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A Decade Of Research On Trends Microplastics In Human Blood And Faeces: Insights From Bibliometric Analysis And Future Directions

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ABSTRACT

Microplastic exposure in the human body is a critical issue that has become a primary environmental concern. This exposure occurs through consuming plastic-contaminated food (such as seafood, vegetables, salt, and rice), water, cosmetics, chewing gum, and instant food or beverages, where human contact with plastic particles is both direct and vulnerable. The possible health hazards of microplastic exposure, particularly chronic diseases caused by plastic particles, require significant attention. The increasing exposure to microplastics Has driven researchers and scholars to continue innovating and developing scientific strategies in response to this emerging trend. This bibliometric analysis aims to examine the trends in publications on microplastic exposure in human blood and faeces based on publications from 2014 to 2024 (the past decade), evaluate the role of international collaborations in different journals, determine the most impactful authors and articles, and forecast the future progression of this research area (as future directions). Method. This study includes 45 documents (35 articles, nine reviews, and one book chapter), with 22 additional articles identified through trend mining on the past decade of microplastic studies in humans. These articles were gathered from the Scopus database, processed through Tableau analysis, and analyzed using VosViewer software. Results. We found that human microplastic exposure has increased significantly over the past decade. This indicates that the topic remains of high interest. Regarding the most significant contribution, China has authored the most publications related to this topic. Commonly used keywords include "(Microplastics OR nanoplastic) AND (Blood OR faeces OR stool OR placenta OR "breast milk" OR meconium) AND Human -tapir -crab -gull -rat -animal -fish -oyster -scallop -enviromental - water -obstetric -algae -fossil -index". In Summary. In sum, it is a crucial source for assessing the current research landscape developments, sampling methods, and future research directions.

Keywords: Enhanced Security Framework; Emerging Field; Practical Relevance; Fuzzy Logic; Network Traffic

Analysis.

Introduction

Plastic is now a crucial part of daily life, found in clothing, coatings, vehicles, and cleaningproducts. It is cheap, durable, lightweight, and flexible, which has led to its replacement of materials like wood, metal, and glass in many uses. Advances in science and technology drive thischange, as plastic is cheaper to produce, more durable, and stronger than traditional materials.

Microplastics have the potential to cause contamination as their particles can undergo biomagnification, where pollutants are transferred through the food chain. One of the largest protein sources is seafood, which is rich in protein and calcium. Although microplastics are not directly consumed as food, they can accumulate in the body through the consumption of aquatic animals and plants and the use of cosmetics. The toxicological effects of microplastics vary acrossorganisms. Several studies have shown that microplastics interact directly with microorganisms, act as carriers for other contaminants, and indirectly interact with microorganisms [22].

Various toxicity evidence in animal models indicates that microplastics can increase oxidative stress and neurotoxic reactions by interacting with energy production and lipid metabolism. Research on human microplastic exposure is still limited. Therefore, studies analyzing the detection of microplastics in human blood and faeces are essential to establish a foundation for policymaking and planning programs to improve maternal and child health, one ofthe targets of the Sustainable Development Goals (SDGs).

Methods

Types of Research

This exploratory review examines microplastic research in human blood and faeces sourced from the Scopus database, spanning 2014 to 2024. The methodology involved retrieving relevant publications using broad and specific keywords. First, a general search for "Microplastic" was conducted to identify the overall volume of related research. Then, a morefocused search was performed using keywords such as "(Microplastics OR nano plastic) AND(Blood OR faeces OR stool OR placenta OR "breast milk" OR meconium) AND Human -tapir -crab -gull -rat -animal -fish -oyster -scallop -environmental -water -obstetric -algae -fossil - index" to narrow results to studies on microplastics in human blood and faeces. Excluded terms were indicated with a minus sign ("-") to refine the search. The final dataset, consistingof 45 publications, was curated using Open Refine and Microsoft Excel. Additional analysis was performed using Tableau and VOSviewer for visual representation and interpretation. This method offers an in-depth overview of microplastic research in human blood and faecesover the past decade (2014-2024).

Bibliometric Analysis

Data Analysis for Trends in International Publication Development on Microplastics UsingVOSviewer Software for Bibliometric Mapping and Network Visualization with Various Features [23]. Bibliometric analysis systematically analyses academic publications to understand trends, patterns, and relationships within a specific research area. In the case of microplastics in human blood and faeces, bibliometric analysis can provide valuable insightsinto the scope, growth, and geographical distribution of research on this topic.

This type of analysis typically involves identifying key publications, authors, and countriescontributing to the field and examining citation patterns to assess the influence of specific studies. By analyzing keywords, co-authorship networks, and publication trends, researcherscan identify emerging areas of interest, collaboration networks, and potential gaps in the existing body of knowledge.

