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Determination of physical and chemical parameters of wastewater before and after treatment in the dairy industry using SBR reactor

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Abstract

The wastewater dairy is one of the most sources for pollution of the environment due to dairy’s high organic content. The main idea of this project has been starting the treatment of wastewater in the dairy industry. Based on the initial analysis that were performed there, we have identified the whey is the main problem of that pollution. Due to needed high capacity and high cost for treatment of the whey, this dairy decided to change the whey’s flow, not discharge in the same direction with wastewater. It uses SBR (Sequencing Batch Reactor) system. This system fills and draws activated sludge for the treatment of water. The water is treated to remove undesirable components, and then discharged. The parameters which are measured for this treatment are physical and chemical parameters. The oxygen values are measured by the oxygen meter. Temperature and pH are measured by the thermometer and pH meter. Biochemical demand Oxygen and chemical demand oxygen is very important parameters for measurement. BOD analysis was performed by the Manometric method or Oxitop instrument. COD analysis were performed by the method 8000 based on DR 2800 Spectrophotometer procedure. Other chemical parameters are measured by DR 2800 Spectrophotometer procedures manual as well. Total suspended solids and volatile suspended solids were prepared by gravimetric method. According to the results obtained from those parameters, we can conclude the effect of treatment of wastewater in the aeration system. We have reached to decrease the values of those parameters leading those to desired values for dairy industry.

Keywords: influent, effluent, BOD, COD, TSS, SVI.

Introduction

Wastewater can be determined as the flow of used water discharged from two main sources: as human sewage and as process waste from making industries [1]. Industrial wastewater is one of the most important sources for pollution of water in the environment. The amount of wastewater depends from processes in different industry and wastewater can be reduced with the improvement of industrial technologies. The dairy industry is one of the most polluted industries. Wastewater from dairy industry contains organic substance which are biodegradable [2]. Due to rapid fermentation, pH results in the low value (to pH=4.5) and oxygen is consumed rapidly [3]. Contrasted with domestic wastewater, the dairy manufacturing wastewater has got much higher values of pollution indicators, and wastewater has to be pre-treated before its drainage [3]. Wastewater treatment process denotes a series of actions or changes. These procedures are the separation, removal and disposal of pollutants present in the sewage. The main processes used in the treatment of wastewater are:

- Physical processes, in which the impurities are removed by separation by particle size, or by gravity.
- Chemical processes, in which the impurities are flocculated by the addition of chemicals, then allowed settling out before removal from the wastewater.
- Biological processes in which the impurities in the waste water are transformed by microorganisms.

Knowing the contents of the influent wastewater is very important and fundamental for successful design and operation of wastewater before treatment of it. There are many reactors that are used for operation of wastewater. One most important reactor for treatment of wastewater in the presence of oxygen is the sequencing batch reactor (SBR). SBR is a fill and draw activated sludge system for treatment of wastewater. Wastewater is added to a batch reactor for treatment and for removing of undesirable components and then discharged. Equalization, aeration and clarification can all be attained using a SBR reactor [4, 5]. SBR system consists of five common steps accomplished in sequence: (1) fill, (2) react (aeration), (3) settle (sedimentation/clarification), (4) draw (the effluent is decanted), and (5) idle [6]. The sludge produced in wastewater by the growth of organisms in aeration tanks is called activated sludge. The term 'activated' derives from the fact that the particles swarm with bacteria, fungi, and protozoa [7, 8]. The role of preliminary treatment is removing of large debris that might plug or block equipment. This often involves bar screens to remove large particulates such as sticks, rocks, rags, etc. Primary treatment is a process where its intention is removing of heavy organic material. The goal of it is collecting and removing the settled sludge, skimming and removing grease and other floating material, and discharging the clarified primary effluent to the next treatment. Secondary treatment provides a high level of removal of biodegradable organic pollutants to protect receiving water quality that clarification alone cannot provide and converts the remaining colloidal material to a biological sludge which rapidly settles. Tertiary treatment refers to processes which are used to further reduce parameter values below the standards set out in national regulations [9,10].

