Promising potentials for the application of sewage-sludge-based biochars as sorbents for PFAS

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Objectives

- Compare the relative abilities of sewage sludge biochars and clean wood chips to sorb perfluorinated carboxylic acids (PFCA)
- Identify possible sorption mechanisms of PFCA for the different biochar feedstocks
- Study the effects of increasing perfluorinated carbon chain-length, competing sorbates, and the presence of soil on sorption

Figure 1: Biochar collection from the ETIA pyrolysis unit at Lindum AS, Norway.

Figure 2: Raw sewage sludge pellets (left) and sewage sludge biochar (right).

Methods

Biochar samples (pyrolysis T = 700°C):

- **ULS**: raw sewage sludge from Ullensaker WWTP (29% carbon)
- **DSL**: digested sewage sludge (13% carbon)
- **CWC**: clean wood chips (91% carbon)

Batch shaking tests with C5-C10 PFCA:

- 100 mg biochar
- 50 mL water
- Spiked with individual PFCAs at 10 concentrations over four orders of magnitude
- Shaken end-over-end for >14 days
- Filtered through 0.45 µm regenerated cellulose filter

- Solid Phase Extraction (SPE) of filtrate
- Analyte quantification with LC-MS/MS at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway

Results

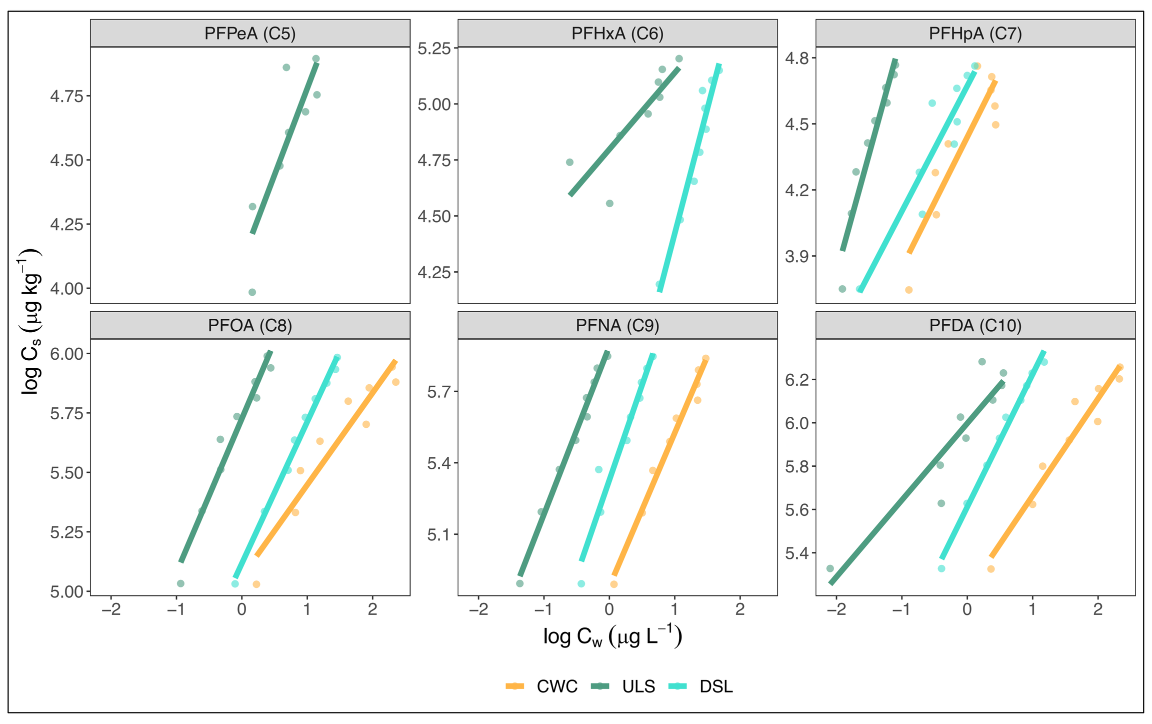

Figure 3: Freundlich sorption isotherms for the ULS, DSL, and CWC biochars. Log C_w is the equilibrium aqueous concentration and log C_s is the equilibrium sorbed concentration

