Effect of Organic Loading Rates on Performance of Treating Dairy Wastewater in a Lab-Scale Sequencing Batch Reactor

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Abstract

This study aims to investigate, the effect of organic loading rates (OLRs), nutrient ratio addition, and sludge retention time (SRT) on treating dairy wastewater in a sequencing batch reactor (SBR) system. This investigation is verified by experiments conducted in 3 phases at 3 different OLRs (1.8, 1.2, and 0.9 kg/m^3d, respectively). Urea ($(NH_2)_2CO$) is added to make a suitable (COD:N:P) ratio of (100:5:1) in dairy wastewater. The SRT is adjusted from 50 days to an appropriate value of 18 days. The obtained results show that the COD, TN, and TP removal efficiencies are increased with decreasing OLRs. Sludge concentration in the SBR tank is stable at 1100 mg/L after adding $(NH_2)_2CO$. In addition, the SBR operated at a suitable SRT (i.e. 18 days) helps the biomass stably, resulting in enhancement of COD, TN, and TP removal. The results are helpful to the design of SBR for treating dairy wastewater.

Keywords: dairy wastewater treatment, sequencing batch reactor, organic loading rates, sludge

1. Introduction

Dairy wastewater contains a very high concentration of pollutants, such as very high COD, BOD, TN, and TP. Therefore, it makes strong pollution in the receiving waters. It is not easy to treat dairy wastewater in a conventional activated sludge. In addition, dairy wastewater is strongly dependent on production processing. Its flow rate fluctuated largely over time. Treating this wastewater in a continuous system may not be a beneficial way. Therefore, using an intermittent way, such as a sequencing batch reactor (SBR) would be a good solution. SBR has been developed and is increasingly applied in wastewater treatment around the world [1]. In the US, Europe, and China, SBR was applied to treat urban wastewater and industrial wastewater [2]. In addition, industrial wastewater from dairy production, pulp, and tanning has been treated by using an SBR system [3-4]. Vietnam, there are many treatment technologies, i.e., conventional activated sludge, anoxic-oxic, anaerobic-anoxic-oxic, trickling filter, SBR, and lagoons, etc., that were applied for domestic and municipal wastewater treatment. Among them, SBR was most used for domestic wastewater treatment [5].

SBR is operated with five consecutive stages, such as wastewater loading, treatment, sedimentation, decanting treated wastewater, and sludge discharge [6]. The biggest advantage of SBR is flexibility in operation, e.g., the aeration and settling times in the reactor could be changed simply [7]. Moreover, biological treatment processes, i.e., BOD treatment, nitrification, denitrification, decomposition, and absorption of phosphorus could be taken place in only one reactor [7]. Because of the above advantages, the secondary clarifier could be removed from the SBR system. In addition, anaerobic conditions could appear

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during the influent filling and mixing stage. This could enhance nitrate reduction and phosphorus decomposition [8]. During the aeration stage, nitrification and phosphorus absorption into biomass could be carried out [9]. Phosphorus treatment in SBR tanks was highly dependent on the amount of organic matter input and the amount of nitrate present in the sludge which was retained from the previous working cycle [10].

Phosphorus treatment could be impaired if the organic up flow content was low and the nitrate content of the sludge was high [11]. Nitrification, denitrification, and phosphorus treatment could be closely related to the low organic load rate for the SBR system [12]. If the input organic matter content was relatively stable, the organic load rate would be largely dependent on the sludge content in the reactor [13]. SBR could be applied as an alternative technology for biological nutrient removal [14-15]. However, its performance was affected by several operational conditions, such as organic loading rates (OLRs), sludge retention time (SRT), and sludge concentration in the reactor. In particular, the novelty aspects of the work include testing a lab-scale SBR at high OLRs for synthetic dairy wastewater.

In addition, the imbalance of carbon and nutrient (i.e., nitrogen and phosphorus) would result in low performance of the SBR. Therefore, an attempt at nutrient ratio addition could provide a good solution. Moreover, maintaining a suitable sludge concentration in the SBR plays an important role during the treatment processes. Therefore, controlling the SRT in the SBR would be the best choice. Those would help to identify suitable operational conditions of the SBR applied to treat real dairy wastewater at higher capacities.

This study aims to improve dairy wastewater treatment efficiency by employing SBR technology. In particular, the effect of organic load rate on the treatment efficiency of the system and the effect of SRT on the amount of activated sludge in the SBR system were examined. In addition, a variation of activated sludge and its characteristics, i.e., sludge volume index (SVI), in the SBR system operated at different conditions were identified. Especially, removal of organic compounds in terms of COD, and nutrients (in terms of total nitrogen and total phosphorus) from dairy wastewater was explored thoroughly in this SBR system.

