

The Disparity in Scientific Production on PFAS in Brazil: Overview and Bibliometric Analysis

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Abstract: Per- and polyfluoroalkyl substances (PFAS) are synthetic substances that are used in several applications such as cosmetics, firefighting foams, non-stick cookware and food packaging since 1940 due to their non-stick, grease, water and oil-resistant properties. One of its main characteristics is their resistance to degradation, accumulating in the environment and human body. PFAS have been associated with adverse health effects such as hormonal disruption, developmental issues, and increased risks of certain cancers. In Brazil and other tropical countries, PFAS have already been detected in drinking water, surface water, groundwater, soils and biota. However, the lack of studies investigating the presence and consequences of these compounds in Brazil is a serious concern as the population is being unknowingly exposed to the associated PFAS-risks through drinking water, contaminated food, or direct contact with polluted soils and water. As a result, the affected communities remain vulnerable and unprotected. Therefore, this work aims to conduct a bibliometric review of PFAS-related research in the country, with a focus on environmental presence, regulatory context, and public health implications. The analysis was conducted using the Web of Science database, covering publications containing the terms “per- and polyfluoroalkyl substances”, “perfluorinated compounds”, “perfluoroalkyl substances”, “polyfluoroalkyl substances”, and “PFAS” in titles, abstracts and keywords. No manual screening was performed to assess the relevance of each document retrieved; therefore, the results reflect the total number of records returned by the search, which may include irrelevant entries or false positives. The search indicated that Brazil lacks PFAS-related publications compared to United States, European countries and China. This scarcity of research highlights a critical gap in environmental management and public awareness in Brazil.

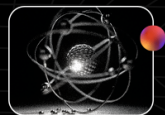
Keywords: PFAS, PFOS, EtFOSA, Brazil.

1. Introduction

Per- and polyfluoroalkyl substances (PFAS) are often referred to as “forever chemicals” because of their high persistence in the environment and human body due to the strength and stability of their unique chemistry. They are a group of man-made substances containing at least one perfluorinated methyl ($-\text{CF}_3$) or a perfluorinated methylene group ($-\text{CF}_2-$). The exceptional strength of the carbon-fluorine bonds is the reason for PFAS’s high thermal and chemical stability [1].

These compounds are found in firefighting foams, non-stick cookware, and food packaging, among other everyday items [2]. Studies showed that PFAS were already found in the blood of the general human population: long-chain polyfluoroalkyl acids (PFAAs) such as perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorononanoic acid (PFNA), and perfluorohexane sulfonic acid (PFHxS) were detected in the blood serum of almost all residents of the United States and other nations [3].

Among the PFAAs, the PFOS is the most studied one. PFOS is a “legacy PFAS” and is



known for its bioaccumulative nature, potential to biomagnify in food webs, and to cause potential adverse health effects in mammals [4,5]. PFOS production was voluntarily discontinued by a major manufacturer in the USA in the early 2000s due to its risks to the human population and the environment. The listing of PFOS and its precursors is in Annex B, the Stockholm Convention on Persistent Organic Pollutants (POPs), which restricts their production and use, since 2009. However, some countries have an authorization under the Stockholm Convention to produce these POPs for a specific purpose. Brazil, for example, is authorized to produce N-Ethyl perfluorooctane sulfonamide (EtFOSA) for use as an active ingredient in Sulfluramid pesticides for the control of leaf-cutting ants in agriculture [6,7].

The main concern regarding the Sulfluramid use is that EtFOSA can degrade to PFOS and other per-and polyfluoroalkyl substances through biological and abiotic mechanisms [7]. PFOS has been linked with development and reproductive toxicity in mammals and humans, being particularly toxic to newborn children and posing relevant ecological risks to the environment [8].

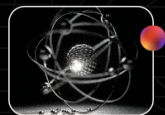
In the year of 2015, Brazil produced between 40 and 60 tons of Sulfluramid pesticide [9]. Researchers reported higher levels of PFOS in the Southwestern Atlantic Ocean than in the North Atlantic Ocean, where PFOS were produced and used in large amounts, and have attributed this increase to the use of Sulfluramid

by Brazil and other South American Countries where the pesticide is commercialized [9-11].

Gilljam et al. [5] reported the presence of EtFOSA degradation products, such as PFOS and perfluorooctanesulfonamide (FOSA), in surface water samples from sites around Todos os Santos Bay (BTS), in the Brazilian state of Bahia. PFOS was detected in all samples (63 - 1061 pg L⁻¹), while FOSA was the most abundant PFAS in some samples (14 - 3362 pg L⁻¹). Considering that both PFOS and FOSA are products of EtFOSA transformation, these findings suggest that the high levels of these PFAS may be associated with Sulfluramid use in the area.

