

An advanced biological treatment for PFAS removal from landfill leachate

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Introduction

In the last decades, the solid waste generation is continuously rising due to socioeconomic and demographic factors increase. Despite efforts to increase the recycling of urban waste, landfilling is still a widely used disposal technique in many countries. Within landfills, waste undergoes a number of physical, chemical and biological processes and releases a variety of pollutants within the landfill leachate, making this matrix one of the most difficult to treat. Recently, in landfill leachate perfluoroalkyl substances (PFAS) have also been found. These micropollutants have also great relevance in the context of the urban integrated water cycle since they are compounds present in many daily uses in the civil and industrial fields. PFAS exposure is linked to a range of health effects, including developmental issues, liver damage, immune system disruption, and an increased risk of certain cancers (Dickman & Aga, 2022). The persistence of PFAS in the environment exacerbates the hazard, as their bioaccumulation in the food chain can lead to prolonged human exposure.

Currently, landfill leachates are usually disposed at municipal wastewater treatment plants, which are not designed to remove PFAS. Among conventional treatment technologies, reverse osmosis has proven to be very effective in removing most PFAS from leachate. However, there is a strong membrane fouling effect and the need for further treatment of PFAS-rich concentrate. Adsorption on activated carbon has variable efficiency for different PFAS and tends to saturate rapidly at high levels of contamination, requiring frequent regeneration or replacement, which contributes to the high operating costs of this technology. (Zhang et al., 2022).

In the present study, the treatment of medium-age landfill leachates containing different PFAS concentrations was investigated at laboratory scale by using a Sequencing Batch Biofilter Granular Reactor (SBBGR). SBBGR is an innovative biological technique which allows to transform the existing activated sludge in a particular kind of sludge made up of biofilm and granules bounded in a plastic porous material. This configuration allows reaching very long sludge retention times (SRTs), longer than 300 days, thus reducing sludge production (up to 8 times). The high SRTs enable enrichment of slow growing microorganisms and forces biomass to use unusual substrates (e.g., PFAS). Furthermore, the particular structure of the biomass (i.e., a mixture of biofilm and granules) favours PFAS absorption on biomass.

Material and Methods

SBBGR consisted of a cylindrical plexiglass reactor (volume: 28L) partially filled with plastic material confined between two perforated plates (bed volume: 11L). Oxygen was insufflated into the liquid phase above the bed and a proper recirculation current conveyed the oxygenated leachate inside the biofilter. SBBGR operated in sequential mode with 8-hour treatment cycles. Each cycle consisted of filling, reaction and discharge phase. Quantification of PFAS in the influent and effluent of SBBGR was conducted with high resolution and accuracy TripleTof 5600 mass spectrometer (ab sciex) interfaced with a ThermoFischer ultra-high pressure liquid chromatography (UPLC).

Three different leachates whose composition is reported in Table 1, from landfills of municipal solid waste located in northern Italy, were used. The PFAS analysed were representative of the two classes of perfluoroalkyl substances (acids and sulfonates) at different length of the carbon chain (from 4 to 12 C atoms).

Table 1. Composition of the three leachates used in the investigation, in terms of PFAS concentrations.

PFASs target	Molecular formula	Concentration (ng/L)		
		<i>leachate 1</i>	<i>leachate 2</i>	<i>leachate 3</i>
PFBA	C ₄ HF ₇ O ₂	8,363	13,235	28,090
PFPeA	C ₅ HF ₉ O ₂	1,643	4,840	23,685
PFHxA	C ₆ HF ₁₁ O ₂	3,318	8,748	22,805

PFHpA	C ₇ HF ₁₃ O ₂	1,103	2,711	16,385
PFOA	C ₈ HF ₁₅ O ₂	10,595	281,300	2,544,000
PFNA	C ₉ HF ₁₇ O ₂	< dl	608	4029
PFDA	C ₁₀ HF ₁₉ O ₂	< dl	665	4528
PFUdA	C ₁₁ HF ₂₁ O ₂	< dl	< dl	< dl
PFDODA	C ₁₂ HF ₂₃ O ₂	< dl	< dl	< dl
PFBS	C ₄ HF ₉ O ₃ S	67,525	68,645	19,275
PFOS	C ₈ HF ₁₇ O ₃ S	556	22,670	142,400
PFHxS	C ₆ HF ₁₃ O ₃ S	207	8,917	41,170
6:2 FTSA	C ₈ H ₅ F ₁₃ O ₃ S	1,664	438	< dl

Results

SBBGR operated for about 2 years. An appropriate feeding program was used during the start-up phase; more than 3 months were required to acclimate the biomass to the typical leachate's salinity (22 mS/cm) and stimulate the involved bacterial species' growth. Figures 1, 2 and 3 show the PFAS removal efficiencies recorded during the treatment of the three leachates by SBBGR system.