Bibliometric analysis can help reveal how this research has evolved (e.g., from 2014 to 2024), highlight the most influential studies and researchers, and map out international collaborations for microplastics in human blood and faeces. This information is essential for guiding future research efforts, identifying areas that require further investigation, andfostering global cooperation in addressing the health implications of microplastic exposure. Bibliometric analysis provides researchers, decision-makers, and stakeholders valuable insights in advancing a specific scientific field.

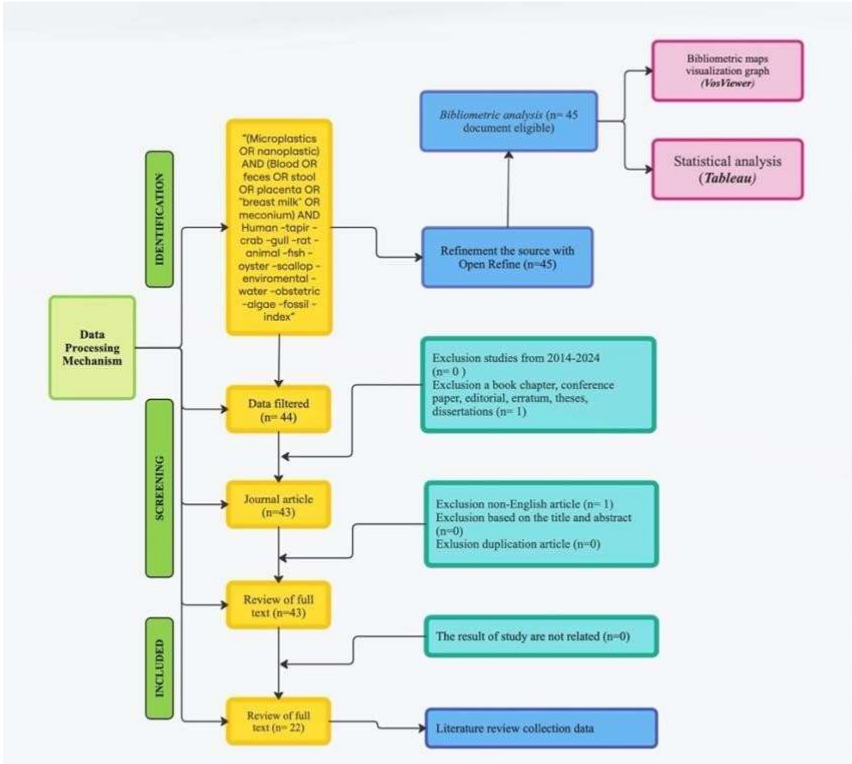

Figure 1. Flow Chart Literature Search on Microplastic Exposure in HumanBlood and Faeces

1) Results of Topic Mining on Microplastics in Human Blood and Faeces

3.1.Most Published Document Types on Microplastic Exposure in Human Blood and Faeces

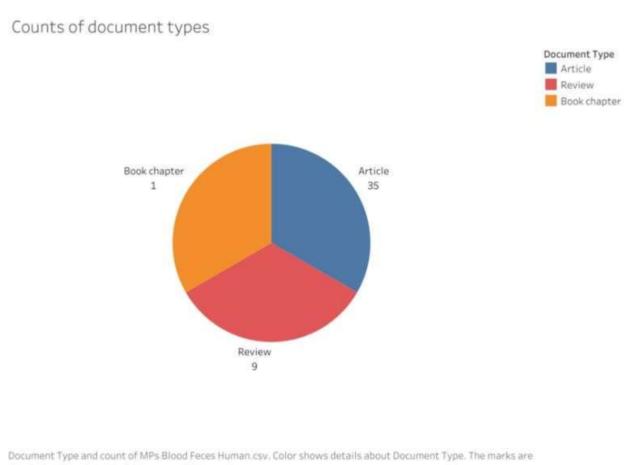

Figure 2. Publication Trends by Year in the Field of Microplastics in Human Blood andFaeces

The visualization of the bibliometric analysis presented in **Figure 2** shows a significant increase in documents over the past 10 years, reflected in the literature on the trends of microplastics in human blood and faeces. The number of articles, reviews, and book chapters are the three main categories of publications that represent the growing interest in this topic. The totalnumber of documents published in this study increased from 2014 to 2024, with the highest growthbeing 77.78% or 35 article documents. This topic is gaining more attention and is projected to keepgrowing. The consistency of government programs can help sustain this trend.

The connection between microplastics in human blood and faeces and the SDGs demonstrates that microplastic pollution impacts the environment and human health. Efforts to reduce microplastic pollution can support the achievement of several Sustainable Development Goals (SDGs), including improving human health, protecting water resources, and ensuring sustainable natural resource management. Therefore, it is essential to take coordinated actions to reduce plastic waste, conduct further research on the adverse effects of microplastics on blood cellsystems, faeces, or the entire human body matrix, raise public awareness of its health impacts, andpromote stricter policies related to plastic and microplastic waste management.

