Research, Society and Development, v. 14, n. 5, e4314548749, 2025
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v14i5.48749

Microplastics and human health: A scientometric analysis

Microplásticos e saúde humana: Uma análise cienciométrica

Microplásticos y salud humana: Un análisis cienciométrico

Received: 04/25/2025 | Revised: 05/07/2025 | Accepted: 05/08/2025 | Published: 05/11/2025

Adriana Lamanna Puga
ORCID: https://orcid.org/0000-0002-7479-4232
Universidade Federal do Estado do Rio de Janeiro, Brazil
E-mail:adrianalamanna2@gmail.com
Rossano Pecoraro
ORCID: https://orcid.org/0000-0002-1015-7744
Universidade Federal do Estado do Rio de Janeiro, Brazil
E-mail: rossano.pecoraro@unirio.br
Samira da Guia Mello Portugal
ORCID: https://orcid.org/0000-0003-3619-3679
Universidade Federal do Estado do Rio de Janeiro, Brazil
E-mail: rossano.pecoraro@unirio.br
Christina Wyss Castelo Branco
ORCID: https://orcid.org/0000-0002-0509-171X
Universidade Federal do Estado do Rio de Janeiro, Brazil
E-mail: cbranco@unirio.br

Abstract
The accumulation of plastics can be seen macroscopically in piles of plastic bottles and bags in landfills, and in a less visible way, microscopically, comprising the microplastics that are everywhere. Our main objective was to evaluate the scientific production on microplastics and human health using the Web of Science database. We focused on estimating the number of publications per year, the most relevant countries in terms of number of publications, highlights of production co-authored within countries, most cited articles, relevant journals in terms of number of publications, and the focus of studies. Seventy-two countries showed scientific production on microplastics and health revealing the importance of the topic throughout the world. The first publications on the subject occurred in Europe and more recently in the Asian countries. The largest number of articles were published by authors from China, but the most cited are from European countries, which were the first to publish on the subject. The journal that ranked first in relevance was the Science of the Total Environment that covers several aspects related to microplastics and human health. Regarding the focus of the studies, the "microplastics in food" category was the one that showed the highest number of publications. From the panorama outlined by our scientometric analysis, a significant increase in publications in recent years is highlighted, gaps are pointed, and paths suggested bettering paving studies on human health and microplastics.
Keywords: Plastic pollution; Scientometric; Scientific production; Public health; Presence of microplastics.

Resumo
O acúmulo de plásticos pode ser visto macroscopicamente, nas pilhas de garrafas e sacolas plásticas em aterros sanitários, e de forma menos visível, microscopicamente, compreendendo os microplásticos. Nosso principal objetivo foi avaliar a produção científica sobre microplásticos e saúde humana utilizando a base de dados Web of Science. Nosso foco foi estimar o número de publicações por ano, os países mais relevantes em termos de número de publicações, os destaques da produção em coautoria com outros países, os artigos mais citados, os periódicos mais relevantes e o foco dos estudos. Setenta e dois países apresentaram produção científica sobre microplásticos e saúde destacando a importância do tema em todo o mundo. O início das publicações ocorreu nos países europeus e mais recentemente nos asiáticos. Autores da China publicaram o maior número de artigos, mas os mais citados são os de países europeus cujos autores primeiro começaram a publicar sobre o assunto. A revista que ficou em primeiro lugar em relevância foi a Science of the Total Environment que aborda diversos aspectos relacionados à questão dos microplásticos e saúde humana. Quanto ao foco dos estudos, a categoria "microplásticos nos alimentos" foi a que apresentou maior número de publicações. A partir do panorama traçado por nossa análise cienciométrica, destaca-se um aumento significativo de publicações nos últimos anos, apontam-se lacunas e sugerem-se caminhos para melhorar os estudos de pavimentação sobre saúde humana e microplásticos.
Palavras-chave: Poluição plástica; Cienciometria; Produção científica; Saúde pública; Presença de microplásticos.

Resumen
La acumulación de plásticos se puede observar macroscópicamente, en las pilas de botellas y bolsas de plástico en los vertederos, y de manera menos visible, microscópicamente, a través de los microplásticos. Nuestro objetivo principal fue evaluar la producción científica sobre microplásticos y salud humana utilizando la base de datos Web of Science. Nos enfocamos en estimar el número de publicaciones por año, los países más relevantes en número de publicaciones, las colaboraciones destacadas con otros países, los artículos más citados, las revistas más relevantes y el enfoque de los estudios. Setenta y dos países presentaron investigaciones científicas sobre microplásticos y salud, destacando la importancia mundial del tema. Las publicaciones comenzaron en países europeos y más recientemente en países asiáticos. Autores de China publicaron el mayor número de artículos, pero los más citados son de países europeos cuyos autores fueron los primeros en publicar sobre el tema. La revista que ocupó el primer lugar en relevancia fue Science of the Total Environment, que aborda diversos aspectos relacionados con la cuestión de los microplásticos y la salud humana. En cuanto al enfoque de los estudios, la categoría "microplásticos en los alimentos" fue la que presentó el mayor número de publicaciones. A partir del panorama trazado por nuestro análisis cienciométrico, se destaca un aumento significativo de publicaciones en los últimos años, se identifican brechas y se sugieren formas de mejorar la investigación sobre la salud humana y los microplásticos.
Palabras clave: Contaminación plástica; Cienciometría; Producción científica; Salud pública; Presencia de microplásticos.

1. Introduction

Throughout ancient and contemporary history, countless records attest human populations changing the surrounding environment. From the use of land for cultivation, managing stones and wood to build or burn, man also walked in a more refined way, improving his well-being. Initially, men made heavy and durable objects, few of them discarded as waste. The practice of reuse was very common. In the last century, examples of this were glass bottles containing milk and soft drinks that were returnable. Nevertheless, since the Second World War, the use of plastic was intensified due to its physical resistance and long life. Unfortunately, around 1960, there was already a large accumulation of plastic items in landfills (Zamora et al., 2020). Although single-use plastic packaging contributes to the safe distribution of food, its increasing use and consequent mismanagement ended up causing serious environmental impacts (Singh et al., 2022).

The accumulation of plastics can be seen macroscopically, in the piles of plastic bottles and bags in landfills and in a less visible way, the microscopic one. The term microplastic was used for the first time twenty years ago (Thompson, 2004) and refers to plastic particles with size between 1.0 μm and 5.0 mm. They are considered as primary those present in personal care products such as exfoliants, and secondary that originated from the fragmentation of larger plastic items due to the action of Ultraviolet (UV) radiation and physical abrasion (Wagner et al., 2014). The ubiquity of microplastics is proven by finding their presence from the deepest regions of the ocean in the Marianas Trench (Peng et al., 2018) to the highest location on earth, the Mount Everest (Napper et al., 2020) and in sediments located in remote areas of Antarctica (Munari et al., 2019).

From the detection of microplastics in organisms of commercial interest such as bivalves and fish, a direct route of microplastics via food to humans was highlighted (Van Cauwenberghe et al., 2014). Thereafter, the detection of microplastics in drinking water, in various processed or unprocessed foods and in the air inside and outside homes (Koelmans et al., 2019; Kwon et al., 2020; Liu et al., 2022; Dris et al., 2017) revealed the multiple routes of microplastics into humans. Currently, three main routes are considered for the entry of microplastics in the human body, namely through inhalation, ingestion, and dermal contact (Damaj et al., 2024). Several studies have reported the presence of microplastics in the human body such as in lung tissues (Amato-Lourenço et al., 2021), in the blood (Leslie et al., 2022), in human feces (Ho et al., 2022), and in urine Pironti et al., 2022). However, to date, the possible presence of microplastics in various organs, tissues and human secretions continues to be explored (Prata et al., 2020; Montano et al., 2023; Zhang et al., 2024).

In the last years, what has been upsetting is the presence of microplastics in early stages of human life, such as in the placenta (Ragusa et al., 2021), in breast milk (Ragusa et al., 2022) and in meconium Liu et al., 2022). Even in foods such as eggs, which are offered to babies from six months onwards (Ministério da Saúde, 2019) the presence of microplastics has

already been diagnosed at a level of 11.67 ± 3.98 particles per egg (Kwon et al.,2020). Furthermore, the daily intake by children who fed only on infant formula was estimated to be approximately 49 ± 32 microplastics per day Kadac-Czapska et al., 2023).

The ongoing rising research on microplastics and human health still has many gaps, despite the efforts of several institutions and research on it. Because of this scenario, the current study aimed to conduct a scientometric review on the theme microplastics and human health. Scientometric is the study of quantitative aspects of science as a discipline or economic activity that involves quantitative studies of scientific activities, including publication and, therefore, overlapping with bibliometrics and are being applied in various fields of research (Macias-Chapula et al., 1998; Yitao et al., 2022). Through scientometric analysis, it is possible to predict trends in the area of research as well as which are the world leaders in a given field of study (Sharma et al., 2022).

Our main objective was to evaluate the scientific production on microplastics and human health through a survey of articles using the Web of Science database. We focused on estimating number of publications per year, the most relevant countries in terms of number of publications, highlights of production co-authored with other countries, most cited articles worldwide, most relevant journals in terms of number of publications and focus of studies. From the panorama outlined by the scientometric analysis, gaps are highlighted, and paths suggested to better paving studies on human health and microplastics.

2. Methodology

Scientific articles on microplastics and human health were extracted from Web of Science, a database that has received international attention due to its high quality and use by researchers around the world (Li et al., 2022). The search on Web of Science Core Collection (WoS) followed the pattern using in the “Topic” field, the keywords “microplastic*” AND “human health”. The language chosen was English and the types of documents were Articles, Review Articles, Early Access, Book Chapters. Conferences were not considered. The search time was from the first occurrence in Web of Science to July 20, 2023. The raw data was retrieved in plain text format from the WoSCC database and mapped using VOSviewer and the R tool Bibliometrix package, which provides a set of tools for quantitative research in bibliometrics and scientometrics (Aria & Cuccurullo, 2017).

