UNIVERSITAT DE BARCELONA

MASTER FINAL PROJECT
MASTER OF ENVIRONMENTAL ENGINEERING

Design of a wastewater treatment plant for the company Lácteos San Antonio in Cuenca - Ecuador.

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Abstract

The care of its use, treatment, release and circulation of water allows water to be considered as a renewable resource, more so according to research carried out by international entities that ensure that 80% of the water used in the world is returned to the ecosystem without any treatment, so it is considered that by 2030 the world will face a 40% deficit of water.

Among these statistics is Ecuador, a country where the discharges of untreated water are mostly discharged into public sewers or river channels. Lácteos San Antonio, company dedicated to the production of products derived from milk, based on the environmental requirements, requires to determine the most favorable technologies applicable for a wastewater treatment plant that fits their realities.

In the present project a study of the most used techniques in Food, Drink and Milk industries around the world, considered within the Best Available Techniques, is carried out, as well as scientific articles of authors who have developed researches of the technologies applied to the treatment of the waste water coming from the processes of the dairy industry in order to define the most indicated processes taking into account their efficiency and adaptability to the realities of the company.

Based on the analyzed information, using the typical scheme of a wastewater treatment plant of the BATs dairy industry and with the main area limitation for the construction of the treatment plant, it is propose an installation that consists of: course screening, fine screening, equalization tank, dissolved air flotation, uploaded anaerobic sludge blanket, sequency batch reactor and sludge thickening, in such a way that it is consolidated as a compact treatment system and that both in its construction and operation costs are profitable for the organization.

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1. Introduction

The need to find alternatives for the preservation of natural resources today is vital. Water, the basis of all forms of life, considered the most important natural resource, after being used, is dumped into different bodies of water, causing different environmental impacts; therefore, its use must be carefully managed and treated. This effluent is called wastewater and its treatment must guarantee compliance with the parameters established in the environmental regulations applicable in each nation

According to the United Nations report on water resources in the world 2015: water for a sustainable world, population growth, urbanization, industrialization, and therefore higher levels of production to satisfy consumption, made possible to predict that by 2030 the world will face a 40% deficit of water. (UNESCO, 2015)

The United Nations Organization for Food and Agriculture, in its website, states that 69% of global water consumption is for agriculture, 19% for industry and 12% for the domestic sector, and that 80% of wastewater returns to the ecosystem without being treated or reused. (AQUASTAT, 2016)

With these index, it can be seen that the productive sector is not only the one that consumes the most, but it is also the area that generates the major water pollution.

These data help to highlight of the vital importance of wastewater treatment and reuse in the industrial sector, and even more in countries that have a negative balance in their water resources.

The United Nations Food and Agriculture Organization's report ¨Reutilización de aguas para la Agricultura en América Latina y el Caribe¨ indicates that 41.7% of municipal wastewater generated in this region is treated. These treatments are distinguished in each country since different methods and technologies are applied, and they do not fully guarantee their correct purification or regeneration. (FAO, 2017)

In the same document, it is mentioned that in Ecuador is estimated that more than 80% of the companies in the agro-industrial, industrial, service and commercial sectors do not treat their wastewater and these are discharged directly into the public sewage system or into river channels. (FAO, 2017)

In the document ¨Prevención de la contaminación de la industria Láctea prepared by the Centro de Actividad Regional para la producción más limpia (CAR/PL)¨ Plan de

Acción para el Mediterráneo del Ministerio de Medio Ambiente de España y la Generalitat de Catalunya, it is mentioned that the main environmental aspects of the dairy industry are related to the high consumption of water and energy in its processes, especially to maintain correct hygienic and sanitary conditions, causing its wastewater to have a high organic content. (CAR/PL, 2002)

Lácteos San Antonio C. A. dedicated to the production of dairy products since 1997 in its plant located in the Industrial Park of the city of Cuenca, province of Azuay in Ecuador, dedicated to the production of dairy products such as yogurt, powdered milk, ultra pasteurized milk, flavored milk, fruit nectars and oat drinks. In accordance with its firm commitment to the environment and sustainable production, it establishes the requirement of creating a new wastewater treatment plant adapt to its physical and economic reality, which allows it to comply with the parameters to be considered within the current limits established by environmental legislation. This will be the general framework of this Project.

For its execution, the required information has been supplied through the Industrial Safety and Environment area in coordination with other areas of the company. The information provided is representative and has been elaborated during different periods of time, considering that there are no important variations due to production issues or climatic seasonality, because in the city of Cuenca the climate is spring-like all year round.

In addition, the company has characterized its waters through tests carried out in its quality control laboratory.

The final implementation of the proposed treatments process will allow for a considerable reduction in the impact produced by the discharge of its effluent into the sewage system, complying with its business commitment to care for the environment and with the country's legal requirements regarding environmental care to avoid possible sanctions that could harm the factory and its partners.

2. Objectives

The general objective of this project is to propose the most suitable technologies for a wastewater treatment plant for the company Lácteos an Antonio.

This general objective includes the following specific objective:

- Collect data that includes a description of the company's processes, the generation of effluents and the characterization of its waste water..
- To carry out a bibliographic study of the best available techniques for the wastewater treatment plants of the dairy industry applicable in Lácteos San Antonio.
- To establish the technologies for the treatment plant of residual waters of Lacteos San Antonio that guarantee the fulfillment of the limits established in the regulations of the concentrations of the effluents.
- Describe the technologies chosen as appropriate for Lácteos San Antonio.
- To inform about the approximate cost in the market of the technologies chosen for the wastewater treatment plant of Lácteos San Antonio.

3. Lácteos San Antonio, Water Flows and Process Description

3.1. Water Sources

Lácteos San Antonio, a company dedicated to the manufacture of dairy products, in its facilities processes raw milk for the manufacture of pasteurized milk, ultra-pasteurized, yogurt, cream, milk drinks with oats, fruit juices, nectars and powdered milk.

Figure 3 describes the general processes carried out at Làcteos San Antonio together with the products elaborated in each of them.

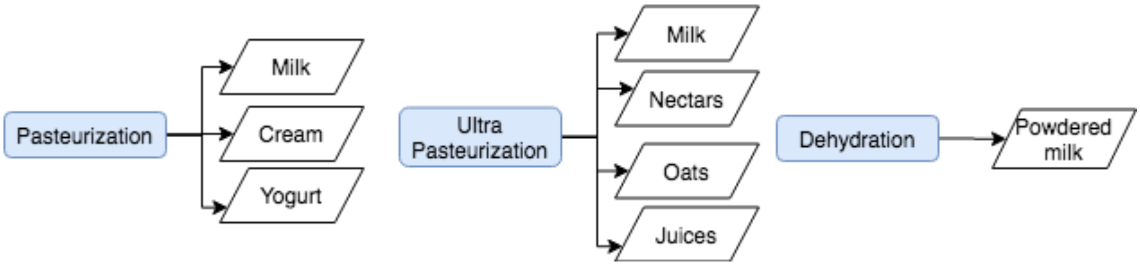

Figure 1. Diagram of Equipment and flows of water, Product and Wastewater in Lácteos San Antonio

The factory's potable water supply comes from three cisterns connected to the city's supply line, which are recorded by two flow meters, as shown in Figure 1.

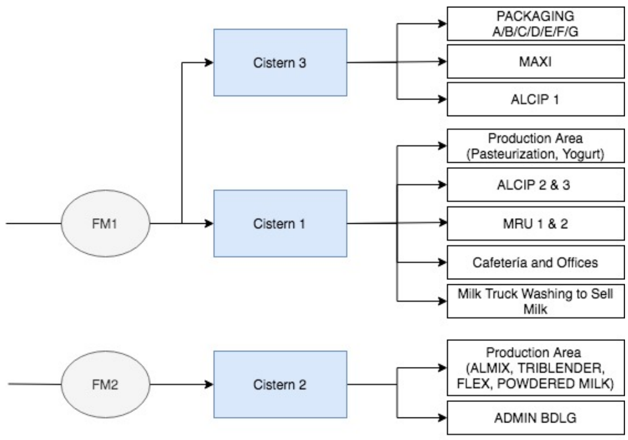

Figure 2. Sections and equipment supplied by cisterns

Figure 2 details the network of water, product and wastewater flows generated in the factory's production processes. The description of the processes presented in it can be found in the following section for a better understanding.

