Analyzing Research Trends in Microplastic Toxicity: A Comprehensive Bibliometric Review

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Abstract

Microplastics (MPs) are pervasive environmental contaminants that pose significant risks to ecosystems and human health. The study of microplastic toxicity has gained considerable attention over the past decade, with a growing body of research exploring their distribution, toxicological effects, and interactions with other pollutants. The primary objective of this bibliometric study is to identify and analyze research trends in microplastic toxicity from 2012 to 2025 using Scopus data. This analysis aims to provide insights into the evolution of research focus, key contributors, and emerging themes in this critical area of environmental science. A comprehensive bibliometric analysis was conducted using Scopus database data covering publications from 2012 to 2025. Tools such as VOSviewer were employed for performance evaluation and science mapping. The analysis of 5563 publications revealed a significant upward trend in annual research output on microplastic toxicity. There has been a notable increase in publications on microplastic toxicity, reflecting heightened scientific interest and awareness. China emerged as a leading contributor to this research area, followed by the United States and India. Early research primarily focused on identifying and distributing microplastics, while recent studies have shifted towards understanding their toxicological effects, including oxidative stress, apoptosis, and interactions with other pollutants. Science of the Total Environment and Journal of Hazardous Materials were identified as the most productive journals in this field, publishing a significant proportion of relevant articles.

Keywords: Microplastics, Toxicity, Bibliometric Analysis, Environmental Pollution

Introduction

Microplastics, defined as particles smaller than 5 mm, have emerged as pervasive pollutants in various environmental compartments, including terrestrial, aquatic, and atmospheric systems (Abad López et al., 2023; Pal et al., 2025). Their presence is primarily due to the breakdown of larger plastic items through processes such as photodegradation, thermal degradation, and biological activities (Pal et al., 2025). These particles are not only widespread but also pose significant risks to both ecosystems and human health. Microplastics originate from various sources, including industrial effluents, personal care products, and the degradation of larger plastic debris (Anbumani & Kakkar, 2018; Ashokkumar et al., 2025). They are found in oceans, rivers, soils, and even the atmosphere, where they can be transported over long distances and come into direct contact with humans through inhalation or ingestion

(Abad López et al., 2023; Ho et al., 2025). The accumulation of microplastics in the environment is exacerbated by their small size and large surface area, which facilitates their interaction with other pollutants (Chen et al., 2023).

The toxicity of microplastics is multifaceted, involving physical, chemical, and biological mechanisms. Physically, their small size allows them to be ingested by a wide range of organisms, from microalgae to higher trophic level species, leading to bioaccumulation and potential biomagnification through food webs (Pal et al., 2025; Rakib et al., 2023; Srinivas & Rajesh, 2025). Chemically, microplastics can adsorb and transport harmful substances such as heavy metals, persistent organic pollutants (POPs), and per- and polyfluoroalkyl substances (PFAS), which can exacerbate their toxic effects (Pal et al., 2025; D.-S. Pei & Yoganandham, 2023; Periyasamy, 2025). Biologically, microplastics can induce oxidative stress, inflammation, and cellular toxicity in organisms. Studies have shown that smaller particles tend to cause more significant toxic effects, including mitochondrial depolarization, reactive oxygen species (ROS) generation, and apoptosis (Luo et al., 2025). These effects can lead to disruptions in essential biological functions, such as feeding, reproduction, and energy metabolism, across various species (Anbumani & Kakkar, 2018; D.-S. Pei & Yoganandham, 2023).

Human exposure to microplastics occurs through multiple pathways, including the consumption of contaminated food and water, inhalation of airborne particles, and dermal contact (Abad López et al., 2023; Ho et al., 2025; Pal et al., 2025). The health risks associated with microplastic exposure include inflammation, organ damage, respiratory issues, and potential carcinogenic effects (Ashokkumar et al., 2025; Nguyen et al., 2025). The complex surface chemistry of microplastics enhances their ability to adsorb pollutants, which can further increase their toxicity and impact on human health (Abad López et al., 2023; Pal et al., 2025). Despite the growing body of research on microplastic toxicity, significant knowledge gaps remain. These include the need for standardized analytical protocols, comprehensive toxicological studies at environmentally relevant concentrations, and a better understanding of the long-term effects of microplastic exposure (Rakib et al., 2023; Thornton Hampton et al., 2022). Addressing these gaps will require interdisciplinary approaches combining toxicology, environmental science, and computational modeling to develop effective mitigation strategies and inform policy development (Nguyen et al., 2025; Thornton Hampton et al., 2022). The pervasive presence and complex toxicity of microplastics necessitate urgent research and regulatory efforts to mitigate their impact on ecosystems and human health.