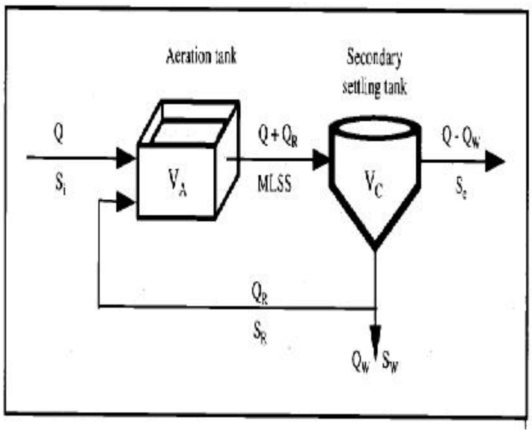


Figure 1: Activated sludge process

Q = inflow, m^3/day, S_i= inflow suspended solids, mg/l

Q_R=return activated sludge, m^3/day

S_R = return activated sludge suspended solids, mg/l

Q_W = waste activated sludge, m^3/day.

S_W = waste activated sludge suspended solids, mg/l

V_A = aeration tank volume, m^3

MLSS = mixed liquor suspended solids in the aeration tank, mg/l

V_C = secondary settlement tank volume, m^3

S_e = outflow suspended solid, mg/l

Based on the figure 1 we can take formulas for:

$$Q_R = \frac{settled\ sludge\ volume(\frac{ml}{l}) x Q(\frac{m^3}{day})}{\frac{1000ml}{l} - settled\ sludge\ volume}$$

$$Q_W = \frac{mass\ of\ sludge\ solids\ wasted\ x100}{S_W}$$

$$\text{Sludge age} = \frac{MLSS(V_A+V_C)}{Q_W \cdot S_W + (Q-Q_W)\, S_e}$$

Physical characteristics of wastewater are its solids content, color, odour and temperature. Color is one of the physical parameter that can be used to assess the general condition of wastewater. Wastewater is less than 6 h old when its color is light brown, while wastewater that have undergone some degree of decomposition or that have been in the collection system for some time has a light to medium grey color. Lastly, if the color of wastewater is dark grey or black, the wastewater contains undergone extensive bacterial decomposition under anaerobic conditions. The black color of wastewater is often due to the formation of various sulphides (ferrous sulphide) [11]. This comes when hydrogen sulphide produced under anaerobic conditions combines with divalent metal, such as iron, which may be present. The fresh wastewater has usually not offensive odour, but when wastewater under anaerobic conditions is decomposed biologically, a variety of odorous compounds are released. The major odorous compound is hydrogen sulphide (the smell of rotten eggs). In the food industries, the origin of the odor in waste water comes from fermentation produces and from the sulphides, mercaptans and amines (Munter). The measurement of temperature is one of most important parameters because most wastewater treatment schemes include biological processes that are dependent from temperature. The temperature of wastewater will change from season to season and also with geographic location. In cold regions the temperature will vary from about 7 to 18 °C, while in warmer regions the temperatures vary from 13 to 24 °C. The best temperatures for wastewater treatment probably range from 77 to 95 degrees Fahrenheit [12]. Turbidity tells the clarity of water is usually measured by its turbidity. Turbidity is an expression of the optical property that cause the light which is either absorbed or scattered by suspended material in water, but it is not a direct quantitative measurement of suspended solids [13, 14]. Chemical characteristics include organic and inorganic compounds present in the wastewater. Measurement of pH parameter is very important. Treatment and environment are affected from the acidity or alkalinity of wastewater. Low pH indicates increasing acidity; while a high pH indicates increasing alkalinity (a pH of 7 is neutral). The pH of wastewater needs to remain between 6 and 9 to protect organisms [2,15]. Nitrogen and phosphorus are important because these are responsible for the growth of aquatic plants. Nitrogen is typically present in influent in the forms of ammonia (NH_3) and organically bound nitrogen. Nitrogen may be present in effluent as ammonia, nitrite (NO_2) and nitrate (NO_3). Phosphorous is presented in influent and effluent primarily in the form of phosphates (PO_4). Large amount of those nutrients can cause problems by increasing the growth of plants, such as algae. During the night, the algae consume the oxygen in the water and produce CO_2. Fish and other organisms die due to a lack of oxygen [16]. Oxygen (dissolved in the mixed liquor) is required for respiration by the micro-organisms in the aeration tank. Too much or too little oxygen in the aeration tank is undesirable for different reasons. Too much oxygen adds unnecessary cost due to increased power consumption, and too little can decrease the metabolism of the micro-organisms and the efficiency of the process [14,17]. Biochemical oxygen demand (BOD) is a very important parameter which shows the quantity of oxygen required by microorganisms to decompose organic compounds in the wastewater. The BOD test takes 5 days to complete and the BOD level is determined by comparing the DO level of a water sample taken immediately with the DO level of a water sample that has been incubated in a dark location for 5 days [16, 18]. The difference between the two DO levels represents the amount of oxygen required for the decomposition of any organic material in the sample [19]. Chemical oxygen demand (COD) measures the amount of oxygen required to oxidize organic matter present in a water sample by means of a strong chemical oxidizing agent [20-22]. F/M ratio is defined as the load of food or substrate (BOD) supplied per day per unit biomass in the reactor (represented by MLVSS-mixed liquor volatile suspended solids) and expressed as kg BOD/kg MLSS/day [23].