This program can be complemented by regulations that emphasize community-based interventions to reduce plastic use in daily life. This would decrease microplastic usage and its health impacts, making it an increasingly compelling and accountable area of research.

3.2 Country Contribution to Publications (Co-authorship with countries)

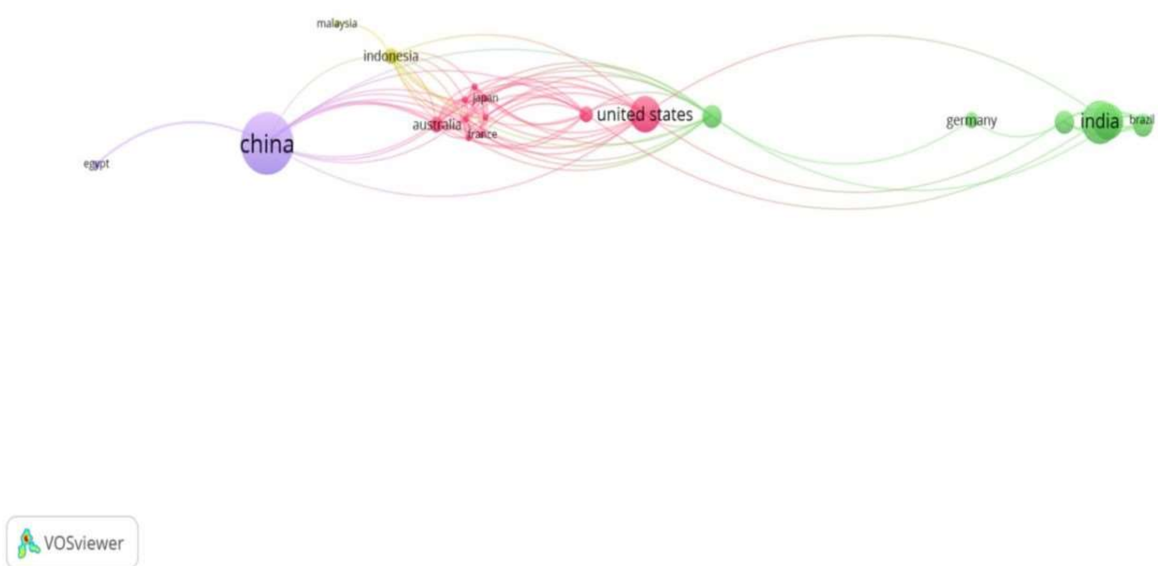

Figure 3. Number of Documents Published by Country

The quantity of publications from a country may represent the extent and spread of authorship within a specific research area. **Figure 3** shows that only 11 countries have at least fivedocuments. The total number of countries listed in the data mining process is 43. Among these, three countries have the highest number of records. The first is China (9 published documents with399 citations). The second is India (6 published documents with 66 citations). The third is the United States (5 published documents with 138 citations.