The search yielded 1492 articles in WoS, from which after a first screening based on reading the abstracts resulted in 840 documents. Subsequently, in a second selection phase, still based on reading the article summaries, 369 documents were considered suitable for the research objective. These last were fully read, and downloaded using the “Export” option in the “Format” “BibTex”. After, in the “Record Content” session, the option chosen was “Complete Registration” and finally obtaining the data in “.bib” format. Data in “.bib” format were used for analysis in the Bibliometrix package.

The VOSviewer software allows to visualize all data through the formation of maps where the nodes formed correspond to the number or frequency and the lines between the nodes correspond to the associations between them (Gao et al., 2019). The Co-authorship Analysis settings, the unit used was “Countries”. The maximum number of countries per document was 25. In the Counting Method, the option was “Full Count”. In the “Maximum Number of Countries per Document” field, it was 25. In the "Choose Thresholds" step, the minimum number of documents for a country was 5. The "Minimum Number of Citations for a Country" setting was 0. Of the 72 countries, 29 met the thresholds. The number of countries that were selected was 29. Some of the 29 items in the network formed were not connected to each other. The VOSviewer software reported that the largest set of connected items in the dataset used consisted of 28 items. The "Yes" option was then chosen to "Show this set of items instead of all items".

For the type of “Co-occurrence Analysis” the unit was “All keywords” in “Counting method” the option chosen was “Full count”. In the “Minimum number of occurrences of a keyword” field, 5 was used. Of the 1591 keywords, 150 reached

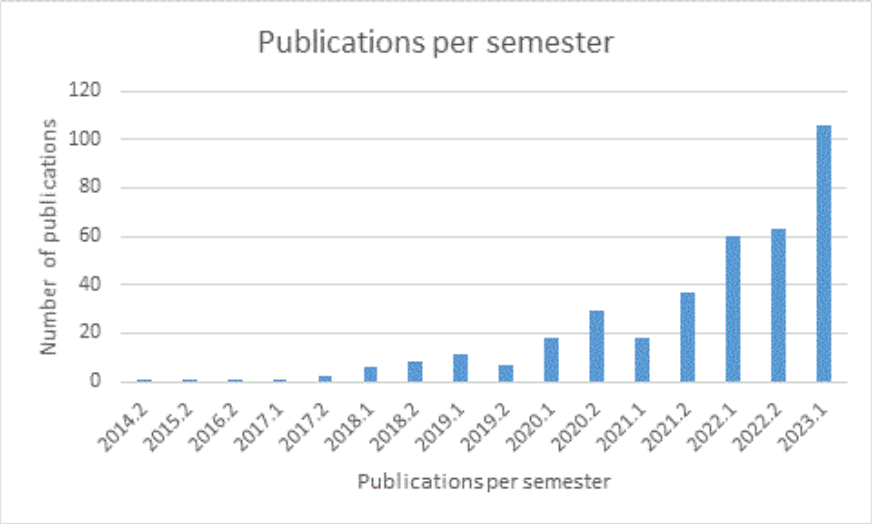
the limit. In the “Number of keywords to be selected” field, the value of 150 was used. In “Network View” the option chosen in “Weights” was “Links”. In “Overlay visualization” in the “Weights” field, “Links” was chosen and in “Score” “Avg. Pub. year" was used.

3. Results and Discussion

3.1 Temporal production of articles

Considering a temporal line, the issue microplastics and health is recent regarding publications (Figure 1). Ten years ago, the topic was few explored but in the last years a tendency for continuous growth on the subject is evident. The first article was published in 2014, corresponding to the study of Van Cauwenberghe & Janssen (2014) that would be considered years after as the second most cited article in the world. This publication described the presence of microplastics in seafood for human consumption and showed the beginning of the attention on human consumption of microplastics via food. In mid-2018 there was an increase in the number of publications reaching a maximum value of 106 publications in the first half of 2023 when the time frame of this study ends.

Figure 1 - Articles published by semester from 2014 (first occurrence of publication).

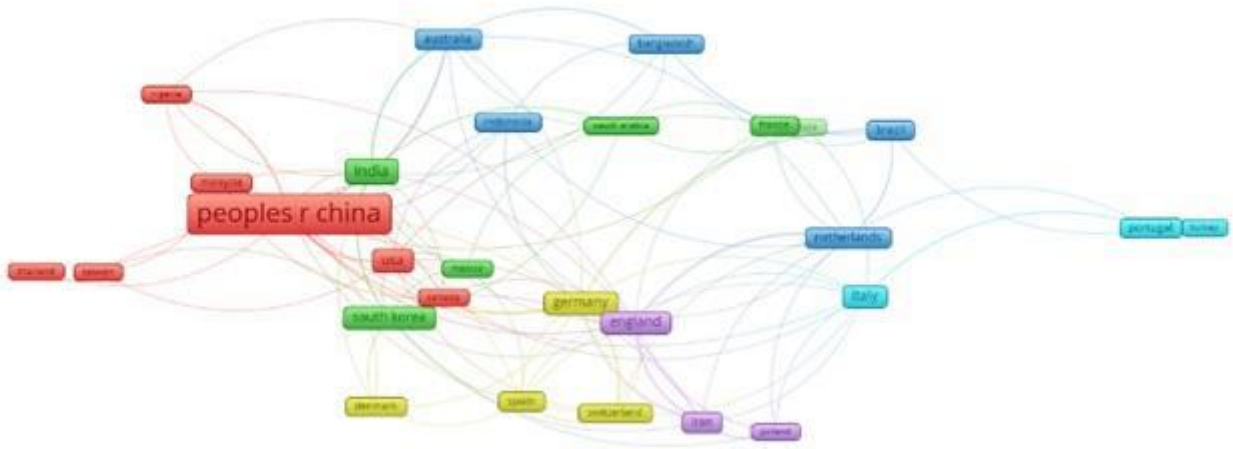


Source: Authors.

3.2 Geographic and temporal distribution of publications on microplastics and human health

Seventy-two countries have researchers publishing on microplastics and health highlighting the threat of these particles and associated compounds for environments, wildlife and humans throughout the world (Ziani et al., 2023). Among them, research connections occur mostly among 28 countries (Figure 2). The VOSviewer plotting shows the countries that most published and the connection within them. The comparison within number of productions is revealed by the size of the rectangles. Six main clusters (sets) were comprised by countries that had the greatest co-authorship networks, which have similar colours. The largest number of articles was published by authors from China that was included in a cluster (red) with Thailand, Taiwan, Nigeria, Malaysia, USA and Canada. Linked to this first cluster there is another one, comprised by Mexico, India, Saudi Arabia, France and South Korea (green cluster) in which a larger production of the two latter is shown. A third cluster (yellow) included countries such as Germany, Spain and Denmark, with the first being the most productive. England, along with Iran and Poland, showed a connection by clustering (lilac cluster). Italy appeared in the same cluster as Portugal and Turkey (light blue) and, finally, Brazil was related to the Netherlands (dark blue cluster).

Figure 2 - Main groups (clusters) formed according to the number of publications by countries and co-authorships between them (Generated by VOSviewer software).



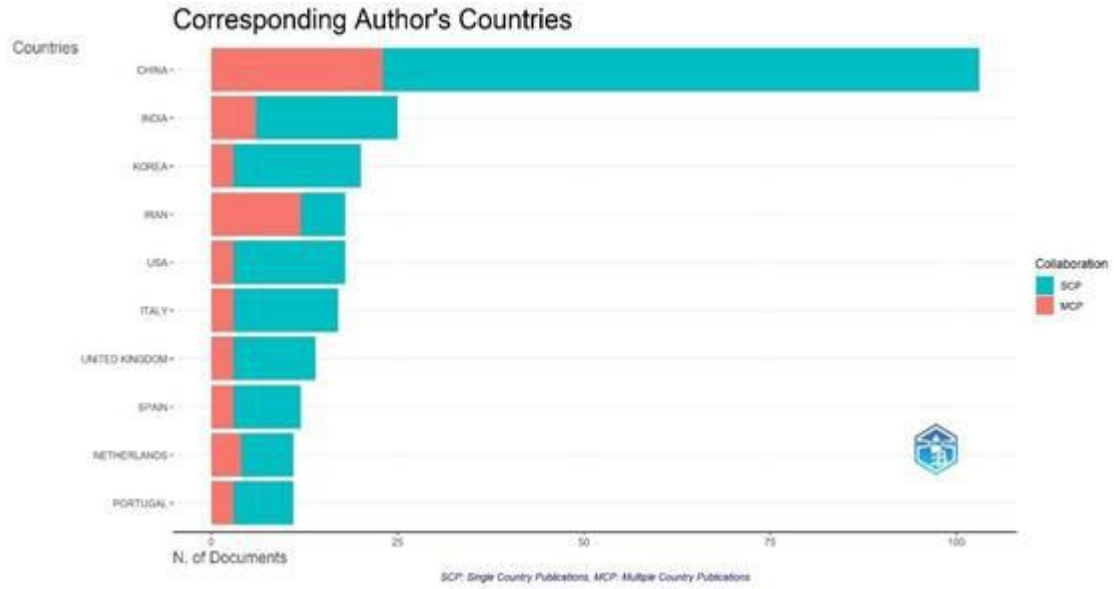
Source: Authors.

