Meta-Analysis of Public Perception on Per- and Polyfluoroalkyl Substances (PFAS)

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Abstract. Poly- and perfluoroalkyl substances (PFAS) are a class of synthetic chemicals widely used in consumer products due to their durability and resistance to water and oil. However, their environmental persistence and potential health hazards, such as immune suppression, liver damage, and increased cholesterol, have raised significant public health concerns. Despite these risks, public awareness of PFAS remains limited, with varied levels of concern across demographic groups. This meta-analysis synthesizes findings from nine studies published between 2018 and 2024 to evaluate trends in public perception of PFAS. Results show a notable increase in publications on PFAS awareness, reflecting a growing recognition of their risks. Analysis of demographic factors reveals that higher educational attainment is generally associated with increased PFAS concern, though the effect varies across education levels. Additionally, racial differences suggest that certain groups, such as Black or African populations, exhibit higher PFAS concern, whereas White and Other groups show lower levels of concern. These findings highlight the importance of targeted public health outreach to enhance PFAS awareness and address demographic disparities. By identifying patterns in public perception, this study provides insights for developing effective communication strategies and policy interventions aimed at reducing PFAS exposure risks.

Keywords: Poly- and perfluoroalkyl substances (PFAS), Demographic analysis, Educational attainment, racial difference.

1. Introduction

Poly- and perfluoroalkyl substances (PFAS) are a diverse class of synthetic chemicals extensively used across industries due to their unique hydrophobic and oleophobic properties. These compounds are present in numerous consumer products, including firefighting foams, non-stick cookware, waterproofing treatments, and stain-resistant fabrics, enhancing product durability and performance. However, PFAS have garnered significant attention due to their persistence in the environment, bio accumulative nature, and potential health hazards. These chemicals, often referred to as "forever chemicals," do not readily degrade, leading to their accumulation in water sources, soils, and biota. Prolonged exposure to PFAS is associated with various adverse health outcomes, including liver and kidney cancer, immune system suppression, thyroid dysfunction, and elevated cholesterol levels. Additionally, there is evidence linking PFAS exposure to developmental issues in children and increased susceptibility to metabolic disorders, raising substantial public health concerns.

Despite the documented risks, public awareness of PFAS remains limited. This knowledge gap contributes to the inadvertent exposure of large populations to these harmful substances, as individuals may unknowingly use products containing PFAS. Recognizing the role of public awareness in mitigating exposure, researchers have increasingly focused on investigating public perceptions of PFAS. Numerous studies have explored the distribution of PFAS contamination, health impacts, and regulatory responses. However, the existing body of research is often fragmented. Studies frequently focus on specific PFAS compounds or geographic regions, such as North America and Europe, leading to a lack of comprehensive understanding on a global scale. Furthermore, limited attention has been given to understanding how regulatory measures or public health campaigns influence public awareness and behavior regarding PFAS.

In recent years, a growing number of studies have examined public perception of PFAS, aiming to address the broader social and environmental implications of PFAS contamination. However, these studies face several challenges. First, many focus on individual PFAS compounds rather than

providing a holistic view of the chemical class. Second, research is often geographically restricted, with a predominance of studies in developed regions, which may not accurately reflect global public awareness. Third, relatively few studies have examined how public awareness evolves in response to regulatory actions, media coverage, or educational campaigns. Understanding these dynamics is essential, as greater awareness could lead to behavioral changes that reduce exposure and inform policy development.

This meta-analysis seeks to address these gaps by systematically reviewing global public perception and awareness of PFAS. By consolidating findings from diverse studies, this analysis aims to provide a comprehensive overview of how various populations understand and respond to PFAS contamination. The study will explore regional variations, common trends, and the impact of regulatory and informational interventions on public awareness. Advanced reference management tools, such as Endnote, will support a thorough review process, ensuring a systematic and organized synthesis of the literature.

The objectives of this meta-analysis are twofold. First, it seeks to enhance public accessibility to knowledge on PFAS, contributing to greater awareness of the associated risks. Informed individuals are more likely to make choices that reduce their exposure to PFAS, potentially influencing market demand for products containing these chemicals. Second, the study aims to provide insights for policymakers and public health advocates, facilitating the development of effective communication strategies and regulatory frameworks. By examining trends, identifying gaps, and highlighting the drivers of public perception, this meta-analysis will inform targeted initiatives that encourage risk-aware consumer behavior and support further research.