$$F/M = \frac{kgBOD/day}{kgMLSS}, \quad \frac{kgBOD}{day} = \frac{BOD\left(\frac{mg}{l}\right)xQ}{1000}, \quad kgMLSS = \frac{MLSS*V_A}{1000}$$

High F/M ratio means low concentration of MLSS and low sludge age. Low F/M ratio means high concentration of MLSS and high sludge age. The sludge volume index (SVI) is used to assess the settling qualities of sludge. The SVI is measured by filling an Imhoff cone (or 1 litre graduated cylinder) with mixed liquor from the aeration tank and allowing the mixture to settle for 30 minutes. The volume of settled sludge (in 1 litre) is read after this period. The total solids (TS) - in a wastewater consist of the insoluble or suspended solids and the soluble compounds dissolved in water. Total solids content of a sample is the mass of solids remaining after a sample has been dried in a 103°C oven for 2 hours, divided by the original mass of the sample [24]. Total dissolved solids (TDS) are those which pass through a filter and are not seen. Only appear as solid material when the sample is dried [2]. Total suspended solids (TSS) are all particles in water that will not pass through a glass fiber filter with a pore size less than 2µm, including sediments, algae, nutrients, and metals [14]. The portion of TS that remains after heating at 550 °C for 1 hour is called Total fixed solids (TFS); the portion lost during heating is Total volatile solids (TVS) [14, 25].

TS= TDS + TSS and TS=TFS+TVS

Material and Methods

2.1 Operation system in this dairy industry

This dairy industry uses SBR reactor for treatment of wastewater. The pilot plant has a capacity of 240 m^3. A provisional air diffusion system has been realized with a capacity of about 20 m^3 air/h. The pilot plant operates with an F/M ratio of 0.1 kg BOD/kg MLSS/day. The plant operates with 2 operation cycles: first cycle (morning, starting at 00:40): settle time 0.5h, decant time 0.5h, fill time about 0.5 h, react time 8, 5 h. Second cycle (afternoon, starting 14:00), settle time 0.5h, decant time 0.5h, fill time about 0.5h, react time 12.5h). The aeration during both cycles can start during or directly after filling. When the oxygen concentration is high it is possible to shut down the aeration, for example during 30 minutes or the air flow can be reduced.

2.2 Determination of physical and chemical parameters

The oxygen was measured by an oxygen meter. Temperature and pH were measured daily by the thermometer and pH meter to ensure favourable environmental conditions in the reactor for biological treatment. Others analyses for influent water were performed once or twice within a month while for effluent water were performed often than twice within a month.