China is increasingly involved in global health issues, and the number of publications increased from 2014 to 2020. In 2022, China published the highest number of scientific articles (Lattu, 2023), and its co-authorships with other countries in Asia and Africa can infer a regional scientific partnership. Meanwhile, our results revealed north-to-north partnership regarding research on microplastic and health since China the most productive country was mostly related to North America countries. Some factors may have driven China's prominence in publications, such as new policy on Science and Technology. This new government approach has been taking place since 1978 in the so-called “Experimentation Phase” and was extended with the establishment of strategic targets for revitalization in the educational and scientific fields (OECD, 2007). The other element that favoured the Chinese scientific productions was the increase in publications in English, which gave greater visibility to its studies to more researchers around the world (Wang, 2016).

In Latin America, Brazil stands out in terms of the number of publications on according to a review carried out by Kutralam-Muniasamy et al. (2020). In this study on current trends and advances on microplastic contamination in the context of Latin American countries, it was reported that among the 78 studies reviewed by the authors, Brazil presented the majority with 27 articles.

Based on the corresponding author's link, ten countries were considered most relevant in terms of published articles (Figure 3). China presented the largest number of documents published in the “SCP” category that is with authors with affiliations from the same country reaching the value of 80 articles and 23 articles published in the “MCP” category. That is, publications with the inclusion of at least one author from a country other than the corresponding author. Among other countries, Iran stands out for having comparatively fewer external co-authorships.

Figure 3 - Production of the top 10 countries taking into account the country of affiliation indicated by the corresponding author of the publication. SCP = indicates publications with only authors from the same country. MCP= indicates publications with authors from several countries (Generated by Bibliometrix package).



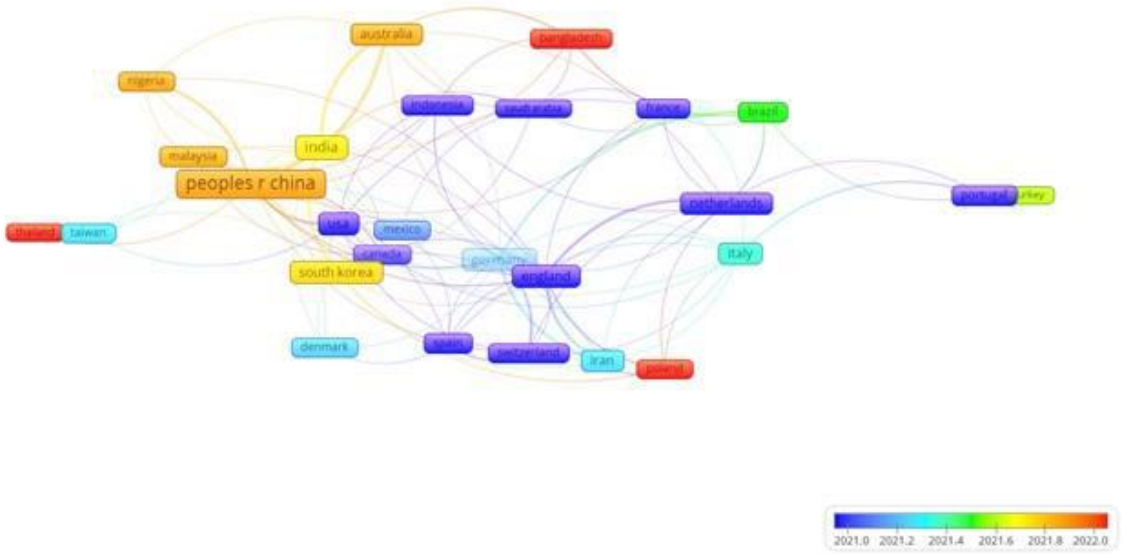
Source: Authors.

Through the results the analysis of the number of articles published per year per country, a relatively short timeline can be seen. The beginning of publications on microplastics and health occurred in European countries and more recently in Asian countries, such as Thailand and Bangladesh (Figure 4a). The temporality among countries regarding the increase in production and co-authorship, is shown by the different colours. The red colour are in countries that have most recently published on the subject, such as Thailand, Bangladesh and Poland. The co-authorship network analysis reinforces the China recent prolific production, as other countries connected with it in the cluster (orange).

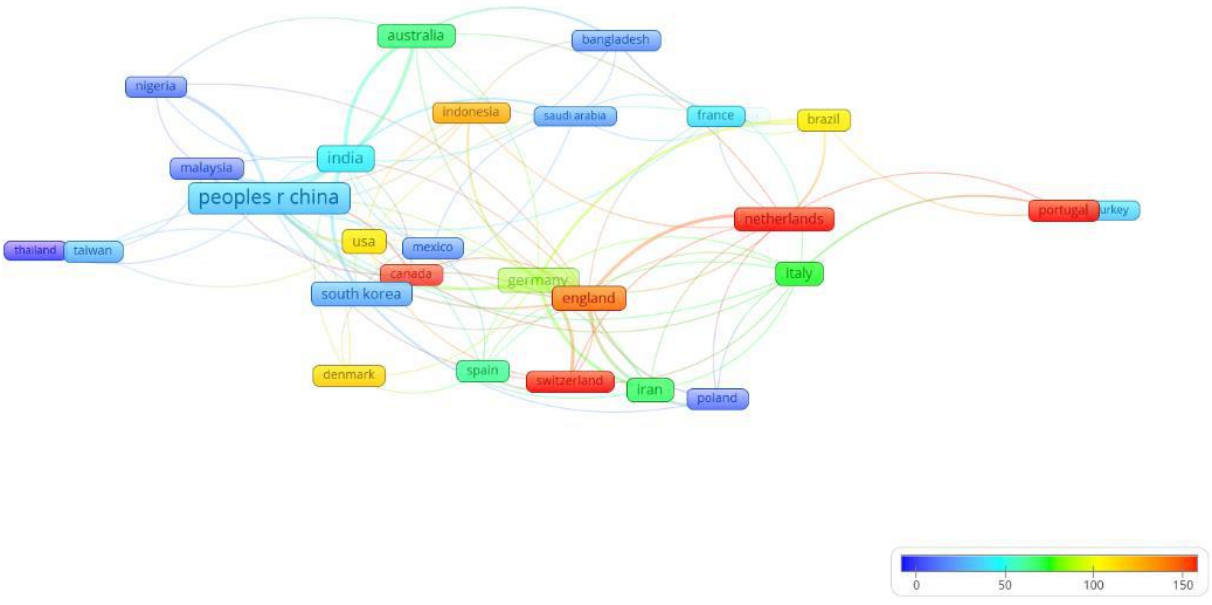
However, in terms of citation, the tendency differs, with the countries firstly published articles with the subject being those with the most cited articles, such as Portugal, the Netherlands, Switzerland and Canada (Figure 4b). Secondly, in terms of cited papers are England, Indonesia, Denmark, USA and Brazil. China, India and South Korea, despite high number of publications, attained lower citations numbers. The impact of publications is just one measure of a country's scientific prowess, and in 2022, China has slightly edged out (27.2%) the United States (24.9%) in the number of most cited papers according to a Japanese science policy institute (Brainard & Normile, 2022).

Figure 4 - Analysis of article production and co-authorship linkage being (a) timeline articles published per country (b) average number of citations per country (Generated by the VOSviewer software).

a)



b)



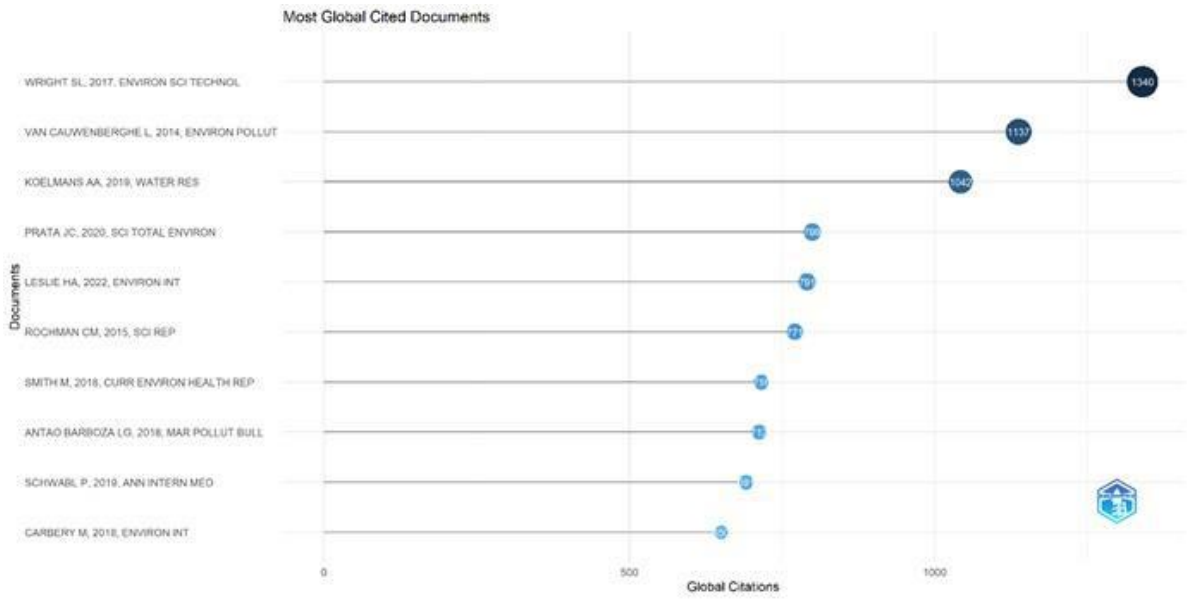
Source: Authors.

3.3 Most cited articles globally

The better country's position in terms of the number of citations is explained by the widely cited articles. Among the ten mostly cited articles (Figure 5) (Frame 1), three are with more than one thousand citations. These are from England (1340), Belgium (1137) and Netherlands (1042 and 791). Despite the highest number of publications showed by China, no publications linked to authors from China were among the ten most cited documents globally.