Ultimately, this meta-analysis aims to deepen understanding of the factors influencing public perception of PFAS, providing valuable insights for more effective public health communication, policy development, and future research directions. By identifying trends and gaps in the literature, this study seeks to contribute to a proactive and well-informed approach to managing PFAS-related risks, benefiting both individual and societal health.

2. Methods

2.1. Data Collection

A comprehensive search was conducted to identify studies related to public perception of PFAS. The search was performed using database Web of Science (WoS) extended collection (Clarivate Analytics) for their title and topic fields, using the following terms: TS = (PFAS) AND (public awareness) + (PFAS) AND (public perception). The following default search condition were applied: i) only publications in English were included; ii) all the publications years were limited to the range from 2014 to 2024, and the end date was fixed as August 2nd, 2024; iii) only two types of publications, “articles” and “early access”, were included (i.e., excluding reviews, perspectives, comments, and editorials). This resulted in a total of 77 articles.

2.2. Study Selection and Eligibility Criteria

All the articles were imported to Endnote 21 to screen for duplicates. One article was excluded due to duplication. [1] To ensure that the studies included in this meta-analysis were relevant and of high quality, a set of inclusion and exclusion criteria were established. Full-text articles were retrieved only if they met the initial screening. Title and abstract were scanned of each paper first, studies were excluded if title and abstract showing irrelevant information. Then full-text articles were scanned based on the following the criteria as shown in Table 1: 1) Original research data about public awareness/perception on PFAS; 2) Research fits the objective of public awareness/perception on PFAS; 3) Demographic data were provided, including age, region, gender, race, and education. Rationales for each inclusion and exclusion criteria are provided in Table 1.

Table 1. Inclusion & Exclusion Criteria for Eligibility of Studies.

Inclusion & Exclusion Criteria	Rationales
I1: Research containing original data about public awareness/perception E1: Excluding review, comment, simulation, modeling etc.	I1 and E1 guarantee extracted date are primary sources from experiments
I2: Available data demonstrating public awareness/ perception are available E2: Excluding research *only* investigating knowledge regarding to PFAS	I2 and E2 guarantee the study is focusing on public altitude
I3: Demographic data of investigated public were available	I3 allows comparisons of public from various ages, regions, and education

During the screening, reviews, comments, studies about PFAS only, and studies not including public awareness/perception were excluded from further analysis.

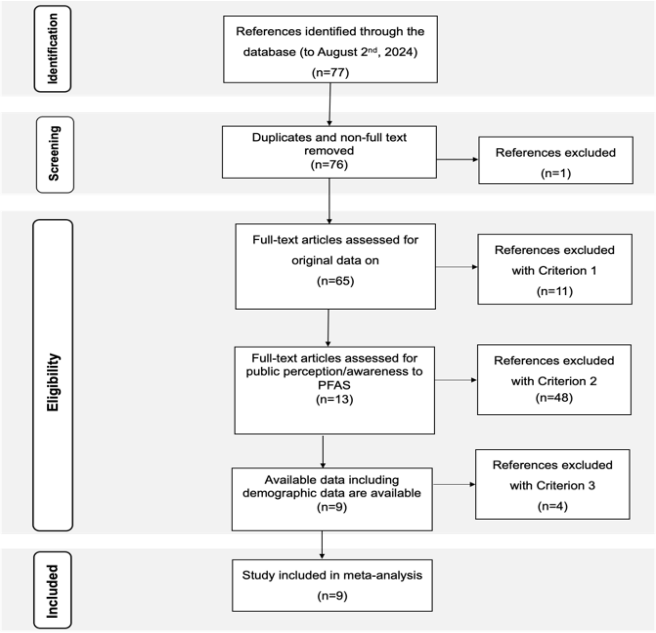

Fig 1. Flow Diagram of the Study and Literature Selection.

