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GLOBAL TRENDS IN RESEARCH ON MICROPLASTIC CONTAMINATION AND RIVER WATER QUALITY: A BIBLIOMETRIC REVIEW

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ABSTRACT

This study aims to analyse global trends in research related to microplastic contamination and river water quality using a bibliometric approach. Microplastics have become one of the most pressing environmental issues in recent decades, mainly due to their significant impact on aquatic ecosystems and potential harm to human health. Along with the increasing attention to this issue, the scientific literature related to microplastics and river water quality has grown rapidly. However, a thorough understanding of the distribution of research, relationships between topics, as well as potential research gaps is still needed to direct future research more effectively. This study used a literature search method through the *Publish or Perish* app, with keywords including "*microplastics*," "*water quality*," "*water pollution," "microplastic contamination,"* and *"river."* The search was conducted from 2014 to 2024, resulting in 50 relevant articles for further analysis. The data obtained was then processed using *VOSviewer* to map and visualise the bibliometric network, identify key clusters, and evaluate the temporal progression of these research topics. The resulting visualisations, including network visualisation, overlay visualisation, and density visualisation, provide deep insights into how key terms are connected and evolve in the literature. The analysis showed that research on microplastics in the context of rivers and water quality is heavily dominated by a few key terms such as "*microplastic," "river*," and "*water*," indicating the high level of scientific attention on this topic. In addition, it was found that research often focuses on the distribution of microplastics, physicochemical parameters of water, and sources of contamination. However, there are some significant research gaps, especially related to the effect of salinity on microplastic distribution, the accumulation of microplastics in river sediments, and the role of wastewater treatment plants in preventing the spread of microplastics to aquatic ecosystems. The conclusion of this study is that despite significant progress in understanding the distribution and impacts of microplastics, many aspects still require further research. In particular, research on the long-term impacts of microplastics and their interactions with other environmental components should be further enhanced. The findings are expected to provide guidance for future researchers to explore under-explored areas and contribute to better environmental management.

Keywords: Microplastic, Water Quality, River Pollution, Bibliometric Analysis, Environmental Research

INTRODUCTION

Environmental problems in modern times are not free from plastic waste that can cause environmental pollution. The plastic waste can turn into pieces with a smaller size and invisible to the eye or commonly called microplastics (Sutan H et al, 2021). With the continuous progress and development of society, plastics have permeated every major aspect of human life and economy. The large-scale production and littering of plastics has a major negative impact on our environment (Bosker T et al, 2018). Plastic waste is still a severe problem in the world. Plastic waste is the accumulation of plastic objects (e.g. plastic bottles and many more) in the earth's environment that negatively affects the lives of living things in the world (Westminster, 2022).

Microplastics have become one of the most recognised environmental issues in recent decades. These tiny plastic particles, which come from various sources such as single-use plastic products, synthetic clothing and vehicle tyres, have been found to contaminate various aquatic ecosystems around the world. Rivers, as one of the main waterways leading to the ocean, play an important role in the transport and accumulation of microplastics. Microplastics accumulated in rivers not only impact water quality, but also aquatic life and, ultimately, human health through the food chain.

In recent years, much research has been conducted to understand the distribution, impacts and mitigation potential of microplastics in aquatic environments. However, this growing literature requires comprehensive analyses to identify key trends, relationships between topics, as well as under-explored areas. Focused and targeted research is essential to fill existing knowledge gaps and develop effective strategies for managing microplastic contamination.

Bibliometric approaches offer a systematic way to analyse and map scientific literature. Using this technique, researchers can identify patterns in scientific publications, including the most researched topics, collaborations between researchers, and the temporal evolution of certain topics. Through this approach, this study aims to evaluate global trends in research on microplastics and river water quality, and to identify potential research gaps that could be the focus of future research.

This study used data from the published literature from 2014 to 2024, and was analysed using the VOSviewer tool to visualise relationships between topics. This analysis not only provides an overview of what has been achieved in microplastics research, but also reveals important areas that still require further research, particularly related to the interaction of microplastics with other environmental parameters and their long-term impact on aquatic ecosystems.

OVERVIEW

In 2016, the world generated 242 million tonnes of plastic waste, of which 12% came from urban areas. Based on the report, plastic waste came from three regions, namely, 57 million tonnes from East Asia and the Pacific, 45 million tonnes from Europe and Central Asia, and 35 million tonnes from North America (Abdulraheem M, 2021). Based on a 2019 report from the Organisation for Economic Co-operation and Development (OECD), plastic waste in the world this year is double what it was two decades ago; most plastic waste ends up in the trash, incinerated or dumped into the environment and only 9% is recycled (OECD, 2022).

The river is a dumping ground for

domestic and industrial waste, and will lead to the sea. Based on data from Lebreton et al. (2017), rivers in Asia contribute 86% of the total plastic waste in the world. The amount of plastic waste from the 20 largest rivers in the world in 2015 was 947,500 tonnes, in the Yangtze river (China) as much as 333,000 tonnes and occupies the first position, while plastic waste in Indonesian rivers occupies the 7th position for the Brantas river and the 10th position for the Bengawan Solo river. In addition, based on research conducted by Cordova and Nurhati (2019), as much as 59% of plastic and styrofoam waste entered Jakarta Bay.

