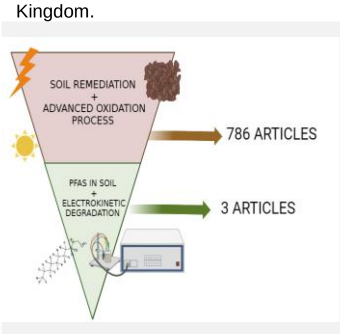
Electrochemical degradation for soil treatments: PFAS in focus

ORAL
Ph.D. Student: N
Journal: CEJ

J. M. S. de Jesus[1], *J. Roberts*[2], *L. H. G. Coelho*[1]*.1)* Centro de Engenharia, Modelagem e Ciências Sociais Aplicadas, Universidade Federal do ABC – UFABC, Av. dos Estados, 5001, B. Bangú, Santo André, SP 09070-200*, Brazil,* *julianams.silva@gmail.com* *(2)* Glasgow Caledonian University, 70 Cowcaddens Road, G4 0BA Glasgow, United Kingdom.



The occurrence of polyfluoroalkyl compounds (PFAS) in Brazilian environmental matrices, such as sulfluramid (EtFOSA), comes mostly from the cultivation of *Pinus* and *Eucalyptus* to control the manifestation of leaf-cutting ants. Classified as an emerging contaminant, EtFOSA poses environmental risks and is harmful to human beings, a fact that motivates the search for solutions to remediate and recover contaminated areas. In this sense, the following study highlights the main scientific findings and gaps in the use of an electrochemical advanced oxidation process to remediate contaminated soils with PFAS.

Introduction

The growing apprehension surrounding PFAS pertains to their enduring and persistent nature in the environment. Notably, compounds such as PFOA and PFOS exhibit half-lives of 41 and 92 years, respectively, in aquatic ecosystems [1]. Anthropogenic origins of PFAS in the environment encompass agricultural practices. Sulfluramid, a common commercial insecticidal bait, contains N-ethyl perfluorooctane sulphonamide (EtFOSA) as its active ingredient. Designated as a Class II pesticide by the World Health Organization (WHO), sulfluramid poses a moderate level of hazard [2].
An advanced oxidation process (AOP), such as an electrochemical process, has been applied for PFAS remediation. Electromigration and electroosmosis are techniques for removing contaminants, which involve charged molecules or their solubilization in the interstitial fluid [3]. This process can be facilitated by adding surfactants and co-solvents. Alternatively, organic contaminants can be decomposed in situ using electrokinetic phenomena. This method introduces agents into the soil matrix capable of degrading or decomposing the contaminants, such as chemicals or nanoparticles [4]. The present study aims to address the main findings and gaps regarding the application of electrochemical techniques for soil remediation.

Material and Methods

Literature research: The Web of Science and Scopus online platforms were used to check the following sets of keywords: (i) “SOIL REMEDIATION" AND "ADVANCED OXIDATION PROCESS”; (ii) "PFAS” AND "ELECTROKINETIC DEGRADATION”. All searches were carried out without time restrictions. VOSviewer Online was also used as a tool for network visualization between the previously selected keywords [5].

Results and Discussion

Overview: The direct analysis of research results to publications and quotations that are substitutes for real events. Figure 1a is an assessment of the question of whether "soil pollution" is inherently "advanced oxidation", which has been claimed, although the literature shows a direct relationship concerning the latest publications on soil remediation through AOPs. However, electrochemistry is a weak claim among the main AOPs, which suggests a gap in this domain compared to other processes such as ozone, photodegradation, and biodegradation. Additionally, in Figure 1b, “soil pollution” and “oxidation” were in a different citation space than “pesticide” and “pesticides”. This suggests that pursuing the fate of pesticides in soil and proposing oxidation methods is a feasible application effort for soil remediation.

