Two liquid phase partitioning bioreactor: A novel method for detoxification of endocrine disrupting phthalates in the environment

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Phthalic acid esters (PAEs) are alkyl or dialkyl esters of phthalic acid and globally used in the manufacture of plastic and polyvinyl chloride for providing flexibility and mechanical strength. Among the different PAEs, DEP (diethyl phthalate) and DMP (dimethyl phthalate) are most widely used for manufacturing a broad range of industrial products such as plastic products, toys, adhesives, paints, printing ink, photography films, insect repellents, pesticides, cosmetic products, medical devices, rocket propellants, etc. Since PAEs are not chemically bound to plastics and other products, they can be easily released into different ecological matrices such as water, air, soil and sediment, during their production and use, thereby posing serious risk to different life forms including human, animal and aquatic organisms. Hence, owing to their endocrine disrupting nature DMP and DEP is a global environmental concern.

In the present study, biodegradation of a mixture of DMP and DEP as dual substrate system was examined in a two-phase partitioning bioreactor (TPPB) (Figure 1) with *Cellulosimicrobium funkei*. During the initial screening of suitable solvents, silicone oil was selected as the nontoxic, biocompatible and non-bioavailable solvent (non-aqueous phase liquid) for further use in TPPB system. The TPPB system was evaluated under batch and fed-batch modes of operation for different initial concentrations of DMP and DEP. Ecotoxicity assessment of the treated water was carried out to evaluate the toxicity removal by the TPPB system.

Under the batch mode of operation, 93% degradation was achieved for a total initial phthalate concentration of 3000 mg/L within 60 h with a degradation rate of 38.75 $mgL^{-1}h^{-1}$ (Figure 2a). In the fed-batch system, complete degradation was observed up to 3500 mg/L total initial concentration of phthalates (1500 mg/L DEP and 2000 mg/L DMP) within 24h (Figure 2b). Ecotoxicity assessment of the treated water revealed a GI (germination index) value of 86.17 and 13.33% brine shrimp mortality. Overall this study revealed very good potential of the TPPB system for DMP and DEP degradation to overcome their toxicity in the environment.

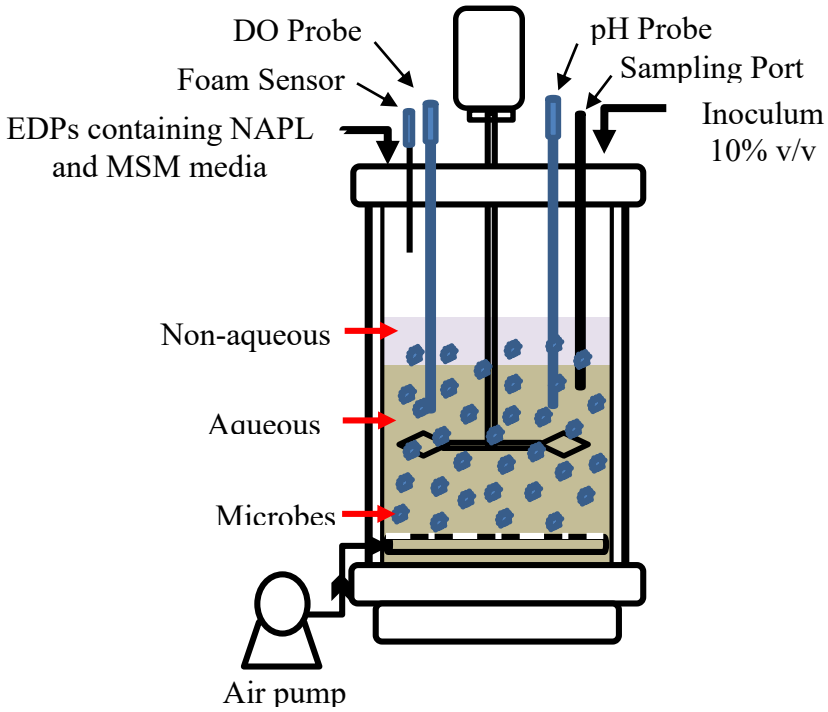

Figure 1: Schematic representation of two phase partitioning bioreactor used in this study.

