discharge into environment. These are peripheral solutions that focus primarily on the chemical, biological and physical treatment of terminal streams. However, they address the symptoms and not the true causes of the

*To whom correspondence should be addressed

environmental problems, and therefore, are not cost-effective or sustainable (Khan et al., 2001).

The essential feature of the pollution prevention program (P2) is the concept of "reduction at source", based on the idea that the generation of pollutant can be reduced or eliminated by increasing efficiency in the use of raw materials, energy, water and other resources (Cagno et al., 2005). Cleaner production intends to integrate the production aims in order to reduce the quantity and toxicity of residues and discharges in terms. Pollution prevention or source generation reduction refers to any praxis, process or technology that seeks the reduction or elimination of the volume, concentration or toxicity of generating source residues (CETESB, 2004; Figueiredo and Santos, 2000; Quaresma and Pacheco, 2000). The concept of cleaner production involves the reduction of negative environmental impacts throughout the product's, life cycle, from extraction of raw material to its final use. Finally, the rationalization of every product utilized, it results in a process savings, producing cheaper and consequently more competitive products (UNIDO, 1999a; SENAI, 1998).

The dairy company studied is a multiproduct factory and its wastewater treatment process is based on six steps: (a) screening; (b) use of Parshall flowmeter; (c) sandtrap/oil and grease separation in a tank; (d) flow equalization in a tank; (e) an activated sludged process; (f) tertiary treatment in three facultative lagoons. However, the process is almost overloaded and requires a more complete diagnosis.

On the other hand, minimization of the pollution index indicator must be evaluated, not only in terms of final treatment, but also as an opportunity to reduce production costs, by optimizing them and increasing process efficiency and profit.

The purpose of this work was to identify operations or processes in which there were opportunities for reducing the impacts of load and volume in effluent treatment at a dairy factory.

MATERIALS AND METHODS

Experiments

The method consisted of evaluating the load coefficient and the volumetric coefficient of the three macrosectors (which combine the production rooms) in a dairy factory. At the same time, behavior of the raw effluent in the treatment station was also analyzed, so that the experiments were conduted over a two-month period.

The macro sectors of the industry are milk reception, fluid products (UHT milk, formulated UHT, pasteurized milk, cream and butter) and dry products (powdered milk and powdered whey). An ultrasonic flowmeter was installed, pipelines that supply water for the washing of tanks, pipes and equipment in each sector or process. This measured water was evaluated in terms of effluent generated. The raw wastewater was measured by the Parshall flowmeter in the treatment station by means of an ultrasonic sensor associated with an on-line integrator (Figure 1). The volume of processed milk in each sector was obtained based on company production reports.

The volumetric coefficient (VC) in each sector was calculated as

$$VC = \frac{V}{v} \tag{1}$$

where V is the volume of effluent generated (or consumed water) and v is the volume of processed milk. The VC unit is shown in cubic meters of generated effluents for each cubic meter of processed milk.

The load coefficients (LC) were calculated for four parameters (BOD, nitrogen, phosphorus and oils and grease) as

$$LC = \frac{A * V}{v} \tag{2}$$

where A is the concentration (mg L^{-1}), V is the volume of effluent generated (L) and v is the volume of processed milk (L). The LC unit is given in milligrams of pollutant for each liter of processed milk, or kilograms of pollutant for each cubic meter of processed milk.

The pH was also measured in order to identify which sectors have the greater effect on the raw wastewater.

Analysis

Compound samples were analyzed. These samples were collected one per hour during the processes.

The analytical methods followed were those of the American Public Health Association – APHA (APHA, 1991). COD was determine, followed by a photometric quantification at 600 nm; nitrogen was analyzed by the classic "macro-Kjeldahl" method; phosphorus was analyzed through acid digestion and was quantified by the vanadomolybdophosphoric method; oils and grease were analyzed by the Soxleth gravimetric method and the pH by direct measurement with a pH meter. BOD was predicted based on company records and it was related to the COD. This COD/BOD ratio was 2.13 (Brião, 2000).

