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Application of Cell Immobilization in the Batch Activated Sludge Treatment of Domestic and Poultry Wastewater Using Carbonized Coconut Shell and Carbonized Rice Hull

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Abstract. Domestic wastewater (DWW) and poultry wastewater (PWW) are some of the primary sources of pollution that affect receiving surface and marine waters, potentially causing eutrophication and other environmental concerns. This study aimed to evaluate the effect of cell immobilization in the performance of batch activated sludge treatment (BAST), particularly nitrification and organic matter removal, in DWW and PWW. Two kinds of cell immobilizers were tested: carbonized coconut shell (CCS) and carbonized rice hull (CRH), both of which are produced from biowaste that are abundantly available in the Philippines. The cell immobilizers were applied in batch reactors seeded with activated sludge (AS) from a sewage treatment facility. Ammonia-nitrogen (NH_3-N) and chemical oxygen demand (COD) concentrations were measured hourly over 6-hour periods via spectrophotometry. Application of CCS in two batches of AS-seeded BAST of DWW showed a 10.12% increase in average COD removal from 341.27 ± 4.97 mg/L to 375.79 ± 3.79 mg/L and an 18.55% increase in average NH_3-N reduction from 23.49 ± 7.77 mg/L to 27.85 ± 4.30 mg/L. On the other hand, application of CRH in two batches of AS-seeded BAST of PWW showed a 10.69% increase in average COD removal from 483.00 ± 28.56 mg/L to 534.65 ± 59.69 mg/L and a 19.92% increase in average NH_3-N reduction from 83.06 ± 12.48 mg/L to 99.61 ± 14.63 mg/L. Comparing the performance between the two immobilizers over three batches of BAST, results showed that CCS-immobilization had higher COD removal of 383.34 ± 7.86 mg/L (DWW) and 605.35 ± 34.37 mg/L (PWW) and higher NH_3-N reduction of 32.10 ± 4.92 mg/L (DWW) and 144.03 ± 3.25 mg/L (PWW) compared to CRH-immobilization with COD removal of 351.90 ± 29.27 mg/L (DWW) and 557.05 ± 41.10 mg/L (PWW) and NH_3-N reduction of 29.44 ± 1.86 mg/L (DWW) and 115.36 ± 17.87 mg/L (PWW). This study has demonstrated that aerobic treatment of DWW and PWW can be improved using cell immobilization, with CCS-immobilization substantially outperforming CRH-immobilization in terms of COD removal and NH_3-N reduction.

Keywords: biological wastewater treatment, domestic wastewater, poultry wastewater, cell immobilization, carbonized coconut shell, carbonized rice hull

1. Introduction

While various wastewater treatment technologies are available today, biological approaches are favored by many due to their effectiveness, cost-efficiency, and environmental safety in removing organic matter, nutrients, pathogens, and specific harmful substances from wastewater (Sravan et al., 2024; Wu & Yin, 2020). The activated sludge treatment (AST) is one of the oldest and most well-established biological technologies (Q. Wang et al., 2017). However, because it is a traditional treatment approach, it is found to be limited in its ability to remove xenobiotics, some heavy metals, and excessively high nutrient loads (Chowdhury et al., 2016; Eerkes-Medrano et al., 2019). One approach to improve the performance of AST is by introducing cell immobilizers. Some materials used for immobilization in studies include calcium alginate (Liu et al., 2018), cellulose triacetate (Ma et al., 2016), and titanium (Ji et al., 2017). In the Philippines, some materials that are both abundant and can be potentially used as immobilizers are carbonized coconut shell (CCS) and carbonized rice hull (CRH). That is why in this paper, the effects of application of CCS and CRH as cell immobilizers in batch activated sludge treatment (BAST) process were investigated. The first phase of this study aimed to compare the performance, in terms of chemical oxygen demand (COD) removal and NH_3-N reduction, of the BAST of domestic wastewater (DWW) and poultry wastewater (PWW) with and without addition of cell immobilizers. In the second phase, the efficacy of CCS- and CRH-immobilized BAST were compared to determine which material yielded better results.

2. Methodology

Time series experiments were conducted to observe the nitrification and organic matter removal in each bioreactor. Each time series iteration or "batch" commenced with the extraction of reactor effluent and addition of fresh feed (DWW or PWW). Furthermore, each iteration lasted 6 hours wherein every hour, sample collection and pH measurement were done, starting from time 0h until time 6h. Therefore, in one time series experiment, a total of seven samples per reactor were collected for NH_3-N and COD analyses. In phase 1 of this study, two batches of time series experiments were conducted while in phase 2, three batches were done. Throughout the experimentation phases of this study, to ensure that the quantity of activated sludge in the bioreactors did not exceed optimal levels, samples were collected from the bioreactors at the beginning of each time series experiment for MLSS testing. The pH levels were also maintained within the ideal range of 6.8 to 8.0, with the addition of $NaHCO_3$ when necessary. Lastly, prior to these time series experiments, the bioreactors have undergone acclimatization for about 3 weeks after seeding with activated sludge, wherein effluent was extracted and fresh feed was added every two days.