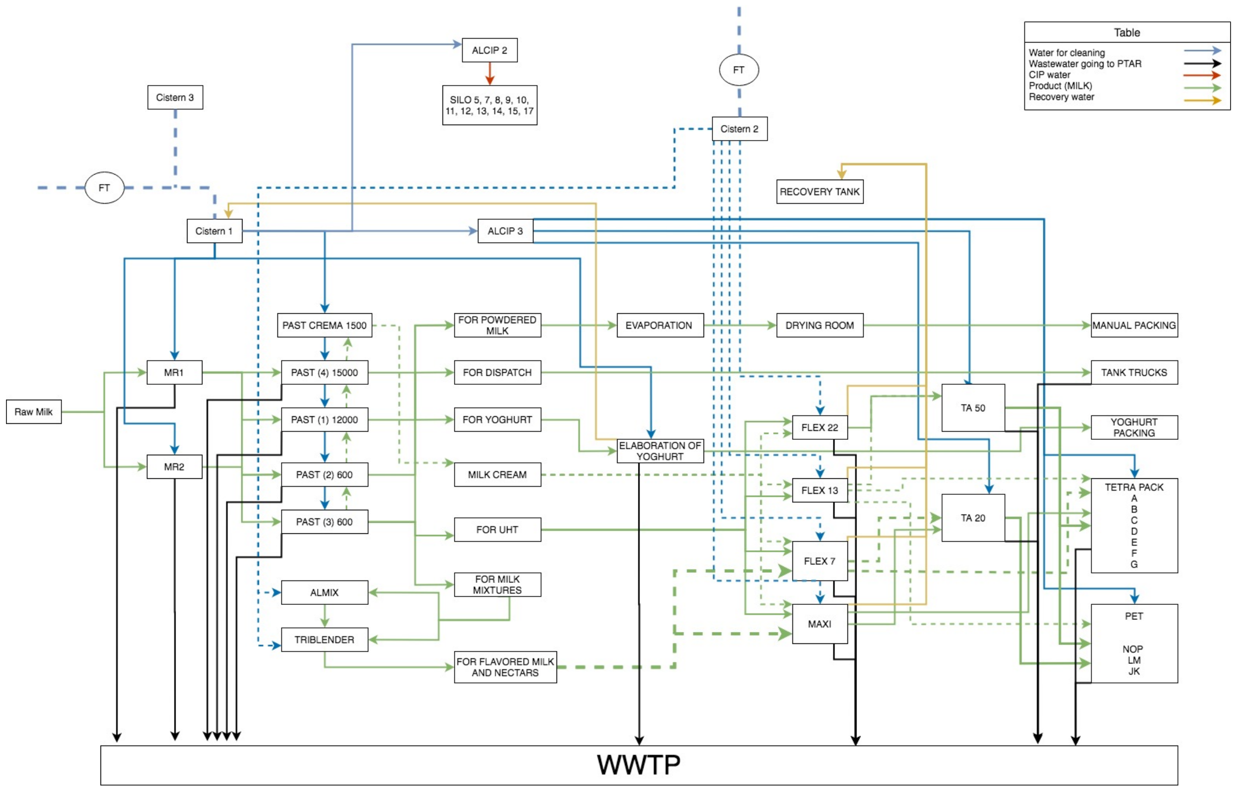

Figure 3. Diagram of equipment and flows of water, product and wastewater un Lácteos San Antonio

Raw milk is brought to the plant in tanker trucks supplied with insulation or refrigeration systems by small suppliers.

The process begins with the entry of the vehicle transporting the raw milk to the reception area, where a visual inspection, manual stirring and sampling are carried out, which are then taken to the laboratory to analyse the quality of the raw material. If it meets the pre-established parameters, goes through a filtration process before being weighed in balance tanks (MRU) to quantify the incoming volumen.

Storage: The factory receives an average of 280000 litres of raw milk per day which is stored in silos (No.13 and No.14) at 4°C. These silos have an insulation system to prevent the raw material from increasing in temperature. The stored milk is gradually evacuated as the in-line process requires it.

3.2. Pasteurization Process

The milk is sent from a flow balance tank to a separate plate heat exchanger in three sections; the first section is used to preheat the milk to a temperature of 45°C, for this, water from the network is used as the hot fluid together with steam.

When the milk leaves the preheating section it goes to a centrifuge, in which a percentage of fat is separated from the milk according to production requirements. This process is called fat clarification and standardization. The surplus cream is stored to follow the process of pasteurized cream.

The second section consists of the pasteurization of the milk, which is carried out by using four pasteurization units (PAST 1, PAST 2, PAST 3 and PAST 4) at a temperature of 72 to 78°C for 15 seconds.

In the last section, the product is cooled down to a temperature of 4 to 6°C and finally stored in a laboratory to ensure that the product meets the requirements.

Pasteurized milk is stored in silos before being sent to any of the production lines. The approximate proportion of its destination is detailed in Table 1.

Table 1. Percentage destination of pasteurized milk

Percentage destination of pasteurized milk	
Destination of pasteurized milk	Quantity
For dispatch	2.50%
UHT milk production	77%
Yoghurt production	0.10%
Powdered Milk production	6.80%
Flavored milk mixes	12.80%

3.3. Cream and Milk Fat

The milk fat and solids removed from the raw milk during standardization are sent to a pasteurization unit dedicated to produce milk cream.

Similar to the milk pasteurization units, the cream pasteurizer (PAST CREAM) has a centrifuge to standardize the fat content of the cream, this flow is treated with UHT using the FLEX or MAXI units (with temperatures from 85 to 96 °C for 20 seconds) and cooling (T< 12 °C). Then the product is temporarily stored in a tank (TA 20) at a temperature T=-12°C or immediately packed.

3.4. UHT

The volume of the pasteurized milk after laboratory tests (Acidity, PH, %MG) is sent to the UHT unit for another pasteurization step.

The UHT units are FLEX 7000, FLEX 13000, FLEX 22000 and MAXI 4000. The pasteurized milk is submmitted to a temperature of 137 to 140°C for 4 to 6 seconds and then quickly cooled to 20°C.

After passing through the UHT process, the product goes to the packaging process or is temporarily stored in an aseptic tank (TA 20 and TA 50) before going to packaging.

3.5. Milk Powder

Some of the pasteurized skimmed milk is sent to the milk powder plant.

The pasteurized milk passes through a two-stage evaporator to produce milk powder.

For each processing cycle, 15.5% of the initial volume of milk is transformed into milk powder. The remaining fluid, known as ¨Agua from Vaca¨(AdV), is currently sent to the sewer. The production frequency for this is 18 hours for 6 days.

3.6. Flavored Milk and Juices

For the elaboration of these products, ultra-filtered water is used which is mixed with pasteurized milk and other products such as powdered oats and fruit nectars.

Two units are used to mix the products (ALMIX and TRIBLENDER) in parallel or in sequence according to the recipe of the final product.

Using the UHT units (FLEX 7000 and MAXI 4000), products such as nectars and fruit drinks are submitted to 98°C for 30 seconds and then rapidly cooled to 20°C.

The product is then sent to the TetraBrick packaging machines to be dosed into the containers.

3.7. Yogurt

For the preparation of yogurt whole milk with a percentage greater than 3.5% of fat matter (FM) is used as raw material.

The milk is preheated to 40-50°C, and then a mixture of other ingredients are added for taste and color. The mixture obtained is pasteurized (at temperatures of 85-90°C for 20 minutes), then cooled and fermented for more than seven hours.

The next step is its filtration and cooling for packaging.

4. Cleaning In Place (CIP)

CIP (Clean in Place) is a cleaning system that consists of an automatic washing in place, in which a solution circulates through the components / production equipment without requiring disassembly of them. The figure 4 describes the three types of systems used in the factory.

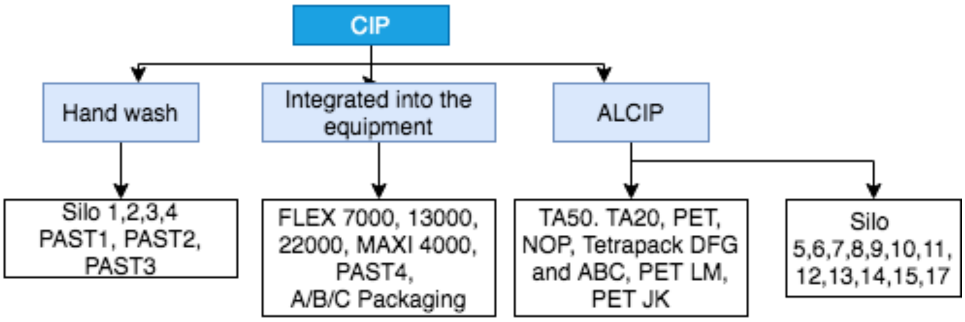

Figure 4. Types of CIP in Lácteos San Antonio

4.1 ALCIP

ALCIP, is a system (CIP) that minimizes time, costs, ensures the quality of food production and reduces environmental impact.

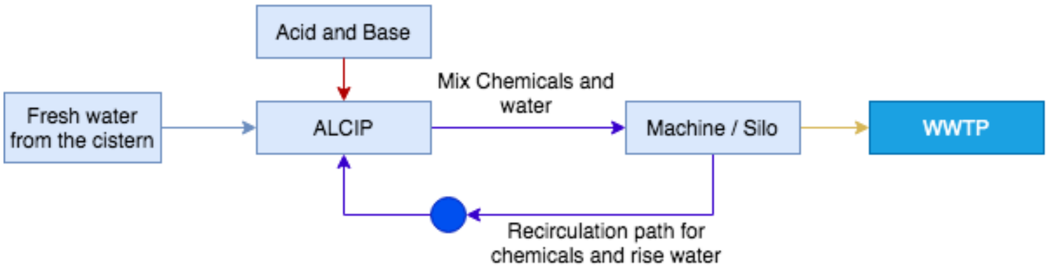

Figure 5. ALCIP Cleaning Scheme

Lácteos San Antonio has three ALCIP units 1 (not in service), 2 and 3. ALCIP 2 and ALCIP 3, serve approximately 70% of the factory's silos, including the pasteurized milk reception silos (also used to store nectar and flavored UHT milk) and the packaging machine.