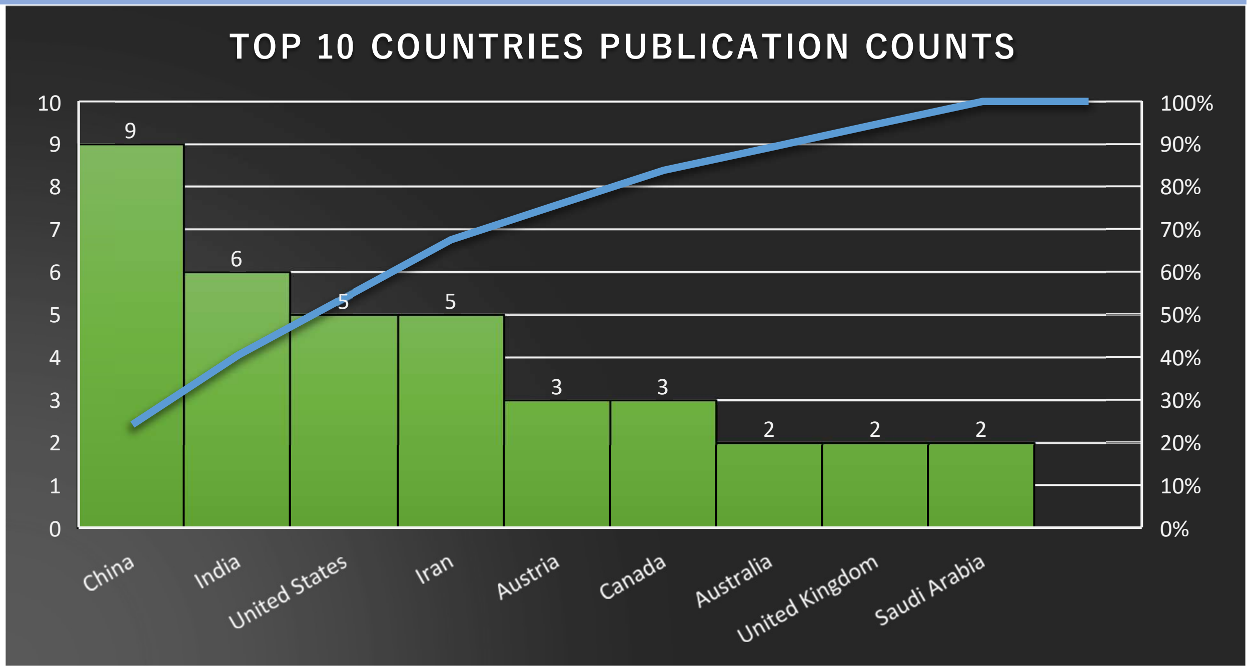

Figure 4. Ten Countries with The Most Publications

Figure 4 displays the ten countries with the highest publication counts, with China holdingthe top position with nine publications.

3.3 Analysis of Author Keyword Co-occurrence Network

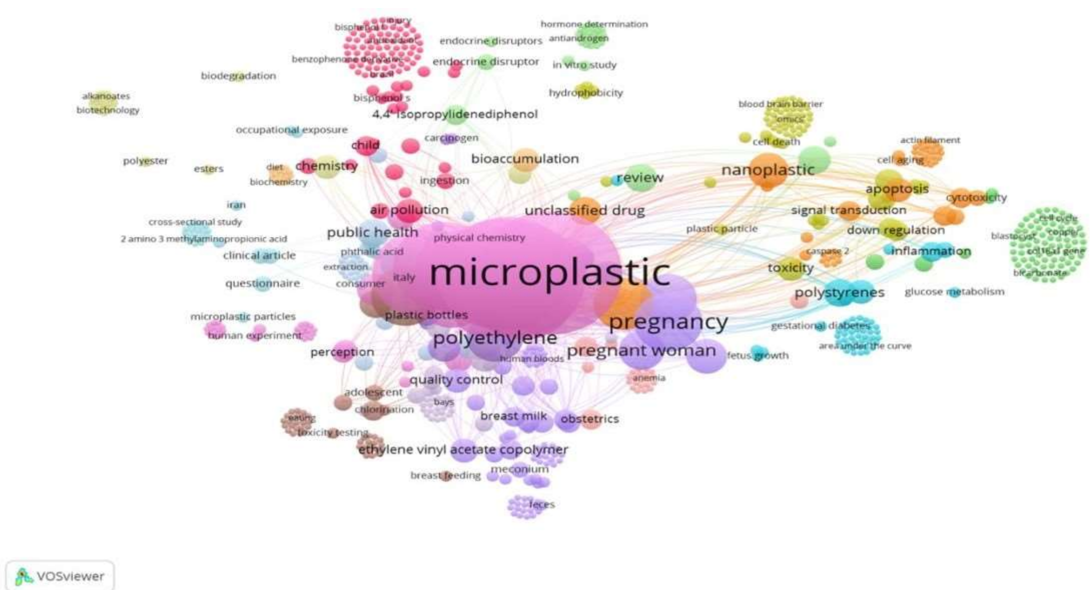

Figure 5. Network Analysis of Author Keyword Co-occurrence

The cluster is divided into 1,000 items and 7 clusters, differentiated by colours in Figure 5.The most prominent cluster is Cluster 1 (pink), which contains 434 items and focuses on microplastics in humans.

The keywords in this cluster are connected to several other clusters in different networks based on author keywords. These include Cluster 2 (dark purple), which focuseson pregnant women, followed by a smaller network (Human Blood) with 60 items, as well as Cluster 3 (light purple), which focuses on faeces and contains 223 items.