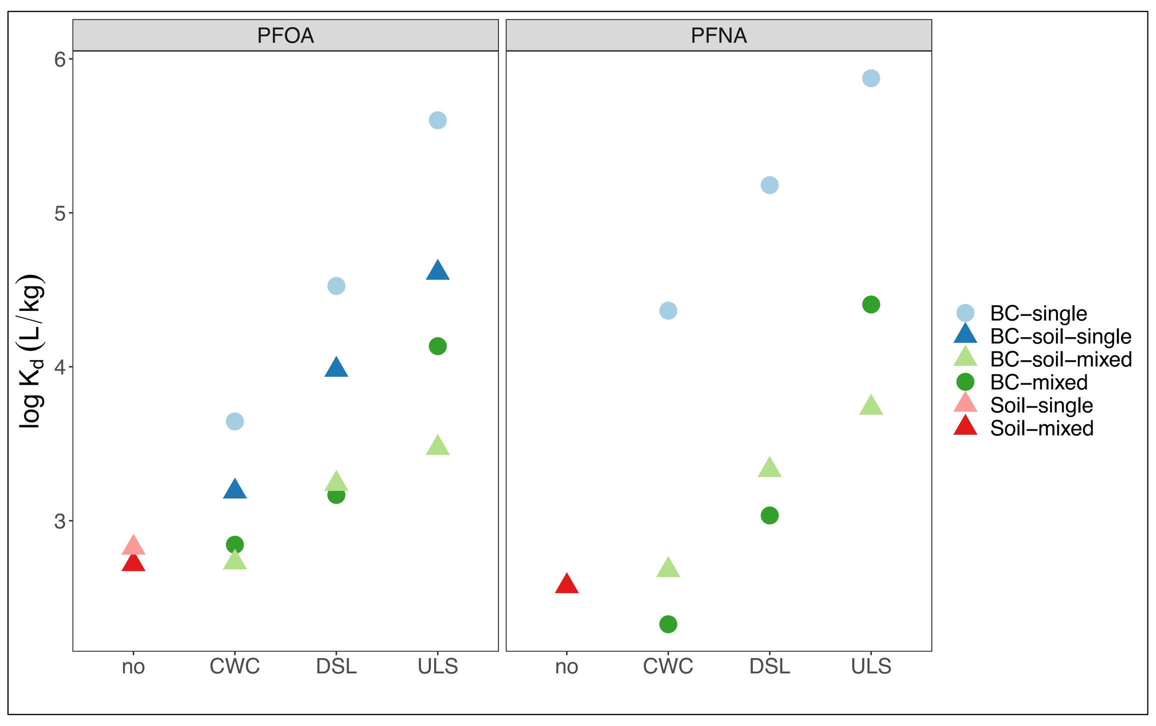

Figure 4: Sorption attenuation in the presence of other PFCAs and soil

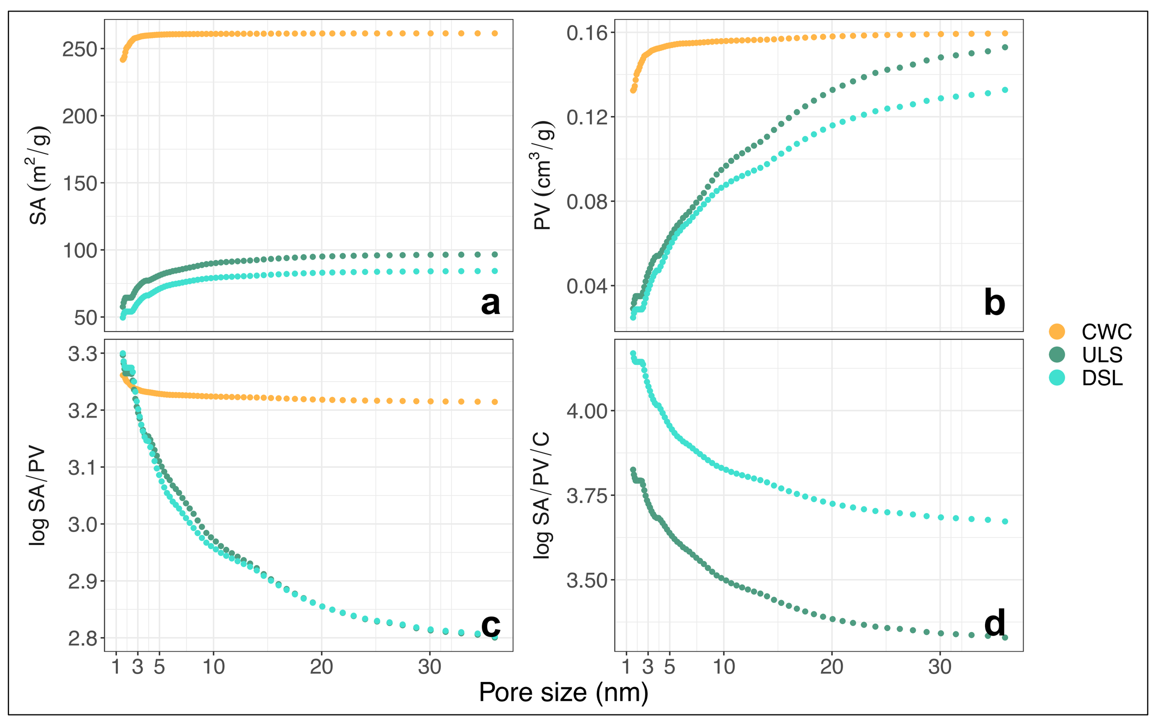

Figure 5: Pore size distribution >1.5 nm by **(a)** surface area (SA), **(b)** pore volume (PV), **(c)** log SA/PV, and **(d)** log (SA/PV)/C (C = carbon)

- Sorption increased from CWC < DSL < ULS, and with increasing perfluorinated chain-length (**Fig. 3**). The Freundlich sorption coefficients (log K_F) found in this study are equivalent to, or higher than, log K_F values for activated carbon reported in previous literature[1,2,3]
- Sorption was attenuated by factors 6-140 in the presence of a cocktail and 8-138 in the presence of soil and a cocktail for PFOA, PFNA, and PFDA (**Fig. 4**)
- Stronger sorption of PFCA to sewage sludge biochars is likely due to a higher fraction of mesopores (2-50 nm, **Fig. 5c**)