Cleaning is done daily at the beginning and end of each production cycle or between product changes by means of two optional cleaning programs according to requirements. The first one is called caustic program, in which water, steam, 1.5 to 2.5% soda solution is used which can be recovered or drained in the same way as its final rinse after the process according to the reading of a turbidimeter. The second is the caustic and acid program, in which once a week a 0.8 to 2% solution of nitric acid is added to the previous wash, which can be recovered or drained in the same way as the previous wash. The final rinse from this second program is recovered for use in the next first rinse. These solutions are recirculated from the ALCIP units to the silos and equipment for a certain time.

4.2 CIP Integrated with the equipment (FLEX, MAXI, PAST 4, and Packaging A/B/C)

The UHT units (FLEX 7000, 13000, 22000 and MAXI 4000), PAST4 and A/B/C packaging equipment have their built-in CIP system similar to the ALCIP. Cleaning is done at the beginning and end of production or when there is a product change in production.
The cleaning unit also performs chemical preparation from 50% caustic soda solution and 35% nitric acid solution and like the ALCIP system, the last rinse is recovered for use in the next first rinse

4.3 Manual Cleaning

The reception silos (SILO 1,2,3 and 4) and the pasteurisers (PAST 1,2 and 3) are cleaned manually by specialised CIP equipment wich emulates the procedure carried out by the ALCIP and is validated by a quality control.
Tankers that transports pasteurized milk must be cleaned and tested for quality before being loaded. The cleaning steps include hot water rinse, caustic soda rinse (2.5% V/V), hot water rinse, peracetic acid rinse, and hot water wash, respectively. All water used in this cleaning is drained to the sewer and the chemicals recovered.
To clean tank trucks containing raw milk from the farm hot water from the FLEX 22000 and MAXI 4000 cooling process is reused, and after cleaning, the water is drained to the sewer.
CIP in the production of milk powder is carried out in two ways, the first is every 3 hours using caustic soda, and the second, where paracetic acid is added after the previous process and lasts a total of 5 hours. The final rinse water in these cleaning procedures is not recovered.
Manual washing is also used on floors to maintain general cleanliness in the factory.

5. Waste Water Sources

5.1. Water consume

The water supply to the factory is accounted for by two flow meters.

Since December 2018, the water consumption of the factory has been measured. From the results obtained, a lower consumption can be observed during the months of March and April 2019, a fact that is associated with the fact that the powdered milk plant was under maintenance. Therefore, for the purpose of this study in a real scenario, using the measured consumption of December 2018, January 2019 and February 2019, the average daily consumption is 600 m^3/day.

Table 2. Total measured water consumption

Total water consumption measured			
Year	Month	Total Consumption m^3	Dayily Average (m^3/d)
2018	December	18072	600
2019	January	18074	
2019	February	17833	
2019	March	16548	524
2019	April	15410	

5.2. Wastewater generation

According to the process described, wastewater is generated at the following points in the production area:

1. Standardization of raw milk (pasteurization area)
2. Discharges of products between production runs.
3. CIP drains
4. Floor cleaning
5. ¨Agua de Vaca¨ (AdV) from milk powder production

Wastewater is collected in the same network of canals that flow by gravity to a collection pit and then poured into the sewer.

For this case study, the volume of wastewater generated by the offices, the cafeteria and the warehouses is not considered, as these is directed to the sewerage.

During the month of July 2019, measurements were taken at Lácteos San Antonio to determine the volumetric flow of the wastewater produced from its processes. For this measurement campaign the flow was measured five times in a time interval and the average was taken as the representative of that hour. A summary of the measured wastewater discharge to be treated is shown in Table 3.

Table 3. Volumetric flows of wastewater for two measurement campaigns

Volumetric wastewater flows for two measurement campaigns:				
Parameter	Unit	17-18 July (Factory)	26-27 July (Factory)	
		Factory	Factory	AdV
Flow	m^3/d	519	413	41
Average	m^3/h	21	17	1.7
Peak	m^3/h	62	37	2.2

The daily flow on July 17-18 is higher than July 26-27 from the same source because the large equipment was cleaned at the same time (FLEX 22000 and TA 50). This generated a flow of 62 m^3/h during approximately 5 hours, corresponding to the duration of the CIP.

The July 26-27 activities are a typical range of activities for any production program.

The flow rate of the AdV was measured separately, using the same method.

5.3. Balance

Table 4 presents a summary of the factory's water balance, comparing the consumption measured from the supply source with the wastewater produced, considering an average production of 280 m3 per day.

Table 4. Summary of the Water Balance and consumption reference

Summary of the Water Balance and consumption reference		
Detail	Quantity (m^3/d)	Reference
Water comsumption measured (Average)	600	Table 2 (Daily Average)
W.W. Measurement generated (Factory +AdV)	454 - 560	Table 3 (Flow)

According to this relationship, the difference in flow between average consumption and effluent generated by production processes would be attributed to consumption generated by process losses, administration facilities, cafeteria, among others that are discharged separately to the domestic sewage network.

5.4. Wastewater characterization

The characteristics of the wastewater from the measurement campaign carried out in the factory are shown in Table 5. Is important to emphasize that the exposed data have been raised by own studies of Lácteos San Antonio and shared by the Department of Safety and Environment for the accomplishment of the present project.

Table 5. Wastewater data from measurement campaigns

Wastewater data from the two measurement campaigns				
Parameter	Unit	17-18 July	26-27 July	
		Factory	Factory	AdV
Flow	m^3/d	519	413	41
Average	m^3/h	22	17	1.7
Peak	m^3/h	62	36	2.2
pH	-	12	12	5
Temperature	°C		29	67
COD	mg/l	5450	5770	78
BOD_5	mg/l	2800	3560	27
Fats & Oils	mg/l	319	437	0.8
VS	mg/l	2	2	2
TSS	mg/l	1088	1163	5
VSS	mg/l	1025	1111	4
TKN	mg/l		117	11
N-NH4	mg/l	2.5	3.9	2.7
Nitrates	mg/l	341	358	2.7
Nitrites	mg/l	0.5	3.5	0.05
P Total	mg/l	9	23	0.05
Cl	mg/l	28	26	0.33

According to the examination of the water used in the plant's processes, the presence of solutions of raw milk, treated milk from spills, leaks or drips, remains of cleaning products such as caustic soda, disinfectants, detergents and additives, among others, can be distinct. Based on this, it can be established that the content of wastewater produced by the activities carried out in the factory are characterized by:

- High organic matter content, highly biodegradable (BOD5/CDQ ratio = 0.61).
- High content of Volatile Suspended Solids (ratio SSV/SST = 0,94).
- High content of fats and oils.
- High nitrogen content.

6. Discharge limits

In Annex I of Book VI of the Unified Text of the Secondary Legislation of the Ministry of the Environment of the Republic of Ecuador (TULSMA): (Environmental Quality and Effluent Discharge Standard: Water Resource dictated under the protection of the Environmental Management Law), it is established within the obligatory dispositions, the permissible limits, dispositions and prohibitions for the discharges in bodies of water or sewage systems. Therefore, under these premises, the treatment to be designed for this case is based on the compliance with these discharge limits directed to the sewage system of the city of Cuenca. Annex A7 of this document contains Table 10. Discharge limits to the public sewerage system of the Ministry of the Environment of the Republic of Ecuador, where the corresponding limit values are detailed.

Table 6 show some of the reference parameters together with the limit values established in the TULSMA Standard.

Table 6. Values obtained from the characterization of wastewater from Lácteos San Antonio and limit values of the TULSMA standard

Parameter	Units	TULSMA	Analyzed Values
Average	m^3/h	-	22
Peak	m^3/h	-	62
pH		6 to 9	12
Temperature	°C	< 35	29
COD	mg/l	500	5770
BOD_5	mg/l	250	3560
Fats & Oils	mg/l	70	437
TSS	mg/l	220	1163
TKN	mg/l	50	117
Phosphorus	mg/l	15	23
Chlorine	mg/l	0,5	28

One of the most important factors to be considered within the development of this project is to consider the limited space in the facilities of Lácteos San Antonio, so when defining the technologies to be used it will be of great importance to ensure that the system is compact.