The most cited article (1,340 citations) was the one conducted by Wright & Kelly (2017) in which the human exposure to microplastics was addressed in a review study. The objectives were to address the routes of exposure to microplastics through food and inhalation, the absorption and translocation of microplastics, and, finally, the potential risks to human health. The second most cited article (1,137 citations), was authored by Van Cauwenberghe & Jansen, (2014) and refers to the presence of microplastics in seafood of commercial importance to human consumption. The objectives of the study encompass the transfer of microplastic particles to humans through the food chain as well as the food safety. The third most cited article, conducted by Koelmans et al., (2019) (1,042 citations), was a review of data available in the literature regarding the analysis of microplastics in drinking water and freshwater sources. The main targets included to measure concentrations of microplastics in water samples, determining particle size and shape, and the analytical quality assurance of the studies evaluated.

Figure 5 - Most cited documents globally, with respective numbers of citations until July 2023 (Generated by Bibliometrix package).



Source: Authors.

Frame 1 - The ten mostly cited publications.

Rank	Article Title	Author, Year, Journal	Country	DOI	Total citations WOS Core Collection
1ª	Plastic and human health: A micro issue	Wright, S.L., 2017, Environmental Science & Technology	England	10.1021/acs.est.7b00423	1340
2ª	Microplastics in bivalves cultured for human consumption	Van Cauwenberghe, L., 2014, Environmental Pollution	Belgium	10.1016/j.envpol.2014.06.010	1137
3ª	Microplastics in freshwaters and drinking water: Critical review and assessment of data quality	Koelmans, A.A., 2019, Water Reseearch	Netherlands	10.1016/j.watres.2019.02.054	1042
4ª	Environmental exposure to microplastics: An overview on possible human health effects	Prata, J.C., 2020, Science of the Total Environment	Portugal	10.1016/j.scitotenv.2019.134455	799
5ª	Discovery and quantification of plastic particle pollution in human blood	Leslie, H.A., 2022, Environment International	Netherlands	10.1016/j.envint.2022.107199	791
6ª	Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalvels sold for human consumption	Rochman, C.M., 2015, Scientific Reports	USA	10.1038/srep14340	771
7ª	Microplastics in seafood and the implications for human health	Smith, M., 2018, Current Environmental Health Reports	USA	10.1007/s40572-018-0206-z	716
8ª	Marine microplastic debris: An emerging issue for food security, food safety and human health	Barboza, L.G.A., 2018, Current Environmental Health Reports	Portugal	10.1016/j.marpolbul.2018.05.047	712
9ª	Detection of various microplastics in human stool: A prospective case series	Schwabl, P.,2019, Annal of Internal Medicine	Austria	10.7326/M19-0618	691
10ª	Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health	Carbery, M.,2018, Environment International	Australia	10.1016/j.envint.2018.03.007	650

Source: Authors.

Seven articles follow the list of the most cited, with citations between 650 and 779. The authors are from England, Belgium, Netherlands, Portugal, USA, Austria and Australia. The literature review carried out by Prata et al., (2020) addressed the effects of microplastics on humans since their recognized omnipresence in several natural environments. The authors focused on the difficulty involved in analyzing samples from human materials, due to a set of rules involved in this type of study. This limitation impairs drawing conclusions on the effects that the exposure to microplastics can have on human health. Leslie et al., (2022) aimed to measure the main types of polymers present in human blood samples, and in various products to which human beings come into contact daily. A great emphasis was on the methodology carried out and importance of the care taken along all analytical procedure to avoid contamination of samples.

The study carried out by Rochman et al., (2015) emphasized the importance of identifying the presence of plastic debris and textile fibers in organisms used for human consumption, such as fish and bivalves. Smith's et al., (2018) addressed the ubiquity of microplastics reaching several organisms, including those used for human consumption such as seafood. This study included the history of microplastics, information about their dispersion, and the new approaches regarding microplastics and their possible toxicity. In the review conducted by Barboza et al., (2018), evidence on the presence of microplastics in the marine environment was highlighted, involving food security and its challenges, and gaps in studies.

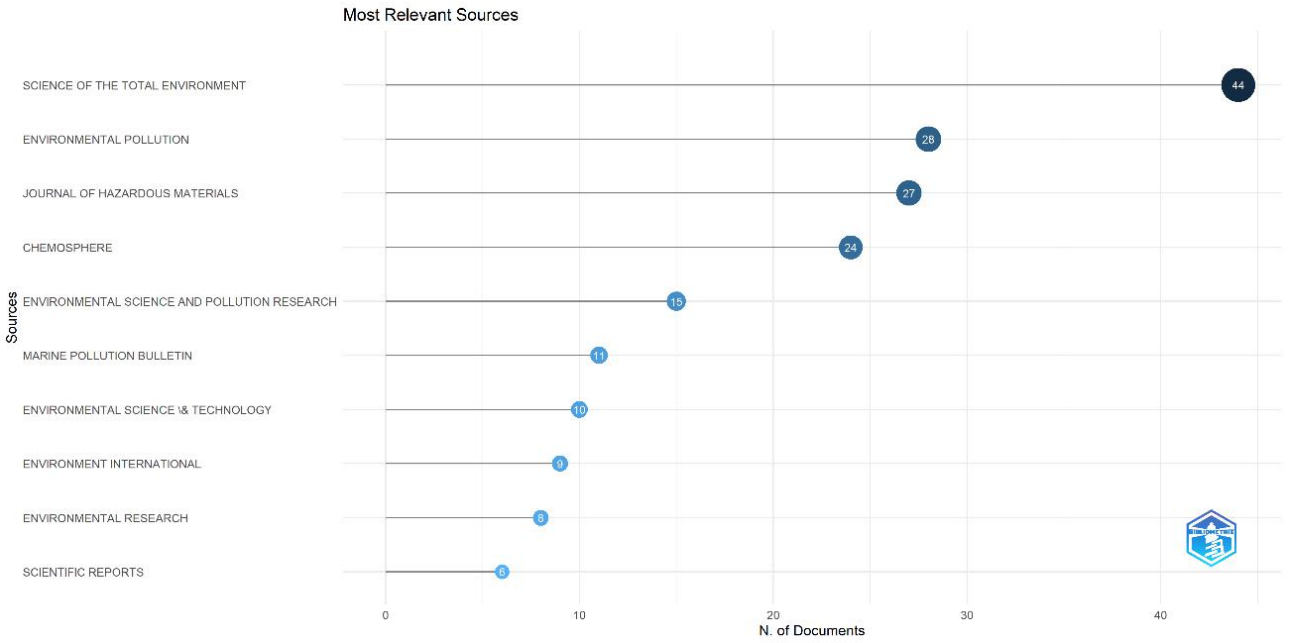
The objective of the research of Schwabl et al., (2019) was to identify microplastics in human feces, verifying whether there is involuntary ingestion of them. In this study, microplastics were found in all samples and the authors characterized the types of polymers present. In the review carried out by Carbery et al., (2018), the objectives were to discuss the implications of a high diet including seafood with microplastics and mixed contaminants to the human health. The authors further discussed the fate of microplastics in the marine environment, factors influencing ingestion, and trophic transfer of microplastics and chemical contaminants.

3.4 Most relevant journals

One of the most important aspects of publications process is the choice of a suitable journal that is likely to accept the authors' research, and in which colleagues will easily access, advancing knowledge and encouraging communication between groups (Ramia, 2023). The selection of a journal for new topics can be a challenge since there are a high number of academic peer-reviewed English language journals being 30,000 classified under Medicine and Health (Suiter & Sarli, 2019) . However, submitting articles to journals that have already published on the topic is a common procedure.

Considering the ten most relevant journals in relation to the number of articles published on the theme microplastic and health (Figure 6), stood out the journal Science of the Total Environment (STOTEN). This journal has the feature of being a multidisciplinary and international journal that includes research connections between environment and human health. STOTEN has an open access publication fee and as the possibility of subscription, in which articles are available to subscribers, developing countries and groups with no open access publication fee. The impact factor according to the journal's website (https://www.sciencedirect.com/journal/science-of-the-total-environment, accessed on 12/23/2023) indicated 9.8.

Figure 6 - Most relevant journals publishing articles on microplastics and human health (in number of articles published until July 20, 2023 (Generated by Bibliometrix package).



Source: Authors.

The second journal highlighted by our study was the Environmental Pollution, a journal that addresses issues related to environmental pollution and consequences for ecosystems and human health. The journal has a fee for the open access, and has the possibility of subscription. The impact factor according to the website (https://www.sciencedirect.com/journal/environmental-pollution/, accessed on 12/23/2023) was 8.9.

The third journal highlighted was the Journal of Hazardous Materials with articles focusing on the areas of Science and Environmental Engineering and with the problems that certain materials can cause on human health and the environment. The journal has a fee for the open access, and has the possibility of subscription. The impact factor according to the website (https://www.sciencedirect.com/journal/journal-of-hazardous-materials, accessed on 12/23/2023) indicated 13.6.

The fourth journal was Chemosphere, a multidisciplinary journal that addresses the issue of chemicals, their fate, their remediation, and environmental effects. The journal has a fee for the open access, and has also the possibility of subscription. The impact factor according to the website (https://www.sciencedirect.com/journal/chemosphere, accessed on 12/23/2023) was 8.8.

The fifth journal highlighted was Environmental Science and Pollution Research, a hybrid journal in which a fee is necessary for the open access choice. This journal focuses on the theme within Environmental Sciences including issues relating to laws and regulations in relation to pollution. The impact factor according to the consultation carried out on 12/23/2023 on the website https://link.springer.com/journal/11356 indicated the value 5.8.