3. Results and Discussion

In the BAST of synthetic DWW, the average COD and NH_3-N levels in all reactors gradually decreased during the 6-hour period, with the reactors employed with immobilization yielding better treatment results. The reactors utilizing CCS achieved an average COD removal of 375.79 ± 3.79 mg/L, representing a 10.12% enhancement over the 341.27 ± 4.97 mg/L average COD removal of the reactors lacking immobilization. Moreover, an 18.55% increase in average NH_3-N reduction was observed, with 27.85 ± 4.30 mg/L for CCS-immobilized reactors and 23.49 ± 7.77 mg/L for reactors without immobilization. Similar results were observed in the BAST of synthetic PWW wherein both COD and NH_3-N levels gradually decreased over the 6-hour period. Utilizing CRH for immobilization showed a 10.69% increase in average COD removal, from 483.00 ± 28.56 mg/L without CRH to 534.65 ± 59.69 mg/L with CRH. Furthermore, CRH application demonstrated a 19.92% increase in average NH_3-N reduction, from 83.06 ± 12.48 mg/L without CRH to 99.61 ± 14.63 mg/L with CRH.

Comparing CCS and CRH as immobilizers in treatment of DWW and PWW, the average COD removal for BAST with CCS-immobilization of DWW and PWW were higher, with values of 383.34 ± 7.86 mg/L (DWW) and 605.35 ± 34.37 mg/L (PWW), compared to COD removal of CRH-immobilized BAST with values of 351.90 ± 29.27 mg/L (DWW) and 557.05 ± 41.10 mg/L (PWW). These represented increases of 8.93% and 8.67% in COD removal from CRH-immobilized to CCS-immobilized BAST of DWW and PWW, respectively. Similar trends were observed for NH_3-N reduction wherein the average reduction for BAST with CCS-immobilization of DWW and PWW were also higher, with values of 32.10 ± 4.92 mg/L (DWW) and 144.03 ± 3.25 mg/L (PWW), compared to NH_3-N reduction of CRH-immobilized BAST with values of 29.44 ± 1.86 mg/L (DWW) and 115.36 ± 17.87 mg/L (PWW). These represented increases of 9.01% and 24.86% in NH_3-N reduction from CRH-immobilized to CCS-immobilized BAST of DWW and PWW, respectively.

4. Conclusion

In conclusion, this study shows that the activated sludge treatment of DWW and PWW can be enhanced through cell immobilization, specifically with either CCS or CRH as immobilizer. Furthermore, CCS-immobilized BAST substantially outperforms CRH-immobilized BAST in terms of COD removal and NH_3-N reduction.

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References

Chowdhury, S., Mazumder, M. A. J., Al-Attas, O., & Husain, T. (2016). Heavy metals in drinking water: Occurrences, implications, and future needs in developing countries. *Science of The Total Environment*, *569–570*, 476–488. https://doi.org/10.1016/j.scitotenv.2016.06.166

Eerkes-Medrano, D., Leslie, H. A., & Quinn, B. (2019). Microplastics in drinking water: A review and assessment. *Current Opinion in Environmental Science & Health*, *7*, 69–75. https://doi.org/10.1016/j.coesh.2018.12.001

Ji, C., Nguyen, L. N., Hou, J., Hai, F. I., & Chen, V. (2017). Direct immobilization of laccase on titania nanoparticles from crude enzyme extracts of P. ostreatus culture for micro-pollutant degradation. *Separation and Purification Technology*, *178*, 215–223. https://doi.org/10.1016/j.seppur.2017.01.043

Liu, J., Li, S., Li, X., Gao, Y., & Ling, W. (2018). Removal of estrone, 17 β -estradiol, and estriol from sewage and cow dung by immobilized *Novosphingobium* sp. ARI-1. *Environmental Technology*, *39*(19), 2423–2433. https://doi.org/10.1080/09593330.2017.1355935

Ma, C., Qin, D., Sun, Q., Zhang, F., Liu, H., & Yu, C.-P. (2016). Removal of environmental estrogens by bacterial cell immobilization technique. *Chemosphere*, *144*, 607–614. https://doi.org/10.1016/j.chemosphere.2015.09.014

Sravan, J. S., Matsakas, L., & Sarkar, O. (2024). Advances in Biological Wastewater Treatment Processes: Focus on Low-Carbon Energy and Resource Recovery in Biorefinery Context. *Bioengineering*, *11*(3), 281. https://doi.org/10.3390/bioengineering11030281

Wang, Q., Wei, W., Gong, Y., Yu, Q., Li, Q., Sun, J., & Yuan, Z. (2017). Technologies for reducing sludge production in wastewater treatment plants: State of the art. *Science of The Total Environment*, *587–588*, 510–521. https://doi.org/10.1016/j.scitotenv.2017.02.203

Wu, G., & Yin, Q. (2020). Microbial niche nexus sustaining biological wastewater treatment. *Npj Clean Water*, *3*(1), 33. https://doi.org/10.1038/s41545-020-00080-4