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BIOLOGICAL PURIFICATION OF CHEMICALLY PRE-TREATED DAIRY WASTEWATER BEFORE DISCHARGE INTO A MUNICIPAL SEWAGE SYSTEMS

GÁBOR GULYÁS,* BENCE FAZEKAS, REGINA VARGA, AND ÁRPÁD KÁRPÁTI

Department of Environmental Engineering, University of Pannonia, Egyetem u. 10, Veszprém, 8200, HUNGARY

Dairy production is one of the most inefficient processes with respect to water usage in the food industry. It was estimated that the production of a litre of milk creates three to four litres of wastewater. Dairy wastewater contains a high amount of dissolved and suspended solids. Moreover, it contains high concentrations of fat, protein, and carbohydrate. Consequently, the dairy wastewater content of organic compounds is high and so is its chemical oxygen demand. The majority of organic compounds are biodegradable with a high biological and chemical oxygen demand ratio. In this work, we examined the biological purification of physico-chemically pre-treated wastewater from a Hungarian milk-processing factory before it was discharged into the public sewage system. The chemical oxygen demand of the pre-treated wastewater ranged from 500 to 2500 mg dm⁻³. We found that it was possible to achieve efficient organic material removal from nutrient-poor wastewater without nutrient dosage contrary to the literature. The activated sludge system manifested efficient organic material removal that required a smaller biological volume. Experiments with biofilms have shown that a thicker biofilm needs more dissolved oxygen, which dictates oxygen input levels to be sufficient for creating an aerobic environment.

Keywords: activated sludge, biofilm, dairy wastewater, chemical oxygen demand, nutrient-poor wastewater

1. Introduction

Milk processing requires high specific water consumption and considerable raw material waste effluents [1]. Wastewater composition depends mainly on the produced material, production process, actual operations of the production process, and the water usage [2]. Clean water is practically used in all the process operations, like cleaning, sterilisation, heating and cooling. Wastewaters produced in these plants are usually polluted with chemicals, used for cleaning the containers, pipes, and some other equipment [2–4]. On average processing a cubic metre of milk produces 3–4 m³ of wastewater [5].

Milk processing effluents (dairy wastewaters - DWW) contain high concentrations of dissolved and suspended solids. They contain high concentrations of fat, protein mainly as fine colloids, and carbohydrate (lactose and lactic acid) [6–9]. Among the carbohydrates, lactose can be found in a high ratio [5]. However, the lactic acid content can also be very considerable in the case of the discharge of whey. Suspended solids of dairy wastewater originate from cheese and cottage cheese as well, but their final concentration highly depends on the processing methods at a given plant.

As a result of these ingredients of an approximate total concentration of around 2 g/g of the effluent, dairy wastewaters can exhibit high chemical oxygen demand (COD). The majority of the organic contaminants are biodegradable. The ratio of biological and chemical oxygen demand (BOD/COD) of the DWW-s is high [10]. All organic contaminants are in principle nutrients for microorganisms of the active sludge (AS) biological treatment. However, preliminary physico-chemical removal of particular components of the DWW, such as fats, most of the proteins, and casein considerably decreases the cost of biological purification required for permitting the discharge of this industrial effluent into municipal sewage systems.

2. Material and Method

We studied the biological purification of physico-chemically pre-treated wastewater from a Hungarian milk processing and dairy factory located in Székesfehérvár. Polyaluminium chloride, hydrochloric acid, and polyelectrolyte were used before flotation. Presently, the mixed wastewater after this treatment is discharged into the public sewage collection system. Intermittently, its COD concentration is higher than the prescribed limit, which results in an extra fee being charged for the discharge and municipal purification.