Miranda et al. [12] also detected PFOS along with EtFOSA in abiotic and biotic matrices collected from the Subaé Estuary, in the BTS. A linear isomer of EtFOSA (L-EtFOSA) was also detected in sediments, also suggesting a possible local source of Sulfluramid in the region. PFAS were also detected in other states of Brazil: Quinete et al. [13] detected PFOS (with concentrations ranging from 0.58 to 6.70 ng L⁻¹), PFOA (0.35–2.82 ng L⁻¹), and PFHxS (0.15–1.00 ng L⁻¹) in drinking water samples from the Guandu Drinking Water Treatment Plant (ETA-Guandu) in the city of Rio de Janeiro.

Although some data points to PFOS contamination in different locations in Brazil, a significant gap remains in the scientific literature regarding the presence of PFAS in aquatic and terrestrial environments, as well as their consequences for biota and the human population in the country. The lack of studies on these



compounds could be harmful to the population since PFAS tend to accumulate in the human body and are suspected to be associated with certain diseases and cancers. Therefore, this work aims to address this data gap by conducting a bibliometric review of PFAS-related studies in Brazil, consolidating the available data. This review will systematically map the current state of knowledge, identify key research gaps, and highlight the urgent need for a more comprehensive understanding of the environmental and public health risks associated with PFAS in the country.

2. Methodology

This work is characterized as bibliometric research with a qualitative-quantitative approach, with the main objective of conducting literature reviews on per- and polyfluoroalkyl substances (PFAS), which are known for their chemical resistance and for causing harmful consequences to human life and the environment.

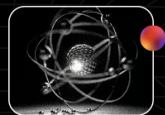
Due to its extensive scientific output, advanced research resources, and credibility in published materials, the Web of Science database was adopted as the main source for collecting academic data on the topic. To locate titles, abstracts, and other scientific works, the terms “per- and polyfluoroalkyl substances” OR “perfluorinated compounds” OR “perfluoroalkyl substances” OR “polyfluoroalkyl substances” OR “PFAS” were used in the search field, aiming to avoid restrictions related to publication period

or region. This choice is justified by the purpose of the study, which is to carry out a quantitative survey of scientific publications on PFAS, focusing on the global distribution of academic production.

After compiling the information, approximately 15,894 articles were filtered according to the country of origin of each study, to establish a geographical visualization of the published documents and to organize a ranking of countries with the highest number of studies. The search results were not manually filtered for relevance of each document retrieved. As a result, the publication counts per country represent the absolute number of records returned by the search string, which may include articles not directly related to PFAS or false positives due to term ambiguity and database indexing limitations. The methodology, nonetheless, can show general bibliometric tendencies and allows for conclusions on the state of PFAS studies in Brazil in contrast with other countries.

Throughout the process, charts were created in Excel based on the intersection between the regional categorization and the publication period, showing both the distribution of PFAS-related articles by country and the annual progression of studies on the topic in Brazil. The organization of these results contributes to the understanding of scientific trends on both global and national scales.

The results obtained were systematized in electronic spreadsheets, allowing the identification of research patterns, scientific gaps,



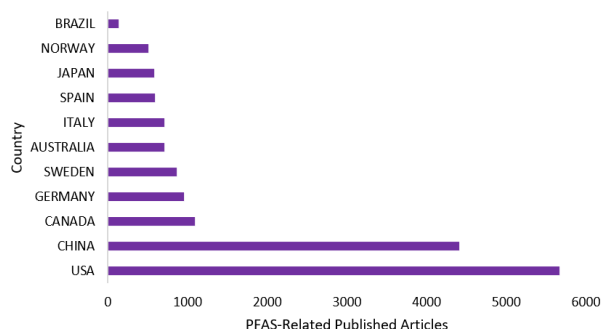
and potential directions for future investigations on persistent chemical substances.

Based on the data, the study aims to present a panoramic view of the current debate surrounding PFAS, reflecting existing approaches, and highlighting the consequences of the lack of comprehensive studies on this harmful substance, as well as its impacts on the environment.