7. Wastewater Treatment for the Dairy Industry

The wastewater produced in the factories differs according to the type and volume of dairy products manufactured, making the choice of a specific treatment difficult.
In order to establish the technology scheme for the Lácteos San Antonio wastewater treatment plant, the approach will be made according to the typical wastewater treatment for the dairy industry defined by the Best Available Techniques and references from previous experiencies in similar activities.
According to the pollutant loads found in the effluents of dairy industries, the alternatives for reducing the environmental impacts generated are diverse, and these treatments can be physical, physical-chemical or biological (Nagappan, et al., 2018). The choice of these treatments will be related to the compliance with regulations or the expected quality of the effluent, so that the treatment processes can reduce the amount of suspended solids, biodegradable organic matter, pathogenic bacteria and other organisms causing diseases, nutrients such as nitrogen and phosphates, among others (Choudhary, 2017).
In order to define the most suitable technologies for wastewater treatment, it is essential to focus on the most efficient and profitable option. Moreover, after its implementation, it must comply with environmental requirements and adapt better to the company's realities (Wang, 2006).
At this point the concept of circular economy plays an important role, generating new concepts in wastewater treatment technologies to obtain low environmental impacts, costs, operating expenses and energy efficiency (Naushad, 2018).
In the documents Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk Industries (2019) and Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques in the Food, Drink and Milk

Industries (August 2006), it is referred that in the FDM Industry, each industry has characteristics that can be identified to be able to carry out the most suitable treatment to its reality. Therefore, it describes that the main characteristics for the residual waters of the milky industry are the great variation of flow, variable pH, high contents of nitrates and phosphorus in addition to high loads of COD and BOD. Based on these described variables, a typical wastewater treatment scheme is presented with the sequence of processes that offer a better treatment quality in this scenario, which is shown in Figure 6.

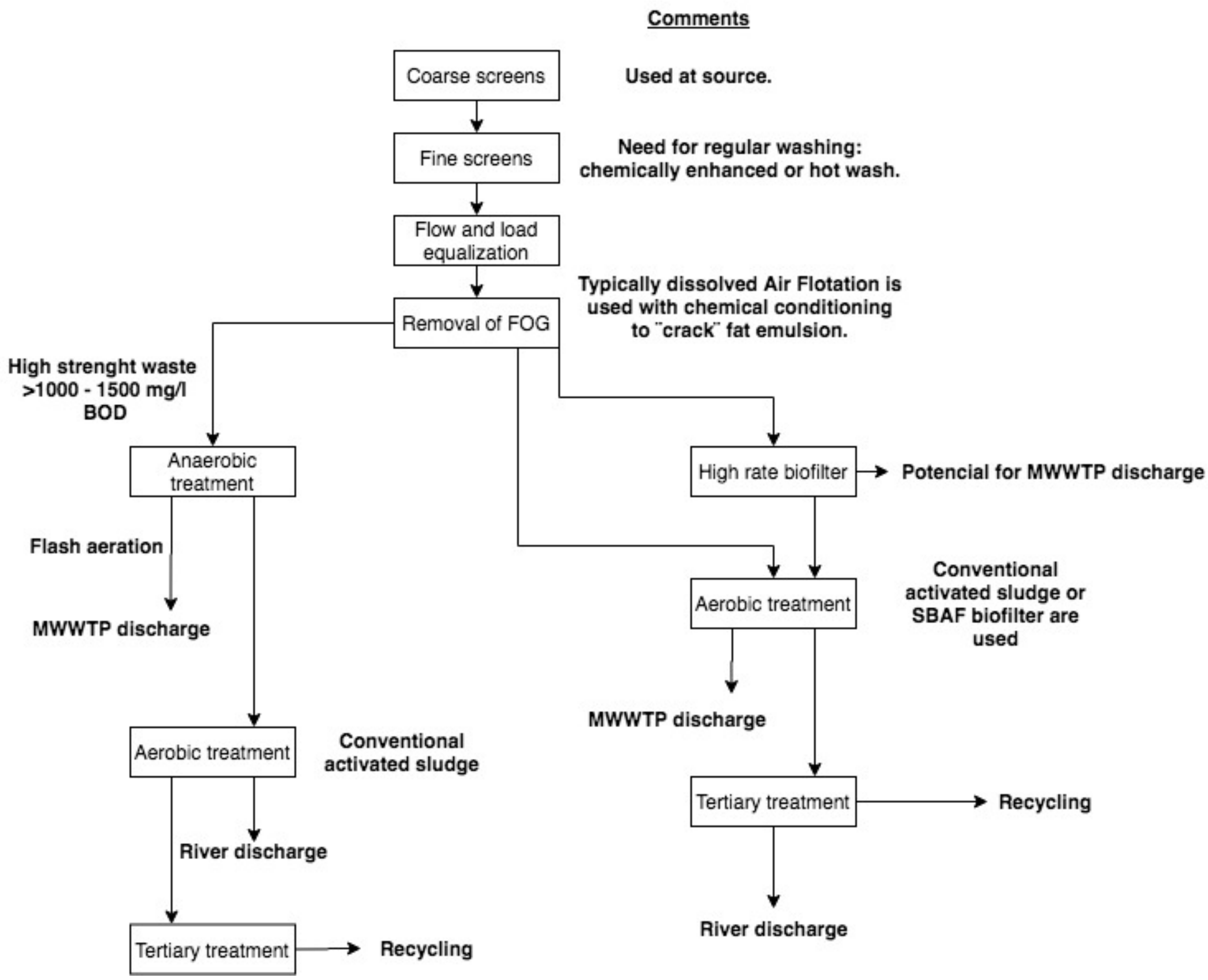

Figure 6. Typical Wastewater treatment applicable to a dairy

(*Source:European Commission, 2006).*

7.1 Primary Treatment

The primary treatment consists of the elimination of solids, whether they are thick, floating or in suspension. In this first stage it is possible to reduce 50-60% of the suspended solids and between 20-30% of the BOD, being of typical use the process of screening, equalization and dissolved air flotation.

Screens are devices whose benefits are the reduction of SS, FOG, BOD, COD, product recovery, separation of difficult to degrade FOG as well as the reduction of odour emissions in the downstream processes of the treatment plant. These devices perform coarse screening for larger materials and fine screening for smaller particles. A parallel plate separator replaces grease traps that can create food safety problems when inside the processing areas due to excessively hot water melting the collected grease.

An equalization tank is used to regulate the flow of the influent because of its variability, allowing it to ensure the composition of the water with respect to the parameters needed for treatment such as pH control or addition of chemicals.

DAF, or Dissolved Air Flotation, is a technique widely used in FDM installations, with no restrictions on its applicability. Compared to other processes such as sedimentation, it requires less space and is more efficient. DAF units can remove up to 50% of suspended solids and 80% of FOG, whose efficiencies can be increased with the application of coagulants and flocculants by up to 85-90%, thus significantly reducing the amount of TSS and the costs involved for subsequent processes.

DAF units are used especially in those wastewater treatment plants of the dairy industry where the presence of fats causes long times of hydrolysis of organic matter that generates difficulties in secondary treatments, thus ensuring an effective operation of subsequent processes (Lomte & Bobade, 2015).

7.2 Secondary Treatment

Based on the proposed wastewater treatment scheme typical of the dairy industry, for the case of secondary treatment, biological treatments are established as the best applicable options, with the application of both aerobic and anaerobic treatment being possible. In order to define the adequate treatment, the following tables 6 and 7 present the main advantages and disadvantages of each one of them.

Table 7. Advantages and disadvantages of aerobic wastewater treatment processess (Source: Giner, 2019)

Advantages of aerobic treatment	Disadvantages of aerobic treatment
Degradation into harmless compounds	Large quantities of sludge produced
	Stripping results in fugitive relases that may cause odours/aerosols
	Bacterial activity is reduced at low temperatures. Neverthless, surface aeration and injection of pure oxygen can be used to enhanced the process
	If FOG is not removed prior to aerobic biological treatment, it may hinder the operation of the WWTP as it is not easily degaded by bacteria

Table 8. Advantages and disadvantages of anaerobic wastewater treatment processes (Source: Giner, 2019)

Advantages of anaerobic treatment	Disadvantages of anaerobic treatment
Low specific surplus sludge production; the lower growth rates mean lower macro/micro nutrient requirements	Mesophilic bacteria, which thrive at 20–45 °C, may require an external source of heat
	Low growth rate requires good biomass retention
Low energy requirements due to lack of forced ventilation	Initial commissioning/acclimatisation phase can be long (not for reactors with granular sludge, e.g. EGSB, seeded with the sludge of operating plants)
Generally lower capital and operating costs per kg of COD removed. These are associated with a decrease in sludge production and lower mixing costs	Anaerobic systems are more sensitive than aerobic systems to fluctuations in temperature, pH, concentration and pollution loads
Produces biogas that can be used for power or heat generation	Some constituents of treated waste water can be toxic/corrosive, e.g. H2S
Small space requirements	
Can be easily decommissioned for extended periods and remain in a dormant state (useful for seasonal manufacturing processes, e.g. sugar beet)	
A particular advantage of the process is the formation of pellets. This permits not only rapid reactivation after months-long breaks in operation, but also the sale of surplus sludge pellets, e.g. for the inoculation of new systems	
Some substances that cannot be degraded by aerobic means can be degraded anaerobically, e.g. pectin and betaine	
Less odour problems, if appropriate abatement techniques are employed	

From the advantages and disadvantages presented and according to the characteristics of Lacteos San Antonio, considering especially the physical space as the greatest limitation, it is considered that the anaerobic treatment is the most indicated; that compared to aerobic treatments is more respectful with the environment, with less emissions and less energy consumption (Georgiopoulou, 2008).