Microplastics, defined as plastic fragments smaller than 5 millimetres (Gesamp, 2015) play a key role in marine pollution. Microplastics have been found on beaches, the sea surface and the seafloor from the shore to the open ocean (Obbard et al., 2014). The presence of microplastics in the ocean is of great concern due to their durability, ubiquity and can be vectors that transfer toxins to organisms as they are concentrated as well as being able to transfer chemicals from seawater to organisms through ingestion. Microplastics are formed by autocatalytic, thermo-oxidative, photo oxidative and biological degradation processes that convert larger particles into micro particles or microplastics (Andrady, 2011). These micro-particles can cause growth delays, resulting in ecological risks and toxicological effects on marine organisms. Microplastics can move from primary to tertiary consumers (Setala et al., 2014).

The first international workshop on the presence of microplastics, and the final results of microplastics on plastic waste in the marine environment held on 9-11 September 2008 at the University of Tacoma USA agreed on the classification of plastics according to their size microplastics have a size (330 µm < 5 mm) that are widespread throughout the swirling currents of the world's oceans are strongly suspected of originating from a very slow decay process, both particles that float or drift in the water column, as well as plastic pieces that degrade into smaller debris that eventually wash up on beaches around the world (Masura et al., 2008)., 2015).

The presence of microplastics in the environment is a problem because they are persistent, contain toxic chemicals and are carcinogenic. Therefore, organisms that consume them will indirectly affect aquatic life. Microplastics can be directly or indirectly consumed by organisms through entanglement, ingestion and interaction. Plastic waste is certain to pollute the oceans, poison marine life, damage coral reefs, which will further damage the balance of marine ecosystems. This microplastic debris can enter the food chain and ultimately impact both human and environmental health (Eriksen et al., 2014; Kole et al, 2017; Wright & Kelly, 2017).

Microplastics can enter freshwater lakes through many sources. They can act as carriers to absorb bacteria, viruses, or pollutants (e.g., heavy metals and toxic organic compounds) that threaten human health through the food chain. Microplastics can exist in surface water and sediments in freshwater lakes after entering the lake through discharge points (Li L et al, 2019).

Globally, it is estimated that 80% of marine plastics come from land and 20% per cent from the ocean (Li et al., 2016). The spread of plastic waste into the environment is inseparable from the use of plastics for disposable products, food and beverage packaging. Plastics in the environment will experience fragmentation due to abiotic processes such as UV radiation from the sun or high temperatures (Urbanek et al., 2018).

Microplastics found in seawater originate from river flows, as the main route of microplastics from terrestrial sources. Microplastics can also come from the activities of communities

around rivers and coastal areas (Fischer et al., 2016).

Microplastics are a part of marine debris that when accumulated in water areas will cause disruption of the food chain (Dewi et al., 2015). The lower limit of particle size included in the microplastic group has not been precisely defined, but most studies take the lower limit of microplastic size of at least 300 µm3 . Microplastics come in a variety of groups that vary greatly in size, shape, colour, composition, density, and other properties.

Microplastics are considered pollutants because they can adsorb toxic chemicals or pathogens and can then be transferred to living organisms through the food chain (Bakir et al., 2012) reviewing the distribution and adsorption behaviour of chemicals on microplastics.

Microplastic-contaminated environments represent a potential vector for the introduction of toxic pollutants containing toxins into food webs (Crawford and Quinn, 2017). Indirectly, microplastics will be eaten by animals in the water, because they have a very small size and the large amount in the ocean makes them ubiquitous and bioavailability to aquatic organisms is high. As a result, it can be eaten by marine biota (Boucher et al., 2016).

Microplastics can also contaminate other organisms, such as soil organisms. The results of studies conducted showed that exposure to microplastics showed significant changes in activity, however, at relevant exposure concentrations, the threat to soil biota would be minimal, other areas with higher concentrations of microplastics can be assumed as an early warning for more severe and harmful effects (Lackmann et al, 2022). Microplastics have potential health impacts on humans due to relevant toxic chemicals and other contaminant vectors that can cause biological chemical and physical damage (Yang et al, 2022).

Fibre and fragment microplastics are categorised as secondary microplastics derived from plastic fragmentation. According to Browne (2011) and Jeyasanta (2020) (44,45), microplastics in the form of fibres are types of microplastics sourced from domestic activities such as laundry waste and other fishing activities such as the use of fishing ropes and nets (Yona et al, 2021). Fibre microplastics can come from clothing fibres, ropes, nets, yarns, paranet, plastic sacks, raffia, for film types can come from plastic bags, food packaging, toiletry packaging, mulch, polybags, low/high tunnel plastic, UV plastic, and for fragment types can come from drinking bottles, jars, buckets, mica folders, paralon pipes, containers/derigants, irrigation pipes, plastic pots (Sutanhaji et al, 2021). The most common type of microplastic found is the fragment type. This is proven because fragments are the result of pieces of plastic products with very strong synthetic polymers (Nugroho, 2018).

RESEARCH METHODOLOGY

This study was conducted using a bibliometric approach to identify global trends in research on microplastic contamination and river water quality. The research process began with the collection of scientific literature data using the Publish or Perish (PoP) application. This application allows researchers to extract metadata from relevant articles based on certain keywords, namely "Water quality," "Microplastics," "Water pollution," "Microplastic contamination," "Dissolved Oxygen," "Biological Oxygen Demand," "Chemical Oxygen Demand," and "river." The search was conducted from 2014 to 2024, with the aim of obtaining a comprehensive and up-to-date picture of research developments on the topic.

From the search results through Google Scholar, 50 articles were selected for further analysis. The

selection of these articles was done by considering the relevance and suitability of the discussion to the research topic. The selected articles were then classified and analysed based on several criteria, namely Year of Publication, Country of Publication, Publisher, Most Cited, and Article Type. This classification aims to understand the temporal and geographical distribution of research, as well as to identify the most influential publishers and article types on this topic.