2. Materials and Methods

2.1. Experimental SBR system

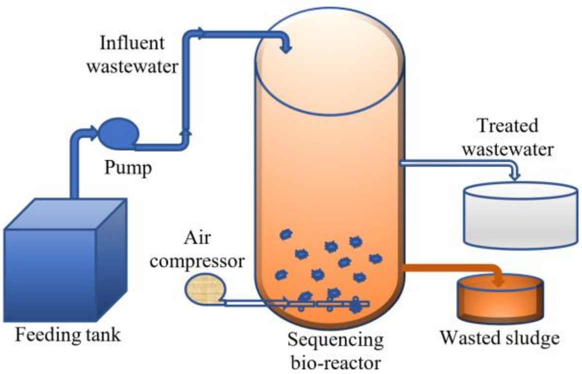

Fig. 1 Diagram of the SBR system used in the study

The study was conducted in a lab-scale SBR system (Fig. 1). The SBR with a cylindrical structure was made of polypropylene plastic material. The SBR system includes a diameter of 90 mm, a wall thickness of 1.5mm, and a height of 950 mm. It could contain a maximum volume of 5.5 L. However, it only operated at a working volume of 4.5 L. A pipe (diameter of 21 mm) for sludge discharge was placed at the bottom of the SBR system to discharge sludge which was controlled by a valve. The effluent was discharged from the reactor by gravity. In this SBR system, the Hailea ACO-238 aerator (220 V, capacity of 60 W, maximum aeration flow rate of 82 L/min, pressure of 0.035 MPa) was used. Aerators were mounted on the back of the tank to supply air to the tank through rubber conductors and air distribution heads. This is to ensure providing a necessary amount of oxygen for microorganisms in the SBR system. In this system, an automatic switch was used to help set the past time, flowmeter, pressure gauge, and electric meter.

2.2. Operation of the SBR system

The system was operated in a cycle of four alternating stages. The operational stages were illustrated in Fig. 2 which included a cycle of four steps, i.e., wastewater filling, aeration/mixing and reaction, sedimentation, and draining clean water (at the same the excess sludge could be removed).

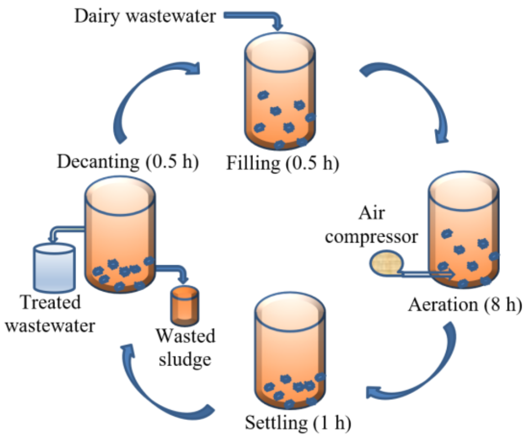

Fig. 2 Operational stages of the SBR system in the study

In addition, the operational conditions in the SBR system could be modified easily by controlling the dissolved oxygen concentration in the aeration stage. In this study, the seed sludge was taken from the aerobic tank in a dairy wastewater treatment plant, located in Gia Lam (Hanoi, Vietnam). The initial sludge concentration of mixed liquor suspended solids (MLSS) was about 2500 mg/L. It was cultivated with the synthetic dairy wastewater in the batch reactor to increase up to 5000 mg/L. After that, it was transferred to the SBR system for treating synthetic dairy wastewater. The study was conducted in 3 phases which corresponded to the OLRs of 1.8 kg/m^{3}d, 1.2 kg/m^{3}d, and 0.9 kg/m^{3}d, respectively. To make a suitable (COD:N:P) ratio of (100:5:1) in synthetic dairy wastewater, urea $(NH_2)_2CO$ was used as a supplementary nutrient source. In this study, the SBR was operated by 4 stages, in which filling was carried out in 0.5 h, aeration was maintained in 8 h, settling lasted in 1 h, and decanting was taken in 0.5 h. Other detailed operational conditions and their purposes were presented in the supplementary material.

2.3. Analytical methods

The input and output samples were taken daily and mostly were analyzed on the same day. In some cases, samples were stored at 4°C in polyethylene bottles for further analysis. The analyzed and measured parameters include: nitrate, ammonium, TN, TP, COD, suspended solids (SS), MLSS, mixed liquor volatile suspended solids (MLVSS), and SVI. Supernatants of all samples were achieved by using vacuum filtration (Model SLSSF03001, Hawach Scientific Co., Ltd., P.R. China) with a membrane pore size of 0.45 μm. The analytical methods used in this study comply with Vietnamese regulations and standard methods [16].