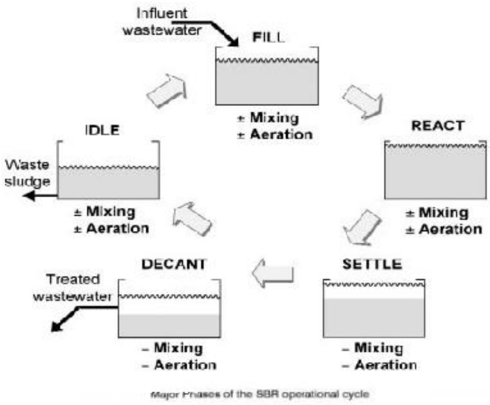


Figure 2: Sequencing batch reactor in the dairy industry

The determination of Nitrates was determined based in the Method 10206 - Dimethylphenol Method TNT plus 835 (0,23-13.50 mg/l NO_3-N); (1,00-60.000 mg/lNO_3). Phosphorus, Reactive (Orthophosphate) and total are determined based on the Ascorbic Acid Method (Method 10209 Reactive; Method 10210 Total UHR (6 to 60 mg/L PO_4^{3-} or 2 to 20 mg/L PO_4- P). Determination of Ammonia in the wastewater was performed according to the Salicylate Method (LR (1 to 12 mg/L NH_3–N). The total Nitrogen was measured by the Persulfate Digestion Method LR (1 to 16 mg/L N). COD analysis were performed by the method 8000 based on DR 2800 Spectrophotometer procedure. The biochemical demand oxygen has started to be measured by the Manometric method or Oxitop BOD, but after this period of taking those samples. We has taken the values of BOD from the ratio between COD and BOD which is COD/BOD=1.7. The Oxitop method is based on the measurement of pressure decrease due to the oxygen consumption by microorganisms oxidizing the organic matter (BOD measurement 5210D- 19th Edition 1995). Total solids (TS) in wastewater are the amount of all solids, which are determined by drying a known volume of the sample in a pre-weighed crucible dish at 105 °C. After cooling in an exsiccator, the crucible dish is again weighed. TSS was determined by using the following formula:

$$\frac{TSSmg}{L} = \frac{(average\ weight\ of\ filter\ with\ sample\ in\ g - average\ initial\ weight\ of\ filter\ in\ g)(\frac{1000mg}{L})}{Sample\ volume\ in\ L}$$

Sludge volume index is a very important indicator that determines if the control of the system is good or bad and it determines how much sludge has to be returned to the aeration tank and how much to take it out from the system (Figure 5 b).

SVI was calculated using the following formula:

$$SVI=\frac{volume\ of\ settled\ sludge\ \left(\frac{ml}{l}\right)x1000}{MLSS\ \left(\frac{mg}{l}\right)}$$

Results and Discussion

As we have mentioned above, the dairy industry is one of the most polluting industry. Effluent water in dairy industry contains soluble organics, suspended solids and trace organics. All these components lead to the high BOD and COD. Due to the fermentation of milk sugar to lactic acid dairy wastes become acidic rapidly. The heavy black sludge and butyric acid odors come from decomposition of casein (Bharati S. Shete and Shinkar NP, 2013). The obtained data in this study were taken for 5 months and we have put in the diagrams and we have discussed. Before starting the design of pilot plant, we wanted to measure the values of the whey since the results let us to understand that the one of the main pollution component in the dairy industry is the whey (Table 1). The pH in the aeration tank was measured every day from August to the December of 2014 by a pH meter and varied from 7-8. The acidic pH is toxic for nitrifying bacteria. The average of the temperature for every week is between 15^{o}C-30^{o}C. The temperature is very important for nitrification process. According to (Sawyer, CN, et al.) if the value of temperature is below 10^{o}C nitrification process stops and nitrification stops when the temperature rises to 50°C. Oxygen requirement is the most important parameter in the activated sludge process for oxidation of the influent organic matter along with cell growth and endogenous respiration of the microorganisms. Dissolved oxygen should not be less than 2 mg/l (Ravi Kumar, P., Liza Britta Pinto, Somashekar, R.K, 2010). If oxygen is lower, the process of nitrification occurs slowly because the nitrifying bacteria react in the presence of oxygen and they are slower growing and are more sensitive to pH and temperature. From the results, the average of the oxygen amount in the aeration tank is 7.23 mg O_2/l. The ratio of COD and BOD is a measure of the biodegradability of the waste water pollution load. The values obtained for BOD_5 are always lower than those for COD because some of the carbon removed during the BOD test is not oxidized and this amount of carbon ends up in the new biomass and because activated sludge bacteria cannot degrade some of the compounds oxidized chemically in the COD test (P. Davies,2005). If, the COD: BOD ratio is 2:1, it means the biodegradability is said to be good. From the results, this ratio is closed with 2:1. The average of COD influent is 3362 mg/l while the BOD influent is 1977.94mg/l. On the other hand, the average of COD effluent is 1027.8 mg/l within 5 months (Figure 6) and the BOD effluent is 604.45 mg/l. Nutrients in the wastewater means nitrogen and phosphorous because those are nutrients for plants and they affect plant growth particularly algae growth in the water. The averages of these nutrients in the untreated water were measured and from the results we can see their values (Figure 3). The average of phosphates is 32.99 mg/l. The average of the N-total is 112.96 mg/l and the average of nitrates compounds is 32.41 mg/l. The averages of these nutrients in the effluent water are: the average of phosphates is 12, 49 mg/l. Average of the N – total is 69.41 mg/l. Average of the NO_3 is 0, 94 mg/l. The average of orthophosphate is 17.02 mg/l. Average of the ammonia compounds is 53.54 mg/l (Figure 4). Removing of nutrients from wastewater is very important. Presence of NH_4^+ compounds cause problem in the environment, strong odor, and strong caustic. Nitrates and phosphates act as a fertilizer. Eutrophication process caused by presence of the phosphors and nitrates is harmful to the aquatic life in the lake. To achieve good nitrification we must have good BOD removal and long solids retention