After the data was collected through the PoP application, the next step was data processing using VOSviewer software. VOSviewer is used to analyse and visualise the relationships between various elements in scientific literature, such as authors, articles and keywords. In this study, the analysis was carried out by setting a minimum occurance value of 4 and the number of terms as many as 25. This process produces several visualisations, namely Network Visualisation, Overlay Visualisation, and Density Visualisation.

Network Visualisation provides an overview of the bibliometric network map that shows the relationship between authors, keywords, and interrelated articles in the analysed literature. Overlay Visualisation is used to display the development of research trends over time, showing how certain topics emerge and evolve in the literature. The Density Visualisation provides a density visualisation, showing areas in the network that have a high concentration of certain elements, such as keywords or authors that appear frequently.

Using VOSviewer, this study mapped global trends in research on microplastic contamination and river water quality, identified key research clusters or groups, and revealed patterns of collaboration between researchers and institutions. The analyses provide insights into the direction of research development in this area and identify research gaps that can be filled by future studies. The tools and approaches used in this study provide a strong foundation for understanding the dynamics of the scientific literature in this increasingly relevant topic.

RESULTS RESEARCH AND DISCUSSION

This section presents key findings from the bibliometric analyses conducted, and discusses the implications of these findings in the context of global research on microplastic contamination and river water quality. The results obtained from data processing using the Publish or Perish application and visualisation with VOSviewer provide a comprehensive overview of research trends, geographical distribution, and collaboration patterns formed in the scientific literature over the past decade. This discussion will also outline the main clusters that emerged from the analysis, identify the most influential topics, and evaluate the temporal progression of issues related to microplastic contamination and water quality. Through these results and discussion, it is hoped to provide an in-depth insight into the existing research landscape, as well as potential future research directions.

Trend Analysis of Publications by Year of Publication

From the analysis of publication trends by year of publication for research on microplastic contamination and river water quality, a significant increase in the number of publications since 2018 was observed. In the early period (2014-2017), no publications were found on this topic, indicating that this issue had not been the focus of extensive research in those years. However, starting in 2018, this trend started to show an increase, with 2 publications detected. This number remained the same in 2019, but experienced a spike in 2020 and 2021 with 5 publications each.

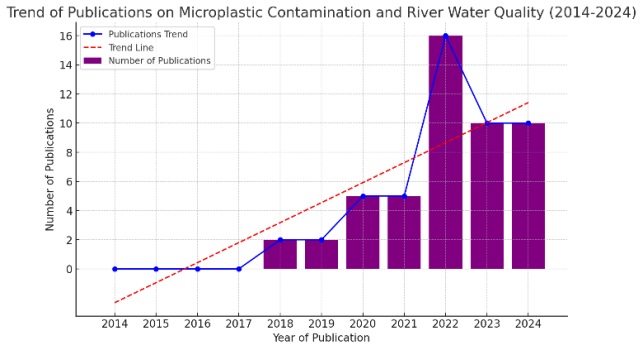

Figure 1. Related Publication Trends from Google Schollar databases using PoP application

The significant increase in the number of publications after 2018 reflects the changing attention and prioritisation in the research community towards environmental issues, particularly related to microplastic pollution. In the early years, this topic may not have received enough attention as global awareness of the negative impacts of microplastics in aquatic ecosystems was still in its infancy. However, as more and more studies show the serious impacts of microplastics on aquatic ecosystems and human health, scientific attention to this topic has increased sharply.

The significant spike in 2022, which recorded the highest number of publications, can be attributed to several factors. One is the global push to achieve environmental sustainability targets, such as those listed in the UN Sustainable Development Goals (SDGs), which encourages more research and publications in this area. In addition, increased funding for environmental research and policy initiatives by various countries may also have contributed to the increase in the number of publications.

The decline in the number of publications after the peak in 2022 could be interpreted as a consolidation phase, where researchers may be reassessing previous results and starting to focus research on more specific aspects or focusing on developing practical solutions. However, the stable number of publications in 2023 and 2024 suggests that research in this area is still continuing, albeit at a slightly reduced pace, and is still a major concern among researchers.

Overall, these trends indicate that although this topic has only developed into a major issue in recent years, it has become one of the important foci in global environmental research, with publications continuing to increase and suggesting that this issue will remain relevant and high on the agenda of environmental research for the foreseeable future.

Analysis of Publication Trends by Article Type

From the analysis conducted on the types of publications in research on microplastic contamination and river water quality, it can be seen that research articles dominate significantly, with a total of 40 publications out of 50 analysed. This suggests that most research in this area is based on empirical studies that emphasise the collection and analysis of field or laboratory data to investigate the impact of microplastics on river water quality.

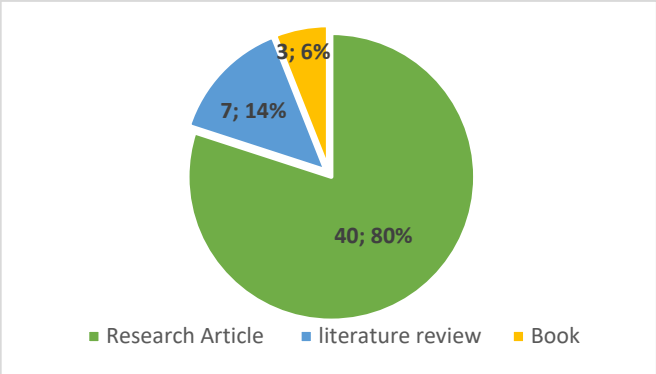

Figure 2. Distribution Of Countries That Publish Related Research

Literature Review or literature review occupies the second position with 7 publications. Literature reviews in this field tend to be used to compile, analyse and interpret the results of existing research, provide an overview of the current state of research and identify gaps that need to be filled by future research. Books in this context may be more comprehensive, bringing together different aspects of research and theory that have been developed in a more in-depth form, and are often intended for education or wider reference.