3. Results and Discussion

3.1. Variation of MLSS, MLVSS, and its ratio during operation

Fig. 3 shows a variation of MLSS, MLVSS, and MLVSS/MLSS ratio over time. In this study, phase 1 was from day 1 to day 17. The system was operated at the organic loading rate of 1.8 kg/m^{3}d. As shown in Fig. 3, the initial MLSS content was

2200 mg/L. The MLSS was reduced to about 1400 mg/L on day 8 due to the unstable mixing and aeration conditions. After the problem was fixed, the MLSS increased over time. At day 15, the sludge content reached the range of 2700 to 2800 mg/L. It seems that, in the first 15 days of operation, the microorganisms were adapting to the new environment; therefore, some microorganisms may have not adapted yet, as the result, the amount of sludge was unstable and tends to decrease. The amount of organic matter indirectly indicates the number of active microorganisms in activated sludge [17].

After 10 days, it is highly likely that the microorganisms in the bioreactor adapted and could grow fast, leading to an increase in the amount of activated sludge. As seen in Fig. 3, the activated sludge was stabilized after 15 days of operation. It could be seen from Fig. 4 that the floc was dark brown when it was newly added to the SBR system. After one week of running the SBR system, the sludge has become a lighter brown and yellow color.

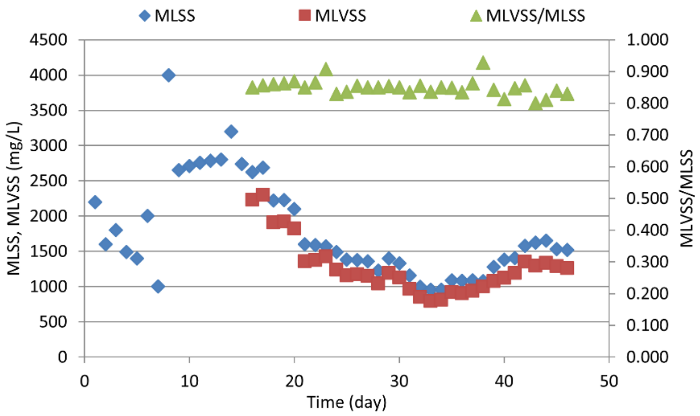

Fig. 3 Variation of MLSS, MLVSS, and its ratio over time

(a) New sludge

(b) After a week

Fig. 4 Changes of sludge floc from dark brown and lighter brown and yellow

After that, the system was operated at phase 2 (OLR of 1.2 kg/m^{3}d). It was decreased by half compared to phase 1. The sludge content decreased very quickly. After three days, the sludge content was decreased to 2100 mg/L, then decreased continuously to 1224 mg/L at the end of phase 2. The reason for the decrease in sludge content in the tank could be explained by the fact that the OLR was halved at the same time as the number of feed supplied, which could reduce the number of microorganisms by half. It should be noted that, before that, microorganisms were growing steadily with a fixed amount of feed added daily. In this condition, the weaker microorganisms could die due to lacking food (carbon source) and oxygen. Therefore, only powerful microorganisms survived [18]. In this phase, the sludge was darker than in the first phase.

In phase 3 (OLR of 0.9 kg/m^{3}d), the MLSS content still tended to decrease to less than 1000 mg/L. This is due to a lack of carbon sources for the growth of microorganisms. In addition, it was reported that microorganisms could not be developed well in low-nitrogen wastewater [19]. Therefore, in this period, a test was applied with supplementary urea $(NH_2)_2CO$ to make a balanced ratio of 100:5:1 for COD:N:P, respectively [13]. After a few days, the amount of sludge remained in the range of 1100 mg/L. It was seen that the sludge became more yellow. The amount of sludge in the SBR tank was stable. During the next period, from day 38 to day 46, the OLR remained the same. At this period, the SRT was adjusted to the appropriate value for the SBR tank (from day 17 to day 19). It was noted that, before the system was adjusted to the appropriate value, the SRT fluctuated in a larger range. Therefore, a certain amount of the excess sludge was withdrawn daily to remove the old sludge in the tank.

After the adjustment, the sludge in the SBR tank was clearly increasing. The concentration of sludge in the tank on day 38 was 1078 mg/L, which was increasing gradually over days, i.e., 1404 mg/L (day 41) and 1652 mg/L (day 44). Thus, the SRT plays an important role in the development of activated sludge. The OLR is an important parameter affecting the characteristics of sludge, i.e., particle size, settling capacity, and microbiological activity of the sludge. It could be seen that low OLR could lead to low sludge formation. It takes a long time to reach a steady state. It should be noted that SBR could be worked well at high sludge concentrations of over 3000 mg/L, whereas the sludge concentration in the traditional activated sludge system is normally lower than 2500 mg/L. This could be a great advantage of SBR in the aspect of reducing the volume of the reactor resulting in lowering the investment cost.

The ratio of MLVSS and MLSS is the ratio of volatile organic matter to the activated sludge content, which is the common parameter used to determine sludge activity [17]. As shown in Fig. 3, the ratio of MLVSS and MLSS during the system operation was in the range of 0.8-0.9. The ratio of MLVSS and MLSS in our study was slightly higher than the mean values reported in the conventional activated sludge 0.7-0.8 [17, 20]. As a result, it is assumed that the activated sludge in the SBR tank has a high content of volatile organic matter.

