Microwave Irradiation-enabled Household On-site Regeneration of Activated Carbon for Sustainable Point-of-Use Removal of PFAS in Drinking Water

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BACKGROUND & OBJECTIVES

Millions of the U.S. people across this country rely on household water treatment (HWT), accomplished by deploying point-of-use (POU) or point-of-entry (POE) devices, for drinking water. However, per- and polyfluoroalkyl substances (PFAS) broadly found in the U.S. drinking water are challenging established HWT technologies. Some of them (e.g., ceramic filters) poorly alleviate PFAS, while others (e.g., RO filtration and granular activated carbon (GAC)), though effective, remained challenged due to inherent technical and economical restrictions. Particularly, they cannot destruct toxic PFAS to provide an ultimate solution to PFAS pollution. *Challenges* for POU removals of PFAS in drinking water include: 1) trace concentrations; 2) low lifetime health advisory or maximum contaminant levels; 3) persistence; 4) prevalence; and 5) fewer technology options available for the POU scenario.

Therefore, the *long-range goal* is to develop sustainable POU technologies for surmounting emerging and persistent contaminants in drinking water.

The *primary objective* of this proposal is to validate, optimize, and demonstrate microwave (MW) irradiation-enabled thermal destruction of PFAS sorbed on activated carbon, thereby enabling a design capable of demonstrating long-term performance for cost-effective POU removal of PFAS in drinking water.

The *central hypothesis* is that household microwave ovens can effectively destruct PFAS on exhausted activated carbon for adsorbent regeneration and PFAS detoxification, thus achieving a cyclic adsorption - regeneration approach to PFAS in drinking water.

METHODOLOGY

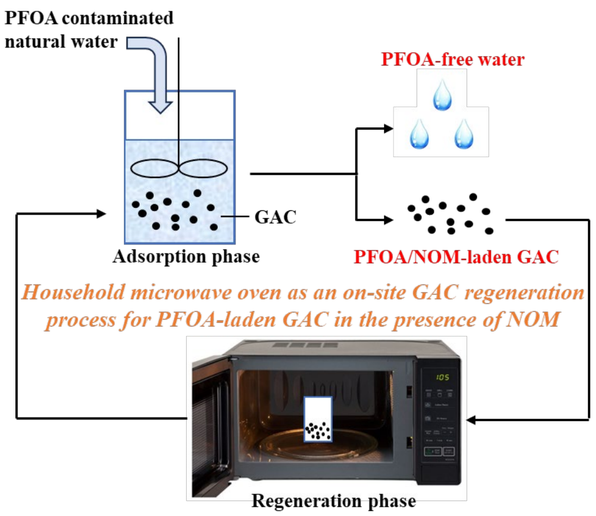


Fig. 1 The overall treatment scheme for PFOA mitigation and GAC regeneration

Fig. 2 The selected GAC

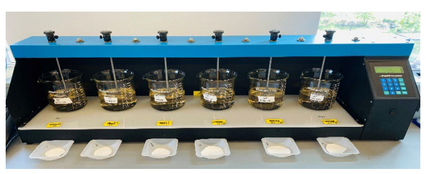


Fig. 3 PFOA adsorption by GAC in the presence of NOM

METHODOLOGY (CONT.)

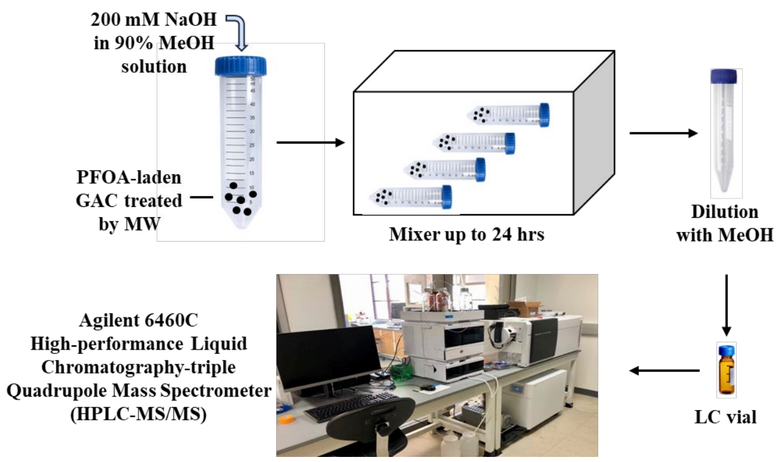


Fig. 4 The treatment scheme for PFOA extraction from GAC and PFOA detection by HPLC-MS/MS

RESULTS

Table 1. The optimization of PFOA extraction from GAC

NO.	Extraction methods	PFOA extraction rate(%)
1	10% NaCl	0.62
2	100% Methanol	7.71
3	90% Methanol	75.02
4	80% Methanol	68.61
5	70% Methanol	57.42
6	60% Methanol	20.25
7	50% Methanol	8.74
8	200 mM NaOH in 90% Methanol	95.93
9	200 mM NaOH in 80% Methanol	88.64
10	100 mM NaOH in 90% Methanol	87.02
11	100 mM NaOH in 80% Methanol	81.40

