PFAS adsorption on granular activated carbon: from modeling their fate to reduce the human health risk for their mixture

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INTRODUCTION

Perfluoroalkyl substances (PFAS) persistence in the environment leads to their presence in drinking water (DW), increasing concerns for their potential human health risk. Worldwide always more stringent limits are posed for PFAS concentration in DW and water utilities need to upgrade or properly manage their plants facing this new challenge. Adsorption onto activated carbon (AC) has been identified as an effective technique to remove PFAS. However, no procedures are available to optimize adsorption process looking at the health risk due to the mixture of PFAS, having both different affinity towards AC and toxicity.

OBJECTIVE

This study aims at modelling the fate of 12 PFAS (C4-C12) in granular activated carbon (GAC) fixed-bed filters and at estimating the health risk due to PFAS mixtures, that is used for optimizing the adsorption process operation.

METHODOLOGY

Lab-scale tests on PFAS adsorption were performed on a real DW, spiked to reach initial concentration of 0.1 µg/L of single PFAS, with 4 ACs. Batch isotherms and rapid small-scale column tests (RSSCTs) were performed. Moreover, a one-year full-scale monitoring campaign was performed on GAC filters in 15 drinking water treatment plants spread in an urban area where the four analysed ACs are used.

Lab- and full-scale results were used to model the breakthrough curves of single PFAS as a function of PFAS concentrations and characteristics, GAC properties and filters operating conditions.

An advanced health risk assessment for mixtures was performed, applying the Relative Potency Factor (RPF) method: RPFs consider the relative toxicity of one PFAS compared to a reference one (PFOA). RPFs are multiplied to the concentration of all

PFAS to convert them into equivalent concentrations of PFOA. Resulting equivalent concentrations are summed up to obtain the mixture concentration (C_{MIX}) and to calculate the mixture risk, as benchmark quotient (BQ_{MIX}), that is the ratio between C_{MIX} and the health-advisory limit.

RESULTS

RSSCTs breakthrough curves (Fig. 1.a) show that, AC performance improves from short-chain hydrophilic to long-chain hydrophobic PFAS.
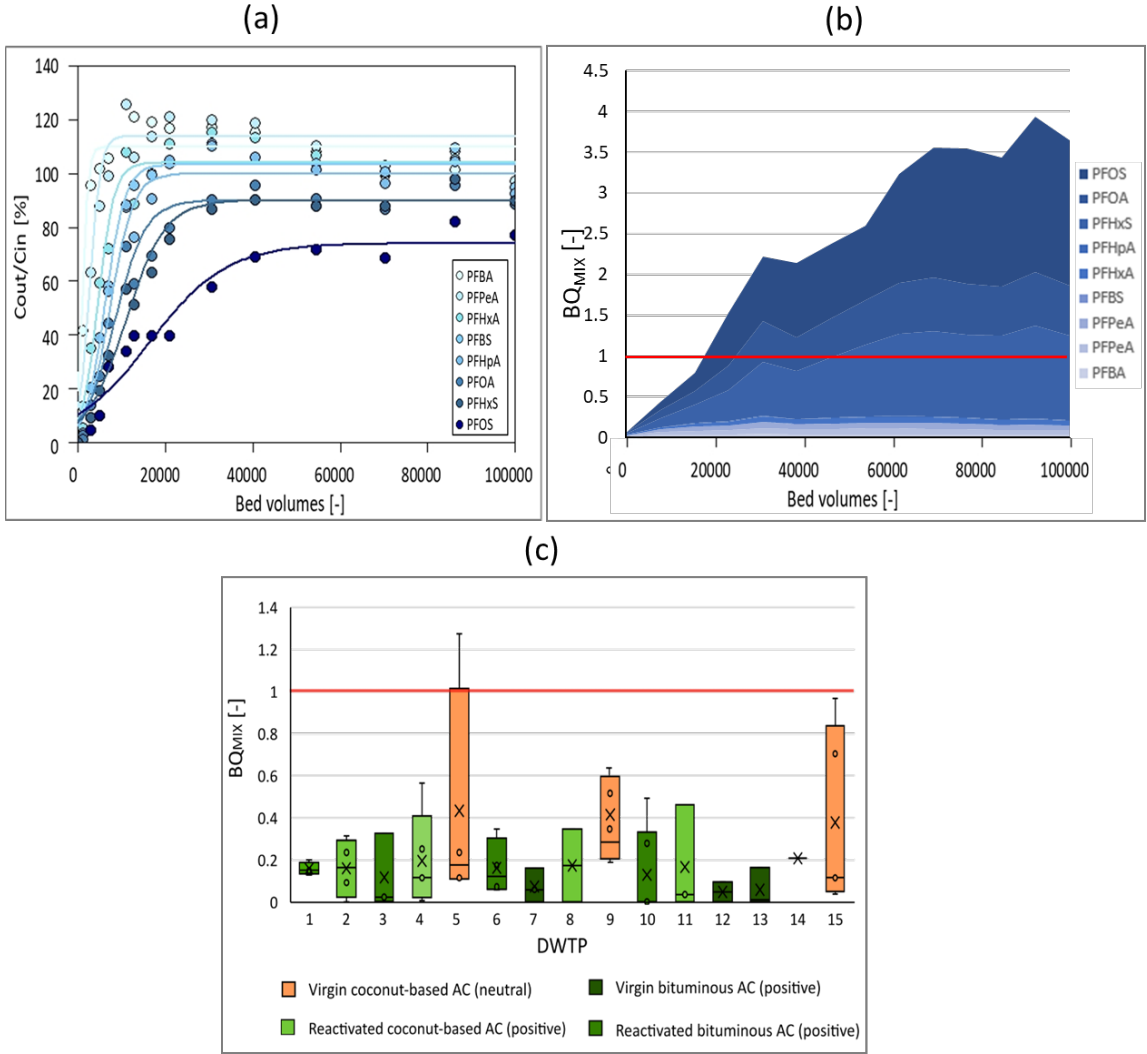

Figure 1. Lab-scale breakthrough of (a) single PFAS concentrations, (b) the overall risk. (c) Overall risk for different drinking water treatment plants (DWTPs).

However, different conclusions are found when looking at the AC performance in terms of breakthrough evaluated as health risk, described by BQ_{MIX} (Fig. 1.b). In fact, while short-chain PFAS reach complete breakthrough within 7'000 bed volumes (BV), the overall risk (BQ_{MIX}) reaches the critical value of 1 (where C_{MIX} is equal to the health-

advisory limit) after 20˙000 BV. This is because short-chain PFAS are characterized by lower toxicity compared to long-chain ones, whose contribution to the overall risk is higher.

Finally, lab- and full-scale studies highlighted that GAC surface charge affects performance more than GAC porosity, as shown in Fig. 1.c where DWTPs with the neutral AC are characterised by higher overall risk. Consequently, GAC surface charge should be checked to select positively-charged GAC to fully exploit electrostatic attraction towards negatively-charged PFAS.

CONCLUSIONS

Adsorption on GAC assure a satisfactory removal of long-chain PFAS, being the most hazardous PFAS. The use of an advanced risk approach to describe adsorption performance provides more insights, with respect the usual approach based on concentration, for a better process design and management.

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