3.2. Variation of sludge volume index at different loading rates

The sludge volume index at different OLRs was presented in Fig. 5. It was noted that the SVI was used to evaluate the efficiency of solid-liquid separation in the reactor. The SVI reflects the settling characteristics of activated sludge and biological suspension [14].

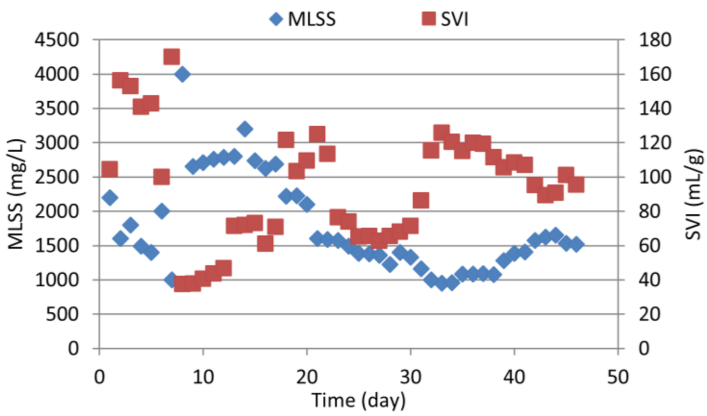

Fig. 5 Variation of sludge volume index over time

If this factor is low, it could help to reduce the decant time in SBR tanks. It also could help to reduce the rear construction area of the sedimentation tank in the wastewater treatment system, resulting in reduced treatment costs. During phase 1 from day 1 to day 17, the SVI fluctuated mainly in the range of 140-150 mL/g (from day 1 to day 6). After that, the SVI fluctuated from 38-47 mL/g. From day 13 to day 17, the SVI was stable in the range of 60-70 mL/g. Thus, from day 9 to day 17, the sludge was settled well.

In the second period from day 18 to day 27, the SVI fluctuated over 100 mL/g (from day 28 to day 22). The OLR was reduced a half, making a reduction in the amount of activated sludge in the tank. In this condition, the sedimentation volume of the sludge was increased, causing the SVI to increase. So, during this time, the sludge was not settled well. From day 23 to day 27, the activated sludge content was decreased continuously. At the same time, the sedimentation volume was decreased by three times. At this period, the SVI ranged from 60-70 mL/g. The SVI is an important parameter to determine the volume of the settling part. The SVI obtained in this work was lower than 100 mL/g which is much lower than that in other works, i.e. 150 mL/g, or even up to 180 mL/g [18]. Low SVI meant the sludge could be settled well. In addition, good settling sludge could control high sludge concentration in the SBR. It also could help to retain sludge in the reactor.

3.3. Effect of SRT on the development of activated sludge

A variation of SRT over time was presented in Fig. 6. The SRT shows the biomass concentration stored in the reactor. This factor could affect simultaneously the ability to remove COD and nitrification in the system. The SRT was maintained by extracting a fixed volume of sludge for each batch. However, in this study, the excess sludge was not withdrawn for each batch. It was only withdrawn with a small volume of 15-50 mL for the MLSS measurement. The SRT was dependent on the amount of biomass in the tank. Besides, it also depended on the biomass available in the volume of water withdrawn, the biomass drifted out of each batch, and the volume of sludge withdrawn.

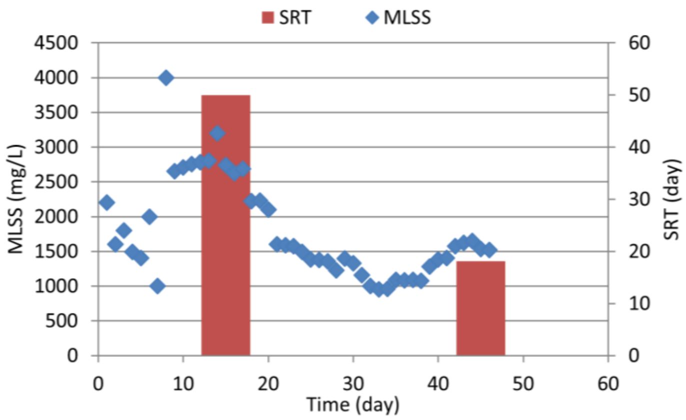

Fig. 6 Variation of SRT over time

In this study, the SRT of the system has fluctuated in a quite wide range. During the initial period of system operation, due to the small amount of sludge withdrawn per day, only 15 mL, the retention times of large systems ranged from day 50 to day 80. From day 23 and onwards, 50 mL of sludge was decanted daily to make the system operate stably. The SRT remained stable for about 35-40 days which was smaller than the first time. However, this SRT was still larger than the suitable SRT of the SBR tank (from day 10 to day 20). Therefore, from day 1 to day 37, the retention time in the system fluctuated over to a high value of 35 days. By day 38, there was an adjustment of SRT to an appropriate value from day 10 to day 20. Instead of withdrawing 50 mL, the amount of sludge was withdrawn daily up to 200 mL. With such extracted sludge volume, the value of SRT from day 38 onwards was from day 17 to day 19.