Methods

Search Strategy and Data Collection

Bibliometrics quantitatively analyzes academic literature, offering insights into research trends, key contributors, and the evolution of scientific knowledge. To identify relevant publications, we used the Scopus database, leveraging targeted search queries to review articles on microplastic toxicity comprehensively. The search strategy included the following: (TITLE-ABS-KEY(microplastic toxicity) AND PUBYEAR > 2012 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re") OR LIMIT-TO (DOCTYPE,"cp") AND (LIMIT-TO (LANGUAGE,"English") AND (LIMIT-TO (PUBSTAGE,"final"). The search was restricted to English-language publications, excluding book chapters and congress abstracts. Data collection was completed in September 2025. The dataset underwent meticulous cleaning to eliminate duplicates and irrelevant entries, ensuring reliability and accuracy. Exported data were saved in TXT format for "full records and references" and Microsoft Excel (.xlsx) format to facilitate

further analysis. The titles and abstracts of the retrieved articles were reviewed for comprehensive evaluation. No articles were excluded during this process. To ensure data accuracy, all records were cross checked. This systematic approach ensured a high-quality data set for analyzing patterns, assessing impact, and tracing the progression of research in microplastic toxicity.

Data Processing and Analysis

Data analysis for trends in international microplastic publications used VosViewer software to display bibliometric graphical mapping and network visualization using several features. Visual maps depicting the relationships between authors, institutions, and research topics were generated for network analysis. This allowed for identifying key patterns, emerging trends, and collaborative clusters within the scientific literature.

