How Can Advanced Oxidative Processes Be Integrated for Oilfield Produced Water Treatment? A Bibliometric Analysis

ORAL/POSTER
Ph.D. Student: N
Journal: NONE

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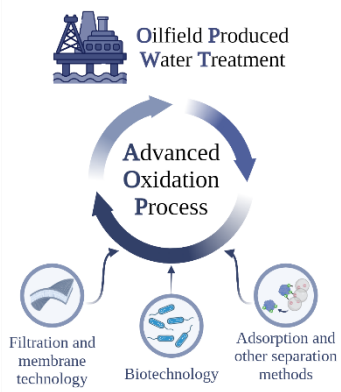


In this study, a bibliometric analysis using the Scopus database and VOSviewer software was performed to map the existing literature on the integration of Advanced Oxidation Processes (AOPs) with other techniques for the treatment of oilfield produced water and to identify future research directions. This research shows a growing interest in the integration of AOPs, especially photocatalytic oxidation and ozonation, with other separation techniques such as osmosis and microfiltration. However, there are research gaps, particularly in the integration of AOPs with adsorption, biotechnology, and electrochemical techniques. These findings highlight opportunities for future research to improve the efficiency and sustainability of the treatment of oilfield produced water treatment in offshore facilities.

Introduction

Oilfield Produced Water (OPW) is the largest effluent from oil and gas production, with over 88 billion barrels produced worldwide, which is expected to double in the next decade [1]. Local regulations, such as Brazil's CONAMA guidelines, dictate treatment levels, particularly regarding total oil and grease (TOG) content [2]. Advanced oxidation processes (AOPs) are promising for the treatment of contaminated water, including OPW, due to their adaptability and effectiveness. They include various techniques such as electrochemical oxidation, photocatalysis, Fenton processes, and ozonation [3]. AOPs can also be integrated with other treatment techniques, allowing the intensification of processes and the compaction of treatment modules, a critical aspect in offshore installations. In this context, this study proposes to carry out a bibliometric analysis using the Scopus database and the *VOSviewer* software to map the existing literature on the integration and/or combination of AOPs with other techniques for OPW treatment and to understand future directions for the integrated application of AOPs for the sustainable management of OPW in offshore facilities.

Material and Methods

The bibliographic database was obtained from the Scopus collection. The search was carried out using the following keywords and Boolean operators *(TITLE-ABS-KEY("produced water") AND TITLE-ABS-KEY("advanced oxidat*" OR aop OR degradat*) AND TITLE-ABS-KEY(integrat* OR combin* OR intensif*))*, limiting the publication range in the last ten years, starting on January 1, 2015 and ending on April 9, 2024. The results were exported in .csv format, as instructed in the *VOSviewer* program manual [4]. Other information obtained from the database itself was also attached to the study. Maps based on Scopus data were created in *VOSviewer* program (version 1.6.19), with co-occurrence of all keywords as the unit of analysis, in full count as the counting method. The minimum number of keyword occurrences was set to 3 and the network visualization was selected. From the list of keywords identified by the software, only those related to produced water treatment processes were selected to create the maps. In the Map View, items are displayed in a circular layout, with the size corresponding to the weight of the item, so that larger items are displayed more prominently. Additionally, items are color-coded to indicate their respective clusters. Connections between items are represented by lines, with thicker lines indicating stronger connections between two items [4].

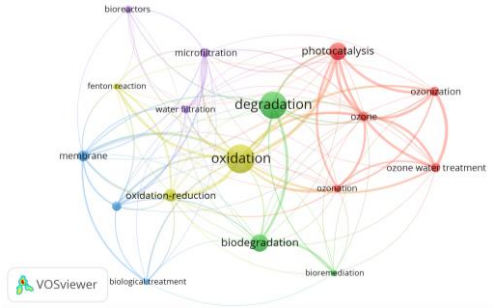
Results and Discussion

The Scopus database search yielded 71 documents, including 35 original articles, 17 review articles, 2 book chapters and 17 conference papers. The year 2023 had the highest number of publications (17 documents). The Scopus citation overview shows an increase in citations since 2016, reaching a total of 2045 citations between 2015 and 2024, with a peak of 577 citations in 2023, indicating a steady increase in interest in the research area over the last 10 years. The *VOSviewer* bibliometric map, shown in Figure 1, was generated from the analysis of the 71 documents. A total of 1219 keywords were identified, of which 141 met the established criteria. Of these, 17 were related to water treatment processes, grouped in 5 different clusters represented by different colors. AOPs are grouped into two main clusters, the yellow and red ones. The yellow cluster includes keywords related to redox reactions, such as the Fenton reaction, and are

discussed in 4 documents, 3 reviews and 1 original article. In the original article, Jiménez et al. (2017) [5] describe the integration of bench-scale dissolved air flotation and sedimentation processes with Fenton and photo-Fenton reactions, resulting in a TOG reduction of 57.6% for Fenton and 73.7% for photo-Fenton processes, respectively.

