Biofilm Business

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Exploring Biological Activity in Granular Activated Carbon during Full-Scale Quaternary Treatment at a Municipal Wastewater Treatment Plant

Birte Raes[1], Daniel Modrall Sperling[2], Lennert Dockx[1], Jan Dries[2], Birgit De Bock[1]

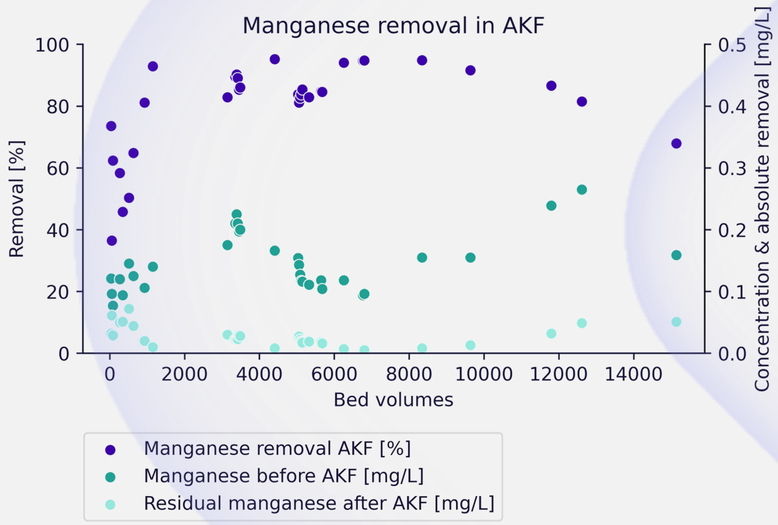
[1] *Aquafin NV, Aartselaar, Belgium.*

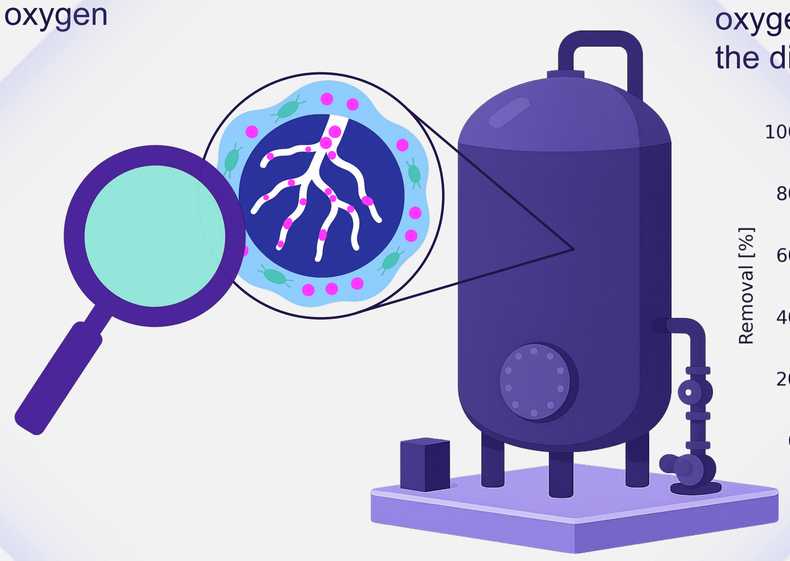
[2] *Antwerp University, Antwerp, Belgium.*

Quaternary treatment for micropollutant removal in a municipal wastewater treatment plant can be done by combining ozone and granular activated carbon filters (AKF). This integrated approach is hypothesized to offer multiple benefits compared to oxidation or adsorption alone. Enhanced availability of biodegradable organic matter and oxygen rich conditions under post-ozonation oxygen-rich conditions might stimulate the development of biological activity on AKF. Biofilm growth on carbon granules may contribute to micropollutant transformation, thereby clearing adsorption sites and delaying carbon regeneration. Biofilm activity in a full-scale AKF is monitored using five complementary approaches.

1. Manganese in water

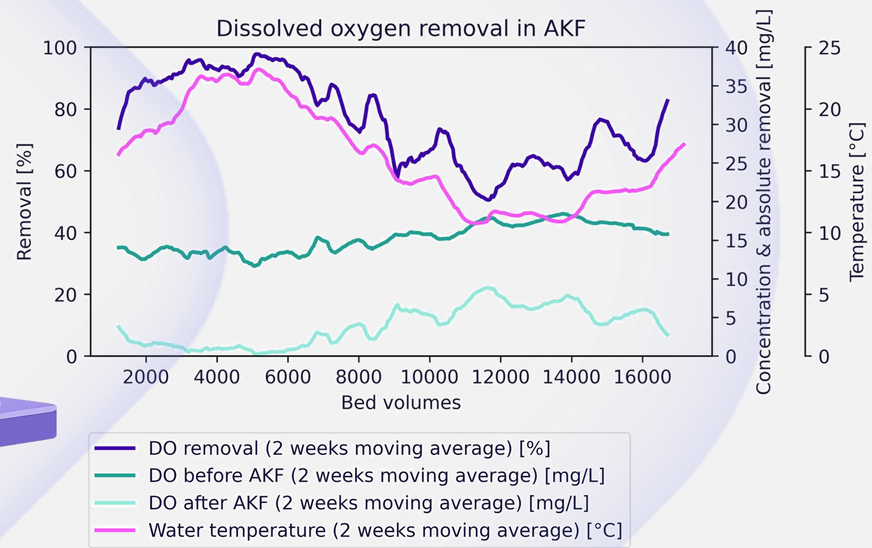
Total manganese concentration is removed by activated carbon. However, it is unclear of reduced removal is due to biofilm activity, to temperature effects or to oxygen limitations.