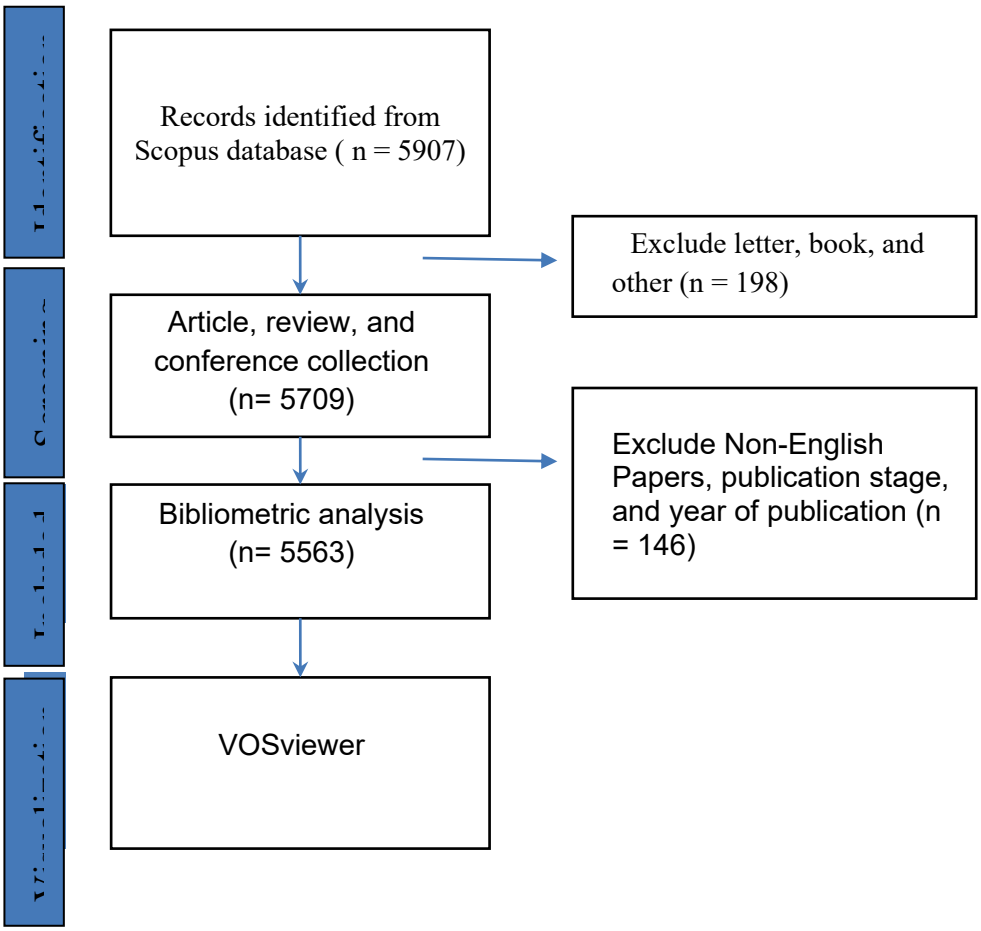

Figure 1. Data Processing and Analysis

Results

Number of Publications on Microplastics Toxicity in the Scopus Database

A search for publications on microplastics toxicity in the ScienceDirect database from 2012 to 2025 found 5563 publications. Table 1 shows the growth of international publications on microplastics toxicity.

Table 1. Number of Publications on Microplastics Toxicity in the Scopus Database

Year of Publication	Number of Publication	Precentage
2025	1345	24,18
2024	1450	26,07
2023	932	16,75

2022	757	13,61
2021	493	8,86
2020	293	5,27
2019	130	2,34
2018	89	1,60
2017	33	0,59
2016	23	0,41
2015	10	0,18
2014	5	0,09
2013	2	0,04
2012	1	0,02
Total	5563	100

Table 1 shows that the number of publications on microplastics toxicity in the Scopus database has increased significantly from 2012 to 2025, with peak growth occurring in 2024, when the number reached 1450 publications (26,07%).

Number of core journals in international publications on microplastics toxicity

Based on the results of a search for core journals publishing on microplastics toxicity in the Scopus database from 2012 to 2025, a total of 25 core journals were found, as shown in Table 2.

Table 2. Number of core journals in international publications on microplastics toxicity

Ranking	Core Journal Name	Number of Publication
1	Science of the Total Environment	791
2	Journal of Hazardous Materials	717
3	Environmental Pollution	514
4	Chemosphere	324
5	Ecotoxicology and Environmental Safety	303
6	Aquatic Toxicology	185
7	Marine Pollution Bulletin	178
8	Environmental Research	102
9	Environmental Science and Technology	99
10	Environment International	95
11	Water Research	83
12	Environmental Science and Pollution Research	80
13	Toxics	73
14	Journal of Environmental Management	68
15	Marine Environmental Research	55
16	Comparative Biochemistry and Physiology Part C Toxicology and Pharmacology	53
17	Environmental Toxicology and Chemistry	46
18	Environmental Toxicology and Pharmacology	44
19	Scientific Reports	43
20	International Journal of Molecular Sciences	41
21	Water Air and Soil Pollution	40
22	International Journal of Environmental Research and Public Health	39
23	Trac Trends in Analytical Chemistry	36
24	Environmental Monitoring and Assessment	32

Ranking	Core Journal Name	Number of Publication
25	Bulletin of Environmental Contamination and Toxicology	30
Total	5563	100

Source : secondary data from the Scopus database

Table 2 shows that microplastic toxicity is most frequently published in the journals Science of the Total Environment (791 publications), Journal of Hazardous Materials (717 publications), and Environmental Pollution (514 publications).

Types of Articles in International Publications on Microplastic Toxicity

Based on the search results for types of articles in international publications on microplastic toxicity in the Scopus database from 2012 to 2025, there were 4,370 research articles, 1,162 review articles, and 31 conference articles.

Number of International Research Publications on Microplastic Toxicity by Subject/Field

Based on the search results for the number of international research publications on microplastic toxicity by subject/field, there were 27 fields as shown in Table 3.