After adjustment of the SRT to the appropriate range, the amount of sludge increased each day. The sludge has a brighter yellow color. Its size was bigger than that in the previous period. So far, dairy wastewater has been mixed with a part of domestic wastewater. This combination wastewater was treated in the SBR at a very high SRT of over 70 days. In such a high SRT, the COD removal was achieved only about 69%. More importantly, some of the sludge was hydrolyzed and degraded at high SRT. This made a reduction of sludge during operation. Therefore, the system performance could be ineffective [20].

3.4. Effect of OLRs on COD removal efficiency

The effect of OLRs on COD removal efficiency was presented in Fig. 7. As illustrated in Fig. 7, in the first phase, with an input COD of 1800 mg/L, COD concentration after treatment was about 163 mg/L, corresponding to a treatment efficiency of 90.9%. By the second phase, when the input COD was reduced to 900 mg/L, COD concentration in the effluent was about 142 mg/L. This means that the treatment efficiency dropped to 84.2%. In this phase, the wastewater after treatment still contained more suspended solids. Its turbidity was higher than that in phase 1. The input COD in phase 2 was 2 times smaller than that in phase 1, but the output COD was similar to that in phase 1. The system was operated stably after urea was added. This helped to adjust the appropriate nutrient ratio of COD:N:P of 100:5:1. At this condition, the input COD content was 1200 mg/L, and the COD after treatment was only 23 mg/L. The treatment efficiency was increased up to 98.1%.

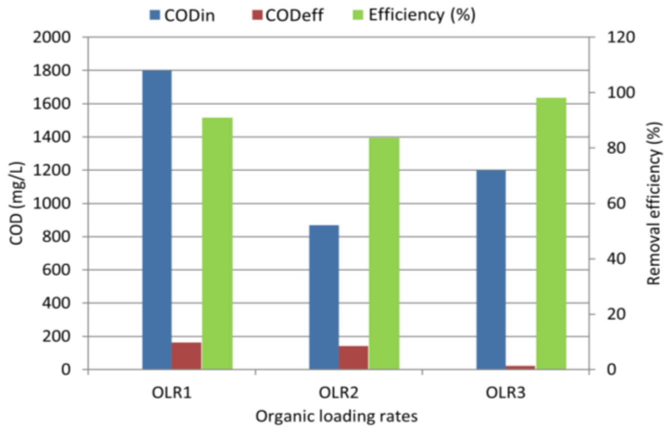

Fig. 7 COD treatment efficiency with different OLRs

It shows that the proportion of nutrients in wastewater plays an important role in increasing COD treatment efficiency [21]. The values of COD removal efficiency in our studies were consistent with prior results (COD removal efficiency from synthetic dairy wastewater using SBR was 94.74%) [14]. So far, a study has been conducted to treat dairy wastewater by SBR under low SRT (i.e., only 5.5 days). The study was carried out for about 60 days at a low OLR of only 0.6 kg/m^{3}d. Under this low OLR, the COD removal efficiency reached only about 84%. However, when OLR was increased to about 1.9 kg/m^{3}d, the treatment efficiency of COD was reduced to only about 62% [21]. The obtained results show that the OLRs have a significant effect on COD removal in the SBR system to treat dairy wastewater.

3.5. *Effect of OLRs on nitrogen treatment efficiency*

The effect of OLRs on nitrogen treatment efficiency was shown in Fig. 8. As shown in Fig 8, the nitrogen content in this wastewater was quite low. At the OLR of 1.8 and 0.9 kg/m^{3}d, the nitrogen concentrations were 18 and 9 mg/L, respectively. After the treatment process, the nitrogen output concentrations were 8.0 and 4.7 mg/L, respectively. Nitrogen treatment efficiencies in the two OLRs reached 55.6% and 47.8%, respectively. The nitrogen concentration in the effluent when the system operated at the OLR of 0.9 kg/m^{3}d was lower than that at the OLR of 1.8 kg/m^{3}d. However, the nitrogen treatment efficiency was reduced at the second loading rate [21].