*Correspondence: gulyasg@almos.uni-pannon.hu

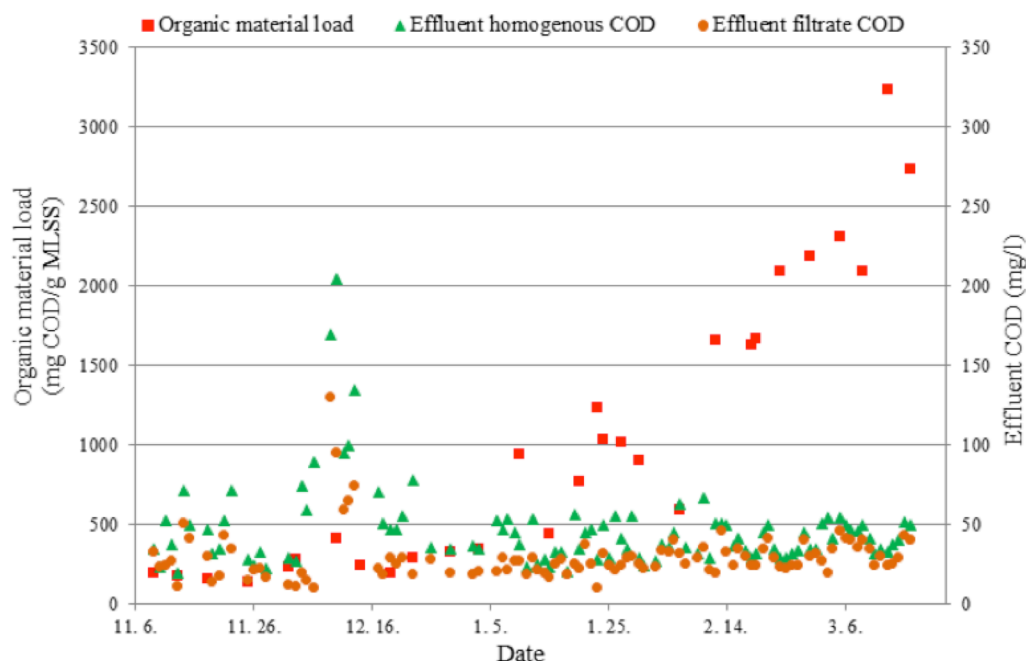


Figure 1. The chemical oxygen demand of the studied activated sludge sequencing batch reactor system.

COD of the pre-treated wastewater normally changed between 0.5 and 2.5 g dm⁻³ during the measurements, while the limit value was 1 g dm⁻³. The total organic material content was commensurable with the suspended solid concentration at the same time the magnitude of dissolved organic compounds was constant. The ammonium concentration in the pre-treated wastewater was low (3–10 mg dm⁻³), while the phosphorous content was negligible. Thus, the wastewater we purified biologically was lacking in N- and P-nutrients. We intentionally did not add any N- or P-nutrients.

We carried out parallel studies in an activated sludge sequencing batch reactor (AS-SBR) and a biofilm system, moving bed biofilm sequencing batch reactor (MBBR-SBR). The activated sludge reactor was inoculated with municipal activated sludge. The growth of biofilm was initiated by the addition of municipal wastewater during the first and second weeks. There were aerobic and anoxic periods in the SBR cycles (approximately in a 3 to 1 ratio) to cater for the needs of different microorganisms. Anoxic periods were used to improve the sludge settling. During the aerobic periods, the maximum dissolved oxygen concentration was set to 2 mg dm⁻³. Mechanical mixing was used during the anoxic phases. The activated sludge concentration in the AS-SBR reactor was between 3 and 5 g dm⁻³, on the contrary in the MBBR reactor it was at most 1 g dm⁻³ in the first part of the experiment.

The volume of biofilm carrier in the reactor was 0.5 dm³ and the total volume of the MBBR-SBR reactor was 2 dm³ giving a filling ratio of 25%. The biofilm reactor was continuously aerated and the dissolved oxygen level had to be increased, when the specific biofilm load considerably increased.

3. Results and Analysis

The sludge-loading rate in both systems was increased continuously throughout the experiment. At the beginning, it was approximately 0.2–0.3 g COD/g MLSS and was slowly raised to over 2 g COD/g MLSS by the end.

On the contrary, the COD of the purified wastewater did not change considerably (*Fig.1*). It was between 20 and 50 mg dm⁻³. The COD was simultaneously measured from the filtered effluents to observe the influence of the suspended sludge content of these effluents.

The treated wastewater was nutrient-poor. According to the demands of microorganisms in biological wastewater treatment, a C : N : P ratio of around 100 : 5 : 1 is optimal. This ratio is typical for communal wastewater. The average relative sludge yield rate is 0.7 g MLSS/g COD if the nutrient ratio is optimal. In our study, we could only measure a low specific sludge yield of approximately 0.1 g MLSS/g COD, which we rationalise by the lack of nitrogen- and phosphorous-nutrients. The COD removal was very effective even at very high sludge loads and with a lack of nutrients.

In the MBBR system (*Fig.2*), the variability of organic material removal was observable. COD of the purified wastewater varied between 50 and 200 mg dm⁻³. The main reason for lower COD removal values was probably due to the inefficient settling of the fine biofilm particles. They could not aggregate as much as the AS sludge flocs can. During the course of settling, the biofilm carriers float up to the surface of the water. This can also limit the proper settling of the sludge if the treated wastewater contained so much suspended sludge.