The sixth journal underscored was Marine Pollution Bulletin that has focus on issues of marine resources, topics related to effluent disposal, pollution and protection of the marine environment. As others above, this journal offers an open access publication fee and as possibility of subscription, in which articles are available to subscribers, developing countries and patient groups with no open access publication fee. The impact factor according to the website https://www.sciencedirect.com/journal/marine-pollution-bulletin, accessed on 12/23/2023) was 5.8.

The seventh journal highlighted by our study was Environmental Science & Technology, a multidisciplinary journal focusing on environmental science and technology. This Journal has as motivation contributions that drive political changes aimed at new decision-making in environmental terms. It is a paid open access journal. The impact factor according to the website (https://pubs.acs.org/journal/esthag, accessed on 12/23/2023) was 11.4.

The eighth journal underscored was Environment International, another multidisciplinary journal that covers the field of Public and Environmental Health Sciences. This journal includes other research topics such as environmental epidemiology and environmental technology for environmental health protection. It is a paid open access journal. The impact factor according to the website (https://www.sciencedirect.com/journal/environment-international, accessed on 12/23/2023) was11.8.

The ninth journal in the list was Environmental Research that also has the characteristic of being multidisciplinary and covering environmental disciplines, and focusing on environmental applicability in the real context in which we live. The journal has a fee for the open access, and has the possibility of subscription. The impact factor according to the website (https://www.sciencedirect.com/journal/environmental-research, accessed on 12/23/2023) was 8.3.

The tenth journal highlighted by our study was Scientific Reports, which presents articles belonging to all areas of natural sciences, psychology, medicine and engineering. It is an open access journal with fee payment. The impact factor according to the website (https://www.nature.com/srep/abouhe, accessed on 12/23/2023) was 4.6.

Among the ten journals that published mostly on microplastic and health, at first place was STOTEN (IF=9.8) that was not the journal with the highest impact factor. Impact Factor (IF) was formulated to evaluate the importance of a given journal based on the citations of the articles contained therein, and to make comparisons within a given field of knowledge in relation to existing journals According to Hauptman (2016). On the other hand, the impact factor can be an important metric for evaluating the production of students and researchers, and in selection processes for scholarships and professional admission examinations. So, academics' careers can be significantly influenced by the academic journal in which they choose to publish their research (Rowley et al., 2020).

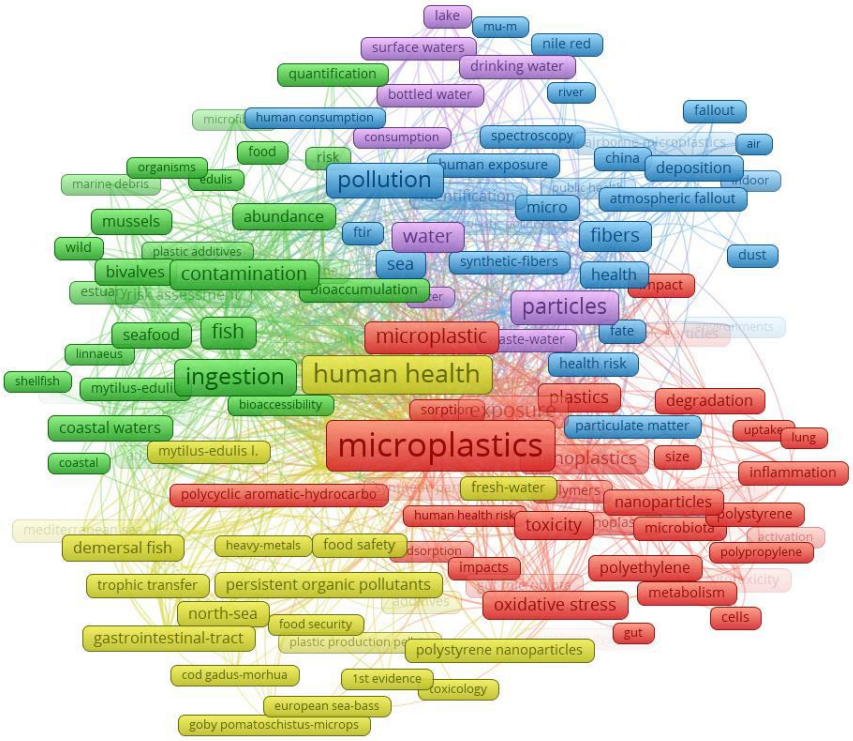
3.5 Main focuses of studies on microplastics and human health

Analyzing the focuses of the articles considering the authorship links, we started with the keywords. From the quantitative aspect of the mentioning of keywords (Figure 7a), we can observe that the word "microplastics" is in a group separate from the duo "human health". Microplastics were firstly associated with types of polymers, particles, uptake, absorption impacts and human health risks, among others. Differently, human health was linked to seafood, food safety, and, like other pollutants, to trophic transfer. Another cluster refers to the contamination of fish and bivalves in coastal waters. In another group, pollution, physical and analytical aspects. In a smaller group, particles, and water, associated with human consumption, surface and bottled water. Aspects relating to human health in all groups formed. All these results show a parallel growth of the subjects microplastics and human health.

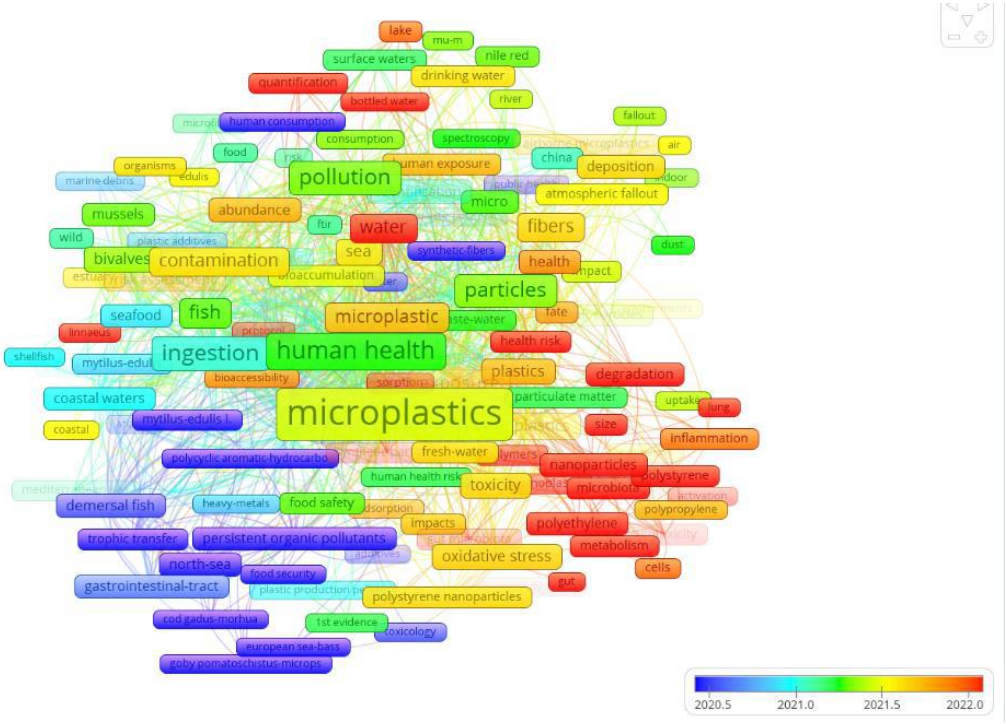
Considering the "All Key Words" (Figure 7b), research growing can be observed in the time delimited by this study. This growth started with marine biota (purple cluster), going to coastal waters and seafood (light blue cluster), and then an increase in titles relating to pollution and contamination (light green and yellow respectively), and, finally, the cluster with most recently used words (red and orange cluster). Both human health and microplastics have been used more after 2021, with recently mixing titles involving water, quantification, types of polymers and health risk (red), inflammation and cells (orange).

Figure 7 - Keyword analysis of articles and co-authorship linking in quantitative (a) and temporal (b) terms (Generated by the VOSviewer software).

a)



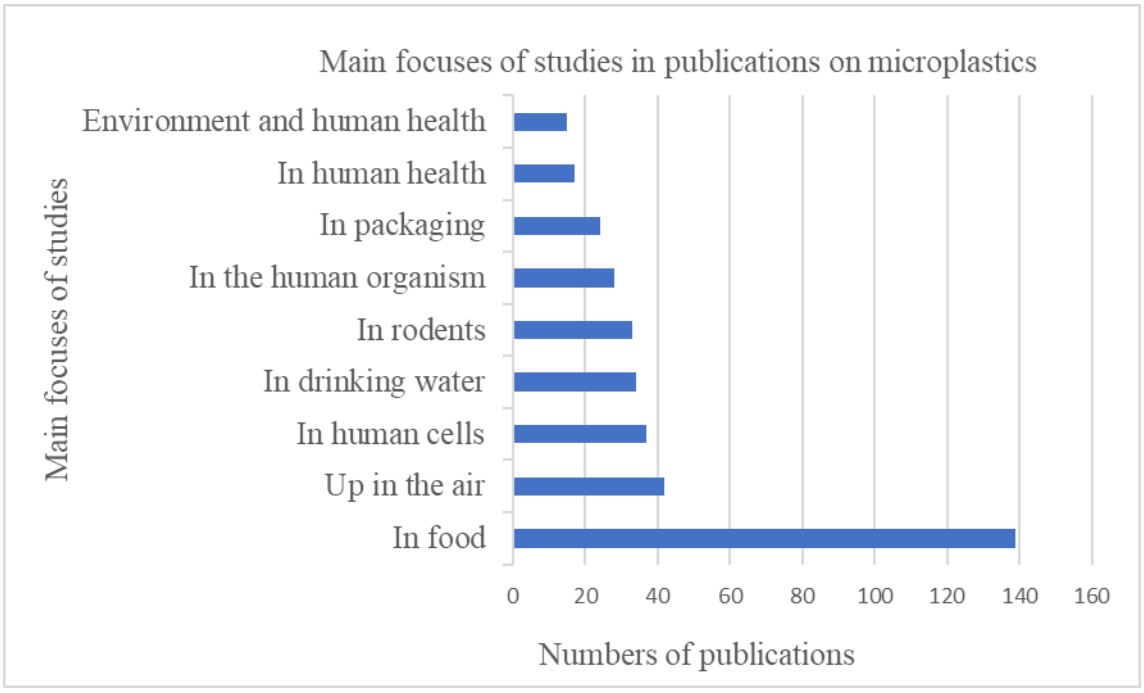
b)



Source: Authors.