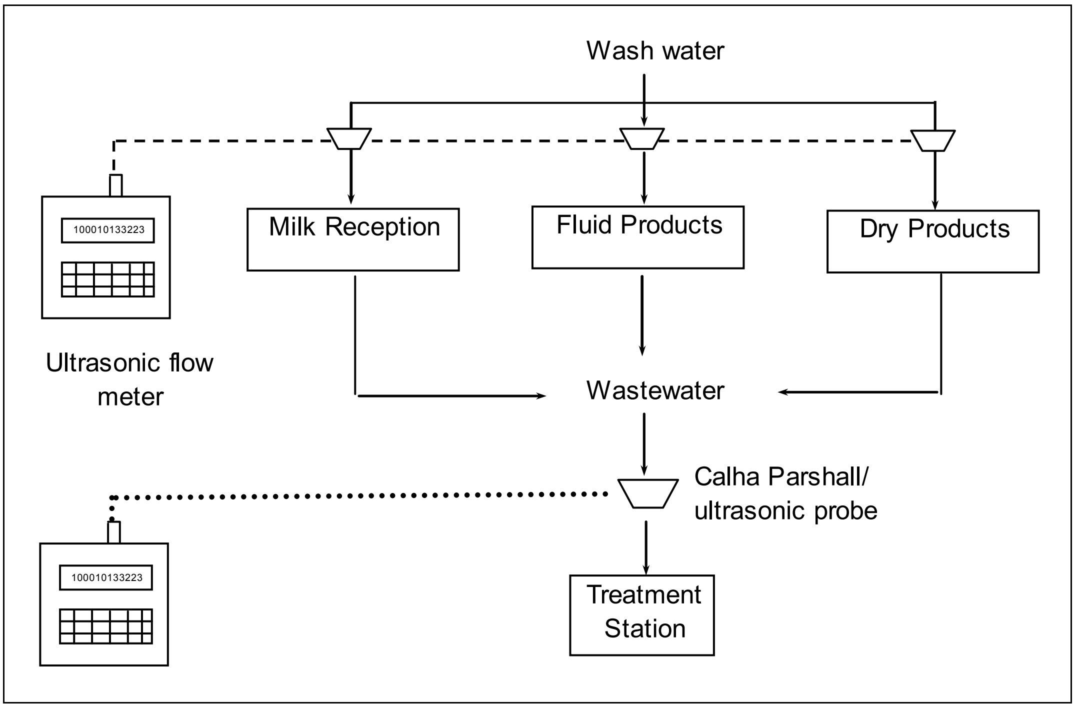

Figure 1: Diagram of macrosectors evaluated by measuring volumes and to collecting samples of wastewater

RESULTS AND DISCUSSION

Average Concentration in the Sectors Evaluated

The average pH values for the three macrosectors and the raw wastewater as well as average COD concentrations, nitrogen, phosphorus and oils and grease are shown in Table 1. The average values for the parameters, which are found in Table 1, do not indicate an excessive discharge load in the treatment system. However, the high standard deviations show that there was a large variation in the parameters evaluated.

Figure 2 illustrates an example of this variation in discharge load; it shows the evolution of COD over the time during which the evaluation was performed. It is possible to identify several peeks, showing that some operations discharge excessive loads on specific days even though they fall within the average values. Figure 3 shows the nitrogen concentration of streams evaluated whilst Figure 4 shows the phosphorus concentration of the same streams. Both figures show a similar behavior for COD; the average concentration is near the lowest acceptable value for treatment in a biological system. However, there are operations discharging excessive organic matter that could overload the treatment system.

Table 1: Average pH, COD and nitrogen, phosphorus and oils and grease concentrations for evaluated sector.

	pH	COD*	Nitrogen*	Phosphorus*	Oil and grease*
Milk reception	10.06±1.60	1794±980	45.3±24.6	25.2±14.2	253.3±105.2
Fluid products	9.62±3,69	2270±797	71.2±38.7	42.1±21.2	523.5±345.2
Dry products	10.43±2.87	2391±1928	88.2±72.9	55.0±38.9	296.6±166.3
Raw wastewater	10.45±1.77	2491±1226	69.4±46.6	37.5±21.1	286.8±217.9

* All values (except pH) in mg L^{-1}.