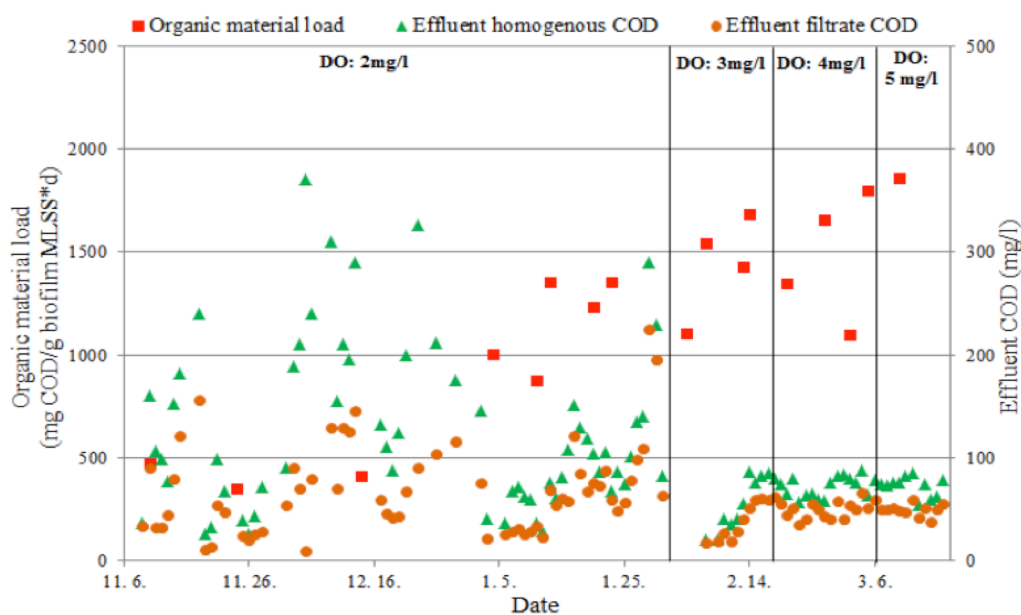


Figure 2. The chemical oxygen demand of the moving bed biofilm sequencing batch reactor (MBBR-SBR) system.

The biofilm loading rate was between 0.2 and 2.0 mg COD/g biofilm MLSS. The biofilm concentration in the MBBR-SBR system was 0.5–1.5 g biofilm dm⁻³ in contrast to the AS-SBR reactor where the activated sludge concentration was 3–5 g MLSS dm⁻³. The MBBR-SBR reactor was operated by a lower hydraulic load.

When the dissolved oxygen concentration was set to 2 mg dm⁻³ over 1 g COD/g biofilm MLSS loading rate, the biofilm could not survive due to limited oxygen diffusion from the liquid phase to inside the biofilm. This corresponds to anoxic conditions at the carrier surface. We had to increase the dissolved oxygen concentration to 3 mg dm⁻³. When the biofilm loading rate increased to 2 g COD/g biofilm MLSS, the dissolved oxygen concentration should be increased further to 5 mg dm⁻³ in order to achieve efficient organic material removal.

4. Conclusion

We observed that it was possible to achieve efficient organic material removal as expressed by the chemical oxygen demand values from pre-treated dairy wastewater both in AS and biofilm treatments without a dose of N- and P-nutrients. This is contrary to what has been proposed in the literature. In the similar active sludge treatment of apple juice effluents even with a proper dosage of urea and phosphate, sometimes we could measure serious sludge bulking because of a lack of micronutrients.

Our results showed that the activated sludge system ensured efficient organic material removal even around 2 g COD/g MLSS loading rate in the case of the pre-treated dairy wastewater. At the same time, the specific sludge load of the municipal sewage treatment plants without nitrification and denitrification is at most 1 g COD/g MLSS. When we have to nitrify and

denitrify the organic carbon load has to be around a third of this value. High loaded systems require a smaller biological volume. Iron ions, which remained in pre-treated wastewater, facilitated the settling of activated sludge, therefore in the AS-SBR system this gives an opportunity for increasing the sludge concentration. Because of an extended sludge concentration the biological volume demand would be reduced. Our experiments with the biofilm system show that the thicker biofilm requires a much greater dissolved oxygen concentration. This fact is mentioned also in some other studies. The oxygen input needs to be balanced against the level for creating an aerobic environment for the biofilm.

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