3.4. Analysis of Author Keyword Co-occurrence Network with Clusters

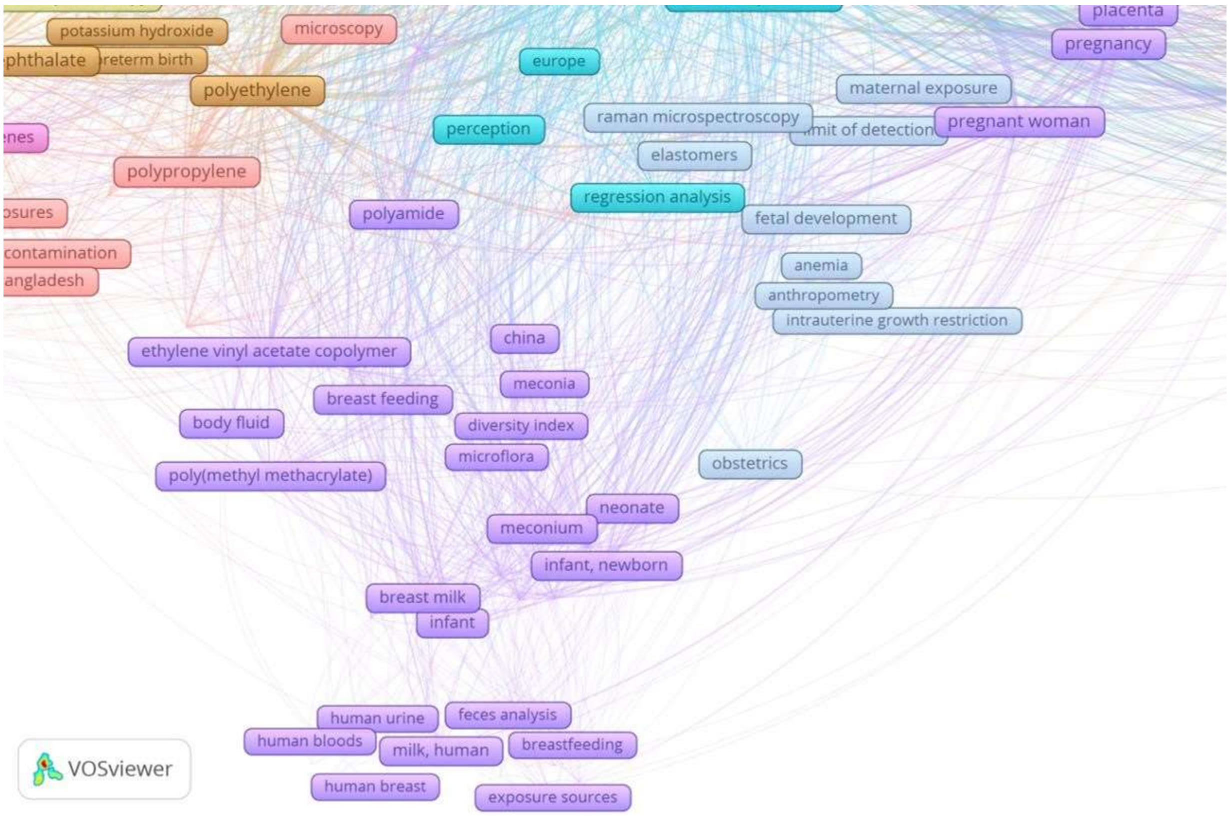

Figure 6. Collaborative Trend Network High Index by Author (2014-2024)

The cluster is divided into 1,000 items and seven distinct clusters, each represented by a different colour, as shown in **Figure 5**. However, when zoomed in and focused on the high-indexkeywords listed in **Figure 6,** the discussion cone corresponding to the topic's keywords—"Humanblood, faeces analysis, and China as the highest publishing country"—emerges.

Additionally, The bibliometric analysis results on microplastics (MPs) in human blood andfaeces reveal several promising, data-driven avenues for future research, as shown throughvisualizing keyword trends over time. According to **Figure 6**, keywords highlighted in purple havebeen frequently used in past studies. In contrast, grey keywords emphasize the health risks associated with microplastic exposure and the methods being investigated for analyzing microplastics, which could lead to breakthroughs when paired with other keywords. This categoryincludes terms such as "Anemia," "Human blood," "Body fluid," and "Faeces analysis." Keywordsin other colours indicate potential associations with microplastic analysis. The bibliometric results from several publications related to the keywords "Human blood" and "Faeces analysis" representemerging novelties, prompting a literature review analysis, the results of which are as follows:

No.	Country (Year)	Population Samples	Method	Variables Measured	Matrix	Result	Ref.
1	Netherland (2017)	This is the first research on MPs in human blood. The study involved 22 healthy adult participants, including men and women, from diverse age groups. Blood samples were collected to detect microplastics in their circulation.	Experiment (FTIR)	Identification of MPs in blood circulation	Blood	All tested blood samples contained microplastics, including polyethene terephthalate (PET) from plastic bottles, polyethene (PE), and polypropylene (PP) found in food packaging, cosmetics, and other products	[26]
2	Australia(2019)	Eight healthy adults from various countries participated in the study	Experiment (FTIR)	Identification of MPs in faeces	Faeces	Different types of microplastics were detected, including polypropylene (PP), polyethene (PE), and polystyrene (PS)	[25]
3	Turkey (2020)	Two healthy volunteer participants, one female and one male	Experiment (FTIR)	Identification of MPs in human peripheral lymphocytes	Blood	Microplastics (MPs) were detected in lymphocytes, with polyethene microplastics causing genomic instability in human peripheral lymphocytes. Chronic exposure to	[10]

						microplastics is	
						expected to contribute to genomic instability in humans, potentially leading to diseases, particularly cancer and DNA damage.	