2.3. Data Extraction and Normalization

Following the initial screening, 9 full-text articles remained for further screening. Data extraction includes year of publication, author, and title, country of publication, sample number, age, race, gender, education, and public awareness/perception. For data shown in tables, data can be extracted directly. For data not shown in manuscript, data can be extracted from supplementary information.

Data were extracted from various categories including knowledge and concern of PFAS, risk judgement for PFAS, emotion for PFAS, and trust in government to indicate the public awareness/perception. All the eligible studies were included in systematic review (3.1). All the data were compiled into an Excel sheet for subsequence analysis.

2.4. Data Analysis

Different scales (dichotomous scales, 5-point or 7-point rating scales, etc.) were used in different papers. Consequently, it was necessary to initially rescale means and standard. In this study, Min-Max normalization was used to ensure comparability across studies with different scales. All public awareness/ perception including concern, knowledge level, risk judgement, trust in government and trust in science, were normalized to a standardized scale. Specifically, data reported on different scoring system were normalized based on Equation (1):

$$Normalized\ value = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

Where X represents the mean score; X_min and X_max are the minimum and maximum score from each study. This normalization allows for a uniform 0 to 1 range, facilitating direct comparison between studies with varying scales.

3. Results

3.1. Systematic Review

A total of 77 studies were initially identified through the literature search. After applying the inclusion criteria, 9 studies were included in the final meta-analysis. [1,2,3,4,5,6,7,8,9] Over the past decade, publication trends indicate a significant increase in academic output on public perception on PFAS with one article in 2018, one in 2021, four in 2023, and three in 2024 (Fig.2). This rising trajectory reflects the scientific community's growing recognition of PFAS-related concerns and heightened public discourse regarding the implications of these compounds. These findings suggest an increasing awareness of environmental and health risks, accompanied by a stronger demand for evidence-based insights into PFAS exposure. Together, this body of research highlights the pressing need for continued exploration of public understanding and the broader socio-environmental impacts of PFAS.

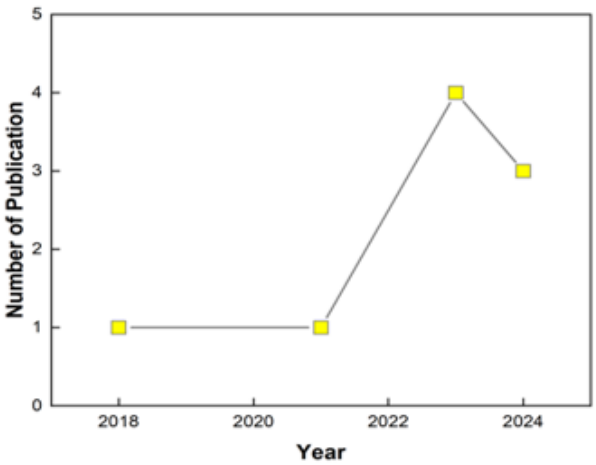

Fig 2. Number of Publications on Public Awareness of PFAS during Last Decade.

The geographic distribution of these studies shows a predominance of research from the United States (n=5), with additional contributions from Australia, China, New Zealand, and Sweden (n=1 each), as illustrated in Fig.3.

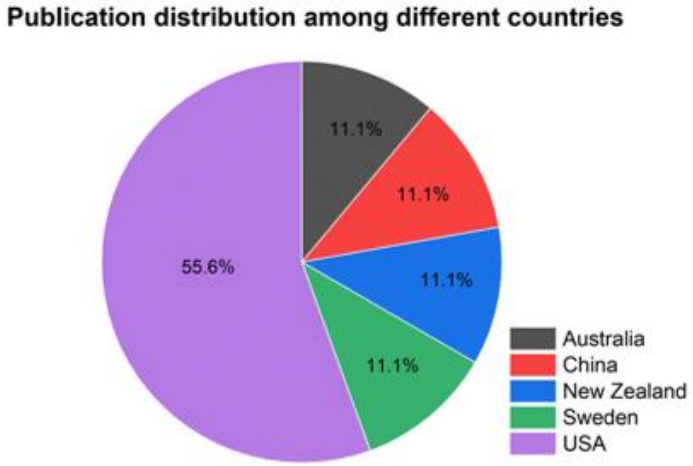

Fig 3. Publication Related to Public Perception for PFAS among Different Countries.

