PhotoBioValue project: Microalgae-bacteria consortium for the bioremediation of urban wastewater in pilot-scale photobioreactors

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Abstract

Two innovative pilot-scale channel photobioreactors (PBRs) were used to culture a microalgae-bacteria consortium in primary urban wastewater. The abundance of total heterotrophs and faecal coliforms, and the concentrations of nitrogen, phosphorus and seven volatile methylsiloxanes (VMSs) were evaluated. Microalgae grew effectively in these PBRs with high nitrogen and phosphorus removal efficiencies. Cultivable faecal coliforms decreased significantly in both PBRs. Promising results are expected on the capacity of these systems for VMS removal.

Keywords: contaminants of emerging concern; photobioreactor; siloxanes; urban wastewater; wastewater treatment.

1. Introduction

Microalgal-bacterial systems have been used to remove a wide range of compounds from wastewater, such as nitrogen, phosphorus, and organic pollutants, as well as promote their disinfection (Amaro et al., 2023; Vo et al., 2024). Volatile methylsiloxanes (VMSs) are contaminants of emerging concern usually found in wastewater and can cause damage to the cogeneration equipment in wastewater treatment plants. Studies on biological systems for VMS removal have shown the ability of some bacteria to degrade these compounds (Pascual et al., 2023). However, no studies have been conducted on the simultaneous removal of conventional pollutants, VMS, and pathogens using microalgae-bacteria consortia.

2. Materials and methods

Approximately 80 L of primary urban effluent were collected from a wastewater treatment plant and continuously exposed to light-emitting diodes (LEDs) lamps at an average light intensity of 140 µmol m^{-2} s^{-1}. The effluent was supplemented periodically with NH_4Cl, KH_2PO_4, and $NaHCO_3$, and a native microalgae-bacteria consortium was established. After 53 days, the biomass was allowed to settle and used to inoculate two 120-L innovative PBRs. The biomass was cultured in fresh primary urban wastewater for 8 days in batch mode. Figure 1 presents the experimental setup. Each reactor consisted of four channels with different widths and illumination inside the walls, but with different flow connectivity between channels: (i) PBR 1 was operated in a partitioned configuration, allowing flow and culture exchange solely between a small opening at the channel base, simulating four semi-isolated reactors (sections 1.1-1.4); and (ii) PBR 2 was operated using an open configuration with unrestricted flow and culture exchange between the channels. Atmospheric air was supplied to the PBRs at 35 L min^{-1}, and temperature and pH were monitored daily.

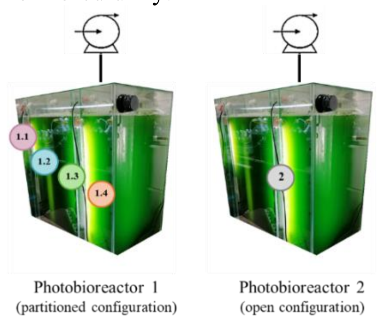

Figure 1. Experimental setup of the PBRs

Microalgal cell concentration (MCC) was evaluated through microscopic cell counting using a Neubauer chamber. The abundance of total cultivable heterotrophs and cultivable faecal coliforms was evaluated using the membrane filtration method and incubation on PCA and m-FC Agar, respectively. The concentrations of nitrogen (N) and phosphorus (P) were determined through spectrophotometric methods. Furthermore, seven VMSs were analysed throughout the experiments in water and intact and disrupted biomass samples. Liquid-liquid extraction procedures were performed for water samples, and a QuEChERS-based extraction methodology was used for biomass, followed by gas chromatography-mass spectrometry (GC-MS) quantification.

3. Results and discussion

Figure 2 presents the time-course evolution of MCC, PO_4-P, and NH_4-N concentrations. Microalgae grew successfully in these disruptive PBRs with specific growth rates up to 0.223 d^{-1}. The total N and P removals were above 81% and 73%, respectively. Sections 1.3 and 1.4 presented the highest growth rates and nutrient removal efficiencies. These are the sections with the highest light supply per unit of culture volume. Therefore, it was expected that these would be the ones with the most effective treatment performance.