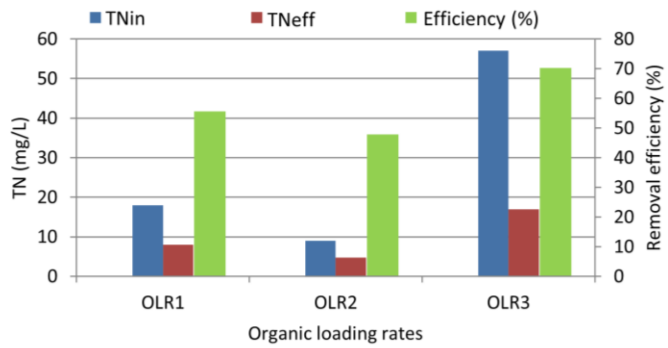

Fig. 8 Nitrogen treatment efficiency with different OLRs

When the SBR system operated with an OLR of 1.8 kg/m^{3}d, the concentration of activated sludge in the tank was in the range of 2700-2800 mg/L. Whereas, at the OLR of 0.9 kg/m^{3}d, the content of activated sludge in the tank was only about 1200 mg/L. Thus, the higher the concentration of activated sludge in the tank, the better the nitrate process would be taken place. The nitrogen treatment consists of two phases such as ammonia is converted to nitrate under aerobic conditions (nitrification process), and nitrate is reduced to nitrogen under low oxygen conditions (denitrification process) [22]. In phase 3, the nitrogen input concentration was 57 mg/L. The activated sludge content in this period was similar to that value in phase 2. At this phase, the output nitrogen was about 17 mg/L, corresponding to the removal efficiency of 70.2% which was greatly increased compared to the previous two phases.

As seen, although the activated sludge content was less than half compared with phase 1, the nitrogen treatment efficiency was still higher than in phase 1. This could be due to the adjustment of an appropriate nutrient ratio. Though the activated sludge content was the same as the operating conditions in phase 2, it was evident that treatment efficiency has greatly increased from 47.8 to 70.2%. Thereby, it was found that the appropriate nutrient ratio played a very important role in the nitrogen treatment process [23]. It was reported that a high OLR could improve the nitrification process. This process mainly happened in the aeration stage. After that, the denitrification process could be carried out in the next stage of settling or mixing without aeration. The denitrification process normally played an important role in treating total nitrogen in the SBR.

3.6. *Effect of OLRs on phosphorus treatment efficiency*

The effect of OLRs on phosphorus treatment efficiency is shown in Fig. 9. As seen from Fig. 9, the phosphorus treatment efficiency was increased with increasing OLRs. The average phosphorus treatment efficiency at 3 levels of OLRs were about 92.2%, 86.7%, and 82.2%, respectively (the phosphorus in the effluent was found to be 2.8 mg/L, 2.4 mg/L, and 3.2 mg/L, respectively). The phosphorus treatment efficiency achieved in our study was comparable to data reported previously (about 90%) [24]. It has been found that bacteria belonging to the family *Comamonadaceae* played an important role in orthophosphate uptake in dairy wastewater and constituted considerable composition in the microbial biomass of activated sludge [24]. Phosphorus compounds in wastewater exist in three types of compounds: single phosphate, polyphosphate, and phosphate-containing organic compounds [25]. In which the following two compounds accounted for a larger proportion [26].

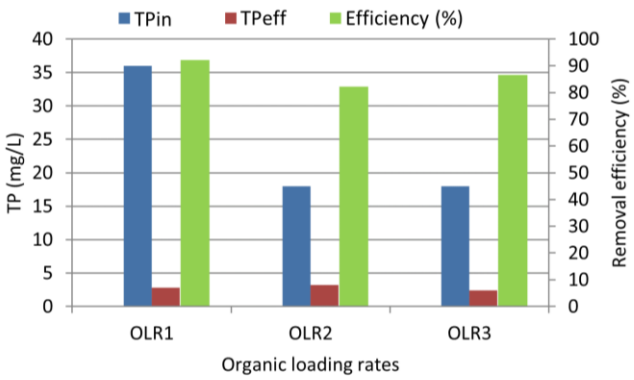

Fig. 9 Phosphorus treatment efficiency with different OLRs

During biological treatment, the phosphorus in wastewater was only absorbed by microorganisms to build cells [27]. Phosphorus treatment was mainly going into the sludge which was then discharged out of the system [28]. The phosphorus content in cells was about 2% (1.5-2.5%) of the dry weight. In the aerobic process, some types of microorganisms could be capable of absorbing phosphates higher than normal levels in microbial cells (2-7%). In which, the excess phosphorus was stored by microorganisms. Under anaerobic conditions, in the presence of organic matter, the excess phosphate was excreted out of the microbial body as a single phosphate [29]. The above phenomenon could be used to remove phosphorus compounds from the wastewater by separating microorganisms with high phosphorus content in the form of sludge [30].

4. Conclusions

Dairy wastewater could be efficiently treated using SBR technology. The effect of OLRs on the treatment efficiency of dairy wastewater was investigated. Besides, the effect of the ratio of nutrient content in the wastewater and the effect of SRT on the development of activated sludge was examined in detail. When the OLR was decreased from 1.8 to 0.9 kg/m^{3}d, the amount of activated sludge in the SBR tank was decreased from 2700 mg/L to 1400 mg/L. The COD and TN treatment efficiency decreased from 90.9 to 84.2%, and from 55.6 to 47.8%, respectively. The OLRs and the proportion of nutrients in the wastewater played a significant impact on the treatment efficiency of COD and TN. Phosphorus treatment efficiency was increased from 82.2 to 92.2% when the OLR was increased from 0.9 to 1.8 kg/m^3d. The phosphorus-accumulated bacteria would be beneficial when the SBR system was operated at higher OLRs.