Table 3. Number of International Research Publications on Microplastic Toxicity by Subject/Field

Ranking	Subject/Field	Number of Publication
1	Environmental Science	4694
2	Pharmacology, Toxicology and Pharmaceutics	1047
3	Medicine	894
4	Agricultural and Biological Sciences	805
5	Chemistry	666
6	Biochemistry, Genetics and Molecular Biology	475
7	Earth and Planetary Sciences	321
8	Chemical Engineering	269
9	Engineering	255
10	Materials Science	155
11	Immunology and Microbiology	102
12	Multidisciplinary	79
13	Social Sciences	70
14	Physics and Astronomy	63
15	Computer Science	60
16	Energy	43
17	Veterinary	28
18	Neuroscience	24
19	Business, Management and Accounting	13
20	Health Professions	9
21	Mathematics	7
22	Decision Sciences	5
23	Economics, Econometrics and Finance	4
24	Nursing	4
25	Arts and Humanities	1
26	Dentistry	1
27	Psychology	1

Table 3 shows that microplastics were most frequently discussed in the subject/field of Environmental Science with

4694 publications, Pharmacology, Toxicology and Pharmaceutics with 1047 publications, Medicine with 894 publications, and the rest in other fields.

Map of the development of international publications on microplastics toxicity research based on keywords (co-words)

Five clusters were obtained based on the results of searching the number of international publications on microplastics toxicity research in the Scopus database from 2012 to 2025 based on keywords (co-words). Cluster 1 consists of items such as acute toxicity, additives, adsorption, aquatic environment, aquatic organisms, bioaccumulation, bioavailability, biochemistry, bioremediation, cadmium, ecosystem, ecotoxicity, environmental monitoring, fish, food chain, health hazard, health risks, human, human health, hydrophobicity, ingestion, invertebrates, marine environment, marine pollution, mortality, nonhuman, particulate matter, plastic bottles, plastic waste, pollution effect, pollution exposure, polyethylene, polyethylene terephthalate, polypropylene, polyvinylchloride, risk assessment, soil, surface property, toxicity, toxicity testing, ultraviolet radiation, water, water pollutant, chemical, zooplankton; cluster 2 consists of items animal cell, animal experiment, animal tissue, animals, call death, cell proliferation, controlled study, cytology, DNA damage, down regulation, female, gene expression, genotoxicity, histopathology, human cell, immune response, in vitro study, in vivo study, inflammation, liver, long term exposure, male, metabolism, nanoparticle, nano plastic, neurotoxicity, polystyrene, protein expression, reactive oxygen metabolism, reactive oxygen species, real time polymerase, reproduction, reproductive toxicity, transmission electron, tumor necrosis factor; cluster 3 consists of items antioxidant, biochemical analysis, biological marker, catalase, chlorophyl, combined toxicity, enzyme activity, enzymes, glutathione, lipid peroxidation, malonaldehyde, microalga, oxidative stress, physiological stress, physiology, plant growth, superoxide dismutase; cluster 4 consists of items bacteria, digestive system, gastrointestinal microbiome, intestine flora, metabolomics, microbial community, microbiota, RNA 16S, ; cluster 5 consists of items larva. For more details on the development of international publications on microplastics toxicity based on keywords (co-words), see Figure 1.

