Reed Straw-Derived Biochar (RESCA) for Effective Adsorption Removal of Per- and Polyfluoroalkyl Substances (PFAS)

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Background/Objectives. Per- and polyfluoroalkyl substances (PFAS) are a class of environmental contaminants widely found in water, sediment, soil, air and biota. Their extreme recalcitrance and profound bioaccumulating potential have raised significant concerns regarding their imminent risk to the human health and natural biota. Unfortunately, PFAS have been detected in drinking water in the US and globally at relatively high concentrations exceeding the health advisory level (i.e., 70 ng/L for PFOA and PFOS together). Since 2002, short-chain PFAS have been developed by several major manufacturers as a replacement of these conventional C8 and higher homologues. To clean up PFAS contamination in impacted water, GAC adsorption is one of the most commonly used remedies given its effectiveness of removing PFOA and PFOS. However, GAC is not effective in adsorbing shorter chain PFAS, such as PFBA and PFHxA, given their reduced hydrophobicity and increased tendency for micelle development. Biochar is an economic and green alternative for GAC and other manufactured carbonaceous adsorbents as it is made from biological wastes via pyrolysis. Biochar has received increasing attention due to its unique feature such as high carbon content and cation exchange capacity, large specific surface area and stable structure. In this present research, we aim to synthesize novel biochar and investigate their adsorption efficiencies to remove short-chain PFAS (C4 to C6).

Approach/Activities. Slow pyrolysis of the dried feedstock materials was employed to produce biochar in a tube furnace under the consistent nitrogen flow. The temperature was increased at 5 ºC min^{-1} and held at an HTT of 500, 700, or 900 ºC for 4 to 6 h. Post treatments with acids, bases, or heated steams were employed for activation. Batch experiments were conducted to investigate the adsorption kinetics and isotherms in 10 mL of synthetic solutions containing different model compounds. The effects of pH and ion strength were assessed. Elemental compositions, specific surface areas, particle size distribution, and surface chemistry were characterized to exploit the adsorption mechanisms of different synthesized biochar.

Results/Lessons Learned. Here, we synthesized reed straw-derived biochar (RESCA) exhibiting exceptional removal efficiencies (>92%) toward short-chain PFAS at environment-relevant concentrations (e.g., 1 µg/L). Pseudo-second-order kinetic constants of RESCA were 1.13 and 1.23 L/(mg h) for PFBA and PFBS, respectively, over six times greater than GAC. SEM imaging and BET analysis revealed the combination of highly hydrophobic surface and scattered distribution of mesopores (2–10 nm in diameter) was associated with the rapid adsorption of short-chain PFAS. RESCA-packed filters demonstrated effective removal of the mixture of three short-chain and three long-chain PFAS in the influent with the flow rate up to 45 mL/min. In contrast, GAC-packed filters were significantly less efficient in the removal of short-chain PFAS, which were also negatively affected by the increase of the flow rate. Efficacy of RESCA-packed filters was also validated in four PFAA-spiked groundwater samples from different sites. Dissolved organic matter (DOC) of >8 mg/L can negatively affect the removal of short-chain PFAS by RESCA. Feasibility of scaling up the RESCA adsorption system was investigated using breakthrough simulation. Overall, RESCA represents a green adsorbent

alternative for the feasible and scalable treatment of a wide spectrum of PFAS of different chain lengths and functional moieties.