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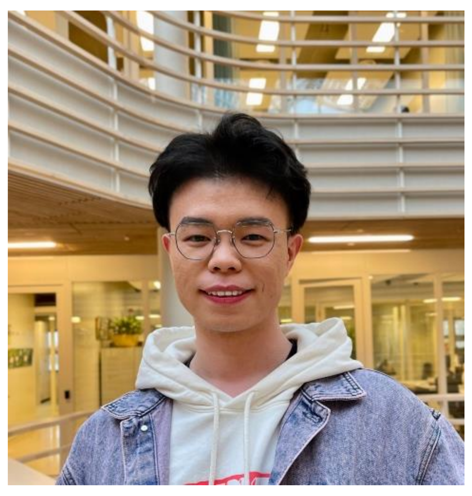
Engineering of biological activated carbon filters for micropollutant removal in wastewater effluent



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Motivation

Micropollutants (MPs), including pharmaceuticals, pesticides, and industrial chemicals, are widely detected in surface waters globally at concentrations from pg/L to µg/L [1]. Wastewater treatment plants (WWTPs) are a primary source of MPs, as inadequate removal during conventional treatment processes leads to their release into surface water through effluents [2]. Recognizing the environmental risks, the European Union updated the Urban Wastewater Treatment Directive for stricter MP removal from WWTPs [3]. This highlights the need for sustainable and efficient quaternary treatment technologies. Biological activated carbon (BAC) filters are a promising technology to remove MPs from WWTP effluent before discharge [4]. Across BAC granules, the MP removal results from a synergy between sorption and biodegradation (Fig. 1). MPs can be temporarily retained through sorption by activated carbon and biofilms, prolonging their biodegradation availability (Fig. 2). The subsequent biodegradation can regenerate partial sorption capacity, extending filters longevity. However, the interdependent effects of sorption and biodegradation to MP removal remain largely unclear.

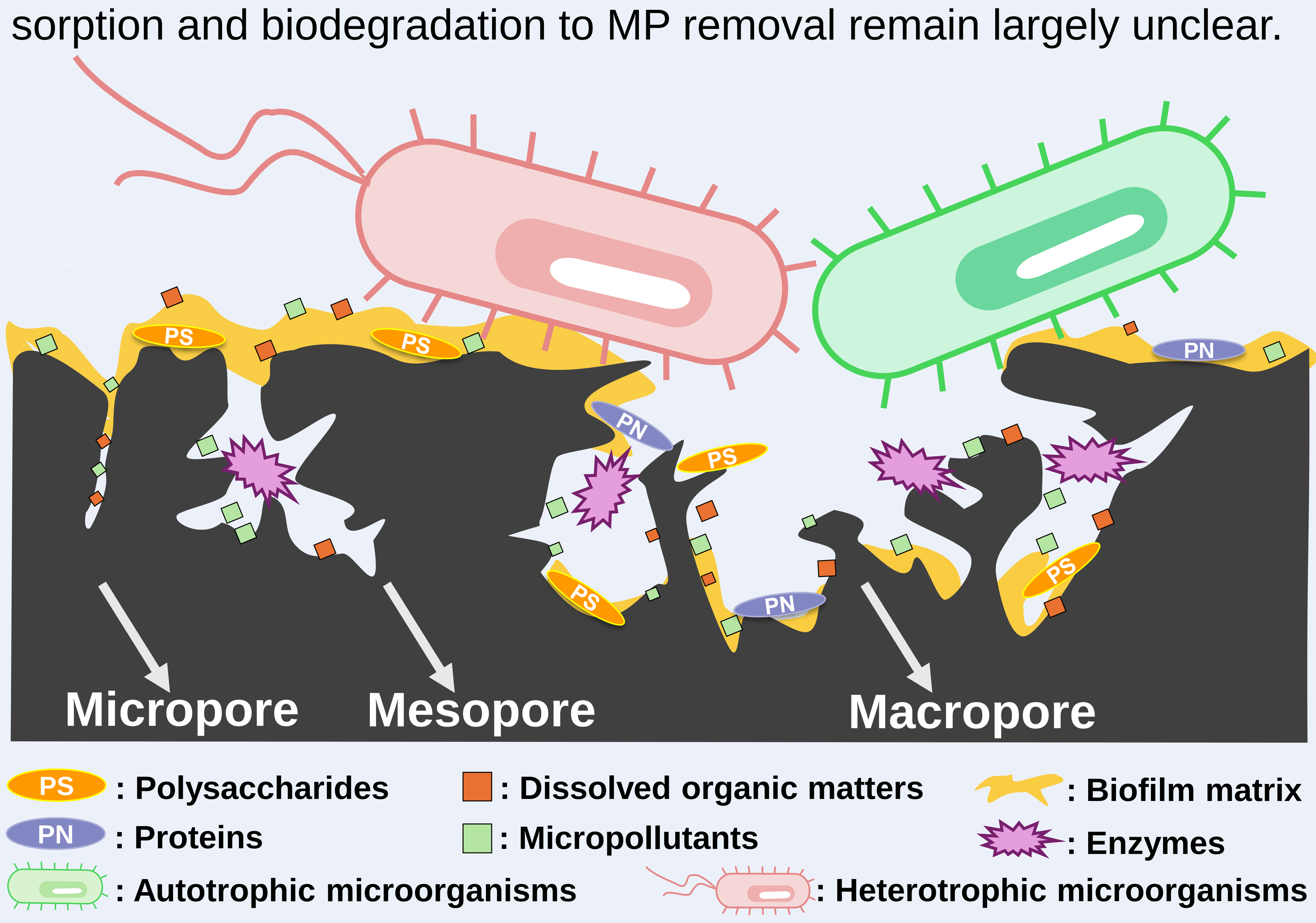

Fig. 1. Illusration of the BAC granules surface.