Anaerobic techniques are generally used in industries where a high level of soluble and readily biodegradable organic material exists, characteristics that are found in the FDM industry and for the dairy industry have worked successfully for BOD concentrations of 1500mg/l to 3000mg/l and above. Unlike aerobic treatments, most of the organic carbon associated with the influent BOD is converted into methane that can be used as fuel, thus generating less sludge to dispose of which leads to higher costs for treatment and disposal, the treatment units are closed which limits the generation of odors.

To achieve an adequate final quality for discharge to a watercourse, the anaerobic system is not sufficient, so it is required to be followed by an aerobic system to decrease the final emission levels, eliminating the hydrogen sulfide, ensuring the aeration of the wastewater for the total decomposition of BOD; this can be done by a subsequent retention tank before discharge. (Giner, 2019), (European Commission, 2006) (Tirado et al., 2016).

The UASB (Upflow Anaerobic Sludge Blanket) reactors, considered as one of the most profitable and efficient anaerobic treatments, were developed for medium and high organic matter load industrial wastewaters, whose benefits are the reduction of BOD and TOC or COD emission levels above 80%, the stabilization of sludge and the generation of methane that can be used as an energy source.

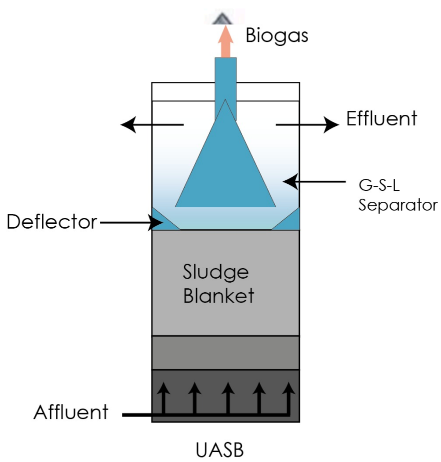

Figure 7. UASB Reactor Scheme

(Source: Arango et al.,2009).

Due to their functionality, UASB reactors are the most used systems in the FDM sector, being appropriate for the treatment of wastewater from the dairy industry. (Giner, 2019, European Commision, 2006, Tirado et al., 2016, Shirule et al., 2013, Naushad, 2018, Preeti et al., 2017)

Performance reports of the UASB reactors in the FDM sector, including the beer, dairy, fruit and vegetable industries, among others, report that the results have been successful in working with initial loads of 5 to 10 kgCOD/ m3 per day, obtaining final levels of between 100 and 500 mg/l with a quantity of sludge generated per kg of COD removed of between 0.04 and 0.08 TSS/kg (Giner, 2019). Table 9 refers to the main advantages and disadvantages of the operation of the UASB reactors disseminated by several authors who have analyzed their implementation in the dairy industry.

Table 9. Advantages and disadvantages of UASB reactor

(Source: Giner, 2019; European Commission, 2006, Tirado et al., 2016, Preeti et al., 2017, Lorenzo, 2006)

<table>
<tr><th>Advantages of UASB reactor</th><th>Disadvantages of UASB reactor</th></tr>
<tr><td>An important advantage is the formation of pellets, which allows a quick reactivation after months of interruption. In addition, pellets can be marketed for the inoculation of new systems.</td><td rowspan="3">Sensitivity to FOG. The levels of fat in the wastewater must be less than 50mg/l, otherwise they have a detrimental effect, since the inhibiting action of the fat for anaerobic treatment does not allow a fast and effective removal. To eliminate this problem, enzymatic hydrolysis of fats is applied as a pre-treatment, producing greater removal efficiencies.</td></tr>
<tr><td>Small space requirements (compact systems with low air demand)</td></tr>
<tr><td>Low sludge production</td></tr>
<tr><td>Low energy consumption and low operating costs</td><td rowspan="3">Additional biological (aerobic) treatment is necessary in the later stages, for which odour reduction may be required.</td></tr>
<tr><td>BOD/COD removal levels above 80%</td></tr>
<tr><td>Production of biogas, in which approximately 75% is methane</td></tr>
</table>

In this way it can be determined that for the secondary treatment, the anaerobic biological treatment is the most indicated option for the reality of Lácteos San Antonio the UASB reactor for the elimination of BOD and TOC or COD.

In order to complete the treatment of wastewater from the dairy industry, it must be considered that the effluent from the process carried out in the UASB reactor contains soluble matter that is not very biodegradable, micro-pollutants such as ammonia-nitrogen and phosphorus that can be difficult to eliminate by means of micro-aerobes or simple sedimentation. Therefore, it is necessary to implement an additional treatment to guarantee that the quality of the effluent is appropriate to be discharged complying with the quality established in the regulations.

Taking into accout the characteristics of the processed water, the Sequencing Batch Reactor (SBR) it could be considered suitable as post-treatment.

The SBR is a variant of the Activated Sludge Process, in which its cycle operation consists of filling, aeration, settlement and decantation periods that can be adjusted to obtain aerobic, anoxic and anaerobic phases.

The SBR is a batch process in which the treated water can be kept in the reactor until the end of the treatment (as long as there is a place to store the influent), this minimizes the dragging of the biomass due to the flow peaks, which improves the quality of the effluent.

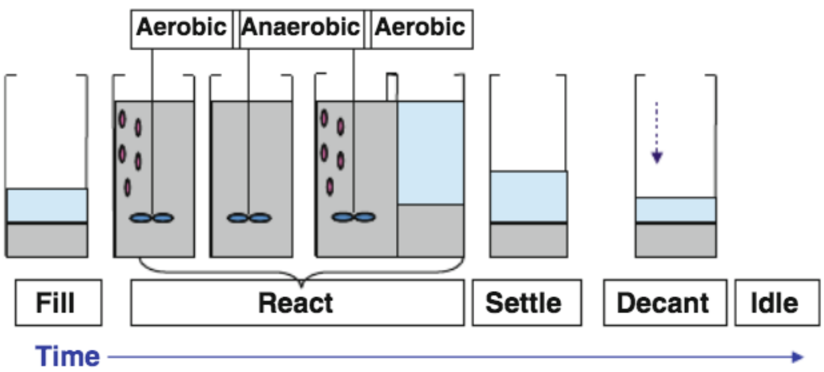

Figure 8. Schematic of sequencing batch reactor (SBR)

(Source: Roy et al., 2010)

The advantages of using an SBR system are:

Table 10. Advantages and disadvantages of the SBR

(Source: Giner, 2019; Moawad et al., 2009; Ali, Abid et al.,2013; Ghodeif, 2013).

Advantages of SBR	Disadvantages of SBR
High treatment efficiencies possible for BOD, COD, TSS, N, P.	Higher operational costs than the conventional activated sludge process
High flexibility in operating conditions.	
	Low pathogen removal.
Compact tank construction	Requires skilled personnel
The advantage over the activated sludge system, in the SBR is not required to pump the activated sludge back to a clarifier.	Dependence on uninterrupted power supply
Unlike conventional systems, sedimentation is performed when there is no flow input and output, avoiding the occurrence of a short circuit.	
Problems generated by temperature variations can be solved by adjusting cycle times and thus not losing efficiency.	
Being a reactor that can nitrify, denitrify and oxidize the substrate and clarify at the same time, it saves space and costs	

Experimental tests and in a pilot plant of residual waters, the combined system eliminated around 85% of TN, in addition to 95% of DQO, 96% of SST and 98% of DBO by nitrification (Ali, Abid et al.,2013).based on the advantages and effectiveness of this technology, it becomes the indicated option for the post treatment to the UASB so that the effluent fulfills the concentrations demanded by the environmental legislation.

7.3 Sludge Treatment

The sludge produced in the treatment of wastewater from the dairy industry has high concentrations of organic compounds in Ecuador depends on the use and disposal options available to the operator in charge. In the case of the city of Cuenca is the disposal in landfills, so the treatment of sludge focuses on reducing its volume by dewatering it in the company's facilities, in order to reduce transportation costs and disposal costs. The sludge thickening technique is the simplest and most widely used, by which the sludge is consolidated in the sedimentation tanks, allowing the storage of primary sludge (organic material and organic solids that are easy to settle and compact without the need for chemical additives) and secondary sludge (flocs that are more difficult to remove), with low energy consumption. The sludge thickening process is enough to reduce the volume of the sludge so that operating costs and disposal are cost-effective (Giner, 2019, Perimal et al., 2017, Sharrer et al., 2010).

8. Treatment process

According to the technologies previously described and on the company's needs, the wastewater treatment plant proposed for Lácteos San Antonio includes Coarse Screens, Fine Screens, Flow and Load Equalization, DAF unit, UASB reactor, Storage tank, SBR reactor, and a Sludge Thickening, as represented in the flow diagram of Figure 7.