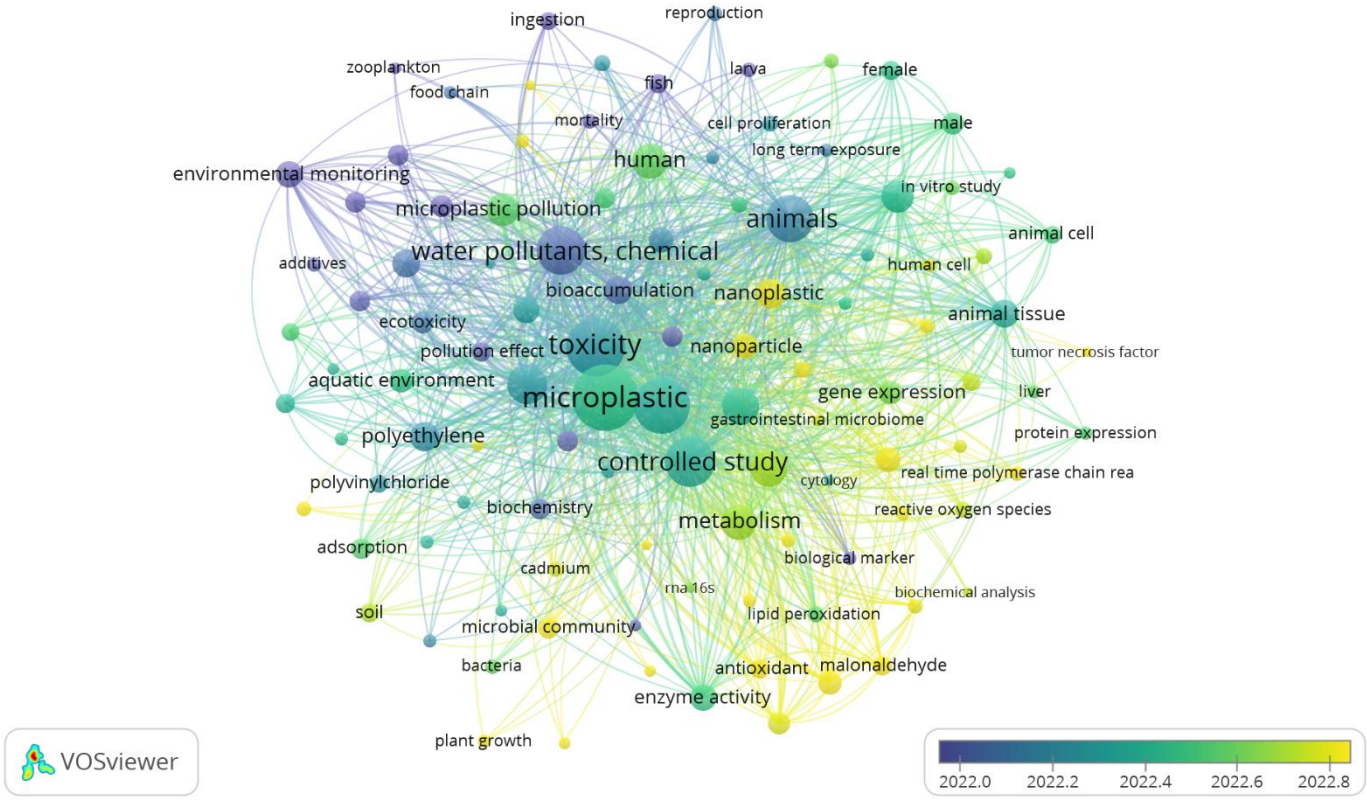

Figure 1. Map of international publications on microplastics research based on keywords (co-words)

Journal analysis

The journal co-citation network (Figure 5) shows that these top journals also form the intellectual core of the field, are often cited together, and thus form the body of knowledge. Using data from Figure 2 and Table 3, an analysis of the journals with the highest volume of publications on microplastic toxicity highlights its impact on the field of research. These journals significantly influence microplastic toxicity research, especially in environmental science. Network analysis or the interrelationship between keywords from these journals shows that microplastic toxicity research has been conducted on both human and non-human impacts.