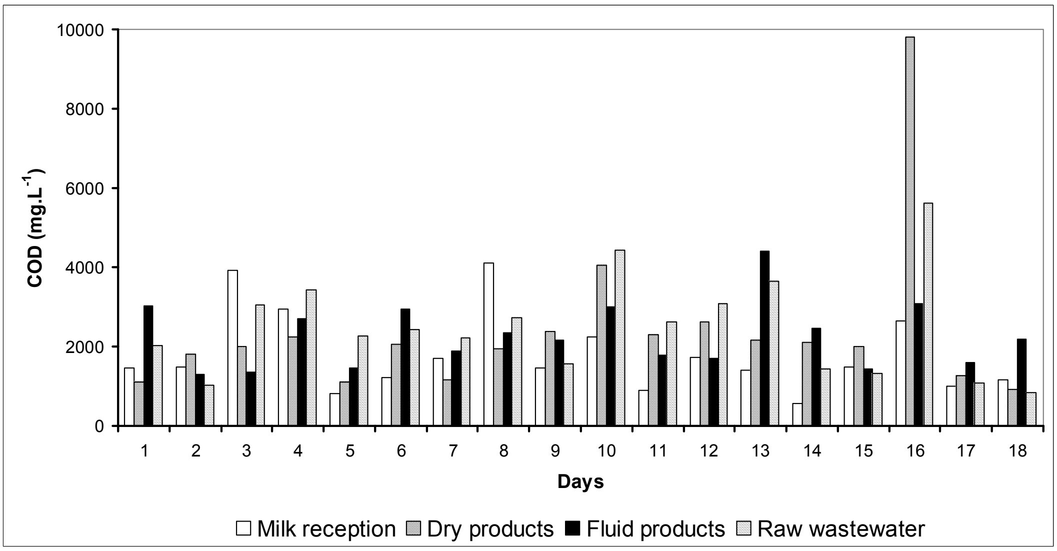

Figure 2: Evolution of COD in the macrosectors evaluated

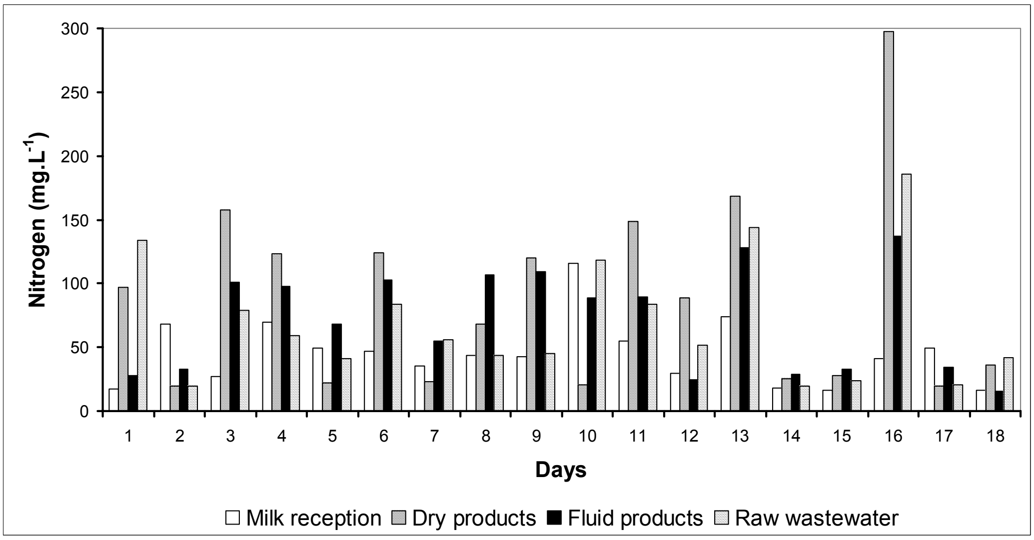

Figure 3: Evolution of nitrogen concentration in the experiments over time

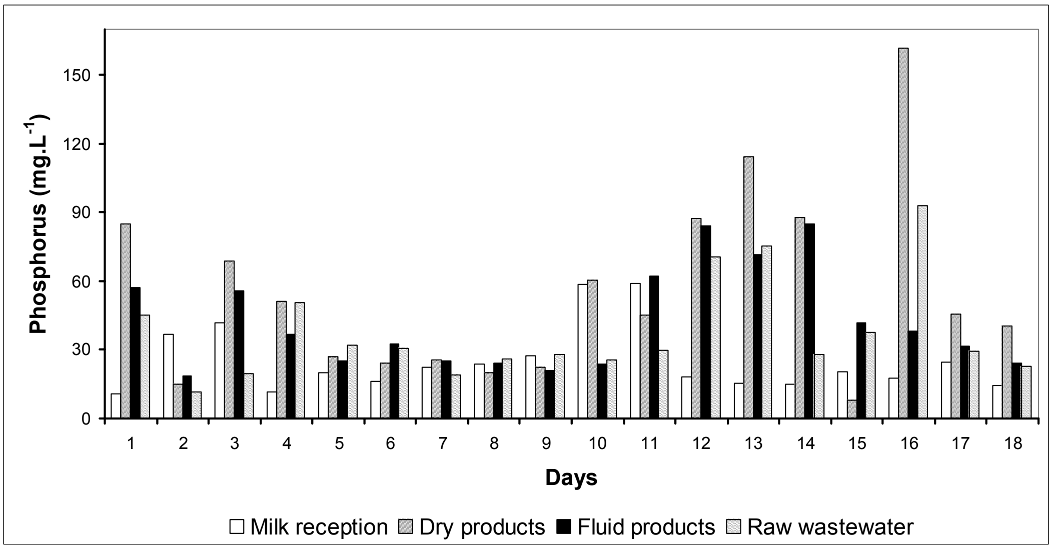

Figure 4: Evolution of phosphorus concentration in the experiments over time

Special attention should be given to the 16th (sixteenth) day, on which the highest value of COD was obtained. On this day, spray dryers used in the production of powdered milk and powdered whey were cleaned, discharging a high load into the wastewater treatment system. However, this cleaning occurs once every twenty days. The milk reception peaks (days 3 and 8) were obtained on rainy days, when the milk trucks arriving at the platform were covered with clay and mud, which had an effect on the COD value. However, the treatment station has a sand trap as the first step in the primary treatment, so there are no negative consequences of the treatment system. The average value for the fluid dairy factory COD is not considered critical (Table 1), but high the effluent value on day 13 shows a clear effect on the raw wastewater, which is attributed to the formulated UHT chocolate milk (a brown color in the sample) production wastes. For the dry products, the average COD value was about 2091 mg L^{-1}.

The increase in raw wastewater COD on the tenth day was related to the CIP solutions discharged by evaporators in the dry products sector (acid and alkaline solutions).

The behavior of pH is shown in Figure 5. Most of streams had of pH elevated values with an average value the raw wastewater of about 10.45 that reaches the station. This is explained by the alkaline cleanings of the CIP system. The alkaline cleanings aim at general fat saponification and removal of organic material. However, the alkaline cleanings are done with greater frequency (at the end of each production cycle), while the acid solutions are circulated once a week. The effects of acid solutions can be verified on days 5, 10 and 16, when a low pH in some sectors. Although, even when the acid cleaning was carried out, the small effect of pH did not reflect a drastic reduction in pH in the raw effluent.

