Bibliometric Analysis on Contaminant Microplastics in Compost (2018 to 2022) Through VOSviewer

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Abstract. Compost is considered not only to improve soil nutrients but also as a carrier of microplastic (MPs) pollution on agricultural land. Bibliometric analysis is a quantitative review approach that employs statistics, data mining, and mathematics to identify new academic trends. It is increasingly more prevalent and is utilized in several academic disciplines. To evaluate the evolution and extension of this body of knowledge and to forecast its future path, the present study analyzed Scopus-indexed research publications on compost from 2018 to 2022. To perform the bibliometric analysis, the VOSviewer software and Scopus Analytics were used. A total of 111 journal articles (n = 77) and conference papers (n = 3) were extracted. The number of research documents published by 111 authors was steadily increasing annually. China is the leading country in the number of publications and research collaborations. The current results offset global scientific efforts on MPs contamination in compost and inform that there is potential for compost to be a carrier of MPs contaminants in plants.

Keywords: Organic waste, pollution, poison, scientific mapping, toxic.

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1 Introduction

Plastic products are widely used in all areas of life because of their extraordinary physical properties and relatively cheap prices. World plastic production has increased by almost 50 % in the last 10 yr and reached 367 × 10^6 t by 2020 [1]. Agricultural systems are the ultimate recipients of a number of pollutants [2] and nanomaterials, including microplastics (MPs), with relatively unknown effects. Microplastics, commonly referred to as plastic waste less than 5 mm in size, have become a growing concern in recent years due to their ubiquity in the environment and potential adverse effects on the health of organisms and ecosystems [3]. One of the contributors to MPs in the agricultural system is the use of compost [4].

MPs-carrying compost that enters the soil interferes with soil microbial activity [5, 6] and will certainly have an impact on plant growth [7]. In addition, MPs can release toxic monomers and/or additives, and act as vectors for other contaminants, which can increase the exposure of organisms to these contaminants [8]. In recent years, compost has made a significant contribution to agricultural production to increase soil and crop fertility, approximately 10 t ha^{-1} to 200 t ha^{-1} [9–11].

As in other agricultural environments, detection of MPs has also been reported in compost fertilizers, and the potential effect of MPs on compost has received great attention [4, 12]. However, there has been no research on MPs contamination in compost that can consider its hazard threshold for use in organic farming. Thus, this work conducted a bibliometric analysis of multiple globally published papers on transportation packaging to provide an overview of its universal outputs and determine its present and future research path.

Bibliometric analysis is a type of quantitative evaluation that integrates statistics, data mining, and mathematics to detect patterns that emerge in a certain academic topic. Now it is gaining popularity and being used in several disciplines of study [13]. Through this method, the authors were able to identify current general issues in MPs contamination in compost and understand that MPs occurrence in compost fertilizer could be considered in composting technology to remove the threat to the agricultural environment. The aim of this work is to evaluate the sources, pollution characteristics, potential impacts, and associated risks associated with MPs, with a particular focus on composted manure in the world. In this research, therefore, all available scholarly works on MPs contamination in compost from 2018 to 2022 were combed through to assess the growth and development of this body of knowledge and to predict its future trajectories.

2 Methodology

Bibliometric studies involve several mathematical and statistical methodologies for analyzing bibliographic data [14]. The bibliometric review method tries to grasp the relationship between journal citations and research performance and offers a succinct evaluation of the current condition of an active or expanding research field. Bibliometric analyses extract the data required for a bibliometric investigation from multiple citation databases, such as Scopus and Web of Science [15]. In addition, additional review approaches, such as meta-analysis, may also be used to manage such data. Both meta-analysis and bibliometric analysis are quantitative methods of review. In bibliometric analysis, the studies may be diverse, unlike in a meta-analysis. In addition, bibliometric studies examine just a quantitative assessment of the properties of an article (such as publications, citations, keywords, and authors) and their interrelationships. However, one must analyze the linkages between the actual results of publications and the extensive usage of meta-analysis in linked research fields. Nevertheless, both approaches may describe the contemporary research topic as well as the trends and directions of the area. In subheadings, the bibliometric investigation's most recent measurements are reported [16].

