Integration of biological and chemical oxidation for PFAS removal from landfill leachate

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Introduction

Despite the increase in fraction of waste sent for energy and material recovery, landfilling is still a widely used practice. Landfill operational and post-operational management requires treatment of leachate, highly concentrated mixture of organic/inorganic chemicals including heavy metals, ammonia, humic acids, nitrogen, inorganic salts, and xenobiotics (Ye, Wenyuan, et al., 2019).

In recent decades, in landfill leachate perfluoralalkyl substances (PFAS) have also been found. These chemicals were synthesized since the 1940s and used in a wide range of industrial and commercial applications. They are renowned for their superior in water and oil repelling and have high thermal stability. (Vo, Phong HN, et al., 2024) Household goods and biosolids enriched in PFASs are discarded to landfills (Stoiber et al., 2020), resulting in a large presence of PFASs (10–416,000 ng/L) in landfill leachate worldwide (Hamid et al., 2018).

Addressing PFAS contamination is an urgent environmental concern that threatens animal and human health. The complexity of the matrix to be treated and high chemical stability of PFAS makes conventional treatments inadequate for their effective removal. In recent years, technologies based on combination of chemical, physical and biological treatments have been used to maximize the outcome.

The current research was aimed to evaluate the removal efficiency of PFASs from landfill leachate through an integrated approach that combines biological treatment, conducted in a Sequencing Batch Biofilter Granular Reactor (SBBGR), with chemical oxidation performed with O_3, O_3/H_2O_2. In SBBGR, sludge is made up of biofilm and granules bounded to a plastic porous material. This configuration allows reaching very long sludge retention time (SRT) longer than 300 days. The high SRT enables reducing sludge production and enrichment of slow growing microorganisms forcing biomass to use unusual substrates (e.g., PFAS).

Material and methods

Three treatment schemes were tested at bench scale: biological, biological with O_3 and biological with O_3/H_2O_2. The experimental plant was set up with a biological unit, a chemical unit and a storage station. The biological unit consisted of a cylindrical plexiglass reactor (volume: 28L) partially filled with plastic material confined between two perforated plates (bed volume: 11L). The chemical unit for ozone treatment consisted of a cylindrical glass reactor (volume: 5 L), an ozone generator and a peristaltic pump to extract liquid from the SBBGR system. When the combined chemical treatment O_3/ H_2O_2 was performed, the unit included a peristaltic pump for H_2O_2 supply.

The plant operated in sequential mode with 8-hour treatment cycles. Each SBBGR cycle consisted of filling, reaction and discharge phase. During chemical upgrading of SBBGR, an additional phase before discharge was scheduled, biological degradation + chemical treatment (O_3 or O_3/ H_2O_2). Two recirculation streams were active in this scheme: the former operating between the SBBGR system and the ozonation reactor, and the latter through the bed of biological unit. The input leachate and the effluent from all treatment schemes were characterized in terms of traditional parameters [such as chemical oxygen demand (COD), biological oxygen demand (BOD_5) total and volatile suspended solids (TSS and VSS), total nitrogen (TN), ammonia, and color removal] and PFASs.

The latter were analysed by high resolution and accuracy TripleTof 5600 mass spectrometer (AB Sciex) interfaced with a ThermoFischer ultra-high pressure liquid chromatography (UPLC).

Results and discussion

The leachate was collected from municipal solid waste landfills located in northern Italy. It was characterized by high conductivity (22 mS/cm), high N-ammoniacal values (1300 mg N/L) and low biodegradability.
Table 1 shows the performances in terms of removal of the main traditional parameters for the investigated treatment schemes. Biological treatment enhanced with 5.7 g/L of O_3 showed the highest COD, solids and colour removal efficiencies and excellent performances of total nitrogen and ammonia removal.

In parallel with the analysis on the traditional parameters, the concentration of selected PFAs was measured at input and output from the three different treatment schemes, as shown in Figure 1. The PFAS compounds analysed have included perfluoroalkyl carboxylic acids and perfluoroalkyl sulfonic acids with different length of carbon chain (from 4 to 12 C atoms). The three treatment schemes showed very different performances. Best performances were obtained by biological treatment alone as it proved to be effective in the removal of long-chain acidic and sulphonated PFAS (100% removal efficiency). Further studies have been planned to investigate the nature of PFAS removal in biological treatment.

Table 1. Removal efficiency of main gross parameters in three different leachate treatment.schemes.

Parameter	**Removal Efficiency %**		
	SBBGR	SBBGR + O_3 (5,7 g/L)	SBBGR + O_3 (5,7 g/L)/H_2O_2 (14 ml/L)
COD	50	72	67
TSS	32	83	82
VSS	56	87	82
TN	92	82	65
NH_3	100	98	67

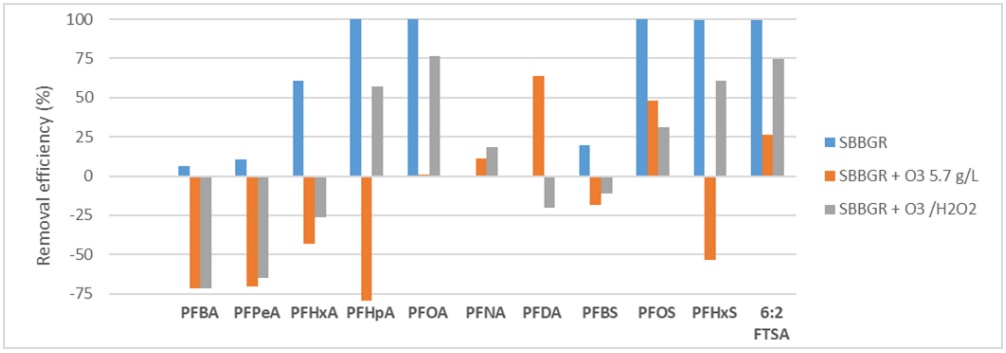

Figure 1. Removal efficiency of investigated PFASs in three different leachate treatment schemes.

References

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