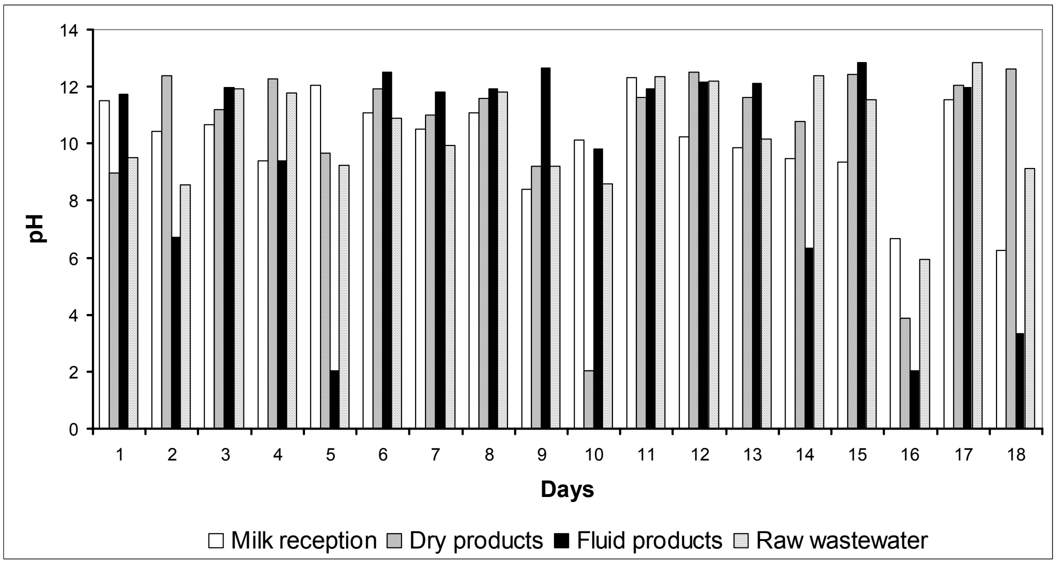

Figure 5: Evolution of pH in the experiments over time

Volumetric Coefficients

Table 2 shows the volumetric coefficients for from milk reception, fluid products, dry products and the raw wastewater.

There is great disagreement among references as to the general volumetric coefficient for the industry (represented by raw wastewater), since there are many differences between the industrial processes and the procedures each production sector. Veysseyre (1988) points out that in the factories which produce several milk products, for each liter of milk 7 to 10 liters of wastewater are generated. Braile and Cavalcanti (1993) report that the area of product elaboration and final product packaging are the biggest sources of effluents in the milk industry. They add that the washing waters correspond to the same volume of processed milk, and the factories which process several products had a volume of wastewater of 1.1 to 6.8 liters for each liter of processed milk. Byylund (1995) reports that typical volumetric coefficients are near 2.5 liters of water/liter of milk, but by economizing 1.0 liter of water per liter of milk can be achieved. In 1986, Carawan (1996) analyzed the milk industry in the United States of America and he found an average of 4 liters of water per liter of processed milk; the author added that by economizing savings, less than 1.0 liter of water consumed per liter of processed milk can be obtained.

The results of this work show that the volumetric coefficient of the industry evaluated is not high. However, UNIDO (1999a) indicates that with good management programs up to 0.5 cubic meter of effluents can be achieved for each cubic meter of processed milk effluents. This value can serve as a reference to water consumption and effluents generation work on minimizing. Thus, if an effluent minimization program is implanted, the difference between 0.666 and 0.5 would represent a savings of almost 25% in water consumption, a percentage which is possible to be achieved according Carawan and Stengel (1996), who reported that in effective pollution reduction programs, a decrease in water consumption up to 25% can be achieved.

Table 2: Volumetric Coefficients (VC) for the macrosectors and the raw wastewater

	Milk reception	Fluid products	Dry products	Raw wastewater
VC ($m^3_{effluent}/m^3_{milk}$)	0.086	0.416	0.741	0.666

Load Coefficients

Table 3 shows the BOD coefficients obtained in this work and the coefficients reported by other authors. It can be observed that the load coefficients of the company evaluated are smaller than the values found in the literature (except the powdered milk and powdered whey production sector – dry products). Some industry waste values that reach 12 kilograms of BOD per cubic meter of processed milk with more than 90% of this BOD resulting from milk loss and with a reduction in wastewater, can be reduced to 1.0 kg of BOD per cubic meter of processed milk (Poester and Leitão, 1989).

The data presented in Table 3 show that the organic load discharged by the milk reception is not excessive, being about ten times smaller than the value for raw effluent. On the other hand, the processing is responsible for the high values of raw effluent organic load, a fact also reported by the authors cited.

In Table 4 the nitrogen, phosphorus and oil and grease coefficients for the three sectors and of the raw wastewater are shown. An evaluation of Tables 3 and 4 demonstrates that there is a equilibrium between the BOD coefficients and other pollutants. The ratio of BOD to nitrogen was between 12 and 18. In the same way, the ratio of BOD to phosphorus was found to be between 20 and 36, indicating a good nutritional ratio that goes into the biological treatment unit. On the other hand, high values of both pollutants can resulting excess on treated effluent, since there is a nitrogen and phosphorus removal limit with this kind of treatment.