The articles selected by the present study were further grouped according to their focus of the research. From these, nine groups of study focus were arranged (Figure 8). A greater number of studies targeted research on "microplastics in food". They encompass studies of several kinds of food, from seafood as shellfish and mussel to processed food items. For example, the study conducted by Makhdoumi et al., (2023) investigated microplastic contamination in the most common salt and sugar brands consumed in Iran, verifying potential risk to human health. In this study, the authors found an average quantity of 55.2 ± 43.7 microplastics/kg in different brands of salt and 57.7 ± 20.6 microplastics/kg in different brands of sugar. The same authors Makhdoumi et al., (2023) explain that the salt and sugar production process can contribute to a greater number of microplastics in the form of fragments than in the form of fibers, for example. The importance of this fact is that the format of microplastics can differ in terms of their fate and toxicity to human health.

Figure 8 - Main focuses of studies in publications on microplastics.



Source: Authors.

Hence, other studies focused on the environment (air), packaging and water, and in human cells and organs, and to a lesser extent on human health and on environment and health. The review conducted by Kacprzak et al., (2022) aimed the study of microplastics in the air, and discussed features of microplastics present in indoor environments. According to those authors, these are important places for human exposition since are where most people spend most of their time. Furthermore, the authors discuss possible methods to help reduce exposure to microplastics in indoor environments, such as the use of air filtration systems, but reinforce that they are not a solution to the problem. Still regarding microplastics in the air, the study of Prata (2018) centred on airborne microplastics that, through inhalation, can cause problems in the respiratory system and highlighted the importance to include identification and quantification of microplastic fibers in human lung tissue biopsies.

Another group of articles comprised the category "microplastics in human cells" with studies using human cell lines in *in vitro* experiments (INMETRO, 2018). An example of the articles belonging to this category is the research of Park et al., (2023) in which human breast cancer cell lines were exposed to fragment-shaped polypropylene microplastics. The authors suggested that such exposure would contribute to breast cancer metastasis. A study conducted by Schirinzi et al., (2017)

considered the cytotoxicity of microplastics and nanoplastics in human epithelial and brain cells. The authors mentioned that the use of the *in vitro* technique in recent years is a higher-yield form of experimentation when compared with in vivo tests.

Among the articles focusing on "microplastics and drinking water" is the research of Buyukunal et al., (2023) that analysed drinking water samples collected in natural spring water, natural mineral water and tap water in Istanbul, Turkey. The authors found that at least 63.6% of the drinking water analysed contained microplastics, being the average number found in tap water, mineral water and natural spring water, respectively, 188±81, 54 ± 19, and 89±76 microplastics per litre. Regarding the same issue, Cox et al., (2019) suggested that avoiding the consumption of bottled drinks can reduce exposure to microplastics, emphasizing that they will continually be identified in items for human consumption.

The studies categorized as "microplastics in rodents" included most experimental research on the toxicity of microplastics. In the article of Danso et al., (2022) , for instance, rats were exposed to three types of microplastics, and cellular responses and histopathological analysis were then evaluated. The authors suggest that exposure to polystyrene and polypropylene microplastics could contribute to lung inflammation. Also in this category, the study conducted by Rodríguez Yunta (2007) dealing with the use of animals in scientific medicine, highlighted that experimentation and observation using animals is based on taking them as a miniature of problems in humans. However, compared to other contaminants, experimental research into the effect of microplastics on mammals is still scarce.

Studies that have attracted a lot of attention from the scientific community and have been publicized on social media and in widely circulated newspapers are in the category of "microplastics in the human body". They included research to detect the presence of microplastics in specific materials from the human body or structures such as in faeces (Ho et al., 2022), human lung tissue (Amato-Lourenço et al., 2021), in human blood (Leslie et al., 2022), human semen (Montano et al., 2023), and others. The detection of microplastics in placenta (Ragusa et al.,2021) has been widely reported by social medias (Carrington, 2024). In the review conducted by Li et al., (2023), a potential influence of microplastics on the development of colorectal cancer was suggested since microplastics could cause damage to the protective mucus barrier in the colon. In another study, Liu et al., (2023) detected microplastics in several human samples such as placentas, meconium, infant faeces, breast milk and infant formula. Yan et al., (2021) investigated possible differences in the characteristics of faecal microplastics in patients with inflammatory bowel diseases and healthy individuals. The authors found higher concentration of microplastics in patients with inflammatory bowel diseases than in healthy individuals, suggesting that patients with inflammatory bowel diseases suffer somehow greater exposure to microplastics in the gastrointestinal tract. In the review carried out by Patil et al., (2022), microplastics were suggested as potential causes of toxicity that will affect the cardiovascular system, possibly developing oxidative stress and interaction between microplastics and cellular components.

The "microplastics in packaging" category presented studies with attention to plastic components in everyday human life. The research conducted by Chen et al., (2023) reported microplastics released from paper cups coated with PE (polyethylene), PP cups (polypropylene) and PS cups (polystyrene) that attained average amounts, respectively, of 2,718; 2,720 and 2,629 particles per liter. The size of the detected microplastics was between 5 and 10 μm with few microplastics larger than 50 μm. On the other hand, Kadac-Czapska et al., (2023) highlighted the importance of understanding the degradation process of plastic material packaging to determine the influence and negative consequences of such waste on the environment, and on both animal and human health.

Addressing the subject "microplastics and human health" are research efforts dealing with the effects of microplastics on human health. These studies are still comparatively fewer in number, maybe due to several gaps that still exist, such as methodological constraints for the analysis and quantification of microplastics in human components and their tested effects on health. In a pioneering study, Willert et al., (1996) showed tissue responses to plastic and metal wear products used in joint prostheses. Those authors found reactions where polyester was used, and the number of particles phagocytosed by the tissue

near the prostheses was very high in most of the cases analysed. They also characterized the presence of polyester as a cause of granuloma formation and a high tendency to necrosis. In the study carried out by Patil et al., (2022), the current situation of pollution related to microplastics, their life cycle, effects on organisms and risk assessment for human health were reviewed. The authors highlighted the ways by which microplastics enter into the human body, through inhalation, ingestion through foods and water, and then the potential effects on various organs. In another systematic review, Krishnan (2023) emphasized that although studies using *in vivo* and *in vitro* animal models help to understand the impacts of micro and nanoplastics on human health, more research is needed to improve detection and quantification methods of micro-nanoplastics in human samples. Regarding the effects of microplastics on human health, the study by Wang et al., (2023) suggests that microplastics can not only promote the proliferation of skin tumor cells but also affect normal skin cells. The microplastic and tumor link has also been suggested by Park et al., (2023) that discussed microplastics aggravating breast cancer metastasis. From another aspect, the study conducted by Zarus et al., (2023), showed evidence of the effects of microplastics on health due to exposure in the workplace. The effects of substances added to plastic materials such as Bisphenol A on the human body were explored by Lang et al., (2008) that indicated that higher concentrations of Bisphenol A were related to cardiovascular disease and diabetes.

In the "environment and health" category, a comparatively smaller number of studies was found. Among them, is the study conducted by Hossain et al., (2020) that highlights the few efforts made to quantify microplastics in freshwater systems such as in Bangladesh. The authors further emphasized the impact of microplastics on soil and on plants, potentially causing a risk to food security and a consequent compromise of the economy of the entire country. The challengers' issues reported by Hossain et al., (2020) regarding the control and quantification of microplastics are of utmost importance since annually in the world, around 360 million tons of plastics are produced and only around 7% is recycled, therefore occurring an accumulation of plastic waste in the environment (Kadac-Czapska, et al.,2023).

4. Conclusion

This study shows microplastic and health as a hot topic for research and with an increasing tendency of new publications coming from several countries throughout the world. China stood out as the most productive county in numbers of studies, showing a wide network of publications co-authored with other countries. Other Asian countries showed a recent tendency to increase in numbers of publications on microplastic and health. Despite being China in the first place regarding numbers of articles, the highest number of citations are linked to articles authored by other nationalities. Countries with the oldest publication history arisen in terms of citation, as the European countries such as England, Belgium, and Netherlands.

Another interesting aspect from the collection of publications raised is that the journal ranked first in relevance was Science of the Total Environment, which was not the one with the highest impact factor among the most relevant. However, this journal seems to cover several aspects related to the subject microplastics and human health. Regarding the focus of the studies, the category "microplastics in food" showed the highest number of studies, probably due to the ubiquitous presence of microplastics in the consumable biota and in various types of food consumed by humans and their potential health consequences.

Notwithstanding the tendency on the increase in the research on microplastics and health, some gaps can be viewed. Among them, methodological issues regarding microplastic quantification and determination in the human body, absence of experimental protocols to test presence and effects of microplastic in the biota, and scientific basis to delineate permissible values for the presence of microplastics in water, soil, food, and terrestrial and aquatic environments.

Acknowledgements

The authors would like to thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the Doctorate scholarship to first author.

References

Amato-Lourenço, L. F., Carvalho-Oliveira, R., Júnior, G. R., dos Santos Galvão, L., Ando, R. A., & Mauad, T. (2021). Presence of airborne microplastics in human lung tissue. *Journal of Hazardous Materials, 416*, 126124. https://doi: 10.1016/j.jhazmat.2021.126124.