The concentration of activated sludge in the SBR tank was increased from 1000 to 1500 mg/L when the SRT was adjusted to an appropriate range. On average, the SVI fluctuated within the range of 60 to 110 mL/g, showing that the settling was relatively good. The results of this study provide valuable information for the application of SBR technology to treat dairy wastewater.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Y. Shao, G. H. Liu, Y. Wang, Y. Zhang, H. Wang, L. Qi, et al., “Sludge Characteristics, System Performance and Microbial Kinetics of Ultra-Short-SRT Activated Sludge Processes,” Environment International, vol. 143, article no. 105973, October 2020.

[2] H. Fernandes, M. K. Jungles, H. Hoffmann, R. V. Antonio, and R. H. R. Costa, “Full-Scale Sequencing Batch Reactor (SBR) for Domestic Wastewater: Performance and Diversity of Microbial Communities,” Bioresource Technology, vol. 132, pp. 262-268, March 2013.

[3] A. S. Stasinakis, P. Charalambous, and I. Vyrides, “Dairy Wastewater Management in EU: Produced Amounts, Existing Legislation, Applied Treatment Processes and Future Challenges,” Journal of Environmental Management, vol. 303, article no. 114152, February 2022.

[4] R. Verma, S. Suthar, N. Chand, and P. K. Mutiyar, “Phycoremediation of Milk Processing Wastewater and Lipid-Rich Biomass Production Using Chlorella Vulgaris under Continuous Batch System,” Science of the Total Environment, vol. 833, article no. 155110, August 2022.

[5] M. H. Trevor Sparks, “Water Treatment: Combined Treatment Systems Meet Vietnamese Challenge,” Filtration + Separation, vol. 50, no. 4, pp. 44-45, July-August 2013.

[6] M. Ruhela, A. A. Wani, and F. Ahamad, “Efficiency of Sequential Batch Reactor (SBR) Based Sewage Treatment Plant and Its Discharge Impact on Dal Lake, Jammu & Kashmir, India,” Archives of Agriculture and Environmental Science, vol. 5, no. 4, pp. 517-524, December 2020.

[7] L. Hao, K. Okano, C. Zhang, Z. Zhang, Z. Lei, C. Feng, et al., “Effects of Levofloxacin Exposure on Sequencing Batch Reactor (SBR) Behavior and Microbial Community Changes,” Science of The Total Environment, vol. 672, pp. 227-238, July 2019.

[8] J. Yao, J. Liu, Y. Zhang, S. Xu, Y. Hong, and Y. Chen, “Adding an Anaerobic Step Can Rapidly Inhibit Sludge Bulking in SBR Reactor,” Scientific Reports, vol. 9, article no. 10843, July 2019.

[9] C. Estrada-Vázquez, A. Salinas-Pacheco, E. Peralta-Reyes, H. M. Poggi-Varaldo, and A. Regalado-Méndez, “Parametric Optimization of Domestic Wastewater Treatment in an Activated Sludge Sequencing Batch Reactor Using Response Surface Methodology,” Journal of Environmental Science and Health, Part A, vol. 54, no. 12, pp. 1197-1205, 2019.

[10] J. Liu, J. Li, S. Piché-Choquette, and B. Sellamuthu, “Roles of Bacterial and Epistylis Populations in Aerobic Granular SBRs Treating Domestic and Synthetic Wastewaters,” Chemical Engineering Journal, vol. 351, pp. 952-958, November 2018.

[11] U. Showkat and I. A. Najar, “Study on the Efficiency of Sequential Batch Reactor (SBR)-Based Sewage Treatment Plant,” Applied Water Science, vol. 9, no. 1, article no. 2, February 2019.

[12] L. Pelaz, A. Gómez, A. Letona, G. Garralón, and M. Fdz-Polanco, "Sequencing Batch Reactor Process for the Removal of Nitrogen from Anaerobically Treated Domestic Wastewater," Water Science & Technology, vol. 77, no. 6, pp. 1581-1590, March 2018.

[13] C. Wu, Y. Peng, S. Wang, X. Li, and R. Wang, "Effect of Sludge Retention Time on Nitrite Accumulation in Real-Time Control Biological Nitrogen Removal Sequencing Batch Reactor," Chinese Journal of Chemical Engineering, vol. 19, no. 3, pp. 512-517, June 2011.

[14] A. H. Khalaf, W. A. Ibrahim, M. Fayed, and M. G. Eloffy, "Comparison between the Performance of Activated Sludge and Sequence Batch Reactor Systems for Dairy Wastewater Treatment under Different Operating Conditions," Alexandria Engineering Journal, vol. 60, no. 1, pp. 1433-1445, February 2021.