Table 5 contains the total values of pollutants discharged monthly into the treatment system. It can be observed that milk reception contributed only 10% of the total BOD. The sector which discharged most BOD, nitrogen and phosphorus was the dry products sector, while the fluid products was the sector most responsible for oil and grease emission.

According to Carawan (1996), each kilogram of effluent BOD corresponds to nine kilograms of milk lost during the process. Thus, adding the stream BODs, it is seen that about 28000 kg of BOD entered to the treatment system per month, corresponding to about 252000 liters of milk lost by the industry. This amount is near 0.7% of the total milk received by the industry, which processes about 36 million liters of milk per month. The 0.7% value is not a bad result. Kirsh and Looby (1999) report that as much as 2% of processed milk can be lost during processing. However, UNIDO (1999a) relates that good waste management programs can achieve milk losses of 0.5%. The difference between 0.7% and 0.5% would mean that almost 72000 liters of milk per month would revert back to the company's account instead of being discharged into the sewers. If it is taken into account that the raw material costs around R$ 0.40 (forty Brazilian cents) or $ 0.16 (sixteen US cents) this would be more than R$ 28,000.00 (twenty eight thousand reais) - or $ 11,520 per month recovery only in raw material.

According to Carawan and Stengel (1996), effective waste management programs can reduce BOD as much as 33%. This would be about 9200 kg of BOD per month, consequently, 83,000 liters of milk, the previously estimated approximate value.

Table 3: Load Coefficients (BOD) for macrosectors (this work) and from other references.

	This work*	Braile and Cavalcanti (1993)*	UNIDO (1999a)*
Milk reception	0.072	0.08	0.2
Fluid products	0.444	3.21	1.3 - 3.2
Dry products	0.832	0.156	0.6 - 12.3
Raw wastewater	0.779	1.3 - 3.2	-

* All values expressed in $kg.m^{-3}$.

Table 4: Nitrogen and phosphorus, oils and grease coefficients for the macrosectors and raw wastewater.

	Nitrogen*	Phosphorus*	Oil and grease*
Milk reception	0.004	0.002	0.022
Fluid products	0.030	0.018	0.218
Dry products	0.065	0.041	0.220
Raw wastewater	0.046	0.025	0.191

* All values expressed in kilograms of pollutant per cubic meter of milk.

Table 5: Total values of BOD, nitrogen, phosphorus and oils and grease discharged into the treatment station

	Milk reception*	Fluid products*	Dry products*
BOD	3032.1	11670.9	13307.0
Nitrogen	162.8	779.4	1045.5
Phosphorus	90.7	461.1	651.8
Oil and grease	911,8	5732,8	3514,5

* All values in kilograms of pollutant per month.

PREVENTIVE ATTITUDES

The action proposed is twofold: (1) a reduction in water consume and (2) minimization of the organic load.

Cleaning by means of the CIP system and the reuse and the recycling of water are examples of processes which reduce the volumetric coefficient. In reference to this topic, it must to be reported the company installed the CIP system, which minimizes water consumption, in most part of the processes; however, there were some exceptions, such as a few trucks that were not adapted with a “spray bowl” for washing by the CIP system. In addition, the spray dryer was operated manually rather than automatically, which consumed large amounts of water.

Water reuse and recycling was a reality in the company. Many processes, such as centrifugal separation with cooling water in a closed circuit recycled water. The filling machines (for UHT milk packaging) were cooled with recovered water and the evaporated water (from the milk evaporator for the production of powdered milk) was used for cleaning trucks and outside floors. The retentate from the reverse osmosis system (used for desalination of boiler feedwater) was mixed into the water supply reservoir. In Figure 6 the sectors where these measures were implemented and the percentage of each to total wastewater are shown. The effluent considered water consumption while the water evaporated in the boiler and cooling towers was not computed in the material balance in Figure 6. The sum of these preventive actions account for a 10% decrease in total wastewater generated.

The company also took action to reduce of effluents loads, which is reflected by the low BOD, nitrogen, phosphorus and oil and grease coefficients. The actions taken were separation of discharged milk by automatic ejection of sludge in the centrifugal separators; segregation of whey from butter for use in animal feed; and recirculation of the first rinse water from the evaporators (which has a high total solids level) at the beginning of the process, reducing the organic load of fluids and dry products.

In spite of the great concern of the company to minimize waste, there were still opportunities for the reduction of previous coefficients. The recovery of solids in the first rinse could be a pollution prevention action. There are examples of milk solids recovered by the use of membrane separation processes (reverse osmosis) used for production ice cream and milk desserts. Three direct results were obtained: minimization of impact of the effluent generated; the production of casein and reuse of the permeated stream, which is of a high quality enough to be used for drinking water (Water, 1996). A central system for treatment of these rinse waters could be installed, recovering the milk solids, mainly from the reception and the fluid products sector.

In Table 5 it can be seen that fluid products is sector most responsible for the emission of oils and grease. This is the direct result of the production of pasteurized cream and butter, which generates effluents with high values for this parameter. In this case, the simple separation of the first rinse water and its use for animal feed would be beneficial in the reduction of organic load. The same procedure could be installed in the manufacture of UHT formulated products. Once again, the membrane separation process was shown to be a promising alternative to the recovery of nutrients found in the effluents. Skelton (2000) reported on grease recovery in margarine processing, which can be reapplied in this process.

