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PFAS characterization and management in landfill leachates: an assessment in 4 Portuguese sites

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Highlights:

- Landfill leachate has a high concentration of PFAS.
- Conventional leachate treatment proves ineffective in PFAS removal.
- Application of reverse osmosis allows the total retention of PFAS present in leachate.

Keywords: PFAS; Landfill; Emerging pollutants.

INTRODUCTION

Per- and polyfluoroalkyl compounds (PFAS) are a family of over 4000 synthetic chemicals extensively used in various products and industries, mainly due to their desirable properties such as high temperature stability, water repellency, and durability [EEA, n.d.; Lenka et al., 2021]. Referred to as "forever substances," PFAS persist in the environment for decades, posing significant risks to human health [EEA, 2019]. In response, European legislation has set limits on PFAS in water and food, and regulated the phased out the use of certain long-chain PFAS compounds [EU Directive 2020/2184; Regulation 2020/748]. Non-hazardous waste landfills receive a large amount of waste containing PFAS, resulting in the production of complex leachates with high organic content and PFAS contamination, which raises concerns about the need for proper treatment and disposal to prevent further environmental contamination [Coffin et al., 2022; Masoner et al., 2020]. The present study had the following objectives:

- Characterize the concentration and types of PFAS present in leachate from 4 Portuguese non-hazardous waste landfills.
- Compare the PFAS removal efficiency of different landfill leachate treatment processes, namely conventional treatment (biological and physical-chemical) and reverse osmosis.

METHODOLOGY

Four Portuguese non-hazardous waste landfills with different characteristics and leachate treatment facilities were selected for this study, as shown in Table 1. Grab and simultaneous samples of raw and

treated leachate were collected at the discharge point of the treatment process. Sampling was carried out during the dry season. PFAS were analyzed by LC-MS according to the accredited method US EPA 537, CEN/TS 15968 in an external laboratory, with individual research of 20 substances. The limits of quantification (LQ) of the method were in the range of 0.3-2 ng/L for all PFAS surveyed.

Site	Waste type	Operation (years)	Waste processed (ton/year)	Leachate treatment
LDF 1	UW	25	116.000	Storage lagoon -> pre-acidification tank -> settling -> reverse osmosis unit
LDF 2	UW	8	163.000	Lagoon with oxygen injection -> biological treatment -> physicochemical treatment with sludge removal
LDF 3	UW	24	6.000	Lagoon with oxygen injection -> biological treatment -> physicochemical treatment with sludge removal
LDF 4	NHIW	11	108.000	Biological treatment -> reverse osmosis unit

Legend: UW - urban waste; NHIW – non-hazardous industrial waste;

Table 1 – Characteristics of the sanitary landfills included in this study.

RESULTS AND CONCLUSIONS

Assessing the individually quantified PFAS, the study showed that PFBS and PFHxA were present in higher concentrations in the four leachates analyzed (>1000 ng/L). These were also the only two quantifiable PFAS in LDL-1 and LDL-4. For the leachates from LDL-2 and LDL-3, 9 individual PFAS were quantified, which were present in a similar concentration profile in these two facilities. Overall, PFBS and PFHxA were found in higher concentrations across four landfill sites, with PFBS reaching levels as high as 86,000 ng/L in LDF-1, possibly due to past industrial waste disposal. PFHxA was present uniformly across all sites, reflecting a trend toward shorter chain PFAS usage. Despite the ban on long-chain PFOS and PFOA, they were still detected in leachates from LDF-2 and LDF-3.

Reverse osmosis treatment in LDF-1 and LDF-4 effectively removed all detectable PFAS from the treated leachate, while for LDF-2 and LDF-3, with biological and physicochemical treatment methods, minimal PFAS removal was observed (<15%). This result is consistent with a comparative study of leachate treatment technologies carried out at 20 landfills in Germany, which identified reverse osmosis as the most effective treatment in removing PFAS, compared to activated carbon adsorption or biological treatment [Busch et al., 2010]. The treated leachate from LDF-2 and LDL-3, containing PFAS, is discharged into municipal sewer collection systems subsequently reaching urban wastewater treatment plants (WWTP) downstream.

Research suggests that most WWTPs with biological treatments exhibit low PFAS removal, and there may even be cases of increased concentration during treatment due to the transformations that occur throughout the treatment process [Lenka et al., 2021; Loos et al., 2013; Marinheiro and Löblich, 2022].

For this reason, WWTPs have been identified as significant contributors to PFAS contamination in aquatic environments [Masoner et al., 2020; Loos et al., 2013]. This study shows that the conventional treatment of leachate based on biological and physicochemical processes does not allow the removal of PFAS and can contribute to the contamination of downstream WWTP tributaries.

In conclusion, this study exposes the significant presence of persistent PFAS substances in landfill leachates and the importance of effective leachate management and treatment solutions to prevent further downstream contamination. Reverse osmosis proved to be highly efficient in PFAS removal, whereas conventional methods are inadequate.

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