time (SRT) because nitrifying bacteria are autotrophs, grow and reproduce slowly. If SRT is too low, the nitrifying bacteria will be washed out. Aerobic conditions are very important for absorption of phosphor by the bacteria, then those organisms release phosphor in the anaerobic conditions and in the end phosphor is removed by the wasting solids. The level of MLSS depends upon the desirability of treated water quality. MLSS level of 3500-5000 mg/L would be optimum in an extended type aeration tank. Optimum F/M in the aeration tank should be 0.1-0.15 (T.Subramani1 K. Arulalan.2012). Obtained average result of MLSS is 3260mg/L. In the December, the MLSS was higher 8g/l than previous months (Figure 5 a), contrasted with the point of having the value of the MLSS much lower in the winter than in the summer. Owing to the BOD load is much lower in the winter than in summer, it means that the MLSS has to be much lower as well. To decrease the value of MLSS is important to remove sludge from the system. Sludge volume results show the increasing of the sludge in the aeration tank during the five months. F/M ratio from the calculations of the results is 0.18. A proper F/M can be achieved by increasing or decreasing the rate of the return activated sludge.

Table 1: The values of the Whey in the dairy industry

Sample -COD (mg/l)	results of sample	dilution	Final results	Date
whey of curd	465	200	93000	28/04/2014
whey of curd	232	200	46400	07/07/2014
whey of curd	315	200	63000	10/07/2014
whey of curd	464	100	46400	15/07/2014
whey of curd	351	100	35100	18/07/2014
whey of curd	314	100	31400	23/07/2014

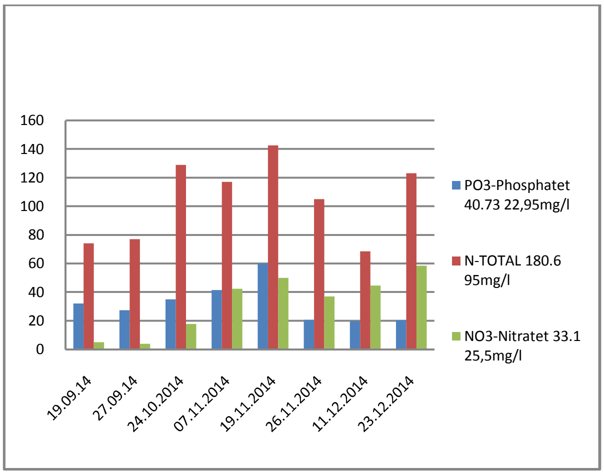


Figure 3: Measured parameters in the untreated water (influent) in the dairy industry