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics, 11*(4), 959–75. https://doi.org/10.1016/j.joi.2017.08.007.

Barboza, L. G. A., Dick Vethaak, A., Lavorante, B. R. B. O., Lundebye, A. K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *Marine Pollution Bulletin, 133*(0025-326X), 336–48. https://doi.org/10.1016/j.marpolbul.2018.05.047.

Brainard, J., & Normile, D. (2022). China rises to first place in one key metric of research impact. Science, *377*(6608), 799–9. https://doi: 10.1126/science.ade4423.

Carbery, M., O'Connor, W., & Palanisami, T. (2018). Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health. *Environment International, 115*, 400–9. https://doi.org/10.1016/j.envint.2018.03.007.

Carrington, D. (2024). Microplastics found in every human placenta tested in study. https://www.theguardian.com/environment/2024/feb/27/microplastics-found-every-human-placenta-tested-study-health-impact.

Chen, H., Xu, L., Yu, K., Wei, F., & Zhang, M. (2023). Release of microplastics from disposable cups in daily use. *Science of The Total Environment. 854*, 158606. https://doi.org/10.1016/j.scitotenv.2022.158606.

Cox, K. D., Covernton, G. A., Davies. H. L., Dower, J. F., Juanes, F, & Dudas, S. E. (2019). Human Consumption of Microplastics. *Environmental Science & Technology, 53*(12), 7068–74. https://doi.org/10.1021/acs.est.9b01517

Damaj, S, Trad. F., Goevert, D., & Wilkesmann, J. (2024). Bridging the Gaps between Microplastics and Human Health. *Microplastics, 3(1),* 46–66. https://doi:10.20944/preprints202309.0288.v1

Danso, I. K., Woo J. H., & Lee K. (2022). Pulmonary Toxicity of Polystyrene, Polypropylene, and Polyvinyl Chloride Microplastics in Mice. *Molecules, 27*(22), 7926. http//: doi.org/10.3390/molecules27227926.

Dris, R., Gasperi, J., Mirande., C., Mandin, C., Guerrouache, M., Langlois, V & Tassin, B. (2017). A first overview of textile fibers, including microplastics, in indoor and outdoor environments. *Environmental Pollution, 221*, 453–8. www.http://doi.org/10.1016/j.envpol.2016.12.013.

Gao, Y., Ge, L., Shi, S., Sun, Y., Liu. M, Wang B, Shang, Y., Wu, J. & Tian, J. (2019). Global trends and future prospects of e-waste research: a bibliometric analysis. *Environmental Science and Pollution Research, 26*(17),17809–20. www.http://doi.org/10.1007/s11356-019-05071-8.

Hauptman, P. J. (2016). Impact or Impact Factor? *Journal of Cardiac Failure, 22*(10), 751-52. www.http://doi.org/10.1016/j.cardfail.2016.08.004

Ho, Y. W., Lim, J. Y., Yeoh, Y. K., Chiou, J. C., Zhu, Y., Keng, P. L., Li, L., & Chan, P. K. S. (2022). Preliminary Findings of the High Quantity of Microplastics in Faeces of Hong Kong Residents. *Toxics, 10*(8), 414–4. www.http://doi: 10.3390/toxics10080414

Hossain, S., Rahman, M. A., Ahmed, C. M., & Kumar, M. S. (2020). Plastic pollution in Bangladesh: A review on current status emphasizing the impacts on environment and public health. *Environmental Engineering Research, 26*(6). www.http://doi.org/10.4491/eer.2020.535

INMETRO. (2018). Inspetores e Auditoria de Estudos com foco In vitro. http://www.inmetro.gov.br/credenciamento/eventos-cgcre/Inspetores-BPL/Inspecao_e_Auditoria_de_Estudos_com_Foco_em_In_vitro.pdf.

Ramia, J. M. (2023). How to select a journal for your research. *World Journal of Gastroenterology, 29* (21), 3379–84. www.http://doi: 10.3748/wjg.v29.i21.3379

Park, J. H., Hong, S., Kim, O. H., Kim, C. H., Kim, J., Kim, J. W., Hong, S., & Lee, H. J. (2023). Polypropylene microplastics promote metastatic features in human breast cancer. *Scientific Reports, 13*(1), 6252. www.http://doi: 10.1038/s41598-023-33393-8

Kacprzak, S. & Tijing, L. D. (2022). Microplastics in indoor environment: Sources, mitigation and fate. *Journal of Environmental Chemical Engineering, 10*(2),107359. www.http://doi.org/10.1016/j.jece.2022.107359.

Kadac-Czapska, K., Knez, E., Gierszewska, M., Olewnik-Kruszkowska, E., & Grembecka, M. (2023). Microplastics Derived from Food Packaging Waste—Their Origin and Health Risks. *Materials, 16*(2), 674. www.http://doi: 10.3390/ma16020674.

Koelmans, A. A., Mohamed Nor, N. H., Hermsen, E., Kooi, M., Mintenig, S. M., & De France, J. (2019). Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water Research, 155*(1), 410–22. www.http://doi.org/10.1016/j.watres.2019.02.054

Krishnan, K. (2023). A Systematic Review on the Impact of Micro-Nanoplastics Exposure on Human Health and Diseases. *Biointerface Research in Applied Chemistry,13*(4), 381. www.http://doi.org/10.33263/BRIAC134.381.

Kutralam-Muniasamy, G., Pérez-Guevara, F., Elizalde-Martínez, I., & Shruti, V. C. (2020). Review of current trends, advances and analytical challenges for microplastics contamination in Latin America. *Environmental Pollution, 267*, 115463. https://doi.org/10.1016/j.envpol.2020.115463

Kwon, J. H., Kim, J. W., Pham, T. D., Tarafdar, A., Hong, S., Chun, S. H., Lee, S. H., Kang, Da.Y. K., Kim, J. Y, Kim, S. B., & Jung, J. (2020). Microplastics in Food: A Review on Analytical Methods and Challenges. *International Journal of Environmental Research and Public Health, 17*(18), 6710. https://doi.org/10.3390/ijerph17186710

Lattu, A. (2023). Open Science in China: An Open and Closed Case. https://www.mpiwg-berlin.mpg.de/observations/open-science-china

Lang, I. A., Galloway, T. S., Scarlett, A., Henley, W. E., Depledge, M., Wallace, R. B., & Melzer, D. (2008). Association of urinary bisphenol A concentration with medical disorders and laboratory abnormalities in adults. *Jama, 300*(11), 1303-1310. https://doi:10.1001/jama.300.11.1303

Leslie, H. A., van Velzen, J. M.M., Brandsma, S. H., Vethaak, D., Garcia-Vallejo, J. J., & Lamoree, M. H. (2022). Discovery and quantification of plastic particle pollution in human blood. *Environment International, 163*(107199), 107199. https:// doi.org/10.1016/j.envint.2022.107199

Li, M., Wang, Y., Xue, H., Wu, L., Wang, Y., Wang, C., Gao, X., Li, Z., Zhang, X., Hasan, M., Alruqi, M., Bokhari, A., & Han, N. (2022). Scientometric analysis and scientific trends on microplastics research. *Chemosphere, 304*,135337. https:// doi.org/10.1016/j.chemosphere.2022.135337

Li, S., Keenan, J.I., Shaw,I. C., & Frizelle, F. A. (2023). Could Microplastics Be a Driver for Early Onset Colorectal Cancer? *Cancers, 15*(13), 3323. https://doi: 10.3390/cancers15133323

Liu, Q., Chen, Z., Chen, Y., Yang, F., Yao, W., & Xie, Y. (2022). Microplastics contamination in eggs: Detection, occurrence and status. *Food Chemistry, 397*, 133771. www.http://doi.org/10.1016/j.foodchem.2022.133771

Liu, S., Guo, J., Liu, X., Yang, R., Wang, H., Sun, Y, Chen, B., & Dong, R. (2023). Detection of various microplastics in placentas, meconium, infant feces, breastmilk and infant formula: A pilot prospective study. Science of The Total Environment, 854 (158699), 158699. www.http://doi: 10.1016/j.scitotenv.2022.158699

Macias-Chapula, C. A. (1998). O papel da informetria e da cienciometria e sua perspectiva nacional e internacional. *Ciência da Informação, 27*(2). www.http://doi.org/10.1590/S0100-19651998000200005

Makhdoumi, P., Pirsaheb, M., Amin, A. A., Kianpour, S., & Hossini, H. (2023). Microplastic pollution in table salt and sugar: Occurrence, qualification and quantification and risk assessment. Journal of Food Composition and Analysis, 119, 105261. www.http://doi.org/10.1016/j.jfca.2023.105261.

Ministério da Saúde (2019). Guia alimentar para crianças brasileiras menores de 2 anos.
http://189.28.128.100/dab/docs/portaldab/publicacoes/guia_da_crianca_2019.pdf

Montano, L, Giorgini, E., Notarstefano, V., Notari, T., Ricciardi, M., Piscopo, M., & Motta, O. (2023). Raman Microspectroscopy evidence of microplastics in human semen. Science of The Total Environment, 901,165922. http://doi: 10.1016/j.scitotenv.2023.165922.