From the bibliometric analysis conducted on publications on microplastic contamination and river water quality, it can be concluded that the majority of research in this field is dominated by research articles, which account for 80% of the total publications. This suggests that empirical research that focuses on data collection and analysis is essential in understanding and addressing the issue of microplastic contamination in the aquatic environment.

Literature reviews, which account for 14% of publications, also play an important role in compiling and analysing findings from various studies, helping to identify trends and gaps in existing research. Meanwhile, Books, while only representing 6% of the total publications, offer a more comprehensive and in-depth view of the topic, often intended for educational purposes or as a scientific reference.

Overall, this distribution reflects a balanced approach between empirical studies, literature analyses, and broader knowledge development in the form of books, all of which make important contributions to advancing understanding and addressing the issues of microplastic contamination and river water quality.

Publication Trend Analysis by Country

From the data provided, it can be seen that research on microplastic contamination and river water quality is spread across different countries around the world, reflecting the global attention to this issue. **China** tops the list with the highest number of publications, with 7 publications. This shows that China has significant attention and contribution in research related to microplastics and water quality, likely fuelled by the country's growing environmental concerns and strong encouragement from the government and research institutions.

Followed by Nigeria and India, each with 5 publications. These two countries show strong engagement in this issue, perhaps because they also face major challenges related to water pollution and the impact of

microplastics on environmental health and large populations.

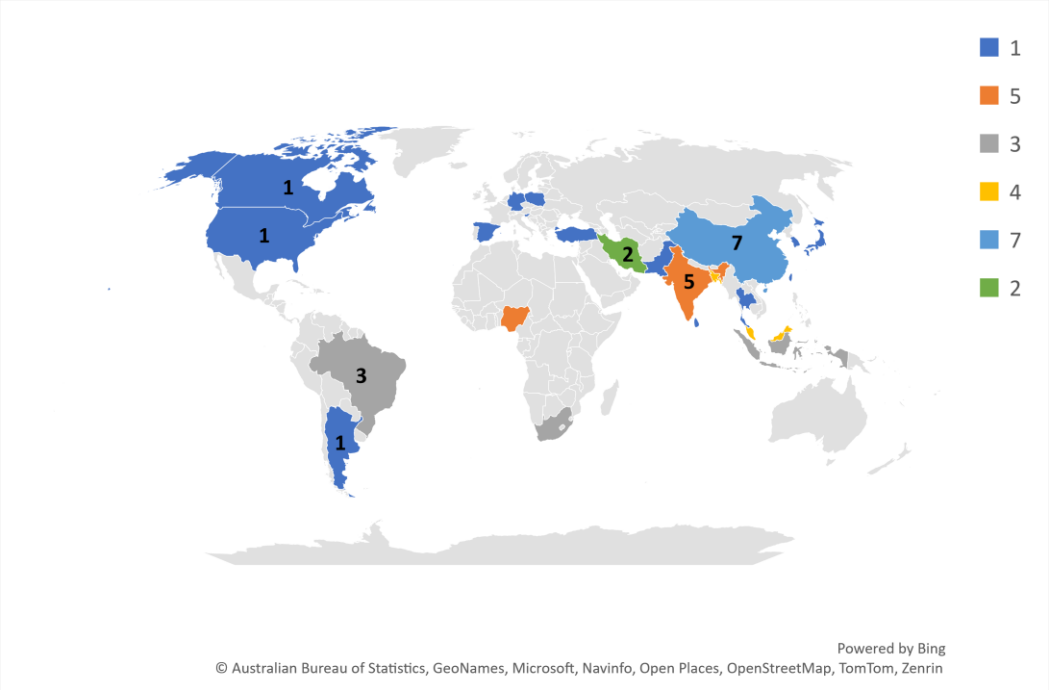

Figure 3. Distribution Of Countries That Publish Related Research

Other countries such as Bangladesh and Malaysia also have significant contributions with 4 publications each, followed by Brazil, Indonesia and South Africa with 3 publications each. The involvement of these countries may reflect a growing awareness of the impacts of microplastics, especially in regions that have rich aquatic ecosystems and are vulnerable to pollution.

Countries such as Canada, Argentina, South Korea, USA, and various European countries (e.g. Germany, Poland, Spain), each contributed one publication. Although smaller in number, these contributions are still important and show that the issue of microplastic contamination is receiving widespread attention, albeit with different intensities in different countries.

Overall, the distribution of these publications reflects that the issue of microplastics in river water quality is not only a concern in developed countries but also in developing countries. This trend demonstrates the importance of global collaboration in addressing far-reaching environmental issues, with countries contributing to the understanding and solutions to address microplastic contamination in their aquatic ecosystems.

Publication Trend Analysis by Publisher

From the data provided, it can be seen that Elsevier dominates as the publisher with the highest number of publications in research on microplastic contamination and river water quality, namely 22 publications. Elsevier's dominance reflects its very significant role in distributing scientific research in the environmental field, especially related to water pollution and microplastic issues.