The total sample size across all studies was with a range of [111, 4181]. In addition, year of 2018 is the first year that the paper of PFAS was published, which indicated that the level of public awareness of perception started to increase during the past 6 years. In 2024, EPA has finalized landmark regulations, bringing PFAS to forefront of both academic research and industry conversation.

All studies employed survey methods and collected general demographic data, including age, gender, and race and education level. PFAS awareness and perception were assessed using various approaches across studies. In four studies, PFAS knowledge was quantified to represent public awareness. [3, 4, 6, 9] Except for two studies, public concern was considered a measure of PFAS awareness and perception. Three studies examined participants' risk judgments, while one study investigated additional factors such as emotions, trust in government, and trust in science. [4] To evaluate these variations, we applied quantitative calculations in this paper to explore differences among the studies.

3.2. Gender Distribution in PFAS Perception Studies

The gender distribution across the studies included in this meta-analysis is displayed in Figure 4. The sample sizes vary significantly among studies, with some surveys including fewer than 500 participants while others exceed 4,000. For instance, reported the largest sample size with over 4,000 respondents. [5] In contrast, smaller studies like and had fewer than 500 respondents, with a larger proportion of male participants.[2,7] While female respondents outnumber males in most studies, one study exhibit an opposite gender distribution [1]

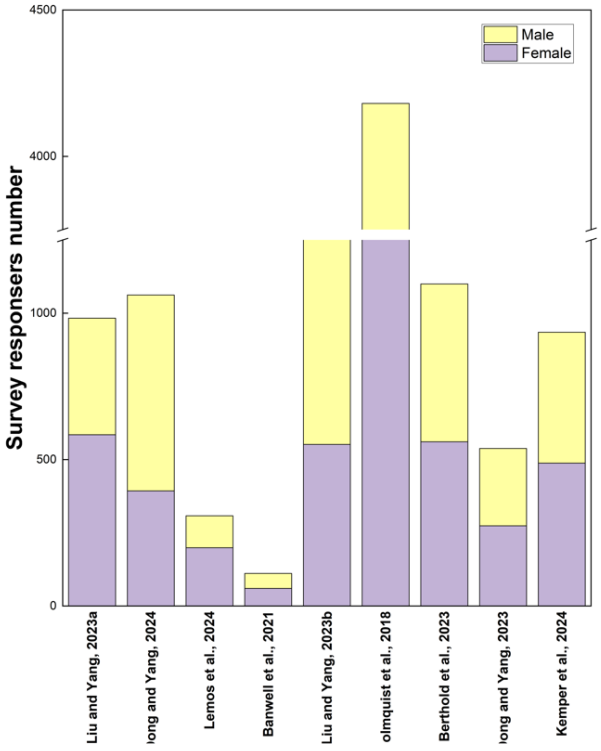

Fig 4. The Gender Distribution among All the Studies.

3.3. Correlation between Public Concern and Educational Levels

Fig. 5 illustrates the Spearman correlation analysis between public concern regarding PFAS and educational levels. For individuals with lower levels of education, including those with “less than high school” and “high school” education, a positive Spearman correlation coefficient was observed. This indicates that within these groups, higher educational attainment is associated with increased concern about PFAS. This trend suggests that among lower educational levels, education may play an important role in raising awareness and increasing concern for PFAS-related risks.

In contrast, for individuals with higher educational attainment, including those with "some college" and "bachelor and beyond" education levels, a negative correlation was found. Particularly, the "bachelor and beyond" group exhibits a relatively strong negative correlation (close to -0.5), suggesting that as education increases within this group, public concern for PFAS decreases. This could imply that individuals with higher education may either feel more informed and therefore less concerned or may perceive the risks of PFAS exposure as manageable due to increased access to resources and protective behaviors.