The red cluster groups AOPs related to oxidation via photocatalysis (the strongest keyword) and ozonation. Photocatalysis is mentioned in 11 documents (5 original articles), while ozonation is mentioned in 8 documents (4 original articles). These processes are integrated with other AOPs and separation techniques such as forward osmosis, microfiltration and flotation, and this correlation is also identified in the Figure 1. Studies such as Taghizadeh et al. (2020) [6] combine forward osmosis with photocatalysis for simultaneous salt removal and OPW treatment, while Jiménez et al. (2019) [7] combine ozonation and H_2O_2 to remove 74% of the total organic carbon in OPW. Ferreira et al. (2021) [8] show that photo-peroxidation improves performance compared to ozonation for oil removal and incrustation reduction, and integration with microfiltration results in a permeate with lower oil content. Liu et al. (2021) [9] perform the integration of ozonation and photocatalysis to treat OPW and enhance the degradation of polycyclic aromatic hydrocarbons. The remaining clusters (blue, green, and purple) show a weak association with the identified AOPs, indicating a research gap in the integration of AOPs with certain separation processes such as adsorption. Furthermore, the absence of studies on advanced electrochemical oxidation techniques in this database is notable. Although there are studies on biodegradation, the link to AOPs is weak.

Figure 1. Visualization map of the keyword co-occurrence network created in the *VOSviewer* software.



Conclusions

The bibliometric analysis using the Scopus database and the *VOSviewer* program reveals a growing interest in the integration of AOPs for OPW treatment. Notable areas of focus include photocatalytic oxidation and ozonation. Integration with separation techniques, such as osmosis and microfiltration, shows promise for effective OPW treatment, although research gaps exist, particularly in integration with separation techniques, such as flotation or adsorption, and electrochemical techniques. These findings highlight avenues for future research to improve the efficiency and sustainability of OPW treatment processes in offshore facilities.

Acknowledgments

This work was financially supported by Petróleo Brasileiro S/A (PETROBRAS) – Project EO&M: Aplicação de Processos de Eletro-Oxidação e Membranas para Aumento da Eficiência de Remoção de TOG da Água Produzida, Process: 2023/00226-0. The authors are grateful to LEMA-UFSC for the available infrastructure.

References

[1] M. Rezakazemi, A. Khajeh, M. Mesbah, *Environmental Chemistry Letters*, 16:2 16 (2017) 367.
[2] Brazil, *CONAMA Resolution 393/07*, (2007).
[3] S. Ghafoori, M. Omar, N. Koutahzadeh, S. Zendehboudi, R.N. Malhas, M. Mohamed, S. Al-Zubaidi, K. Redha, F. Baraki, M. Mehrvar, *Separation and Purification Technology*, 289 (2022) 120652.
[4] N.J. van Eck, L. Waltman, VOSviewer Manual, (2023).
[5] S. Jiménez, M.M. Micó, M. Arnaldos, E. Ferrero, J.J. Malfeito, F. Medina, S. Contreras, *Chemosphere*, 168 (2017) 309.
[6] M. Taghizadeh, D. Yousefi Kebria, F. Qaderi, *Water Supply*, 20 (2020) 240.
[7] S. Jiménez, M. Andreozzi, M.M. Micó, M.G. Álvarez, S. Contreras, *Science of The Total Environment*, 666 (2019) 12.
[8] A.D. F. Ferreira, D.R.B. Coelho, R.V.G. Santos, K.S. Nascimento, F. de A. Presciliano, F.P. da Silva, J.C. Campos, F.V. da Fonseca, C.P. Borges, S.E. Weschenfelder, *Environmental Science and Pollution Research*, 28 (2021) 12803.
[9] B. Liu, B. Chen, B. Zhang, X. Song, G. Zeng, K. Lee, *Journal of Hazardous Materials*, 402 (2021) 123456.