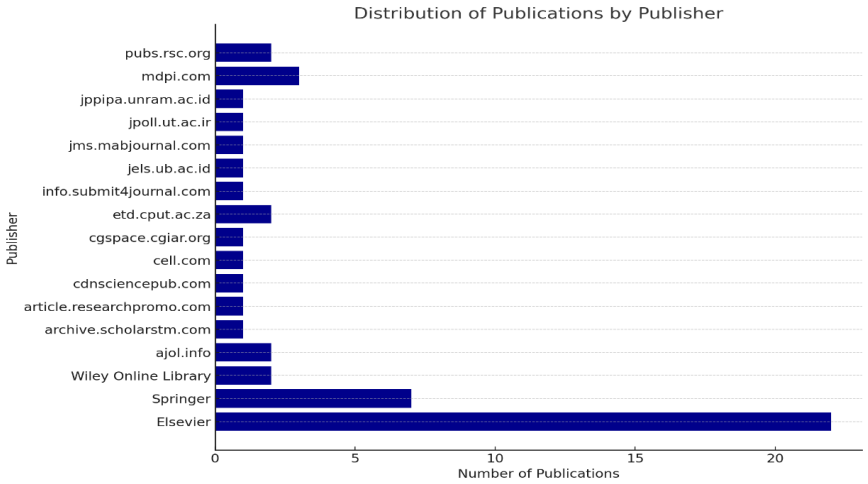

Figure 4. Distribution Of Countries That Publish Related Research

Below is a horizontal bar graph in dark blue colour showing the distribution of publications by publisher. This graph clearly illustrates the dominance of Elsevier as the main publisher with the highest number of publications, followed by Springer and several other publishers. The dark blue colour provides a good contrast, so that the comparison of the number of publications among various publishers can be seen clearly.

Springer came in second with 7 publications, which also shows an important contribution to the field, although not as large as Elsevier. Contributions from MDPI.com with 3 publications, as well as Wiley Online Library, ajol.info, etd.cput.ac.za, and pubs.rsc.org with 2 publications each, show that some other publishers also play an important role in disseminating research related to this topic.

Other publishers with only one publication, such as archive.scholarstm.com,article.resea rchpromo.com, cdnsciencepub.com, cell.com, and a few others, show that although their contributions are smaller, they are still part of the publishing landscape in this field.

The horizontal bar graph shows the distribution of publications by various publishers, clearly illustrating Elsevier's dominance in distributing research in this area. Overall, this trend shows that large publishers play a key role in disseminating scientific knowledge on the issue of microplastic contamination and river water quality, but the contribution of smaller publishers cannot be ignored.

Analysis of Publication Trends by Citation

From the data provided, it can be seen that the number of citations received by an article is an important indicator of the influence and relevance of the research in the scientific community. The article **by** T Kataoka, Y Nihei, K Kudou, and H Hinata titled "Assessment of the sources and inflow processes of microplastics in the river environments of Japan", published in 2019 by Elsevier, topped the list with 481 citations. This shows that this article is a major reference in studies related to microplastics in the river environment, especially in understanding the sources and inflow processes of microplastics.

The second highest-cited article was by M Barletta, ARA Lima and MF Costa with 357 citations. This article was also published by Elsevier in 2019 and addresses the distribution, sources and consequences of various

pollutants, including microplastics in South American estuaries. This demonstrates the high relevance of this research in the context of pollution in estuarine ecosystems.

Table 1. Publication Trends by Citation

Citation	Author's	Title	Years	Publisher	Country
481	T Kataoka, Y Nihei, K Kudou, H Hinata	Assessment of the sources and inflow processes of microplastics in the river environments of Japan	2019	Elsevier	Japan
357	M Barletta, ARA Lima, MF Costa	Distribution, sources and consequences of nutrients, persistent organic pollutants, metals and microplastics in South American estuaries	2019	Elsevier	Brazil
341	J Bayo, S Olmos, J López-Castellanos	Microplastics in an urban wastewater treatment plant: The influence of physicochemical parameters and environmental factors	2020	Elsevier	Spain
196	CJ Tien, ZX Wang, CS Chen	Microplastics in water, sediment and fish from the Fengshan River system: Relationship to aquatic factors and accumulation of polycyclic aromatic hydrocarbons by ...	2020	Elsevier	Taiwan
137	P Vasistha, R Ganguly	Water quality assessment of natural lakes and its importance: An overview	2020	Elsevier	India
129	G Zhou, Q Wang, J Zhang, Q Li, Y Wang, M Wang...	Distribution and characteristics of microplastics in urban waters of seven cities in the Tuojiang River basin, China	2020	Elsevier	China
94	NR Buwono, Y Risjani, A Soegianto	Distribution of microplastic in relation to water quality parameters in the Brantas River, East Java, Indonesia	2021	Elsevier	Indonesia
87	D He, X Chen, W Zhao, Z Zhu, X Qi, L Zhou...	Microplastics contamination in the surface water of the Yangtze River from upstream to estuary	2021	Elsevier	China

		based on different sampling methods			
73	MRM Zaki, PX Ying, AH Zainuddin, MR Razak...	Occurrence, abundance, and distribution of microplastics pollution: an evidence in surface tropical water of Klang River estuary, Malaysia	2021	Springer	Malaysia
67	G D'Avignon, I Gregory-Eaves...	Microplastics in lakes and rivers: an issue of emerging significance to limnology	2022	cdnsciencepub	Canada

Furthermore, an article written by J Bayo, S Olmos, and J López-Castellanos in 2020 with 341 citations discussed microplastics in urban wastewater treatment. This article was also published by Elsevier and showed great influence in research related to how physicochemical parameters and environmental factors affect microplastics in wastewater.

From this analysis, it is clear that the highest-cited articles are generally published by Elsevier, confirming the dominant role of this publisher in disseminating high-impact research in the field of microplastics and river water quality. Furthermore, the data shows that research on microplastics in rivers and aquatic systems is becoming increasingly important, with some articles receiving hundreds of citations in a relatively short period of time.