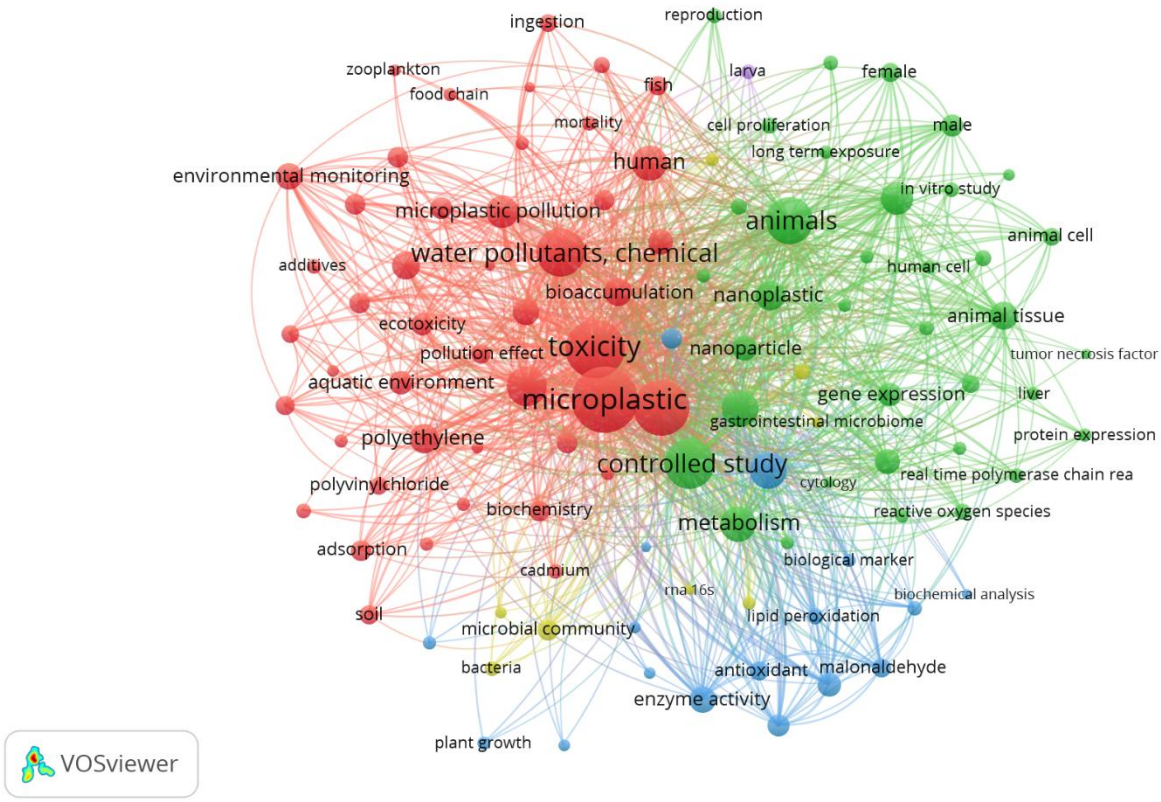

Figure 2. Journal collaboration network

Discussion

Over the years, the focus of microplastics research has evolved. Initially centered on pollution and environmental distribution, recent studies have increasingly emphasized toxicity, species-specific impacts, and health risks (Cao et al., 2024; Mishra et al., 2024; Wang et al., 2023). Key emerging topics include the oxidative stress induced by microplastics, their interactions with other pollutants, and the development of mitigation strategies. China has emerged as a leading contributor to microplastics research, followed by the United States and European countries. This geographical distribution highlights the global nature of the research efforts (Aunno, 2016; Jeong & Choi, 2019; Liu et al., 2024; Yang et al., 2025).

Research focuses on the toxic effects of microplastics on aquatic and terrestrial ecosystems and human health. Key mechanisms include oxidative stress, inflammation, and apoptosis. There is a significant emphasis on developing standardized methods for detecting and analysing microplastics in various environmental media. Studies increasingly examine microplastics' combined effects with other pollutants, such as heavy metals, which can enhance their toxicity and bioaccumulation. Research highlights the potential health risks of microplastics, including respiratory and gastrointestinal issues, and their role in diseases such as cancer (Du et al., 2024; Liu et al., 2024; Luo et al., 2025; J. Pei et al., 2024; Yang et al., 2025).

The bibliometric analysis provides crucial insights for addressing knowledge gaps, promoting collaboration, and guiding evidence-based policies to mitigate the impacts of microplastics on marine ecosystems. The findings offer insights and future research directions for microplastics pollution prevention and environmental protection, which can inform the development of policies and strategies to address this environmental challenge. The analysis underscores

the critical role of global partnerships in advancing the understanding of microplastic-related issues. It emphasizes the need for more comprehensive investigations to thoroughly examine the prolonged health implications of microplastics. The bibliometric analysis provides a comprehensive overview of the research landscape on microplastic pollution, helping researchers to identify knowledge gaps and emerging trends, which can guide future research directions and inform policymakers and stakeholders on where scientific efforts should be concentrated to understand better and address the impacts of microplastic pollution (Du et al., 2024; Hazarika & Sudhier, 2024; Mishra et al., 2024; Xing et al., 2025; Yildirim et al., 2024).

Conclusion

Based on the results and discussion, it can be concluded that the development of research on microplastics between 2012 and 2025 through the Science Direct platform peaked in 2024, with a total of 1,450 publications (26.07%). The Science of The Total Environment journal published 791 international publications on microplastic toxicity. There were 4,370 research articles, 1,162 review articles, and 31 conference articles. The number of international publications on microplastic toxicity was most discussed in the subject/field of Environmental Science, with 4,694 publications. Furthermore, co-word analysis can be grouped into five main clusters. The author suggests that more specific keywords are needed to expand the scope of the research results and obtain more relevant and comprehensive information.