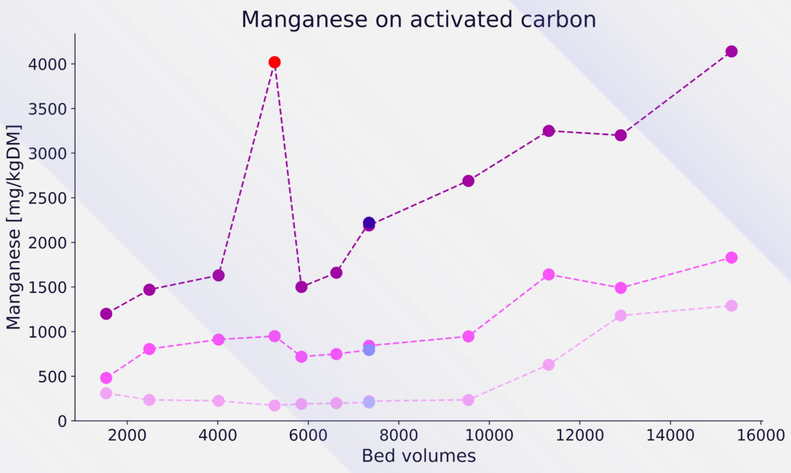
2. Oxygen uptake

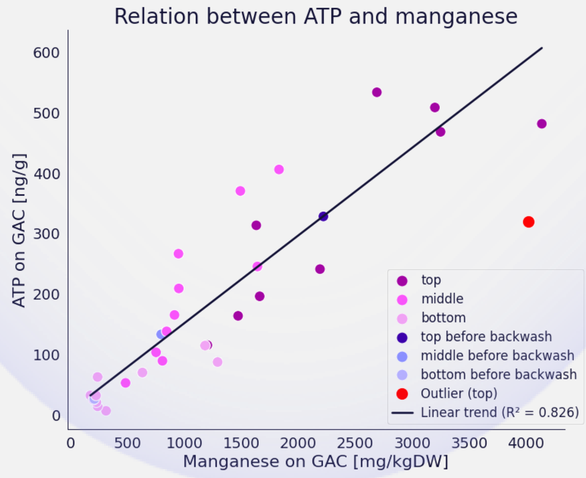
Oxygen consumption by activated carbon leads to oxygen limitation in summer. In winter, temperature influences both oxygen solubility and treatment performance, complicating the distinction between effects driven by these two.



3. Manganese on carbon

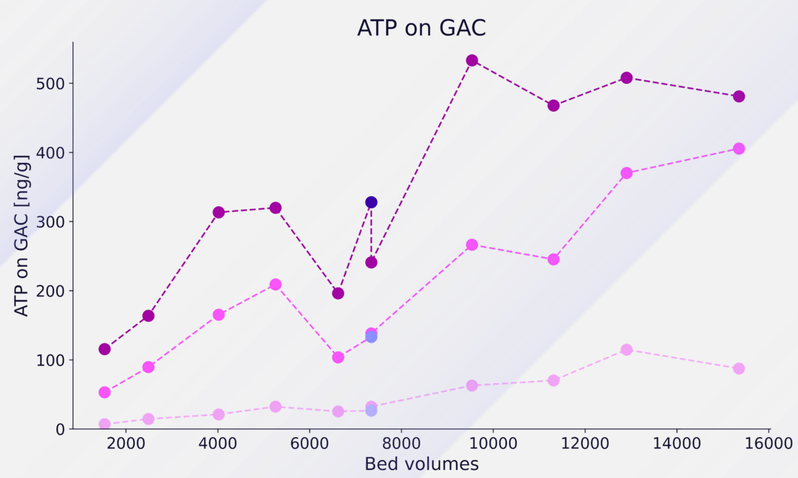
Removed manganese is fixed on the carbon and therefore increasing in time. Layers are clear and backwash has no impact on the concentration. Manganese seems to be a good proxy for ATP.





4. ATP on carbon

Adenosine triphosphate (ATP) is an energy carrier that drives processes in living cells, therefore indicating biofilm activity. Layers are clear and activity increases in time. Backwash has minor impact on ATP in the top layer.



5. Microbial community profiling

Samples for 16S rRNA sequencing are collected since start-up of the AKF in April 2025 and are stored for batch analysis after 1.5 years of operation (~25,000 bed volumes). Sequencing aims to characterize biofilm communities at the top, middle, and bottom of the carbon bed and to assess temporal shifts in microbial composition. Literature links micropollutant biodegradation to nitrifying bacteria, due to enzymatic activity, and manganese-oxidizing bacteria, associated with biogenic manganese oxides acting as catalysts[a,b].

Conclusion

Monitoring biofilm activity in granular activated carbon filters using water-phase analyses proved challenging, as temperature effects dominated and masked trends. Measurements on the carbon provided clearer temporal patterns. Manganese correlated with ATP and is a practical proxy due to its robustness. Despite frequent and discontinuous backwash, distinct layering is observed in the carbon, with biological activity increasing over time, which is promising for extending carbon lifetime. Future sequencing will clarify biofilm composition under low-ammonium conditions.

References: (a) Wang, G., Hambly, A. C., Dou, Y., Wang, G., Tang, K., & Andersen, H. R. (2022). Polishing micropollutants in municipal wastewater using biogenic manganese oxides in a moving bed biofilm reactor (BioMn-MBBR). J. Hazard. Mat., Vol. 427. https://doi.org/10.1016/j.jhazmat.2021.127889; (b) Bernadet O., Larasati A., van Veelen H.P.J. , Euverink G.J.W., Gagliano M.C. (2023) , Biological Oxygen-dosed Activated Carbon (BODAC) filters: A bioprocess for ultrapure water production removing organics, nutrients and micropollutants, J. Hazard. Mat., Vol. 458. https://doi.org/10.1016/j.jhazmat.2023.131882.

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