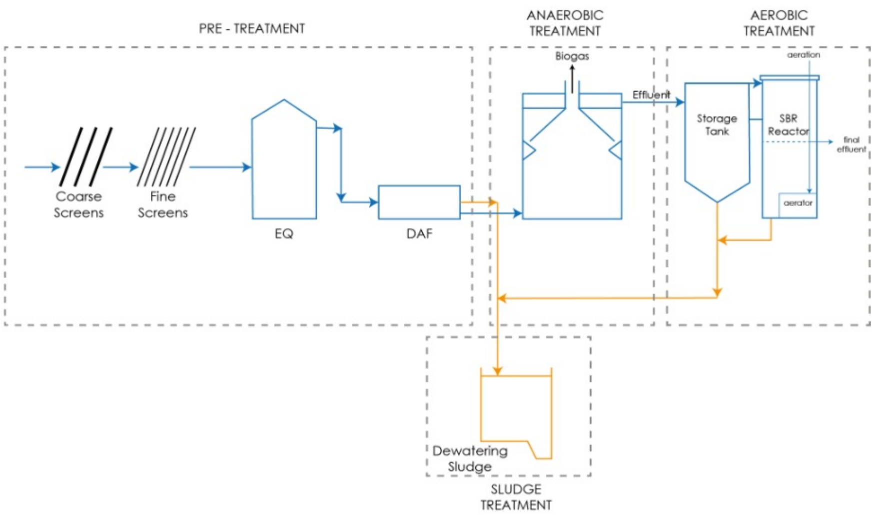

Figure 9. Scheme of Lácteos San Antonio wastewater treatment technology

The wastewater treatment plant processes are detailed below.

8.1 Pretreatment

Pretreatment consists of screening that allows the removal of large solids, sand, grease and oil in order to avoid mechanical damage to pipes and system equipment.

8.1.1 Screening

A screen is a device of parallel bars, rods, grids, perforated plates or wires with openings, usually of uniform size, that are used to retain the coarse solids found in wastewater. The openings are generally circular or rectangular and the space between the bars to remove very thick materials can be 60 - 20 mm. and for finer screening a gap between the grids of less than 5 mm., emphasizing that openings of 1 - 1.5 mm are less susceptible to blockage than those of 2 - 3 mm. Typical separation spaces are 0.02 - 2 mm for screen surfaces of 0.1 - 3.0 m2 (maximum throughput 300 m3/m2/h) (Giner, 2019, Nozaic, 2009).

Clogging of screens is a common problem that leads to the need for frequent cleaning. Due to the common problems of screen cleaning, it is recommended to use a curved screen since it takes advantage of the constant overflow to clean itself and thus avoid blockages. When blockage is due to fat deposits (common in the meat, dairy and fish sectors), regular chemical cleaning and/or hot water cleaning can be applied (Giner, 2019).

In this case, curved screens are recommended, with a 10 mm clearance between the screens for coarse screening and a 1.5 mm clearance between the screens for fine screening.

8.2 Primary Treatment

The primary treatment consists of equalization and chemical precipitation and flotation.

8.2.1 Equalization

At Lácteos San Antonio, the generation of waste water depends directly on a production plan, the frequency of cleaning and maintenance carried out on the equipment, containers, pipes and tanks in the factory, so the flow rates and pollution load entering the treatment plant are highly variable throughout the working day.

Flow equalization is beneficial from the moment of plant design to avoid over-sizing, optimizing resources, providing greater process control and the advantage of extending the life of the facilities.

The most commonly used method for sizing the tank is based on the variation in volumetric flow, which is done by monitoring the evolution of the actual accumulated flow over the period of analysis and comparing it with the average volume. It is important that the calculated value of the tank volume is increased by 20% (Metcalf & Eddy, 1995) as a safety measure due to the integration of aeration/agitation equipment, the possibility of recirculation of internal plant currents and changes in inlet flows.

In equalization-homogenization plants that are located before primary sedimentation and biological treatment, the provision of a sufficient degree of mixing to prevent sedimentation of solids, concentration variations and sufficient aeration devices to avoid odor problems must be taken into account, in addition to the fact that in-line homogenization allows for considerable buffering of constituent loads in subsequent processes. (Metcalf & Eddy, 1995)

In order to maintain an optimum pH for the operation of coagulants and flocculants of the physical-chemical processes that follow, a mechanical agitation should be carried out in the homogenization tank whose retention time will vary according to the inlet flow.

8.2.2 Chemical Precipitation and Flotation (DAF)

In the DAF (Dissolved Air Flotation) system, air is dissolved in the wastewater at a pressure of several atmospheres and then released until it reaches atmospheric pressure. (Metcalf & Eddy, 1995) The DAF system consists of applying the flotation induced by microbubbles with diameters between 40 and 70µm that are released by a system of submerged turbines that suck the water from the surface. In this process, inorganic chemical reagents such as iron, aluminum and activated silica salts are added and used to add solid particles to facilitate the absorption of the air bubbles. Various organic polymers are also used to modify the nature of the air-liquid and/or solid-liquid interfaces. (Metcalf & Eddy, 1995)

This operation brings the wastewater to a tank in which the separation of the treated water and the floating particles takes place. The treated water is commonly discharged through the perimeter of the top of the tank in which there are grooved troughs.

The particles (suspended solids, fats and oils) on the surface of the tank are collected by a mechanical scraper system and are separated as flotation sludge.

The sands that are in the form of sediment at the bottom of the tank are sucked by a system of pumps that take them to a tank intended for storage.

The sediment and flotation sludge obtained are subjected to processes of concentration and natural drying, having in this way drained that are returned again to the head of the plant and solid waste of low density and sand must be delivered to authorized waste managers.

8.3 Secondary Treatment

The secondary treatment consists of the UASB anaerobic treatment and the SBR aerobic treatment.

8.3.1 Upflow anaerobic sludge blanket process (UASB)

The Upflow Anaerobic Sludge Blanket (UASB) process was one of the most important advances in anaerobic technology for treating wastewater with medium and high organic load concentrations. The UASB tube bioreactors operate in a continuous regime and in an upward flow, this means that the wastewater enters the bottom of the reactor and is distributed upwards through a sludge blanket in which the generation of gases plays a very important role in providing a sufficient mixture so that the organic matter is degraded and these gases are collected in the upper part of the reactor. The liquid effluent obtained from the process then passes through a sedimentation tank to collect the solids that have escaped from the reactor and can be recycled there (RIFFAT, 2012, Tirado et al., 2016).

The main characteristic of the UASB process is the formation of a dense granular sludge which is influenced by the characteristics of the wastewater, the reactor geometry, the upward flow velocity, the HRT and the organic load rates; but this can be a disadvantage, since its formation can take several months, and in some cases it has even been required to supply seeds from other facilities to accelerate this process (RIFFAT, 2012).

In reactor operation, most organisms grow on the surface and in the interstices of the pellets, while the nucleus may contain inert extracellular material. Bacteria carry out the reactions and then by natural convection a mixture of gas, treated wastewater and sludge granules rises to the top of the reactor, where three-phase separators separate the final wastewater from the solids (biomass) and biogas (Giner, 2019).

The volumetric loading rates can vary from 0.5 to 40kg/ $m^3 \cdot d$, the HRT can vary from 6 to 14h, the ascent speeds from 0.8 to 3.0 m/h, depending on the type of wastewater and the height of the reactor.

For design purposes, the critical elements to consider are the influent distribution system, the gas-solids separator and the effluent removal system (RIFFAT, 2012).

11.3.2 Sequencing Batch Reactors (SBR)

SBR is a variant of the activated sludge process. In this process the different stages of the activated sludge are carried out in the same reactor in which the levels of BOD, TOC or COD, phosphorus and nitrogen are reduced. This technique is applied to high or low BOD wastewater.

The SBR reactor process consists of filling, aeration, settlement, decanting and resting cycles which allows one reactor to perform a work as a sequence of reactors in addition to a clarifier.

For this technology, the investment capital is lower and the operating costs are higher than those of the activated sludge technology.

There are many reports of the implementation of the SBR system in wastewater treatment plants of the dairy industry and it is known that it is used as a technique to ensure compliance with the effluent concentrations required by legislation used as a post treatment after anaerobic treatment (Giner, 2019, Moawad et al., 2009).

8.4 Sludge Treatment

Thickening is the simplest procedure to remove a part of the liquid fraction of the sludge obtained from the wastewater treatment and allows it to consolidate in the sedimentation tanks.

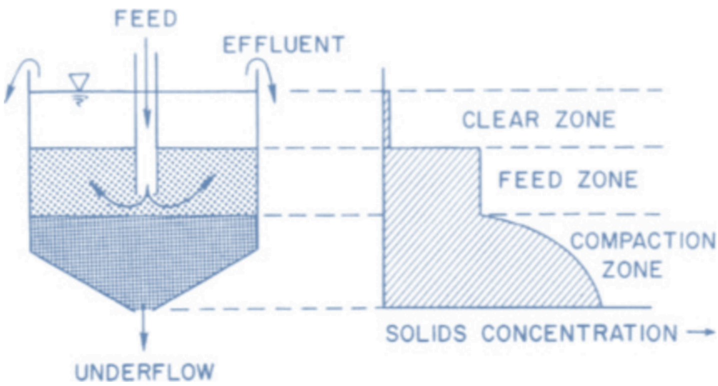

Figure 10. Gravity thickener scheme

(Source: J. Jeffrey, Ruth F. & P. Aarne, 1998)

Thickening efficiency of the sedimentation process improves when the sedimentation tank has a larger and smaller diameter, since the most important variable is the height of the sludge layer underneath the supernatant.