2.1 Determining the study's scope and data collection

In bibliometric analysis, the first factor to evaluate is the magnitude of the research. Before the study can begin, the scope and quantity of studies to be evaluated must be specified in detail. Otherwise, the findings would be substandard, riddled with errors, and conflicting with the primary objective of the research. It is essential to thoroughly assess the keywords employed in data collecting.

2.2 Sample size and data extraction

When the amount of bibliometric data is considerable and the scope of the literature review is too vast for a manual examination, bibliometric analysis should be explored. Bibliometric analysis is recommended only when there are at least 200 articles to evaluate in the references. It was discovered that the average category-standardized citation impacts of bibliometric studies with lower sample sizes (200 articles) varied greatly, rendering this technique inappropriate [17]. Therefore, the present research included trial-and-error approaches and keyword filtering and decided that the sample size was enough for bibliometric analysis. Important to the bibliometric investigation was the selection of a suitable database to gather data from the literature. As stated, the data for this research were extracted from the Scopus database in Microsoft Excel (.csv) format [18].

2.3 Bibliometric analysis

Every bibliometric research relies on performance assessment, network analysis, and scientific mapping as its foundation. Performance analysis is a method for analyzing publication and citation metrics (*e.g.*, appraisal of the total number of published articles and citations; h-index) [19]. Hirsch defines the h index as "a scientist possessing index h if h of his or her Np articles each have at least h citations and the remaining Np - h papers each have at least h citations" [20]. Science mapping (or bibliometric mapping) examines the effects and strengths of relationships between specific article attributes using the co-occurrence weight and total link strength of each item. It encompasses citation analysis, bibliographic coupling, co-citation analysis, co-word (keyword) analysis, and co-authorship analyses. Network analysis may enhance the output quality of bibliometric mapping. Standard network analysis approaches include metric evaluation, grouping, and visualization. Scopus data including total publications, number of articles per active year, yearly total citations (as assessed by frequency), and h-index were utilized to support the performance analysis in this research. Scopus analytics capabilities were used for performance evaluation of SLN-related academic output. Moreover, the data file was used in conjunction with the VOSviewer program for scientific mapping and network analysis [21]. The VOSviewer is extensively used in bibliometric research. van Eck and Waltman [22] designed the program to simplify the development and presentation of comprehensible bibliometric maps. It performs an outstanding job of collecting pertinent information, recognizing similarities between articles that meet the same criteria, and identifying the overall theme that runs across the chosen papers. In addition, VOSviewer provides three separate viewing modes, including network visualization, overlay, and density visualization. The sole reason why researchers utilized network visualization was because it enabled them to easily examine how various keywords and publishing topics are associated based on characteristics such as co-occurrences, co-authorship, and country. It also uses color to signify the prevalence and relevance of certain research. As a phrase becomes increasingly prevalent across several academic disciplines, the contrast of its related line becomes more pronounced. On the other hand, a pale tint indicates a weak association [23].

3 Results and discussion

3.1 Biobliographic extraction

In this work, the authors searched database from https://www.scopus.com/, based on [TITLE-ABS-KEY (microplastics AND in AND compost)]. The search recorded 111 studies (Table 1), covering articles, reviews, book chapters, and conference papers, published from 2018 to 2023. These documents (n = 77) between 2018 and 2022 accounted for 78.28 % of the Scopus-indexed research output. Furthermore, the authors sorted original publication papers (n = 52) published in English between 2018 and 2022 to achieve the objectives of this research. The reason there are so many research articles in this field is because both the academic and professional communities are becoming more interested in it. According to preliminary studies, Piehl *et al.* [24] found the emergence of MPs in conventional agricultural soils. One of the causes of this emergence is the application of compost made from organic waste, livestock manure, and biosolids [25, 26]. In general, polyethylene is the most common type of polymer, followed by polystyrene and polypropylene. The likelihood of MPs contamination will be higher in areas where agricultural plastics are applied, such as greenhouses, mulch, or silage films, or fertilizers containing plastics (waste sludge, biowaste compost) [24, 27]. The application of municipal organic waste compost and sewage sludge in agroecosystems increases soil fertility but can also be a source of MPs [28–30, 9]. Annual compost use of 4.07×10^6 t in agriculture and horticulture in Germany is estimated to account for 817 t of MPs [31].