Munari, C., Infantini, V., Scoponi, M., Rastelli, E., Corinaldesi, C., & Mistri, M. (2017). Microplastics in the sediments of Terra Nova Bay (Ross Sea, Antarctica). *Marine Pollution Bulletin, 122*(1-2),161–5. www.http://doi: 10.1016/j.marpolbul.2017.06.039

Napper, I. E., Davies, B. F. R., Clifford, H., Elvin, S., Koldewey, H. J., Mayewski, P. A., Miner, K. R., Potocki, M., Elmore, A. C., Gajurel, A. P., & Thompson, R. C. (2020). Reaching New Heights in Plastic Pollution—Preliminary Findings of Microplastics on Mount Everest. *One Earth, 3*(5),621–30. http://doi.org/10.1016/j.oneear.2020.10.020

OECD. (2007). OECD Reviews of Innovation Policy China: Synthesis Report. OECD Publishing, Paris. . https://www.oecd.org/en/publications/oecd-reviews-of-innovation-policy-china_9789264039643-en.html

Park, J. H., Hong, S., Kim, O. H., Kim, C. H., Kim, J., Kim, J. W., et al. (2023). Polypropylene microplastics promote metastatic features in human breast cancer. Scientific reports, 13(1), 6252.

Patil, P. B., Maity, S., & Sarkar, A. (2022). Potential human health risk assessment of microplastic exposure: current scenario and future perspectives. *Environmental Monitoring and Assessment, 194*(12). http://doi: 10.1007/s10661-022-10539-1.

Peng, X., Chen, M., Chen, S., Dasgupta, S., Xu, H., Ta, K., Du, M., Lil, Z., Guo, Z., & Bai, S. (2018). Microplastics contaminate the deepest part of the world's ocean. *Geochemical Perspectives, 9* (1),1-5. https://doi: 10.7185/geochemlet.1829

Pironti, C., Notarstefano, V., Ricciardi, M., Motta, O., Giorgini, E., & Montano, L. (2022). First evidence of Microplastics in Human Urine, a Preliminary Study of Intake in the Human Body. *Toxics, 11*(1),40. https://doi: 10.3390/toxics11010040.

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. *Science of The Total Environment, 702* (134455). http://doi.org/10.1016/j.scitotenv.2019.134455

Prata, J. C. (2018). Airborne microplastics: Consequences to human health? *Environmental Pollution, , 234*, 115–26. https://doi: 10.1016/j.envpol.2017.11.043

Ragusa, A., Notarstefano, V., Svelato, A., Belloni, A., Gioacchini, G., Blondeel, C., Zucchelli, E. De Luca, C., DAvino, S., Gulotta, A. Carnevali, O. & Giorgini, E. (2022). Raman Microspectroscopy Detection and Characterisation of Microplastics in Human Breastmilk. *Polymers,14*(13),2700. https://doi.org/10.3390/polym14132700

Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali. O., Papa, F., Rongioletti, M. C. A., Baiocco, F., Draghi, S. D'Amore E., Rinaldo, D. Matta. M., & Giorgi, E. (2021) Plasticenta: First evidence of microplastics in human placenta. *Environment International ,146*(106274), 106274. https://doi.org/10.1016/j.envint.2020.106274.

Rochman, C. M., Tahir, A., Williams, S. L., Baxa. D., Lam, R., Miller, J. T., Foo- Ching, T. Werorilangi, S. & Teh, J. S. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Scientific Reports*, (1), 1-10. https://doi:10.1038/srep14340.

Rodríguez, Y. E. (2007) Ética de la Investigación en Modelos Animales de Enfermedades Humanas. *Acta bioethica, 13*(1), 25–40. https://doi.org/10.4067/S1726-569X2007000100004

Rowley, J., Sbaffi, L., Sugden, M., & Gilbert, A. (2020). Factors influencing researchers' journal selection decisions. *Journal of Information Science, 48*(3), 321-35.https://doi.org/10.1177/0165551520958

Schirinzi, G. F., Pérez-Pomeda, I., Sanchís, J., Rossini, C., Farré, M., & Barceló, D. (2017). Cytotoxic effects of commonly used nanomaterials and microplastics on cerebral and epithelial human cells. *Environmental Research, 159*, 579–87.https:// doi: 10.1016/j.envres.2017.08.043

Schwabl, P., Köppel, S, Königshofer, P., Bucsics, T., Trauner, M., Reiberger, T., & Liebmann, B. (2019). Detection of Various Microplastics in Human Stool. *Annals of Internal Medicine, 171*(7),453. https://doi.org/10.7326/M19-0618

Sharma, D, Jaiswal, S., & Kaur, G. (2022). Scientometric analysis and identification of research trends in microplastic research for 2011–2019. *Environmental Science and Pollution Research*, (29), 84312–84324. https://doi.org/10.1007/s11356-022-20872-0

Singh, A. K., Itkor, P., Lee, M, Shin, J., & Lee, Y. S. (2022). Promoting sustainable packaging applications in the circular economy by exploring and advancing molded pulp materials for food products: a review. *Critical Reviews in Food Science and Nutrition, 15*,1–16.https://doi.org/10.1080/10408398.2022.2088686

Smith, M., Love, D. C., Rochman, C. M., & Neff, R. A. (2018). Microplastics in Seafood and the Implications for Human Health. *Current Environmental Health Reports, 5*(3), 375–86. https://doi: 10.1007/s40572-018-0206-z

Suiter, A. M., & Sarli, C. C. (2019). Selecting a Journal for Publication: Criteria to Consider. *Missouri Medicine*,116(6),461–5. PMID: 31911720, PMCID: PMC6913840.

Thompson, R. C. (2004). Lost at Sea: Where Is All the Plastic? *Science, 304*(5672),838–8. https://doi.org/10.1126/science.1094559

Van Cauwenberghe, L., & Janssen, C. R. (2014). Microplastics in bivalves cultured for human consumption. *Environmental Pollution, 193*(0269-7491),65–70. https://doi.org/10.1016/j.envpol.2014.06.010

Wagner, M., Scherer, C., Alvarez-Muñoz, D., Brennholt, N., Bourrain, X., Buchinger, S., Fries, E. Grosbois, C., Klasmeier, J., Marti, T., Rodriguez-Mozaz, S., Urbatzka, R. Dick Vethaak, A. Winther-Nielsen, M. & Reifferscheid, G. (2014). Microplastics in freshwater ecosystems: what we know and what we need to know. *Environmental Sciences Europe, 26*(1). https://doi.org/10.1186/s12302-014-0012-7

Wang, Y., Xu, X., & Jiang, G. (2023). Microplastics exposure promotes the proliferation of skin cancer cells but inhibits the growth of normal skin cells by regulating the inflammatory process. *Ecotoxicology and Environmental Safety, 267*, 115636. https://doi.org/10.1016/j.ecoenv.2023.115636

Wang, L. (2016). The structure and comparative advantages of China's scientific research: Quantitative and qualitative perspectives. *Scientometrics, 106*, 435-452. https://doi.org/10.1007/s11192-015-1650-2

Willert, H. G., Semlitsch, M., & Peltier, L. F. (1996). Tissue reactions to plastic and metallic wear products of joint endoprostheses. *Clinical Orthopaedics and Related Research®, 333*, 4-14.

Wright, S.L ., & Kelly, F. J. (2017). Plastic and Human Health: a Micro Issue? *Environmental Science & Technology, 51*(12), 6634–47. https:// doi.org/10.1021/acs.est.7b00423

Yan, Z., Liu, Y., Zhang, T., Zhang, F., Ren, H, & Zhang, Y. (2021). Analysis of Microplastics in Human Feces Reveals a Correlation between Fecal Microplastics and Inflammatory Bowel Disease Status. *Environmental Science & Technology, 56*(1), 414–21. https://doi: 10.1021/acs.est.1c03924

Yitao, Su., Chao, Y., Huajun, L., Siqi, Z., Zhang, R., Dong, Y., D., Tanveer, S. K., & Hai, J. (2022). Health risk analysis of microplastics in soil in the 21st century: A scientometrics review. *Frontiers in Environmental Science,* (10), 976237. https:// doi.org/10.3389/fenvs.2022.976237

Zamora, A. M. Caterbow, A., Nobre, C. R., Duran, C. Muffett, C. Flood, C., Rehmer, C. Chmnitz, C. Lauwigi, C. Arkin, C. Da Costa, C. Teles, D. B., Amorim, D. Azoulay, D., Knoblauch, D., Seeger, D. Moun, D., Da Silveira, I., Patton, J. Hausmann, J., Faroni-Perez, L., Guerrero, L. Mederake, L. Xavier, L.Y., Vianna, M., Fernandez, M. Montenegro, M. Eriksen, M. Santos, M. Ziebarth, N. Marcucci, N., Speranskaya, O., Zimermann, P., Da Rocha, R. L., Kallee, U. Ribeiro, V. V., Hernandez, V Gürtler, S., & Feit, S. (2020). Atlas do Plástico: Fatos e números sobre o mundo dos polímeros. https://br.boell.org/pt-br/2020/11/29/atlas-do-plastico .

Zarus, G. M., Muianga, C., Brenner, S., Stallings, K., Casillas, G., Pohl, H. R., Mumtaz, M. M., & Gehle, K. (2023). Worker studies suggest unique liver carcinogenicity potential of polyvinyl chloride microplastics. *American journal of industrial medicine, 66*(12), 1033-1047. https://doi.org/10.1002/ajim.23540

Zhang, D., Wu, C., Liu, Y., Li, W., Li. S., Peng, L., Kang, L., Ullah, S. Gong, Z., Li, Z. Ding, D., Jin, Z., & Huang, H. (2024). Microplastics are detected in human gallstones and have the ability to form large cholesterol-microplastic heteroaggregates. *Journal of hazardous materials, 467*,133631–1. https://doi: 10.1016/j.jhazmat.2024.133631

Ziani, K., Ioniță-Mîndrican, C. B., Mititelu, M., Neacșu, S. M., Negrei, C., Moroșan, E., Doina Drăgănescu, D., & Olivia-Teodora, P. (2023). Microplastics: A Real Global Threat for Environment and Food Safety: A State of the Art Review. *Nutrients, 15*(3):617. https://doi: 10.3390/nu15030617