[15] M. Custodio, R. Peñaloza, C. Espinoza, W. Espinoza, and J. Mezarina, "Treatment of Dairy Industry Wastewater Using Bacterial Biomass Isolated from Eutrophic Lake Sediments for the Production of Agricultural Water," Bioresource Technology Reports, vol. 17, article no. 100891, February 2022.

[16] R. B. Baird, A. D. Eaton, and E. W. Rice, Standard Methods for the Examination of Water and Wastewater, 23rd ed., Washington: the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF), 2017.

[17] J. Fan, F. Ji, X. Xu, Y. Wang, D. Yan, X. Xu, et al., "Prediction of the Effect of Fine Grit on the MLVSS/MLSS Ratio of Activated Sludge," Bioresource Technology, vol. 190, pp. 51-56, August 2015.

[18] O. Alagha, A. Allazem, A. A. Bukhari, I. Anil, and N. D. Muazu, "Suitability of SBR for Wastewater Treatment and Reuse: Pilot-Scale Reactor Operated in Different Anoxic Conditions," International Journal of Environmental Research and Public Health, vol. 17, no. 5, article no. 1617, March 2020.

[19] Y. Yuan, J. Liu, B. Ma, Y. Liu, B. Wang, and Y. Peng, "Improving Municipal Wastewater Nitrogen and Phosphorous Removal by Feeding Sludge Fermentation Products to Sequencing Batch Reactor (SBR)," Bioresource Technology, vol. 222, pp. 326-334, December 2016.

[20] M. Vukovic, F. Briški, M. Matošic, and I. Mijatovic, "Analysis of the Activated Sludge Process in an MBR under Starvation Conditions," Chemical Engineering & Technology, vol. 29, no. 3, pp. 357-363, March 2006.

[21] G. Vijayan, R. Saravanane, and T. Sundararajan, "Influence of Nitrogen Residue on the Performance of Sequencing Batch Reactor (SBR) in Wastewater Treatment–A Review," International Journal of Environmental Monitoring and Protection, vol. 3, no. 1, pp. 1-16, February 2016.

[22] Y. Duan, Y. Liu, M. Zhang, Y. Li, W. Zhu, M. Hao, et al., "Start-Up and Operational Performance of the Partial Nitrification Process in a Sequencing Batch Reactor (SBR) Coupled with a Micro-Aeration System," Bioresource Technology, vol. 296, article no. 122311, January 2020.

[23] S. Basu and B. M. Kumar, "Evaluation of Bench Scale SBR for Removal of Nutrients from Domestic Wastewater," World Environmental and Water Resources Congress, May 2006. https://doi.org/10.1061/40856(200)16

[24] B. Gil-Pulido, E. Tarpey, E. L. Almeida, W. Finnegan, X. Zhan, A. D. W. Dobson, et al., "Evaluation of Dairy Processing Wastewater Biotreatment in an IASBR System: Aeration Rate Impacts on Performance and Microbial Ecology," Biotechnology Reports, vol. 19, article no. e00263, September 2018.

[25] M. Abdulgader, Q. J. Yu, A. Zinatizadeh, and P. Williams, "Biological Treatment of Milk Processing Wastewater in a Sequencing Batch Flexible Fibre Biofilm Reactor," Asia-Pacific Journal of Chemical Engineering, vol. 4, no. 5, pp. 698-703, September/October 2009.

[26] S. Sirianuntapiboon, N. Jeeyachok, and R. Larplai, "Sequencing Batch Reactor Biofilm System for Treatment of Milk Industry Wastewater," Journal of Environmental Management, vol. 76, no. 2, pp. 177-183, July 2005.

[27] J. P. Kushwaha, V. C. Srivastava, and I. D. Mall, "Sequential Batch Reactor for Dairy Wastewater Treatment: Parametric Optimization; Kinetics and Waste Sludge Disposal," Journal of Environmental Chemical Engineering, vol. 1, no. 4, pp. 1036-1043, December 2013.

[28] K. Kim, "The Characteristic of the Sequencing Batch Reactor (SBR), Anaerobic Sequencing Batch Reactor (ASBR) and Sequencing Batch Biofilm Reactor (SBBR)," https://home.engineering.iastate.edu/~tge/ce421-521/koobum.pdf, June 08, 2022.

[29] M. Kraume, R. Scheumann, A. Baban, and B. El Hamouri, "Performance of a Compact Submerged Membrane Sequencing Batch Reactor (SM-SBR) for Greywater Treatment," Desalination, vol. 250, no. 3, pp. 1011-1013, January 2010.

[30] C. Tayà, A. Guisasola, and J. A. Baeza, "Assessment of a Bioaugmentation Strategy with Polyphosphate Accumulating Organisms in a Nitrification/Denitrification Sequencing Batch Reactor," Bioresource Technology, vol. 102, no. 17, pp. 7678-7684, September 2011.