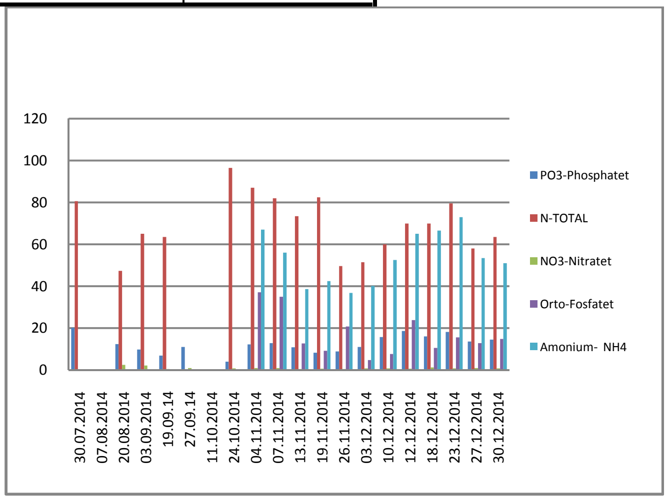
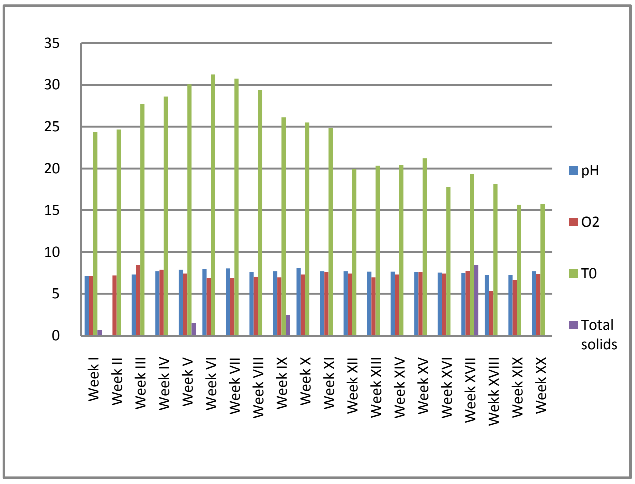
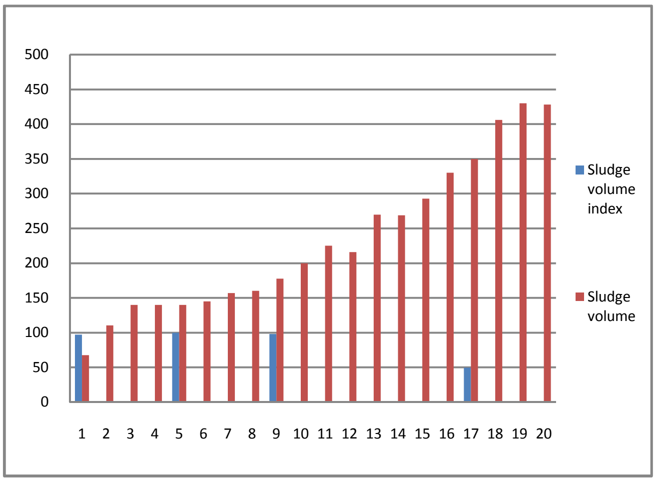


Figure 4: Measured parameters in the treated water (effluent) in the dairy industry



(a)



(b)

Figure 5: a, b Measured parameters in the aeration tank

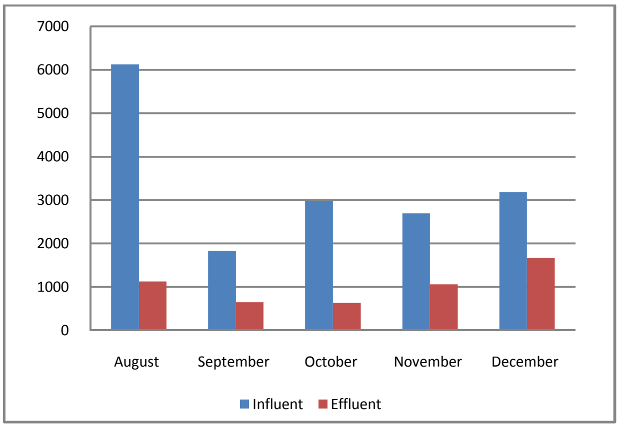


Figure 6: Measured of Chemical Oxygen Demand (COD) in the untreated and treated wastewater in the dairy industry

ConclusionS

Sectors of the dairy industry are big polluters. The water which flows from dairy industry presents a risk environment based on the content of milk's products. The samples were tested in the water before and after treatment. Looking at the test results we conclude that there is bacteria grow and oxygen consumption. When there is no oxygen consumption, the oxygen concentration will be about 10 mg/l thus, there is a biological activity. Based on all results, showing after treatment, we can see the effect of SBR in the operation of this treatment. Even though, it is a difficult process and complex operation, we can conclude the effect of treatment in dairy industry through activated sludge. Respecting the conditions which are so critical and measuring of all parameters carefully lead to the desired values for all parameters of treated wastewater in the dairy industry.

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