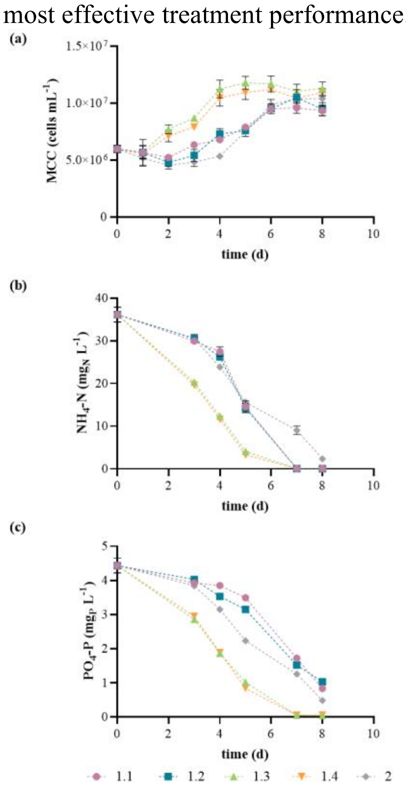

Figure 2. Evolution of MCC (a), NH_4-N (b), and PO_4-P (c) concentrations throughout the experiment.

Figure 3 presents the bacterial quantification of cultivable heterotrophs and faecal coliforms. After 8 days, total cultivable heterotrophs decreased by approximately 1.2 and 1.5 log in sections 1.3 and 1.4, respectively. Cultivable faecal coliforms decreased significantly in all PBRs. Therefore, these results indicate a possible negative correlation between microalgal growth and the abundance of faecal coliforms. In another pilot-scale study using the open configuration under similar conditions, a significant VMSs concentration decrease was found in the aqueous phase, together with VMS accumulation inside the cells and adsorption to the biomass. Therefore, promising results are expected in this pilot-scale study, and microalgae-bacteria consortia could be a solution to remove siloxanes from urban wastewater.

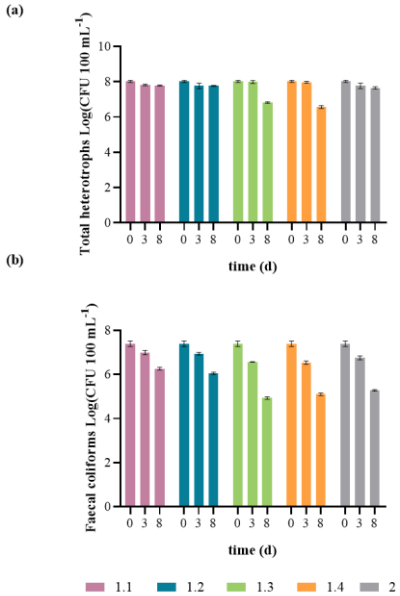

Figure 3. Bacterial quantification in terms of total cultivable heterotrophs and faecal coliforms.

4. Conclusions

Microalgae grew successfully and N and P were removed effectively in all PBRs, while the abundance of cultivable faecal coliform decreased considerably. Promising results are expected regarding VMS removal and the significant potential of microalgae-bacteria consortia in the bioremediation of wastewaters was confirmed.

References

Amaro, H. M., Salgado, E. M., Nunes, O. C., Pires, J. C., Esteves, A. F., (2023). Microalgae systems-environmental agents for wastewater treatment and further potential biomass valorisation. Journal of *Environmental Management*. **337,** 117678.

Pascual, C., Lebrero, R., Cantera, S. (2023). Toward a sustainable and cost-efficient biological-based platform for siloxanes removal. *Critical Reviews in Environmental Science and Technology*. **53,** 70-86.

Vo, T. P., Danaee, S., Chaiwong, C., Pham, B. T., Kim, M., Kuzhiumparambil, U., Songsomboon, C., Pernice, M., Ngo, H. H., Ralph, P. J. (2024). Microalgae-bacteria consortia for organic pollutants remediation from wastewater: A critical review. *Journal of Environmental Chemical Engineering*. **114213**.

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