One or two tanks may be considered for thickening, in the case of using one, the sludge inlet should be located at the top of the tank preferably with a baffle plate to minimize hydraulic disturbances and in the case of using two tanks, they should be arranged so that one is at rest while the other is in the process of filling, but this will depend on the primary sludge removal model. The retention time of the sludge depends on the nature of the sludge and excessive retention should be avoided to

prevent odors and corrosion due to anaerobic conditions. It is recommended that the tank has a fence thickener to reduce the stratification of the sludge and to release water and gas through agitation.
The sludge thickener alone is a cost effective solution to reduce the volume of the sludge and its subsequent disposal off site (Giner, 2019).

9. Investment Costs

Having identified the technologies of Lácteos San Antonio's wastewater treatment plant through this study, the Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in the Food, Beverage and Dairy Industries has been used to have a reference of the approximate costs that the investment of its implementation could incur. For this the text cites investment reports for a treatment plant with equalisation tank, dissolved air flotation (DAF)), UASB reactor, optimisation of existing aerobic biological treatment, biogas conditioning (drying, compression) for treatment of around 1 000 m3/day of waste water and a COD load of around 4.5 t COD/day for a cost of 2 million EUR.

10. Conclusions

Based on the necessity of implementing a wastewater treatment plant by Lácteos San Antonio using the least amount of area possible and whose operating costs are cost-effective for the company, the development of this study the following conclusions:
- In the document Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk Industries, (2019) of the most suitable technologies used for the treatment of waste water applicable to the flow and characteristics of the waste water of Lácteos San Antonio are exposed so that the requirements of the environmental regulations can be fulfilled.
- The pre-treatment recommended includes the use of coarse and fine sieves in which a first separation of solids that can be found in the influent and a first partial elimination of SS, FOG, BOD, COD, to continue with an equalization tank to regulate the flow rates and be able to condition the water quality for the following processes.

- The use of a DAF system is necessary in wastewater treatment plants of the dairy industry to reduce the problems generated by long hydrolysis times due to the presence of FOG in the anaerobic treatment and especially in the UASB reactor.

- The UASB reactors are the option considered due to the great diffusion for the treatment of residual waters of the dairy industry, consolidated as one of the most profitable and efficient anaerobic treatments with a reduction of the levels of BOD and TOC or COD superior to 80%, in addition to its capacity of methane generation it turns it into a source of useful energy generation for the company.

- The implementation of an SBR is recommended in order to eliminate the soluble matter that is not highly biodegradable, micro-contaminants such as ammonia-nitrogen and phosphorus that are present in the UASB effluent and that in the predecessor processes are not treated so the treatment plant effluent has the values of concentrations to be discharged to the sewage system.

- The treatment of sludge, based on the realities of the operators in the city is established as a thickening of sludge for subsequent disposal in landfills, considering this solution as the most appropriate for the moment, but that in the future can be evaluated to implement a more specialized process and seek greater use of the sludge generated in the treatment plant.

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Appendix

A1.

Wastewater discharge from pasteurisation and standardisation units.

A1.1 Wastewater discharge from pasteurisation and standardisation PAST1 12000.

Table A1.1 *Wastewater discharge from pasteurisation and standardisation PAST1 12000.*

PAST (1) 12000				
NaOH (kg)	12		No. of intermediate wash:	2
Peracetic Acid (ml)	800		Activity duration (h):	10
HNO3 (kg)	8			

Water quantities per stage				
Element in the cleaning circuit	**Initial**	**Intermediate**	**Each 18-minute download**	**Final**
H2O (L)	1000	0		0
NAOH Preparation (L)	300	300		300
H2O (L)	1000	1000		1000
Peracetic Acid (L)	300	0		0
H2O (L)	1000	0		0
HNO3 (L)	0	0		300
Milk sludge (L)			16	
Subtotal Discharged Water (L)	3000	1000	0	1000
Total Discharged Water PAST (1) (L)	5000			

A1.2

Wastewater discharge from pasteurisation and standardisation PAST2 6000.

Table A1.2 *Wastewater discharge from pasteurisation and standardisation PAST2 6000.*

PAST (2) 6000				
NaOH (kg)	7		No. of intermediate wash:	2
Peracetic Acid (ml)	500		Activity duration (h):	10
HNO3 (kg)	5			

Water quantities per stage				
Element in the cleaning circuit	**Initial**	**Intermediate**	**Each 18-minute download**	**Final**
H2O (L)	600	0		0
NAOH Preparation (L)	200	200		200
H2O (L)	500	500		500
Peracetic Acid (L)	200	0		0
H2O (L)	1000	0		0
HNO3 (L)	0	0		200
Milk sludge (L)			8	
Subtotal Discharged Water (L)	2100	500	0	500
Total Discharged Water PAST (1) (L)	3100			

A1.3

Wastewater discharge from pasteurisation and standardisation PAST3 6000.

Table A1.3 *Wastewater discharge from pasteurisation and standardisation PAST3 6000.*

PAST (3) 6000				
NaOH (kg)	7		No. of intermediate wash:	1
Peracetic Acid (ml)	500		Activity duration (h):	8
HNO3 (kg)	5			

Water quantities per stage				
Element in the cleaning circuit	**Initial**	**Intermediate**	**Each 18-minute download**	**Final**
H2O (L)	600	0		0
NAOH Preparation (L)	200	200		200
H2O (L)	500	500		500
Peracetic Acid (L)	200	0		0
H2O (L)	1000	0		0
HNO3 (L)	0	0		200
Milk sludge (L)			8	
Subtotal Discharged Water (L)	2100	500	0	500
Total Discharged Water PAST (1) (L)	3100			

A1.4

Wastewater discharge from pasteurisation and standardisation PAST4 15000.

Table A1.4 *Wastewater discharge from pasteurisation and standardisation PAST4 15000.*

PAST (4) 15000				
NaOH (kg)	15		No. of intermediate wash:	1
Peracetic Acid (ml)	100		Activity duration (h):	10
HNO3 (kg)	10			

Water quantities per stage				
Element in the cleaning circuit	**Initial**	**Intermediate**	**Each 18-minute download**	**Final**
H2O (L)	0	0		0
NAOH Preparation (L)	0	0		500
H2O5 (L)	2000	0		2000
Peracetic Acid (L)	500	0		0
H2O (L)	2000	0		0
HNO3 (L)	0	0		2000
H2O (L)	0	0		2000
Milk sludge (L)			16	
Subtotal Discharged Water (L)	2000	0	0	2000
Total Discharged Water PAST (1) (L)	4000			

A1.5

Wastewater discharge from pasteurisation and standardisation PAST 1500 CREAM.

Table A1.5 *Wastewater discharge from pasteurisation and standardisation PAST 1500 CREAM.*

PAST 1500 CREAM	
NaOH (kg)	7
Peracetic Acid (ml)	500
HNO3 (kg)	5

Water quantities per stage				
Element in the cleaning circuit	**Initial**	**Intermediate**	**Each 18-minute download**	**Final**
H2O (L)	200	0		0
NAOH Preparation (L)	150	0		150
H2O (L)	500	0		500
Peracetic Acid (L)	150	0		150
H2O (L)	500	0		500
HNO3 (L)	0	0		0
Subtotal Discharged Water (L)	1200	0	0	1000
Total Discharged Water PAST (1) (L)	2200			

A1.6

Wastewater discharge from pasteurisation and standardisation Yogurt.

Table A1.6 *Wastewater discharge from pasteurisation and standardisation Yogurt Pasteurizer*

YOGURT	
NaOH (kg)	7
Peracetic Acid (ml)	500
HNO3 (kg)	5

Water quantities per stage				
Element in the cleaning circuit	**Initial**	**Intermediate**	**Each 18-minute download**	**Final**
H2O (L)	500	0		300
NAOH Preparation (L)	250	0		250
H2O (L)	300	0		300
Peracetic Acid (L)	0	0		0
HNO3 (L)	250	0		250
H2O (L)	300	0		300
Subtotal Discharged Water (L)	1100	0	0	900
Total Discharged Water PAST (1) (L)	2000			

A2.