- A higher carbon-fraction in the pore wall matrix (lower log SA/PV/C ratio) of ULS biochar is hypothesized to explain why PFCA sorb stronger to ULS than to DSL (**Fig. 5d** and **Fig. 6**)

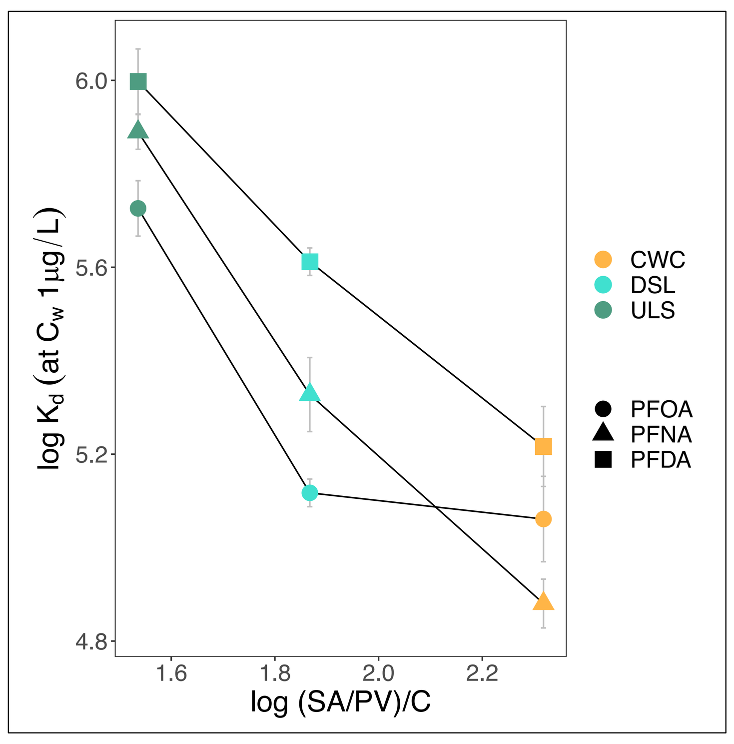

Figure 6: Relationship between log (SA/PV)/C (C = carbon) ratio and log K_d for PFOA, PFNA and PFDA across biochar samples.

Conclusion

- The strong sorption of PFCA found to sewage sludge biochars is promising for their incorporation in a circular economy, for example their use as fertilizers, sorbents in wastewater treatment plants, or as amendments to PFAS-contaminated soil
- Future work should aim at further investigating the ratios between surface area, pore volume, carbon, and minerals (mainly Ca and Fe) in determining the sorption affinity of PFAS and other organic contaminants to sewage sludge biochars

References:

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