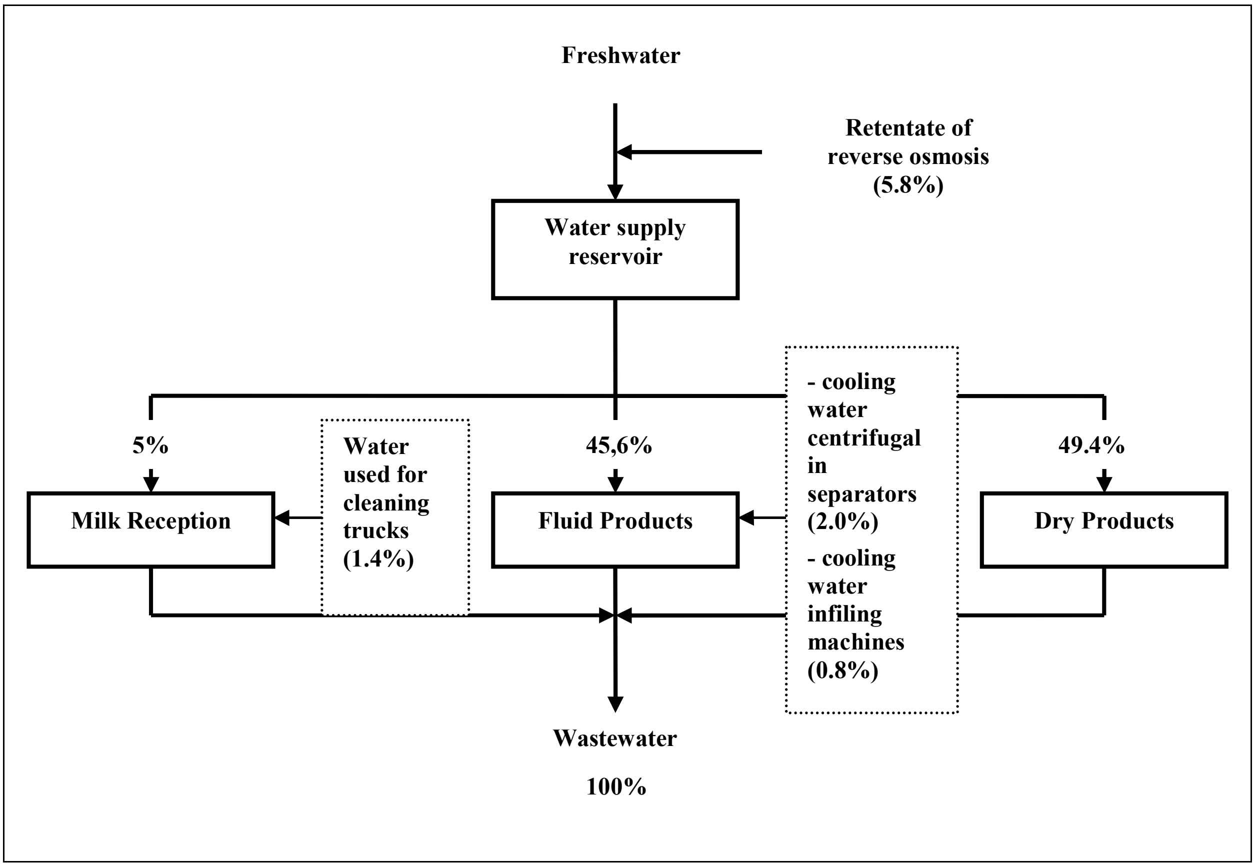

Figure 6: Mass balance for process water used in the factory

"Dry cleaning" is utilized frequently in other food industries, such as in the bakery industry (Carawan, 1999) and in shrimp processing (Carawan, 1996a). It could be adapted to the spray dryers for the scratching and/or the sweeping of the adhered powdered milk preceding the first flush, which would remove a large part of the solids adhering to the equipment. This operation is more attractive for use in the old equipment, which is cleaned manually. These solids could be added to the reservoir that receives the first rinse.

Membrane technologies have been applied successfully to reclaim the effluent that evaporates in the evaporator. In some cases, the use of permeated into drinking water or even to the boiler feedwater is possible (Mavrov and Bélières, 2000; Mavrov et al., 2001; Novalic et al., 1998). On days with high production of powdered milk or powdered whey, large amounts of these effluents were generated, so the cleaning of trucks and floors external did not use all the effluent, which was thus discharged. Energetic benefits can also be obtained with this water, since it is discharged at 55-60ºC into an integrated system (Figure 7). This water could warm up the boiler feedwater by means of heat exchangers (generating a savings of fuel oil) and could be used as make-up water for cooling towers, which do not require excellent quality in terms of organic content.

The discharge of CIP solutions after a long period use of is a common praxis in the dairy industry. The result of its negative effect can be observed in Figure 2, an effluent with pH values which vary from about 2.0 to 13.0. Processes with ultrafiltration and nanofiltration membranes have been studied for regeneration of these solutions, keeping the organic load and continuing use of the solutions (Novalic et al., 1998a; Trägardh and Johansson, 1998). However, a careful economic study aiming to evaluate this possibility must be done.