Other articles with lower citations (under 200 citations) still show significant contributions, especially in the context of regional studies such as in Taiwan, India, Indonesia and Malaysia. Despite fewer citations, these articles show strong relevance at the local and regional level, providing important insights into the issue of microplastics in various geographical contexts.

Overall, these citation trends indicate that research on microplastics in river water quality is in high demand and widely recognised, with a number of studies becoming important pillars in the development of knowledge in this area. Highly cited articles are generally studies that make major contributions to the understanding of microplastic processes, distribution and impacts in the aquatic environment.

Analysis of Word Occurrence in Articles

Based on the frequency analysis of word occurrence in research articles related to microplastic contamination and river water quality, it can be seen that several terms appear frequently, reflecting the main focus of current research. Terms such as "river" and "water" appeared with a high frequency of 54 and 26 times respectively, signalling that rivers and water quality are the main focus of microplastic studies. Much of this research centres on how microplastics are dispersed and affect the water quality of rivers, which are the main transport routes for microplastics from pollution sources to the ocean and other environments. In addition, the term "microplastic" appears 49 times, indicating that the study of microplastic particles is at the centre of much research, both in terms of their source, distribution and impact on the environment.

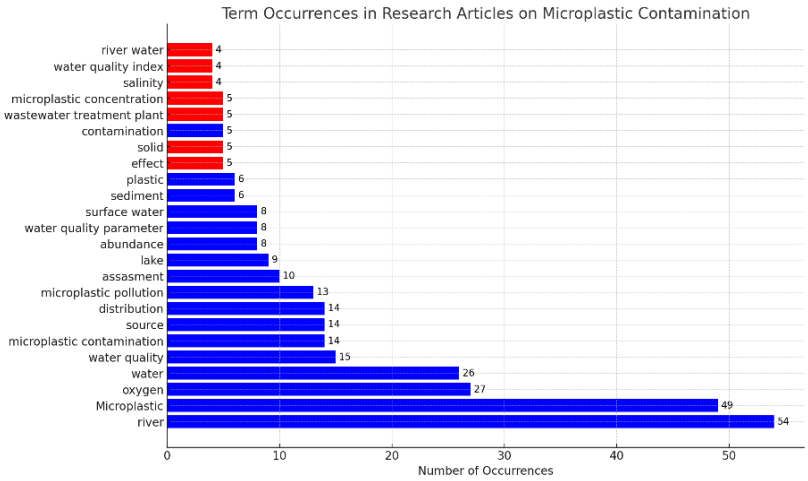

Figure 5. Distribution Of Word Occurrences In Articles

Words such as "oxygen" and "water quality" also appeared frequently, 27 and 15 times respectively, indicating that studies often explore how microplastics affect water chemistry parameters, such as dissolved oxygen levels. This is important for assessing their impact on the health of aquatic ecosystems. However, despite the dominance of these terms, there are several terms with lower frequency of occurrence, indicating research gaps that could be further explored.

Terms such as "river water" and "water quality index," which only appeared 4 times each, suggest that while river water quality is often discussed, there is room to further explore how existing water quality indices can be adjusted to more accurately reflect the presence of microplastics. In addition, "salinity," which also appeared 4 times, suggests that the relationship between salinity and microplastic distribution may be under-researched, even though this factor can influence the behaviour of microplastics in a variety of water bodies, including estuaries and the ocean.

The terms "solid" and "effect" appeared 5 times each, indicating that the interactions between microplastics and other solid particles and the long-term effects of microplastics on ecosystems still need to be explored. This reflects the need for more in-depth research to understand the combined impact of different types of particles and the possible effects at a broader ecosystem scale. In addition, "wastewater treatment plant," which also appeared 5 times, suggests that while wastewater treatment is a critical pathway to prevent the release of microplastics into the environment, the effectiveness of existing technologies in filtering out microplastics still needs further research.

Finally, "microplastic concentration" also appeared 5 times, showing that the concentration of microplastics in water, despite being an important parameter, is still relatively under-researched. The measurement of microplastic concentrations in different types of waters and how these concentrations change over time or due to human intervention is another area that needs more attention.

Overall, while research on microplastics and river water quality has progressed rapidly, there are still some under-explored areas. Terms with low frequency of occurrence, such as "river water," "water quality index," "salinity," "solid," "effect," "wastewater treatment plant," and "microplastic concentration," indicate significant research gaps. Further research in this area would be

valuable to develop more effective mitigation strategies and better environmental policies, as well as to understand the impacts of microplastics more comprehensively across different aquatic ecosystems.

Discussion of VOSviewer Network Visualisation

The network visualisation generated using VOSviewer provides a comprehensive overview of the relationships and interconnections between the various terms that frequently appear in research on microplastic contamination and water quality. This figure maps key interconnected terms, highlighting how these concepts are connected in the analysed scientific literature.