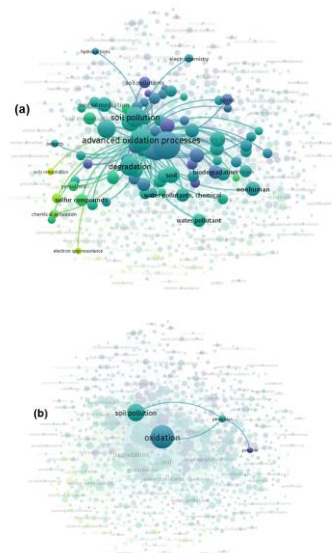


Figure 1. Co-occurrences of keywords ‘SOIL’ and ‘REMEDIATION’ refined by ‘ADVANCED OXIDATION PROCESSES’; 786 most cited papers published in Web of Science and Scopus 2014–2024.

In this sense, a broader study of published research highlighting specific electrochemical processes seems worthwhile.

Electrochemical application: Among the 786 articles applied for research only three evaluated the electrochemical degradation of PFAS in soil (Table 1). According to Table 1, the main PFAS evaluated in soil matrices were perfluorooctanesulphonic acid (PFOS) and perfluorooctanoic acid (PFOA) in distinct concentrations. Among the obtained data only Sorengård *et al.* [8] evaluated the electrolytic process efficiency in contaminated soils, the others applied raw soil and spiked to reach the desirable analyte concentrations.

Regarding electrochemical apparatus, all present articles conducted lab-scale experiments and applied regular electrodes, without reactive species generation as the goal, in which electromigration was the main mechanism for pollutant removal.

Soil type was also an important aspect of PFAS removal, and the selected studies highlighted the effect of soil characteristics on process efficiency. For example, Ganbat *et al.* [2022] highlighted the selection of kaolin clay for PFAS degradation due to its low permeability, low carbon content, and low cation exchange capacity. As well as the absence of The kaolin soil's organic matter content and non-reactivity enabled the study of PFOA mobility under direct electric fields in the electrokinetic system without any interference.

Table 1. Electrochemical degradation applied for PFAS in soil: experimental conditions and opportunities.

Article	Year	PFAS	Soil type	Electrodes	Electric power conditions	Removal efficiency	By-products investigation	Eco-compatibility assays
[6]	2022	[PFOA]= 100 mg kg^{-1}	Kaolin clay	Graphite	10 and 20 mA	75.68%	No	No
[7]	2022	PFOA e PFOS (10 µg g-1)	Silty clay soil	Ti/Ir_2O_5	24 V	PFOA = 51.7%; PFOS = 33.0%	No	No
[4]	2019	PFASs (n=23)	Surface contaminate soil	Stainless steel	0.19 and 0.38 mA cm^{-2}	20% shortest-chained PFASs	No	No

Conclusions

According to the reviewed data, using the electrochemical process for PFAS remediation in soil is still lacking in the present literature. VOSviewer tool allowed us to establish the relation between the main investigated aspects regarding soil remediation through the advanced oxidation process and PFAS removal. Electrochemical technologies showed an emerging opportunity to treat PFAS in situ, and no by-products and eco-compatibility have been evaluated.

References

[1] J. Falandysz, B. Jiménez, S. Taniyasu, Chemosphere, 291 (2022), 132876.
X. Author, Y. Author, Z. Author, *Journal name*, volume (year) first page.
[2] S. Singer, J. Roberts, Mass Matters (BMSS), 97(2023), 12.
[3] L. Katherine, S. Brian, S. Stephen, A. Chris, I. Maria, Electrochemistry in the Environment, MA2022-2, 2088.
[4] S. Mattias, N. Georgios, PE. Jensen, A. Lutz, Chemosphere, 232 (2019), 224.
[5] K. Andrew, Publications, 11 (2023), 10.
[6] G. Namuun, A. Ali, ZL. John, L. Thomas, AA. Raed, MH. Faris, K. Elika, KS. Akshaya, H. Alaa, K. Hadi, Environmental Technology & Innovation, 28 (2022) 102938
[7] H. Jie, L. Guoao, L. Mingrui, C. Liang, Y. Ye, HF. Paul, J. Song, Chemosphere, 287 (2022), 132205.