Table 1. Bibliographic extraction.

Type of documents	2018 to 2023		2018 to 2022	
	Number	Percentage	Number	Percentage
Article	72	64.86	51	66.23
Review	25	22.52	16	20.77
Book chapter	10	9	6	7.79
Conference paper	3	2.70	3	3.89
Letter	1	0.90	-	-
Total	111	100	77	100

3.2 Overview of research performance

Prior to compose bibliometric mapping, the Scopus publications were evaluated for their productivity, which provides a descriptive analysis of how different variables (such as keywords, publication kinds, authors, institutions, countries, and journals) perform in Scopus searches. In this work, this research revealed the production per productive year of publishing, the total yearly citations, the h-index, the most-cited articles, and the most relevant publications. This data was compiled with the use of "document search results" from Scopus. Understanding the performance of research output in a certain field requires a careful examination of the yearly frequency of scientific article publication. Table 2 displays the annual rate of article publication from 2018 through 2022, totaling 77 publications. In 2018, the lowest number of articles was seen. Environmental Science and Agricultural and Biological Sciences majority of the 54 publications in 2022. Research on MP in compost was published in these two journals (Scientific Reports and Journal of Hazardous Materials) because of their Environmental Science specialization.

Table 2. Publication performance analysis.

Years	Number of articles	Citation
2022	39	1 373
2021	18	617
2020	13	158
2019	4	13
2018	3	0

Citation counts measure the impact of a publication or an author by measuring the number of times other publications cite each. Table 2 and Table 3 include citations for years and scientific works. Compared to previous years, 2021 and 2022 have the highest proportion of citations. Due to the small number of scientific papers, 2018 was the most impactful year for MP in compost research. The study of large microplastic particles (MPsP, 1 mm to 5 mm) in compost analyzed by Fourier Transform Infrared Spectroscopy (FTIR) showed that there were 39 MPP kg^{-1} to 102 MPP kg^{-1} Total Solid (TS) [30]. Extraction and identification of environmental samples from municipal biowaste compost, showing 36 ± 9 microplastic particles per 10 g compost, and detection of polystyrene (PS) and polypropylene (PP) [32]. Meanwhile, the results of a study in the Netherlands regarding high-quality compost from municipal organic waste and from garden and greenhouse waste showed that it was contaminated with MPs, containing (2 800 ± 616) MPs kg^{-1} and (1 253 ± 561) MPs kg^{-1}, respectively [9]. Meanwhile, in Chicken Manure (CM), Sludge (SC), and Domestic Waste (DW), the MPs concentrations were (14 720 ± 2 468) grains kg^{-1}, (8 600 ± 1 428) grains kg^{-1} , and (11 640 ± 3 565) grains kg^{-1}. [33]. Wu *et al.* [4] found that MPs was present in compost with animal manure in 19 farms and poultry farms with three different species in Southern China. A total of 115 items of MPs of manure and 18 items of MPs for feed were identified as types of PP and PE which were dominated by colorful fragments and fiber [4].

Table 3. Top-cited articles.

Rank	Title of the article	Year	Total citation	Ref
1	Identification and quantification of macro- and microplastics on an agricultural farmland	2018	390	[24]
2	Microplastics in agricultural soils on the coastal plain of Hangzhou Bay, east China: multiple sources other than plastic mulching film	2020	304	[34]
3	Microplastics as pollutants in agricultural soils	2020	274	[11]
4	Particulate plastics as a vector for toxic trace-element uptake by aquatic and terrestrial organisms and human health risk	2019	274	[35]
5	Microplastics in soil: a review on methods, occurrence, sources, and potential risk	2021	253	[36]
6	An overlooked entry pathway of microplastics into agricultural soils from application of sludge-based fertilizers	2020	175	[37]
7	Microplastics in municipal mixed-waste organic outputs induce minimal short to long-term toxicity in key terrestrial biota	2019	149	[38]

Continued on the next page.