4	China (2021)	Human cell cultures as samples for in vitro studies	Experiment (FTIR)	Offers a clearer understanding of the toxic effects of microplastics at the molecular and physiological levels (both in vivo), focusing on cellular and DNA damage, inflammation, organ dysfunction, and long-term impacts on human health	Human cells, such as epithelial cell cultures, blood cells, and other cell types	Microplastics induce oxidative stress, causing cell and DNA damage, inflammation, and organ dysfunction. Smaller and irregularly shaped microplastics are more harmful due to their enhanced ability to penetrate cells and tissues. Further studies are needed to understand long-term effects and improve guidelines for managing microplastic exposure.	[11]
5	Netherlands (2022)	This study analyzed blood samples from 22 individuals with no history of direct exposure or employment related to	Experiment (FTIR)	Identification of MPs in human blood	Blood	Over 77% of human blood samples contained plastic particles, indicating significant exposure. The identified microplastic polymers	[12]

		plastics, ensuring that the contamination did not originate from highly exposed sources.				included PET, PE, PS, and PP.	
6	China (2023)	Exposure to microplastics in the blood of pregnant women and its impact on fetal health through environmental surveys	Experiment (FTIR)	Identification of MPs in the environment	Blood	Microplastics (MPs) exposure during pregnancy may disrupt fetal health, development, and growth, with potential risks of complications, low birth weight (LBW), and long-term decline in neurological function	[16]

7	Spanyol and Saudi Arabia (2023)	Breast milk and placenta samples were gathered from women who had recently given birth, while meconium and faeces samples were collected from newborns. Furthermore, samples were obtained from filtered washes of hand and face skin, head hair, saliva, urine,	Experiment (FTIR)	Identification of MPs in human	Placenta, colon, stool, lung, sputum, breast milk, urine, liver, skin, colectomy, liver tissues, pulmonary, kidneys, saphenous vein tissue, spleen, and blood samples	Microplastics (MPs) have been found in human samples such as placenta, stool, lung, sputum, liver, breast milk, and blood. The types of MPs include PS, PE, PVC, and PET.	[24]
		sputum, pulmonary tissues, infant faeces, lung tissues, colectomy specimens, liver, kidneys, spleen, and saphenous vein tissue from healthy volunteers.					

8	United States (2023)	Testing blood and faecal samples from people in major U.S. cities for microplastics	Experiment (FTIR)	Identification of MPs in human blood and faeces or stool	Blood and faeces or stool	FTIR analysis found microplastics in human blood and stool, with the highest contamination levels in individuals exposed to plastic pollution through consumption.	[13]
9	Iran (2023)	Iran citizen	Experiment (FTIR)	Identification of MPs in human blood and faeces or stool	Blood and faeces or stool	Microplastics, including PE, PS, PET, and polyester polymers, were found in human blood and stool, correlating plastic pollution levels with microplastic accumulation in the human body and potential health impacts.	[15]
10	Indonesia (2024)	Exposure to MPs in faeces or stool	Experiment (FTIR)	Detection of MPs in the faeces of pregnant women	Faeces	Ten MP polymer types were identified in the faeces or stools of pregnant women.	[17]

Table 1. Bibliometric Results Based on Keywords from Supporting Publications

2) Discussion

Based on the results of the systematic bibliometric review analysis, as visualized in **Table 1and Figure 6**, leading scientists have extensively studied the global development of microplasticsin human exposure sources. Several publications frequently employ one of three types of microplastic testing. The techniques that have been utilized for the analysis of MPs in human samples fall into three categories [24]:

A. Microscopy (stereo microscopes, optical microscopes, scanning electron microscope (SEM), fluorescence microscopes after Red Nile Staining): reported for an initial visual and physical characterization of MPs

B. Spectroscopy (Raman, FTIR): to investigation of MPs polymer

C. Separation (Chromatography coupled with mass spectrometric detection, i.e. pyrolysis gas chromatography.mass spectrometry (py–GC–MS), high-performance liquid chromatographywith tandem mass spectrometry (HPLC–MS/MS)): used for qualitative and quantitative analysis of the main types of polymers in the biological Samples (concentrations of MP).