3. Results and Discussion

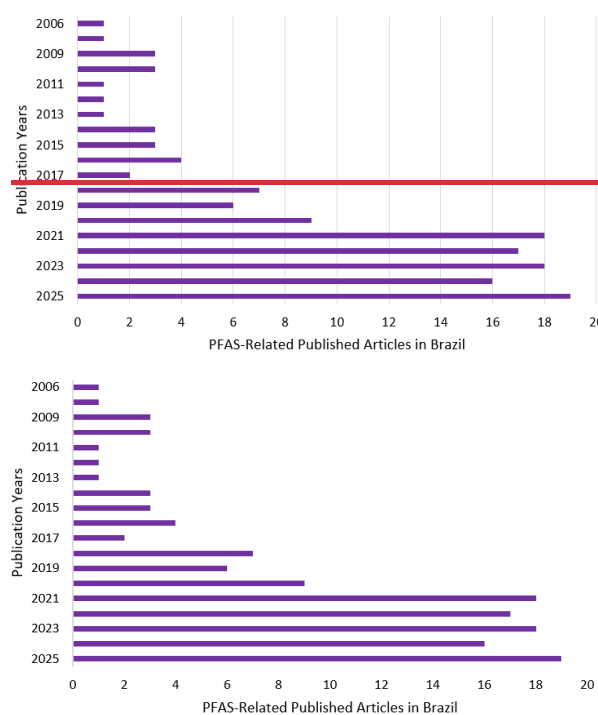
Figure 1 shows the relation of how many articles were published for each country since 1990. It is possible to see that the United States is leading the PFAS studies with 5,668 published articles, followed by China with 4,414 articles and Europe. Among the 141 countries, Brazil ranked 26th in the list of most publications related to PFAS. It was the country with the most published articles in South America, however it was a very low number compared to other regions: only 133 PFAS-related articles were published in Brazil.

Figure 1. Distribution of PFAS-Related Articles by Country.

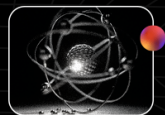


In the Web of Science database, it was reported that the first PFAS-related articles published in Brazil was in 2006, while the USA has been publishing about this theme since 1991. Figure 2 presents the relation of published articles about PFAS in Brazil for each year. The data revealed that the article production about PFAS is still very scarce, especially considering that the reported figures represent absolute counts. This means that, based on the keywords used in this bibliometric review, fewer than 133 publications have been produced in Brazil to date.

Figure 2. Yearly Distribution of PFAS-Related Studies in Brazil.



Although there is international recognition of the risks associated with PFAS, Brazilian laws still lack specific regulatory standards that encompass the entire life cycle of



these substances, including their production, use, and disposal. In contrast to Brazil's legislation, the United States Environmental Protection Agency (EPA) has already established strict limits for PFAS concentrations in drinking water: for PFOA and PFOS, the maximum levels cannot exceed 4 parts per trillion (ppt), while PFNA, PFHxS and GenX Chemicals (a newer generation of compounds developed as substitutes for PFOA) has even more stringent thresholds [14].

The Ordinance GM/MS No. 888/2021 [15], issued by Brazil's Ministry of Health, does not specifically address these compounds in its drinking water standards. Furthermore, neither Brazilian Institute of Environment and Natural Resources (IBAMA) nor Brazilian Health Regulatory Agency (ANVISA) has implemented specific regulations for environmental management or surveillance of consumer products containing PFAS.

The absence of such regulation represents a critical gap in public health oversight and protection, given the extensive evidence regarding the harmful effects of PFAS on both the environment and human health. Compounds such as PFOA and PFOS, which are already banned or restricted in several jurisdictions, have been associated with a range of adverse effects and dysfunctions, including liver diseases, reproductive issues, and even certain types of cancer [16,17].

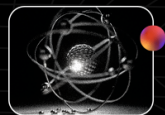
Furthermore, PFAS such as PFHxS and GenX have been detected in drinking water, cookware, food packaging, and even waterproof

clothing. These substances exhibit high environmental persistence — even in remote regions — as well as long biological half-lives in the human body, which can exceed five years [17]. In Brazil, studies have already reported the presence of PFAS in wastewater treatment plants, rivers, and groundwater, particularly in areas adjacent to industrial zones and landfills [18].

The absence of specific guidelines hinders the development of public policies for environmental surveillance, control, and remediation, while also making it difficult to hold polluting companies accountable. Considering the cumulative risks of these substances and the current lack of effective methods for removing them from the environment, there is an urgent need to establish a national regulatory framework based on the precautionary principle. Such a framework should aim to align Brazil with international best practices — both ethical and effective — for the control, mitigation, and safe substitution of PFAS.

4. Conclusion

The results showed that scientific production on PFAS is concentrated in leading countries, particularly the United States, China, and members of the European Union, which have been consolidating public policies, regulations, and mitigation technologies aimed at addressing this contamination. Brazil is the leading country in PFAS-related research in South America, although it still has a relatively small number of



publications compared to countries from other continents.

The absence of specific regulations aimed at the control, monitoring, and disposal of PFAS substances in Brazilian territory constitutes a critical gap in environmental and health management. The lack of legal limits for the presence of these compounds in drinking water, food, and consumer products, as well as the lack of guidelines on their use in industrial and agricultural processes, exposes the population to invisible and potentially irreversible risks.

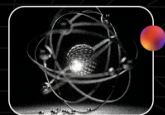
It is important to broaden the public debate on the topic, promoting awareness among civil society and strategic sectors of the economy about the risks associated with these substances. Addressing the impacts associated with PFAS requires a collective, coordinated, and evidence-based effort that integrates science, politics, legislation, and social participation.

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