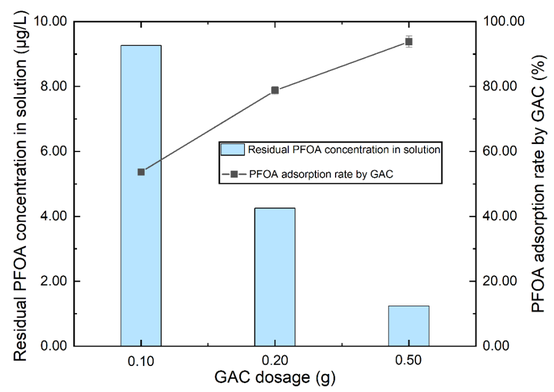


Fig. 5 Effect of GAC dosage on PFOA adsorption (Experimental condition: $PFOA_{initial}$ = 20 μg/L; DOC = 4 mg/L; $pH_{initial}$ = 7.00; reaction time = 24 hrs; and temperature = 20 ± 1 °C)

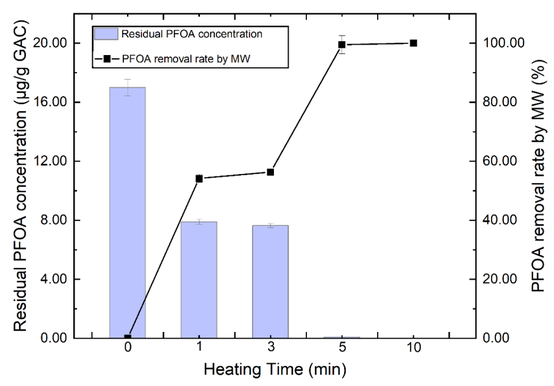


Fig. 6 Effect of heating time on PFOA destruction from GAC by microwave (Experimental condition: GAC = 0.50 g)

RESULTS (CONT.)

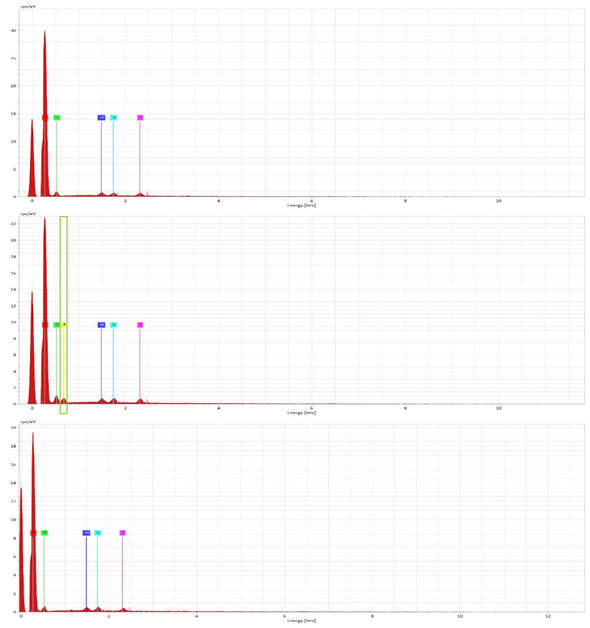
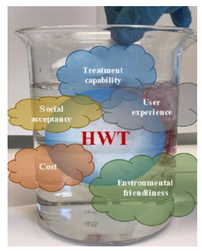


Fig. 7 Comparison of energy dispersive X-Ray spectroscopy (EDS) spectra of GAC under different conditions: (a) fresh GAC, (b) PFOA-laden GAC, and (c) PFOA-laden GAC treated by MW (Experimental condition: GAC = 0.50 g; $PFOA_{initial}$ = 20 μg/L; DOC = 4 mg/L; $pH_{initial}$ = 7.00; adsorption time = 24 hrs; and MW heating time = 10 min)

IMPLICATIONS



- ***Treatment capability*** - MW thermal regeneration permits recurring GAC adsorption of PFAS, while chemically destructing toxic PFAS.
- ***Environmental friendliness*** - Low energy footprint due to rapid MW regeneration; less GAC wastes; and minimal leaching from GAC.
- ***User experience*** - Household MW ovens makes the operation easy.
- ***Economic viability*** - No financial needs for additional equipment except MW ovens (a common kitchen appliance), repeated use of GAC, and lower expenses for less waste disposal.
- ***Social acceptance*** - The above-stated merits foster public acceptance and market adoption.

CONCLUSIONS

Household microwave oven can serve as an on-site PFOA-laden GAC regeneration process. A 5-min heating time achieved a remarkable 99.48% removal rate of PFOA, while extending the heating time to 10 min resulted in a complete elimination of PFOA.

FUTURE WORK

- Implement microwave irradiation of multiple PFAS-sorbed GAC (e.g., PFOS, PFNA, PFBS, PFBA, and GenX).
- Examine performance of the repeated adsorption - regeneration cycles.
- Lifecycle analysis.

ACKNOWLEDMENT

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