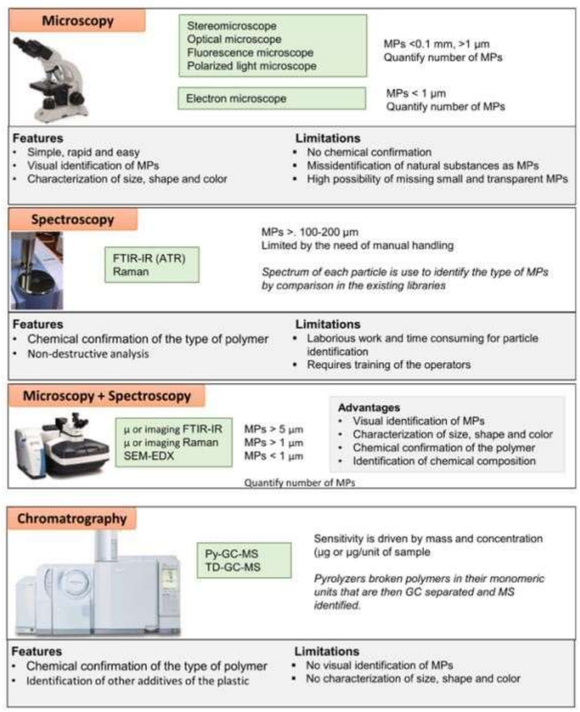

Figure 7. Advantages and drawbacks of the methods employed to identify and quantifyMPs in human samples [24]

Overall, this study calls for adopting stricter policies in the management of plasticpackaging and promoting sustainable practices within the clothing and textile, food and beverage, and plastic production industries. Humans are primarily exposed to microplastics (MPs) through consuming contaminated food, especially seafood such as fish, sea salt, honey, beer, and other fooditems. A secondary route of exposure is through inhalation of air and dust that contain MPs. Seafood, a valuable source of nutrition, plays a significant role in the human diet, but consuming contaminated seafood increases health risks, mainly when eating whole fish. Studies support this, revealing the presence of microplastics in various commercially harvested marine species like shellfish, oysters, crabs, shrimp, and fish [18-20].

Consuming these contaminated aquatic species exposes humans to microplastics, raising concerns about food safety. The buildup of microplastics in the food chain, particularly in fish andcrustaceans, is a significant source of human exposure, and the contamination of food with microplastics could have serious health implications. Daud et al. (2023) found microplastics in *Nemiptus japonicas* and *Rastrelliger sp.* fish along the Tamasaju coast, consumed by local communities. Microplastic exposure through food poses health risks, including digestive issues, hormonal disruptions, and increased cancer risk. This highlights the urgent need to control plastic pollution to protect human health, especially in coastal areas [27[. Moreover, another study explains that microplastics are obtained through exposure via the food chain and through the frequency of skincare or beauty cosmetic use. The skincare trend has steadilyincreased as many people become more aware of beauty knowledge and the desire to maintain healthy, radiant skin. However, they often overlook that microplastic exposure also originates fromthe cosmetic containers, which then accumulate in the blood [9].

In Indonesia, research has investigated the presence of microplastics (MPs) in the faeces of pregnant women, who could be exposed to MPs from various sources. A review [1] has documented the global emergence of MPs from numerous potential sources. The main route of exposure is through seafood consumption, as MPs can enter the human body via the food chain, including through fish and other seafood [2-5]. Recent research has shown that the number of microplastics (MPs) in faeces varies considerably based on seafood consumption. A study conducted at the Paotere fish market in Makassar, Indonesia, discovered microplastic fragments inthe digestive tracts of 28% of 76 fish samples, including striped mackerel, Spanish mackerel, andshortfin scad [6]. A different study also found MPs in blood clams (Anadara granosa) from the coastal regions near Makassar [7]. Therefore, consuming seafood may lead to the presence of MPsin the faeces of pregnant women [17].

For pregnant women, exposure to plastics can affect the fetus. Microplastics accumulate in the placental syncytiotrophoblast. The syncytiotrophoblast helps transport nutrients across the placenta. All polystyrene particles, whether they can cross the placental barrier or not, collect in the syncytiotrophoblast. This layer controls the movement of nanoparticles in the placenta [8]. Particles compatible with microplastics (MPs) may trigger pathological processes such as apoptosis, inflammation, and oxidative stress, signs of metabolic disturbances that could contributeto diseases like syndrome, diabetes, obesity, and others [21].

Research on microplastics in the human body between 2014 and 2019 remained in its earlystages, with limited studies available. However, much of the focus has been on microplastics in seafood and food containers and the associated risks of human exposure through the food chain. Several studies have started to document the presence of microplastics in human faeces and the possible health risks related to microplastic buildup. These studies lay the groundwork for ongoingresearch into the implications on human health, particularly their detection in biological matrices while highlighting the growing issue of plastic pollution. Each year, at least one publication on thistopic emerged.