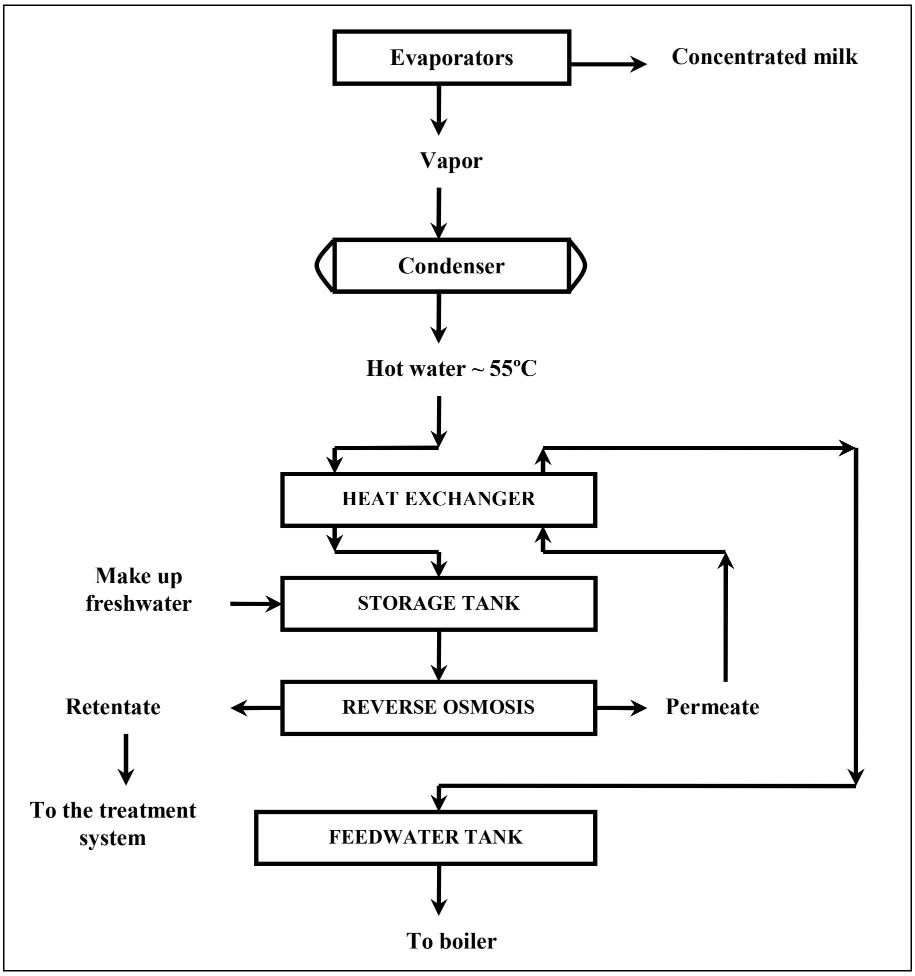

Figure 7: Diagram of the reuse of water evaporated in the production of milk powdered.

CONCLUSIONS

Sectors of dairy production are big pollutors. Effluents from the production of fluid and dry dairy products present environment risks if not properly evaluated and treated, and preventive programs can reduce the volume of emissions and the organic load, decreasing the costs end-of-pipe treatment.

Several measures were taken by the company studied to reduce water consumption and organic load, resulting in coefficients that were lower than those in other references. However, other preventive measures could be studied:

- The treatment of the water that evaporated in the production of powdered milk by the membrane separation process is a great opportunity to reclaim water, although the investment costs are still high. Only this action could reclaim nearly 10% of the total fresh water. Besides, energetic gains could be achieved with the installation of a reverse osmosis system;
- The installation of tanks to separate the first rinse water is a cheap alternative for reducing the load coefficient; the content of these tanks could be used for animal feed;
- Another way to reduce the organic load could be to install a reverse osmosis system to reclaim milk solids from the first rinse water in equipment and pipe lines; in addition, the retentate could be used for other milk products and the permeate as boiler feed water;
- "Dry cleaning" with a spray dryer is a good opportunity to separate milk solids, thereby avoiding washing them out at the treatment station.

Lastly, the installation costs of any process will be variable, which can hinder the minimization of effluents and reduction of organic loads.

NOMENCLATURE

A	Concentration of pollutant	g m^{-3}
BOD	Biochemical oxygen demand	mg L^{-1}

CIP	Cleaning in place	dimensionless
COD	Chemical oxygen demand	mg L^{-1}
LC	Load coefficient	kg pollutant m^{-3} milk
P2	Pollution prevention	dimensionless
UHT	Ultra-high temperatures	dimensionless
v	Processed milk volume	m^3
V	Effluent volume	m^3
VC	Volumetric coefficient	m^3 effuent m^{-3} milk

REFERENCES

American Public Health Association – APHA, Standard Methods for the Examination of Water and Wastewater, 19th ed., Washington, D.C. (1991).

Braile, P.M., Cavalcanti, J.E.W.A., Wastewater Treatment Handbook (Manual de tratamento de águas residuárias). Cetesb, São Paulo (1993).