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Author Contribution and Competing Interest

All authors contributed significantly to the conception, design, analysis, and interpretation of data. Each author participated in drafting or critically revising the manuscript and approved the final version for publication. The authors declare that they have no competing interests related to the content of this manuscript.

References

Abad López, A. P., Trilleras, J., Arana, V. A., Garcia-Alzate, L. S., & Grande-Tovar, C. D. (2023). Atmospheric microplastics: exposure, toxicity, and detrimental health effects. *RSC Advances*, *13*(11), 7468–7489. https://doi.org/10.1039/d2ra07098g

Anbumani, S., & Kakkar, P. (2018). Ecotoxicological effects of microplastics on biota: a review. *Environmental Science and Pollution Research*, *25*(15), 14373–14396. https://doi.org/10.1007/s11356-018-1999-x

Ashokkumar, V., Chandramughi, V. P., Mohanty, K., & Gummadi, S. N. (2025). Microplastic pollution: Critical analysis of global hotspots and their impact on health and ecosystems. *Journal of Environmental Management*, *381*(October 2024), 124995. https://doi.org/10.1016/j.jenvman.2025.124995

Aunno, T. D. (2016). *primary care workforce capacity*. *00*(0), 1–10. https://doi.org/10.1097/HMR.0000000000000094

Cao, Y., Ma, Y., Han, Y., Bian, J., Yu, X., Wang, Z., Liu, J., Feng, W., Deng, Y., & Miao, Q. (2024). Effect and environmental behaviour of microplastics in soil. *Waste Management and Research*, *42*(7), 511–519. https://doi.org/10.1177/0734242X231190811

Chen, J., Guo, C., Xuan, Y., & Ding, T. (2023). Analysis and toxicity of microplastics in organisms and humans originated from aquatic environment. *TrAC - Trends in Analytical Chemistry*, *168*(August), 117293. https://doi.org/10.1016/j.trac.2023.117293

Du, Z., Yu, X., Li, X., Zhang, L., Lin, Y., He, Y., Wu, Y., Baspakova, A., Afashar, A., Suleimenova, R., Berdygaliev, A. B., Ramankulova, A., Kandygulova, G. J., Mussin, N. M., Mahdipour, M., Zhilisbayeva, K. R., Tanideh, N., Tamadon, A., Li, M., … Sharma, S. (2024). Examining the Presence of Microplastics in Wastewater: A Bibliometric Analysis and Overview. *Fate of Microplastics in Wastewater Treatment Plants: Occurrence,*

Identification, Potential Factors, and Future Perspectives, *139*(5), 1–16. https://doi.org/10.1201/9781003438793-1

Hazarika, R., & Sudhier, K. G. (2024). Scientometric Analysis and Visualization of Research on the Effects of Microplastics on Marine Life. *Journal of Scientometric Research*, *13*(2), 485–495. https://doi.org/10.5530/jscires.13.2.39

Ho, C. M., Feng, W., Li, X., Ngien, S. K., Yu, X., Song, F., Yang, F., & Liao, H. (2025). Microplastic distribution and its implications for human health through marine environments. *Journal of Environmental Management*, *382*(April), 125427. https://doi.org/10.1016/j.jenvman.2025.125427

Jeong, J., & Choi, J. (2019). Adverse outcome pathways potentially related to hazard identification of microplastics based on toxicity mechanisms. *Chemosphere*, *231*, 249–255. https://doi.org/10.1016/j.chemosphere.2019.05.003

Liu, W., Zeng, M., Li, Y., Chen, G., Wen, J., & Wang, J. (2024). Deciphering the research of Micro(nano)plastics: An in-depth bibliometric expedition into ecotoxicological impacts and research trends. *TrAC - Trends in Analytical Chemistry*, *172*(January). https://doi.org/10.1016/j.trac.2024.117608

Luo, W. Q., Cao, M. T., Sun, C. X., Wang, J. J., Gao, M. X., He, X. R., Dang, L. N., Geng, Y. Y., Li, B. Y., Li, J., Shi, Z. C., & Yan, X. R. (2025). Size-dependent internalization of polystyrene microplastics as a key factor in macrophages and systemic toxicity. *Journal of Hazardous Materials*, *490*(October 2024), 137701. https://doi.org/10.1016/j.jhazmat.2025.137701