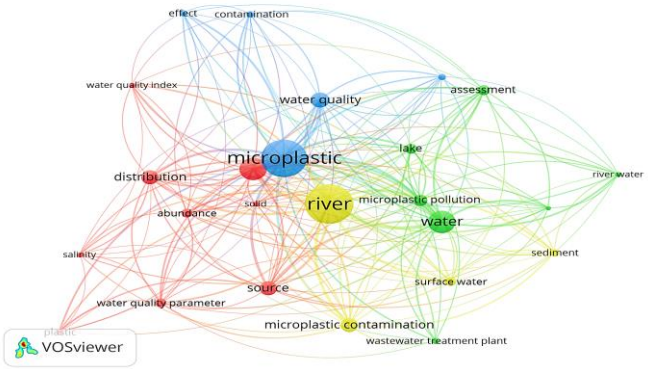

Figure 6. Network Visualisation Overview Publications

1. Cluster 1: Abundance, Distribution, Oxygen, and Others
   The first cluster, which consists of 9 items such as abundance, distribution, oxygen, plastic, salinity, solid, source, water quality index, and water quality parameter, shows the main focus on the physicochemical parameters of water and the distribution of microplastics. These terms are often used together to assess how microplastics are distributed in different water media and how they affect overall water quality. For example, oxygen and water quality index are important parameters used to measure the impact of microplastics on the health of aquatic ecosystems.
2. Cluster 2: Assessment, Lake, Microplastic Pollution, and Others
   The second cluster, with 7 items including assessment, lake, microplastic pollution, microplastics contamination, river water, wastewater treatment plant, and water, focuses on evaluating microplastic contamination in various aquatic ecosystems, such as rivers and lakes. It also covers the important role of wastewater treatment plants in managing microplastic contamination. The close relationship between lake, river water, and microplastic pollution highlights the importance of freshwater ecosystems in microplastic studies.
3. Cluster 3: Contamination, Effect, Microplastic, and Others
   The third cluster, which consists of 5 items including contamination, effect, microplastic, microplastic concentration, and water quality, shows a focus on the effects of microplastics on water quality. The terms effect and contamination indicate that research in this cluster often focuses on the negative impacts of microplastics on aquatic environments, as well as how

microplastic concentrations affect various water quality parameters.

4. Cluster 4: Microplastic Contamination, River, Sediment, and Surface Water
   The fourth cluster, which consists of 4 items such as microplastic contamination, river, sediment, and surface water, describes the relationship between microplastics and the physical environment of waters such as rivers and sediments. Research in this cluster tends to focus on how microplastics accumulate in river sediments and surface water, and their long-term impacts on ecosystems.

Through this visualisation, it can be identified that while there are strong relationships between some key terms such as microplastic, river, and water quality, there are also areas that show potential research gaps. For example, terms such as salinity, solid and water quality index, while related, suggest that research examining how salinity affects microplastic distribution or how water quality indices can be modified to reflect microplastic impacts is under-explored. Similarly, wastewater treatment plants, while important in mitigating microplastic contamination, still require further research to evaluate and improve their effectiveness.

This network visualisation from VOSviewer provides deep insights into how different concepts related to microplastics and water quality are connected to each other in the scientific literature. The clusters identified show a varied research focus, ranging from the distribution of microplastics to their impacts on water quality and ecosystems. However, the analysis also revealed significant research gaps, particularly related to aspects such as salinity, other solid particles, and the role of wastewater treatment plants in addressing microplastics. Research in these areas can make a major contribution to understanding and addressing the problem of microplastic contamination in aquatic ecosystems more thoroughly. Through this network analysis, researchers can better understand the structure of existing knowledge and direct research efforts to areas that require further exploration.

VOSviewer Overlay Visualisation Discussion

The overlay visualisation generated using VOSviewer provides a temporal overview of the development of research related to microplastic contamination and river water quality. In this visualisation, the colour of each term indicates the time of occurrence in the literature analysed, with the colour spectrum ranging from dark blue to yellow, depicting the occurrence of the term from 2021 to 2022.

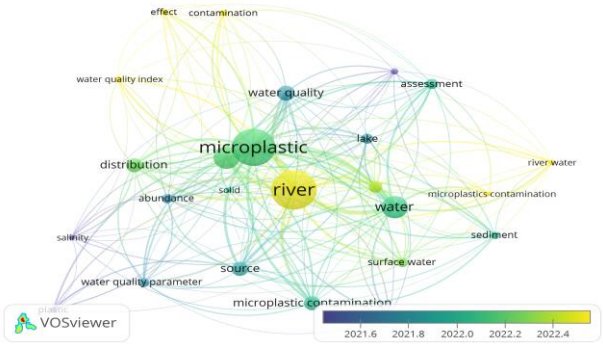

Figure 7. Overlay Visualisation Overview Publications

1. Cluster 1: Focus on Distribution and Physicochemical Parameters
2. Terms such as distribution, abundance, oxygen, plastic, and water quality parameters that belong to this cluster, tend to appear earlier in the research, with colours tending more towards blue and green. This suggests that research on the distribution aspect of microplastics and its relation to physicochemical parameters of water is a topic that is explored by researchers first.
3. Cluster 2: Evaluation and Impacts of Microplastics in Various Ecosystems
4. Terms such as assessment, lake, microplastic pollution and river water appear in this cluster and show a more varied colour from green to yellow, indicating that research in this area is ongoing and growing. Particular attention is paid to the evaluation of microplastic impacts in various freshwater ecosystems such as rivers and lakes, as well as the role of wastewater treatment plants in mitigating microplastic pollution.
5. Cluster 3: Microplastic Impacts and Concentrations
6. The terms contamination, effect, microplastic, microplastic concentration and water quality that make up this cluster tend to appear in lighter colours, indicating that research on the impact of microplastics and the measurement of their concentrations is becoming more relevant in the current literature. This indicates an increased interest in understanding the specific effects of microplastics on water quality and aquatic environments in greater depth.
7. Cluster 4: Microplastics in Sediment and Surface Water
8. In this cluster, terms such as sediment, surface water and microplastic contamination are shown in yellow, indicating that these topics are a very recent focus of research. Research on how microplastics accumulate in river sediments and surface water, as well as their long-term impacts, is receiving increasing attention in recent publications.