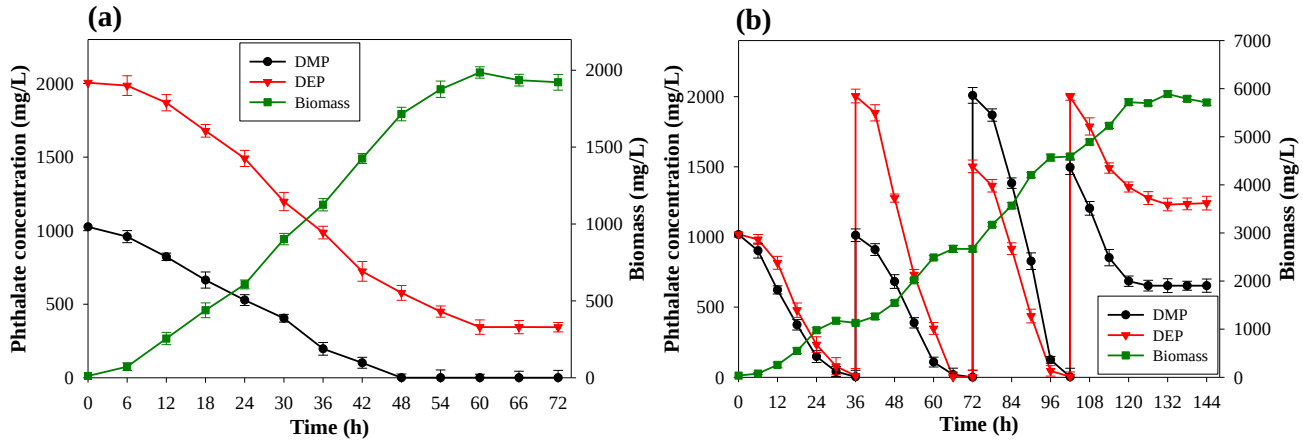

Figure 2: Biomass growth of *Cellulosimicrobium funkei* and EDPs biodegradation profile in TPPB system under (a) batch and (b) fed-batch mode.

References

Perpetuo, E. A., da Silva, E. C. N., Karolski, B., & do Nascimento, C. A. O. (2020). Biodegradation of diethyl-phthalate (DEP) by halotolerant bacteria isolated from an estuarine environment. Biodegradation, 31(4–6), 331–340.

Prasad, B., & Suresh, S. (2015). Biodegradation of dimethyl phthalate ester using free cells, entrapped cells of Variovorax sp. BS1 and cell free enzyme extracts: A comparative study. International Biodeterioration and Biodegradation, 97, 179–187.

Lu, M., Jiang, W., Gao, Q., Zhang, M., & Hong, Q. (2020). Degradation of dibutyl phthalate (DBP) by a bacterial consortium and characterization of two novel esterases capable of hydrolyzing PAEs sequentially. Ecotoxicology and Environmental Safety, 195, 110517. https://doi.org/10.1016/j.ecoenv.2020.110517

Sharma, N., Kumar, V., Maitra, S. S., Lakkaboyana, S. K., & Khantong, S. (2021). DBP biodegradation kinetics by Acinetobacter sp.33F in pristine agricultural soil. Environmental Technology and Innovation, 21, 101240.

Zhao, H. M., Du, H., Lin, J., Chen, X. Bin, Li, Y. W., Li, H., Cai, Q. Y., Mo, C. H., Qin, H. M., & Wong, M. H. (2016). Complete degradation of the endocrine disruptor di-(2-ethylhexyl) phthalate by a novel Agromyces sp. MT-O strain and its application to bioremediation of contaminated soil. Science of The Total Environment, 562, 170–178.