Brião, V.B., Study of Pollution Prevention in a Dairy Industry. Master's Thesis. University of Maringa, Maringa, Brazil (2000).

Byylund, Gösta, Tetra Pak Dairy Processing Handbook. Tetra Pak Processing System, Sweden, (1995).

Cagno, E., Trucco, P., Tardini, L., Cleaner Production and Profitability: Analysis of 134 Industrial Pollution Prevention (P2) Project Reports, Journal of Cleaner Production, 13, 593-605 (2005).

Carawan, R.E., Dairy CEOs: Do You Have a $500 Million Opportunity? North Carolina Cooperative Extension Service, North Carolina (1996). Available on line at http://ww.bae.ncsu.edu/ programs/ extension/ publi cat/wqwm/cd29.html.

Carawan, R.E., Stengel, M.J., Water and Wastewater Management in a Dairy Processing Plant. North Carolina Agricultural Extension Service, North Carolina (1996). Available on line at http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/cd28.html.

Carawan, R.E., Prevent Polution in Shrimp Processing. North Carolina Cooperative Extension Service, North Carolina (1996a). Available on line at http://www.bae.ncsu.edu/ programs/extension/publicat/wqwm/cd25.html.

Carawan, R.E., The BOD Diet Plan: Waste Management Tips for Breaded-Food Plant Employees. North Carolina Cooperative Extension Service, North Carolina (1999). Available on line at http://www.bae.ncsu.edu.

CETESB – Companhia de Tecnologia de Saneamento Ambiental, Pollution Prevention. CETESB, São Paulo (2004). Available on line at http://www.cetesb.sp.gov.br/ambiente/prevencao_poluicao/conceitos.asp

Chmiel, H., Mavrov, V., Bélières, E., Reuse of Vapour Condensate from Milk Processing Using Nanofiltration, Filtration and Separation, 37, nº 3, 24 -27 (2000).

Figueiredo, M. da G., Santos, M.Sales dos, Wastewater Treatment Station from textile industry – Optimization by Implant of Pollution Prevention Attitudes. XXVII Interamerican Congress of Sanitary and Environmental Engineering Proceedings, Porto Alegre (2000).

Khan, F.I.; Natrajan, B.R., Revathi, P., Green Pro: A New Methodology for Cleaner and Greener Process Design, Journal of Loss Prevention in the Process Industries, 14, 307-328 (2001).

Kirsh, F.W., Looby, G.P., Waste Minimization Assessment for A Dairy. U.S. Environmental Protection Agency, Washington, D.C. (1999). Available on line at http://www.es.epa.gov/techinfo/reserch/reduce/rrel420.html.

Mavrov, V., Bélières, E., Reduction of Water Consumption and Wastewater Quantities in the Food Industry by Water Recycling Using Membrane Process, Desalination, 131, 75-86 (2000).

Mavrov, V., Chmiel, H., Bélières, E., Spent Process Water Desalination and Organic Removal by Membranes for Water Reuse in the Food Industry, Desalination, 138, 65-74 (2001).

Metcalf and Eddy. Tratamento y Depuracion de las águas residuárias. McGraw Hill, New York (1991).

Novalic, S., Dabrowski, A., Kulbe, K.D., Nanofiltration of Caustic and Acid Cleaning Solutions with High COD. Part 1: Recycling of Sodium Hydroxide, Journal of Food Engineering, 38, 125-132 (1998).

Novalic, S., Dabrowski, A., Kulbe, K.D., Nanofiltration of Caustic and Acid Cleaning Solutions with High COD. Part 1: Recycling of HNO_3, Journal of Food Engineering, 38, 133-140 (1998a).

Poester, J.L., Leitão, M.R., Agroindustry Wastewater Treatment. SENAI, Porto Alegre (1989).

Quaresma, M. Yamamoto do Vale; Pacheco, C. E. Medeiros. Evaluation of Techniques of Pollution Prevention Applied to Galvanoplasty Industry. XXVII Interamerican Congress of Sanitary and Environmental Engineering Proceedings. Porto Alegre (2000).

Ramjeawon, T. Cleaner Production in Mauritian Cane-sugar Factories. Journal of Cleaner Production, 8, 503-510 (2000).

SENAI - Serviço Nacional de Aprendizagem Industrial, Clean Technologies National Center - CNTL, Cleaner Prodution. SENAI, Porto Alegre (1998).

Skelton, R., Membranes in Food Processing, Filtration and Separation, 37, nº3, 28-30 (2000).

Trägardh, G., Johansson, D., Purification of Alkaline Cleaning Solutions from the Dairy Industry Using Membrane Separation Technology, Desalination, 119, 21-29 (1998).

UNIDO - United Nations Industrial Development Organization, Wastewater. Vienna (1999a). Available on line at http://www.unido.org .

UNIDO - United Nations Industrial Development Organization, What's Cleaner Production? UNIDO, Vienna (1999b). Available on line at http://www.unido.org/doc/5151.

Veysseyre, R., Lactologia Técnica, Composiçión, Recogida, Tratamiento y Tranformación de la Leche. Acribia, Zaragoza (1988).

Water, H. New Zealand Dairy Group – Anchor Products Ltda. U.S. Environmental Protection Agency, Washington, D.C. (1996). Available on line at http://es.epa.gov/techinfo/facts.