Based on **Table 1**, the field of microplastic research in humans is still emerging. However,several studies have already explored a range of human biological matrices, including urine, liver,heart, lungs, skin, peripheral blood cells, sputum, spleen, kidneys, and saphenous vein tissue. While the volume of publications identified through Scopus journal mining remains limited, the quality of the research conducted remains high. These studies provide a critical foundation for advancing our understanding of the potential interrelationships between human matrices that haveyet to be thoroughly investigated, posing a significant challenge and opportunity for future research in this area. Based on Table 1, several vital similarities are noted:

a) **Increased Recognition from Microplastics:** Microplastics detected inside human biological matrices, including faeces, blood, and organs, are increasingly detected using advanced methods like spectroscopy and microscopy.

b) **Sources and Exposure:** Microplastics in the human body mainly come from seafood, contaminated food, drinking water, air, and everyday products, with microfibers and plastic fragments as the primary contributors.

c) **Potential Health Impacts:** Accumulated microplastics may cause inflammation, oxidative stress, and endocrine disruption, although long-term effects are not well established.

d) **Research Challenges:** Key challenges include isolating microplastics from biological samples and understanding their harmful mechanisms, as well as the difficulty of assessing health impacts due to their small concentrations in the body.

Meanwhile, the differences in microplastic research in blood, faeces, and human matrices between 2014 and 2024 can be summarized as follows:

1. **Matrix Types Examined:**
   2014-2019: Primarily focused on human faeces due to accessible collection and analysis. **2020-2024:** Expanded to blood, urine, and organ tissues (liver, lungs) to explore microplasticdistribution and effects on vital organs.
2. **Analytical Methods:**
   2014-2019: Relied on optical microscopy and basic spectroscopy (FTIR, Raman).
   2020-2024: Utilized advanced techniques like mass spectrometry, electron microscopy, andchromatography for more accurate detection.
3. **Health Impact Findings:**
   2014-2019: Focused on potential toxicological risks with limited clinical evidence.
   2020-2024: Explored more detailed effects, including inflammation, immune disruption,carcinogenicity, and impacts on the endocrine and reproductive systems.
4. **Research Scale and Sample Size:**
   2014-2019: Limited sample sizes and animal models.
   2020-2024: Larger human sample sizes and longitudinal studies to assess long-term effects.
5. **Geographical and Social Focus:**
   2014-2019: Focused on regions with high plastic pollution (Europe, Asia).
   2020-2024: Included developing countries and addressed social disparities in microplasticexposure.

However, this study has several limitations. To begin with, the topic was sourced from the Scopus search engine. Research published in sources not indexed by Scopus was excluded. Second, Scopus citation counts are generally more conservative than Google Scholar, potentially leading to underestimating citation numbers. Third, to narrow down the topic during the journal mining process, it was necessary to capture search results as screenshots for archiving purposes,

which complicates the mining process. A slight difference in wording could significantly affect thenumber of journals and citations retrieved. Lastly, the number of review documents or articles reported by specific institutions and researchers still needs to be expanded and encompass variouspapers, such as studies that incorporate original research, viewpoints, editorials, reviews, letters tothe editor, case reports, etc.

Research shows considerable international interest in the presence of microplastics in humans.However, this interest is still concentrated in limited research hubs. Achieving specific objectivesrequires more significant funding, and raising awareness among funding agencies about this needis essential. The limited availability of funding, laboratory resources, equipment, and materials forstudying microplastics in human blood and faeces remains a critical factor in the few researchers able to contribute to publishing scientific papers. This highlights the need for broader and more collaborative participation in research on human microplastic samples.

The findings of this study convey the message that there is a need for efforts to enhance and develop innovations in analyzing and creating more compact and sophisticated detection tools in multi-centre studies across various institutions and educational sectors. Additionally, future effortsshould focus on designing research with more precise mechanisms to improve outcomes in detecting microplastics in human blood and faeces. It is crucial to formulate research policies specific to each country at the policy level, focusing on enhancing infrastructure and funding to support human microplastic research in the short, medium, and long term.

3) Summary and Recommendations

A bibliometrics study on microplastic research in human blood and faeces reveals a growing trend, with 22 publications worldwide. Studies show that microplastics (MPs) have beendetected in blood and faeces and in various human matrices, including placenta, skin washes, hair,saliva, urine, lung tissue, and vital organs like kidneys and the liver. Detecting and characterizingMPs in human samples requires established methodologies, such as microscopy, spectroscopy, andseparation techniques, due to concerns about their potential health impacts.

Data visualized using VOSviewer and Tableau indicate China as the leading contributor, followed by India and the United States. Key authors include Wang and Jun (384 citations), Malafaia and Guilherme (303 citations), and Guo and Xuetao (194 citations). The results highlightthe need for targeted research aligned with the Sustainable Development Goals (SDGs) and the development of more explicit policy frameworks to mitigate health risks and create cost-effective,comprehensive methods for MP analysis in complex human matrices.

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Conflict of Interest

Nothing has been declared.

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