Understanding the Carbon Footprint of Fixed Media PFAS Treatment Systems: Life Cycle Assessment and Eco-Efficiency Analysis

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Background/Objectives. This study compared the impact of scale in fixed media PFAS treatment systems on the carbon footprint (CF) using Life Cycle Assessment (LCA) and eco-efficiency analysis. To further reduce the CFs of the current systems while minimizing the associated costs, i.e., optimizing the systems' eco-efficiency, alternative scenarios based on treatment media management (e.g., closed-loop) and energy source were studied.

Approach/Activities. Following an Attributional LCA modeling approach, the LCA study was developed according to ISO 14040:2006 and ISO 14044:2006 standards. The CF was assessed using the SimaPro v9.3.0.3 software, the Ecoinvent database v3.8, and the Environmental Footprint 3.0 method. ISO 14045:2012 was followed for the eco-efficiency analysis to identify the treatment option with the best service value and lowest CF. The approach considered raw materials extraction, processing, transportation, system's use stage and end of life. Results were normalized to the quantity of PFAS (PFOA + PFOS) removed (ton CO_2e/ kg PFAS removed). Eco-efficiency analysis was conducted based on total operational cost ($k). Results of the study are based on 21 months of operational data from two systems installed for the treatment of PFAS-containing water (System A: capacity 100 gallons per minute (gpm) and System B: capacity 700 gpm) with granular activated carbon (GAC). Five scenarios were evaluated: *i)* business-as-usual scenario - only for System B (scenario *iB*): all new GAC, disposed after use. USA grey electricity mix for on-site system's energy consumption; *iii)* Closed Loop scenario - for System A (scenario *iiA*) and B (scenario *iiB*): 90% of GAC reused after reactivation process, ~10% losses from transport and treatment replaced by new GAC. USA grey electricity mix for on-site system's energy consumption; and *iii)* Closed Loop & Renewable Energy scenario – for System A (scenario *iiiA*) and B (scenario *iiiB*): closed loop GAC with on-site system's energy consumption modified to USA green electricity.

Results/Lessons Learned. The System B scenarios resulted in CFs (per ton CO_2e/ kg PFAS removed) of: *iB*) 2,466, mainly due to the GAC production (88%); *iiB)* 504, a CF reduction of 80% compared to *iB*; and *iiiB)* 345, a reduction of 86% compared to *iB)*. The energy efficiency of the water treatment process increased with scale leading to System B, treating 700 gpm, having the lowest CF scenarios. System A's CF per ton CO_2e/ kg PFAS removed was: *iiA)* 1,470 and *iiiA)* 533. The reduced scale of the system (100 gpm) resulted in an ~200% increase in CF of *iiA)* compared to *iiB)* due to the on-site energy consumption (accounting for 67% of the total CF). Switching to green electricity resulted in CF reductions of ~30% for System B and ~60% for System A. In conclusion, the larger System B Closed Loop offers an optimized CF promoting centralized treatment. Transition to renewable energy in any scenario is the most eco-efficient solution and should be incorporated, particularly if centralized treatment is impractical.