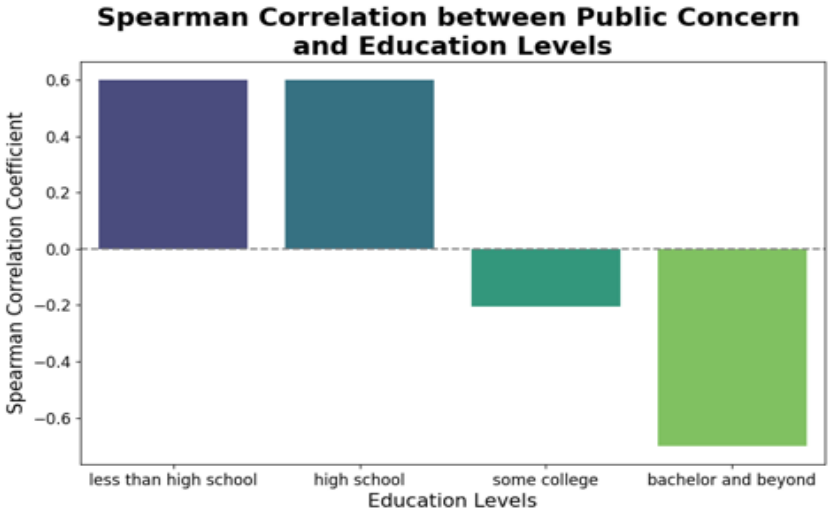

Fig 5. Spearmen Correlation between Public Concern and Education Levels.

3.4. Correlation between Public Concern and Race

The relationship between race and PFAS concern is presented in Fig. 6, with Spearman correlation coefficients calculated for each racial demographic. The Black or African group displays a strong positive correlation, indicating high concern with increased awareness. The Asian group also shows a moderate positive correlation, suggesting a similar trend, albeit weaker. In contrast, the White and Other groups exhibit negative correlations, particularly in the other category, where higher awareness does not correspond to increased concern. This suggests that individuals in these groups may perceive PFAS risks as less immediate or manageable through regulations.

These findings highlight the need for targeted communication strategies. Outreach efforts should reinforce awareness among groups with positive correlations, while addressing potential barriers or misconceptions among those with negative correlations, ensuring that PFAS awareness campaigns effectively reach all racial groups.

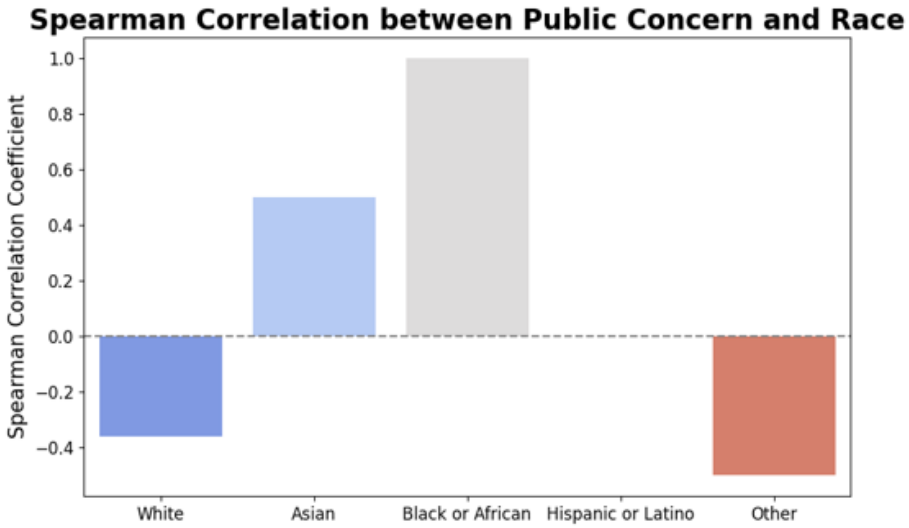

Fig 6. Spearman Correlation between Public Concern and Races.

4. Conclusion

In conclusion, this meta-analysis underscores the need for coordinated public health efforts to raise PFAS awareness through targeted educational programs that address demographic disparities. By promoting informed decision-making and enhancing public understanding of PFAS, these efforts can contribute to reduced exposure to PFAS-related risks and support more effective public health policies. Future research should aim to include diverse and balanced sample populations, further exploring how educational and regulatory interventions impact public perception.

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