Technological challenge

For the MP removal, BAC filters combine sorption, desorption, oxidation, biodegradation, and precipitation. Understanding the individual contribution of these mechanisms is still challenging. To maintain functional BAC filters and advance their applications, further investigations and fundamental insights are needed to generate appropriate solutions. For instance, a critical challenge is decoupling the real retention time needed for biodegradation from the empty bed contact time (EBCT), as it directly affects MP removal. Elucidating the biodegradation pathways is also complicated due to the involvement of diverse (extracellular) enzymes. Moreover, varying operational parameters can shape different microbial communities and biofilm characteristics.

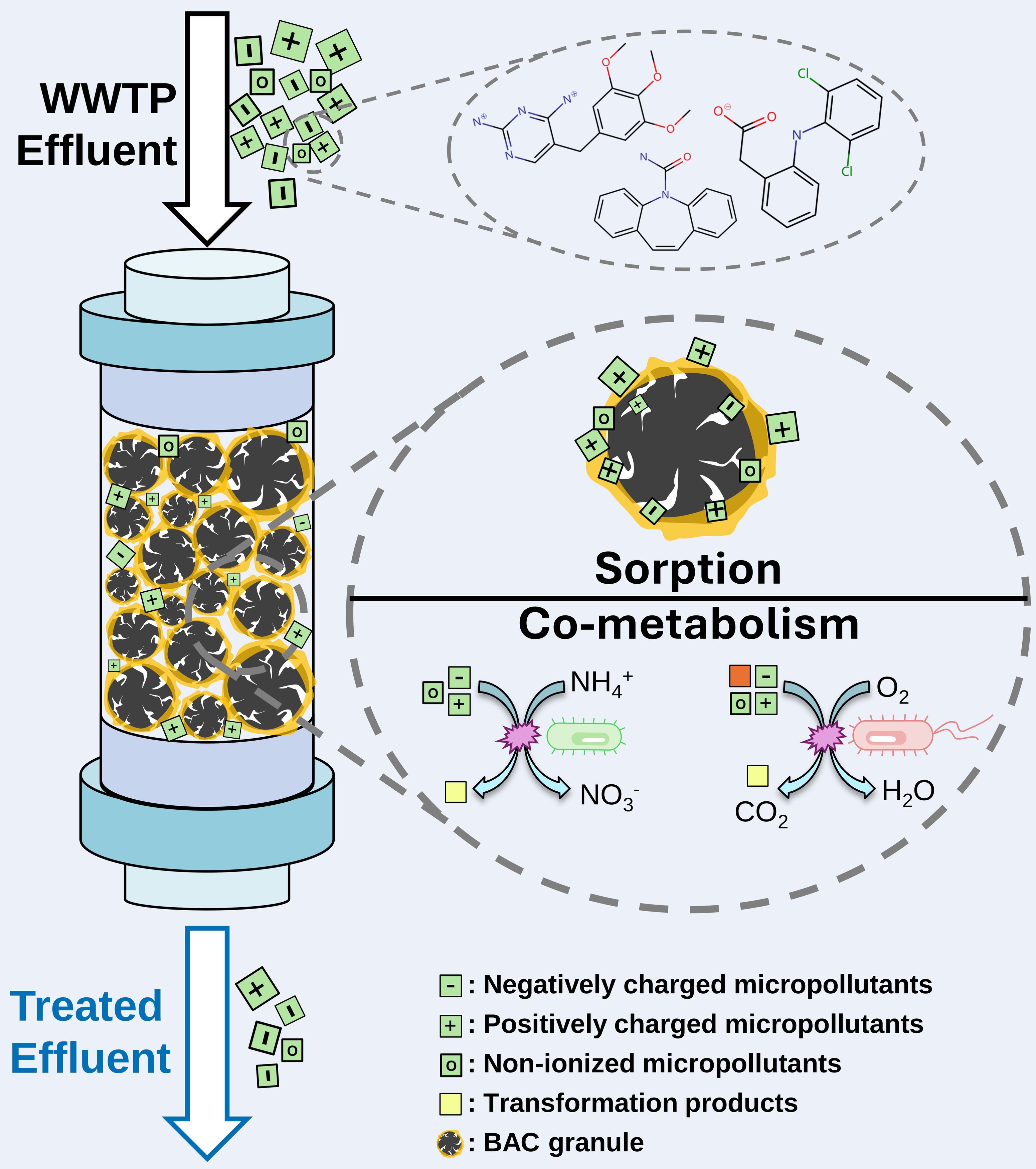

Fig. 2. Schematic of main MP removal pathways in BAC filters.

Research goals

This project aims to enhance our understanding of the mechanisms driving effective MP removal in BAC filters, providing insights to optimize their field applications. Specifically, the project seeks to answer the following questions:

1. How are MPs retained through BAC granules before being biodegraded and/or desorbed? How long does this retention last, and how does it differ from the EBCT?
2. How do the interdependent interactions between activated carbon adsorption, biofilm sorption, and biodegradation influence the removal of MPs with different properties?
3. What (extracellular) enzymes and transformation products are involved in the biodegradation of MPs within BAC filters?
4. How do operational parameters, such as oxygen dosing, affect microbial communities and biofilm characteristics that are relevant to MPs retention and removal?

References

[1] Wilkinson, J.L., et al., PNAS, 2022. 119(8): p. e2113947119.
[2] Luo, Y., et al., Sci. Total Environ., 2014. 473-474: p. 619-641.
[3] European commission, 2024. COM/2022/541.
[4] Bernadet, O., et al., J. Hazard. Mater., 2023. 458: p. 131882.

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