Factory Water CIP generators

Table A2.1 *Factory Water CIP generators*

Factory Water CIP generators		
User	**Activity**	**Water Consumption/Discharge (m^3)**
Yogurt	CIP	3.00
ALCIP2	CIP Silo 5	6.67
ALCIP2	CIP Silo 7	5.34
ALCIP2	CIP Silo 8	6.67
ALCIP2	CIP Silo 9	2.15
ALCIP2	CIP Silo 10	6.67
ALCIP2	CIP Silo 11	6.67
ALCIP2	CIP Silo 12	6.67
ALCIP2	CIP Silo 13	6.67
ALCIP2	CIP Silo 14	2.57
ALCIP2	CIP Silo 15	6.67
ALCIP2	CIP Silo 17	6.67
ALCIP3	CIP TA50	11.00
ALCIP3	CIP TA20	11.00
ALCIP3	CIP Packer NOP	3.00
ALCIP3	CIP Packer DFG	9.00
MRU1	CIP	4.30
MRU2	CIP	4.30
FLEX 7000	CIP	4.00
FLEX 13000	CIP	6.00
FLEX 22000	CIP	8.00
MAXI	CIP	4.00
Own CIP	CIP for A	7.50
Own CIP	CIP for B	7.50
Own CIP	CIP for C	7.50
Silo 1	CIP	2.75
Silo 2	CIP	2.75
Silo 3	CIP	2.75
Silo 4	CIP	2.75
Total		164.5

A3.

Breakdown of packaging water consumption.

A3.1 Packer Program (A/B/C)

Table A3.1 *Packer Program (A/B/C) wáter consumption*

Packer Program (A/B/C)			
Washing Steps	**Flow (L/h)**	**Time(s)**	**Volume (L)**
First Wash	9000	60	150
Caustic	9000		0
Second Wash	9000	720	1800
HNO3	9000		0
Third Wash	9000	720	1800
Total			3750

A3.2

Packer Program (NOP/D/F/G)

Table A3.2 *Packer Program (NOP/D/F/G) wáter consumption*

Packer Program (NOP/D/F/G)			
Washing Steps	**Flow (L/h)**	**Time(s)**	**Volume (L)**
First Wash	9000	400	1000
Caustic	9000		0
Second Wash	9000	200	500
HNO3	9000		
Total			1500

A4.

Standardization of raw milk

A4.1 Raw milk standardization process and wastewater generation

During the separation of the milk fat and solids from the raw milk, some of the fat and solids are discharged from the centrifuge (milk sludge).

The frequency of this discharge is every 18 minutes with a duration of 20 seconds and its magnitude is proportional to the capacity of each pasteurizer.

Table 5 provides an average daily flow (milk sludge discharge and CIP cleaning) for each pasteurizer; it is important to indicate that the values may change according to the hours of operation and the maximum flow occurs when two pasteurization units are in operation at any given time.

The cream pasteurizer, by its side, works in a similar way.

Table A4.1 *Estimation of wastewater generation from pasteurizers*

Estimation of wastewater generation from pasteurizers			
Unit	**Days of Operation**	**Water consumption[1] (m^3/day)**	**Discharge[2] (m^3/day)**
PAST1	Weekend	7.8	8.33
PAST2	Every day	4.8	5.1
PAST3	Every day	4.1	4.3
PAST4	Every day	9.5	10
PAST CREMA	At least one day a week	2.8	2.8
Total Week		128.2	135.3
Daily Average		18.3	19.3

[1] Σ of initial, intermediate and final discharge.
[2] Σ water consumption plus milk sludge.

Full details of the consumption information can be found in Appendix 1.

A5.

UHT units (FLEXI and MAXI)

A5.1 Consumption and discharge flows of UHT units

Wastewater generated by UHT units is due to CIP cleaning and product discharge (less than 1% of product is lost in discharge) at the end of the process of a production batch.

Table A5.1 shows the calculated consumption (data provided by the factory) and the discharge flows for each unit.
The values used for consumption are based on flows measured by area operators and on the manufacturer's data sheet.

Table A5.1. Estimation of wastewater generation from sprayers.

Consumption and discharge flows of UHT units				
Units	**Use**	**Consumption (m^3/d)**	**Download to PTAR (m^3/d)**	**Recovery (m^3/d)**
FLEX 7000[2]	Heat exchangers	12	12	
FLEX 13000[2]	Heat exchangers	12	12	
FLEX 22000[1]	Heat exchangers	38	0	38
MAXI[1]	Heat exchangers	29	0	29
FLEX 7000	CIP	4	4	
FLEX 13000	CIP	6	6	
FELX 22000	CIP	8	8	
MAXI	CIP	4	4	
TOTAL		113	46	67

Notes:
[1]. The flow measured by the operators.
[2]. Based on the manufacturer's sheet.

The cooling water recovered in the FLEX 22000 and MAXI units is sent to the recovery tank which has a volume of 60 m^3.

A6.

Consume and discharges of the CIP and Floor Clenaing

A6.1CIP

Table A6.1 shows an average of the amount of water discharged into the sewerage network monitored over a 5-month period at the factory (data provided by the factory), highlighting some of the units sanitized by the CIP units, and then showing the values to be considered:

Table A6.1. *Consumption and Discharges from CIP Units.*

Consume and Discharges from the CIP Units			
Units	**Activities**	**Water Consumption /Disharge (m^3/d)**	**Comments**
ALCIP 2	CIP from Silo 5	6.67	Based on the CIP unit capacity of 8000L/h and a cleaning time of 50 minutes
ALCIP 2	CIP froml Silo 7	5.34	
ALCIP 2	CIP from Silo 8	6.67	Based on the CIP unit capacity of 8000L/h and a cleaning time of 50 minutes
ALCIP 2	CIP from Silo 17	6.67	Based on the CIP unit capacity of 8000L/h and a cleaning time of 50 minutes
ALCIP 3	CIP TA 50	11	Equipment reference : 11m^3/CIP for a 50m^3 tank
ALCIP 3	DIP Packer NOP	3	Appendix 3(2x CIP/d)
ALCIP 3	CIP Packer D/F/G	9	Appendix 3; 2xCIP/d for 3 separate units
Integrated	CIP for A	7.5	Appendix 3; 2x CIP/d
Manual	Silo 1	2.75	Equipment reference : 11m^3/CIP for a 50m^3 tank; adjusted for the volume of the smallest tank
Manual	Yoghurt	3	Appendix 1; Σ of the initial and final discharge

A6.2 Floor cleaning

The amount of wastewater generated by floor cleaning is highly variable and has not been quantified during measurement campaigns.

A7.

Discharge limits to the public sewage system (TULSMA - Ecuador)

Parámetros	Expresado como	Unidad	Límite máximo permisible
Caudal máximo		l/s	1.5 veces el promedio horario del sistema de alcantarillado.
Cianuro total	CN^-	mg/l	1,0
Cobalto total	Co	mg/l	0,5
Cobre	Cu	mg/l	1,0
Cloroformo	Extracto carbón cloroformo (ECC)	mg/l	0,1
Cloro Activo	Cl	mg/l	0,5
Cromo Hexavalente	Cr^{+6}	mg/l	0,5
Compuestos fenólicos	Expresado como fenol	mg/l	0,2
Demanda Bioquímica de Oxígeno (5 días)	$D.B.O_5$.	mg/l	250
Demanda Química de Oxígeno	D.Q.O.	mg/l	500
Dicloroetileno	Dicloroetileno	mg/l	1,0
Fósforo Total	P	mg/l	15
Hierro total	Fe	mg/l	25,0
Hidrocarburos Totales de Petróleo	TPH	mg/l	20
Manganeso total	Mn	mg/l	10,0
Materia flotante	Visible		**Ausencia**
Mercurio (total)	Hg	mg/l	0,01
Níquel	Ni	mg/l	2,0
Nitrógeno Total Kjedahl	N	mg/l	40
Plata	Ag	mg/l	0,5
Plomo	Pb	mg/l	0,5
Potencial de hidrógeno	pH		5-9
Sólidos Sedimentables		ml/l	20
Sólidos Suspendidos Totales		mg/l	220
Sólidos totales		mg/l	1 600
Selenio	Se	mg/l	0,5

Parámetros	Expresado como	Unidad	Límite máximo permisible
Aceites y grasas	Sustancias solubles en hexano	mg/l	100
Alkil mercurio		mg/l	**No detectable**
Acidos o bases que puedan causar contaminación, sustancias explosivas o inflamables.		mg/l	Cero
Aluminio	Al	mg/l	5,0
Arsénico total	As	mg/l	0,1
Bario	Ba	mg/l	5,0
Cadmio	Cd	mg/l	0,02
Carbonatos	CO_3	mg/l	0,1
Sulfatos	$SO_4^{=}$	mg/l	400
Sulfuros	S	mg/l	1,0
Temperatura	^oC		< 40
Tensoactivos	Sustancias activas al azul de metileno	mg/l	2,0
Tricloroetileno	Tricloroetileno	mg/l	1,0
Tetracloruro de carbono	Tetracloruro de carbono	mg/l	1,0
Sulfuro de carbono	Sulfuro de carbono	mg/l	1,0
Compuestos organoclorados (totales)	Concentración de organoclorados totales.	mg/l	0,05
Organofosforados y carbamatos (totales)	Concentración de organofosforad osy carbamatos totales.	mg/l	0,1
Vanadio	V	mg/l	5,0
Zinc	Zn	mg/l	10