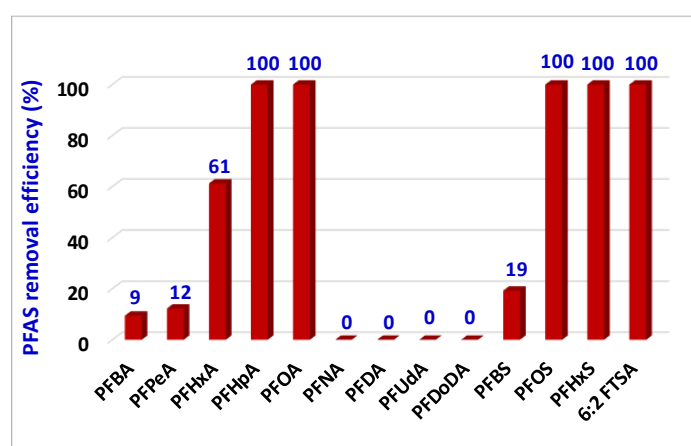


Figure 1. Removal efficiency of investigated PFAS during the treatment of leachate 1.

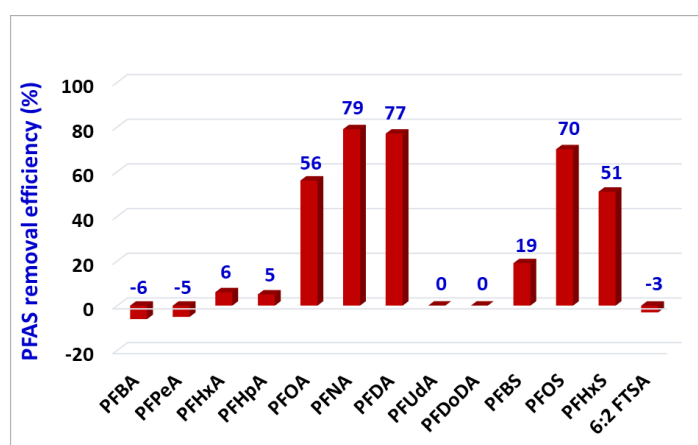


Figure 2. Removal efficiency of investigated PFAS during the treatment of leachate 2.

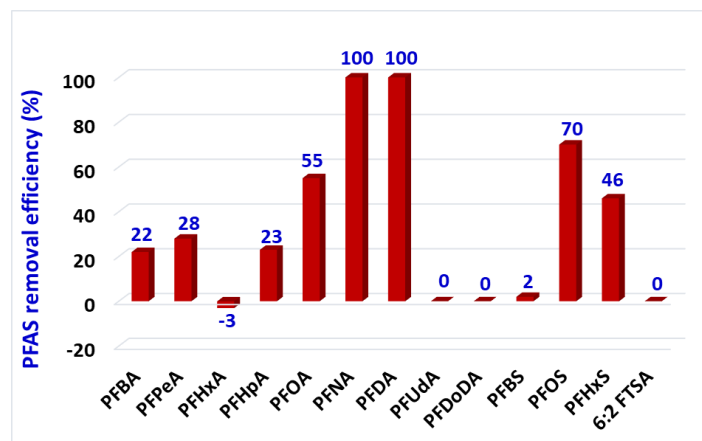


Figure 3. Removal efficiency of investigated PFAS during the treatment of leachate 3.

The data in Figure 1 show that SBBGR was able to ensure a complete removal of long-chain PFAS. PFOA and PFOS removal efficiency decreases to 56% and 70%, respectively, after increasing influent value by 26 and 40 times, respectively, during the treatment of leachate 2. Finally, when the SBBGR was fed with the leachate 3, PFOA and PFOS removal efficiency remains the same of the previous period despite the increase of the influent value (i.e., 9 and 6 times, respectively).

References

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