This overlay visualisation shows that topics related to microplastic distribution and water physicochemical parameters have long been a major focus of research, while the study of microplastic accumulation in sediments and surface water, as well as their impacts on freshwater ecosystems, is a more recent and rapidly developing area of research. This suggests that while much is understood about the distribution of microplastics, there are still significant research gaps in terms of their long-term impacts, especially in relation to sediments and surface water, which require further study.

As such, this temporal analysis not only reveals how research in this area has evolved, but also helps identify areas that require further attention. Future researchers can direct their efforts to further explore these new topics, which are still in the early stages of knowledge development.

VOSviewer Density Visualisation Discussion

The density visualisation generated using VOSviewer provides an overview of the density of occurrence of key terms in the literature addressing microplastic contamination and river water quality. In this visualisation, lighter coloured areas (yellow and red) indicate a high concentration of occurrences of certain terms in the literature, while darker areas (green and blue) indicate a lower density.

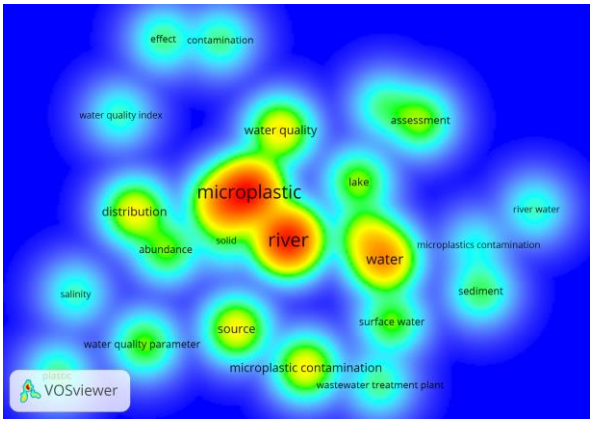

Figure 8. Density Visualisation Overview Publications

High Density: Microplastic, River, Water

Terms Such As Microplastic, River And Water Show A Very High Density, Indicated By The Bright Red Colour. This Indicates That Research On Microplastics In The Context Of River Water Is A Major Focus In The Analysed Literature. The Use Of These Terms Is Very Common, Signalling That Many Studies Are Highlighting How Microplastics Spread In Rivers And How It Affects Water Quality In General.

Medium Density: Water Quality, Distribution, Source

The Terms Water Quality, Distribution And Source Appear With Medium Density, Marked In Yellow. This Shows That While These Terms Are Frequently Used, They Are Not As Common As Key Terms Such As Microplastic Or River. Research Using These Terms Typically Focuses On How Microplastics Affect Water Quality, Their Distribution In Different Aquatic Environments, And The Source Of The Microplastics.

Low Density: Sediment, River Water, Wastewater Treatment Plant

Some Terms Such As Sediment, River Water, And Wastewater Treatment Plant Appear With A Lower Density, Marked In Green To Blue. While These Topics Are Important, The Lower Density Indicates That There Are Fewer Studies Specifically Targeting These Topics. This Could Signal A Research Gap That Could Potentially Be Explored Further. For Example, Studies On How Microplastics Interact With River Sediments Or The Role Of Wastewater Treatment Plants In Microplastic Mitigation Are Less Explored.

Very Low Density Area: Salinity, Water Quality Index, Plastic

Terms Such As Salinity, Water Quality Index, And Plastic Show Very Low Density, Indicated By The Dark Blue Colour. This Indicates That These Topics Are Still Rarely Addressed In The Existing Literature, Despite Having Great Potential For Further Research. For Example, How Variations In Salinity Affect The Behaviour Of Microplastics Or How Water Quality Indices Can Be Developed To Better Reflect The Presence Of Microplastics Are Areas That Could Be The Focus Of Future Research.

This Density Visualisation Provides Insight Into How Topics Related To Microplastics And Water Quality Are Distributed In The Scientific Literature. High-Density Terms Indicate Well-Established And Frequently Discussed Research Areas, While Low-Density Terms Signify Research Gaps That Could Be Further Explored. Researchers Can Utilise This Information To Identify Areas Poorly Covered By Previous Research And To Develop Studies That Fill These Knowledge Gaps, Particularly In The Context Of Microplastic Interactions With Sediments, The Influence Of

Salinity, And The Role Of Wastewater Treatment Plants.

CONCLUSIONS

The conclusion of the overall analysis of this article reveals how research on microplastic contamination and river water quality has evolved and indicates future research directions. Based on bibliometric analyses using tools such as VOSviewer and Publish or Perish, it was identified that the main focus of current research revolves around the distribution of microplastics in rivers and their impact on water quality. Terms such as microplastic, river and water emerged as dominant key words, reflecting the high level of scientific interest in how these tiny particles spread and alter environmental parameters.

The network visualisation and density visualisation analyses also show that, although many studies have been conducted, there are still significant research gaps. Areas such as the influence of salinity on microplastic behaviour, the interaction of microplastics with sediment, and the effectiveness of wastewater treatment plants in reducing microplastics in aquatic environments remain under-explored. Further overlay visualisations show that research on these topics is still in its infancy, especially in the context of microplastic accumulation in river sediments and surface water.

Overall, this analysis shows that while there is already a fairly in-depth understanding of the distribution and impacts of microplastics in freshwater ecosystems, further research is needed to fill in the gaps in existing knowledge, particularly in relation to the long-term aspects and complexity of interactions between microplastics and other environmental components. Thus, future research can be more focussed on these areas, which have the potential to make significant contributions to environmental management and policies related to microplastics.

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