Mishra, M., Sudarsan, D., Santos, C. A. G., da Silva, R. M., Beja, S. K., Paul, S., Bhanja, P., & Sethy, M. (2024). Current patterns and trends of microplastic pollution in the marine environment: A bibliometric analysis. *Environmental Science and Pollution Research*, *31*(15), 22925–22944. https://doi.org/10.1007/s11356-024-32511-x

Nguyen, M. K., Lin, C., & Nguyen, D. D. (2025). Microplastic pollution associated with probabilistic human health risks: Potential hazards, critical factors, challenges, and limitations. *Marine Pollution Bulletin*, *221*(June), 118528. https://doi.org/10.1016/j.marpolbul.2025.118528

Pal, D., Prabhakar, R., Barua, V. B., Zekker, I., Burlakovs, J., Krauklis, A., Hogland, W., & Vincevica-Gaile, Z. (2025). Microplastics in aquatic systems: A comprehensive review of its distribution, environmental interactions, and health risks. In *Environmental Science and Pollution Research* (Vol. 32, Issue 1). Springer Berlin Heidelberg. https://doi.org/10.1007/s11356-024-35741-1

Pei, D.-S., & Yoganandham, S. T. (2023). Molecular Toxicity Mechanism of Microplastics in the Reservoir. In *Reservoir Ecotoxicology* (pp. 173–181). Springer International Publishing. https://doi.org/10.1007/978-3-031-26344-6_15

Pei, J., Qu, M., Sun, L., Wang, X., & Yin, Y. (2024). The relationship between indoor air quality (IAQ) and perceived air quality (PAQ) – a review and case analysis of Chinese residential environment. *Energy and Built Environment*, *5*(2), 230–243. https://doi.org/10.1016/j.enbenv.2022.09.005

Periyasamy, A. P. (2025). Functionalized textile microplastics: A closer look at the issues, strategy, and legislation on the microplastic reduction. *Kuwait Journal of Science*, *52*(3), 100395. https://doi.org/10.1016/j.kjs.2025.100395

Rakib, M. R. J., Sarker, A., Ram, K., Uddin, M. G., Walker, T. R., Chowdhury, T., Uddin, J., Khandaker, M. U., Rahman, M. M., & Idris, A. M. (2023). Microplastic Toxicity in Aquatic Organisms and Aquatic Ecosystems: a Review. *Water, Air, and Soil Pollution*, *234*(1). https://doi.org/10.1007/s11270-023-06062-9

Srinivas, G., & Rajesh, K. (2025). Ecological impact of microplastic pollution on marine food webs. *International Journal of Aquatic Research and Environmental Studies*, *5*(1), 390–407. https://doi.org/10.70102/IJARES/V5I1/5-1-37

Thornton Hampton, L. M., Bouwmeester, H., Brander, S. M., Coffin, S., Cole, M., Hermabessiere, L., Mehinto, A. C., Miller, E., Rochman, C. M., & Weisberg, S. B. (2022). Research recommendations to better understand the potential health impacts of microplastics to humans and aquatic ecosystems. *Microplastics and Nanoplastics*, *2*(1). https://doi.org/10.1186/s43591-022-00038-y

Wang, Y., Liu, G., Wang, Y., Mu, H., Shi, X., Wang, C., & Wu, N. (2023). The Global Trend of Microplastic Research in Freshwater Ecosystems. *Toxics*, *11*(6), 1–13. https://doi.org/10.3390/toxics11060539

Xing, Z., Fu, W., Li, L., & Wu, S. (2025). Bibliometric analysis of microplastics research: Advances and future directions (2020–2024). *Continental Shelf Research*, *285*(November 2024), 105371. https://doi.org/10.1016/j.csr.2024.105371

Yang, Y., Chen, Y., Gao, Y., Jin, Y., & Xu, F. (2025). Mapping research frontiers in microplastics-induced oxidative stress: a bibliometric analysis (2010–2024). *Frontiers in Environmental Science*, *13*(April), 1–5. https://doi.org/10.3389/fenvs.2025.1555341

Yildirim, G., Anindita, M., Pan, X., Rahman, S., Alim, M. A., Shaik, R., & Rahman, A. (2024). Bibliometric Insights into Microplastic Pollution in Freshwater Ecosystems. *Water (Switzerland)*, *16*(22). https://doi.org/10.3390/w16223237