Table 3. Continue.

Rank	Title of the article	Year	Total citation	Ref
8	The effects of three different microplastics on enzyme activities and microbial communities in soil	2021	117	[39]
9	Global concentrations of microplastics in soils - a review	2020	105	[40]
10	Microplastic detection in soil amended with municipal solid waste composts as revealed by transmission electronic microscopy and pyrolysis/GC/MS	2018	102	[28]

Another source that contributes to MPs in compost is household waste [Rural Domestic Waste (RDW)]. MPs was found at RDW composting plants located in Chisong City and Lincheng City in China's Zhejiang Province. It was found as much as (2 400 ± 358) items kg^{-1} (dry weight) MPs in the RDW compost product. On identification using FTIR, it turns out that the main MPs forms are fiber and film. Types of polymers found PS, PP and polyethylene (PE) [41]. Supporting previous findings, Edo *et al.* [12] conducted a similar study to identify MPs in municipal organic waste samples. The study was conducted in five composting sites located in northeastern Spain. As a result, MPs was found in all samples, the concentration of plastic impurities in the range of 10 grains g^{-1} to 30 grains g^{-1} of dry compost. The concentration of small fragments and fibers (equivalent diameter < 5 mm) was in the dry weight range of 5 $grain^{-1}$ to 20 $grains^{-1}$ and was dominated by fiber (25 % of all particles < 500 m). Five polymers represent 94 % of plastic goods: polyethylene (PE), polystyrene (PS), polyester (PET), polypropylene (PP), polyvinyl chloride (PVC), and polymethyl methacrylate/acrylic (PMMA) polymer in order of abundance [12]. Another study found that MPs in green compost contained (5 733 ± 850) particles kg^{-1} in autumn and (6 433 ± 751) particles kg^{-1} in winter, while in food compost (3 783 ± 351) particles kg^{-1} in autumn and (4 066 ± 658) particles kg^{-1} in autumn Winter [42].

3.3 Bibliographic mapping

Bibliographic mapping technologies facilitate the monitoring of research progress and the creation of new trends, therefore facilitating the management of the huge volumes of information created by the rapid speed of research [43]. Using VOSviewer, the final data output visualization and bibliographic mapping were done. After the final article database had been checked, updated, and screened by VOSviewer, it was used for bibliographic mapping using in-app algorithms to generate a visual file. For this purpose, the VOSviewer, an open-source Java tool that allows trend research via the viewing of bibliometric maps, was used [44].

The visualization used a co-occurrence analysis of the articles' keywords to identify study clusters and then investigated the emerging research trend. Keywords indicated the core concepts and advancements of each article's subject topic. A keyword co-occurrence network is advantageous for knowledge mapping since keywords represent the development of a research topic and the actual article content. The co-occurrence frequencies in the VOSviewer are determined by the author's keywords in the literature database. The authors used a total of 1 470 keywords for 111 research documents. Table 4 shows the most frequently occurring keywords, which had total link strength of 15 845 and 117 occurrences. The justification for adopting this minimal keyword occurrence rate is that the more frequently the term occurs, the more popular the research subject. After adopting the Full Count method, these authors' keywords were mapped into five clusters (Figure 1) based on

VOSviewer software. Five big clusters of contaminant MPs in compost: microplastic (yellow nodes), soil pollution (red nodes), plastic (blue nodes), fertillizers (purple nodes), and general indicators (green nodes).

Table 4. Most highly occurring author's keywords.

Number	Keywords	Cluster	Occurences	Total link strenght
1	Microplastics	1	85	1 290
2	Composting	1	67	1 136
3	Microplastic	1	56	1 125
4	Plastic	1	48	1 018
5	Compost	1	47	849
6	Plastics	2	43	935
7	Soil	3	40	892
8	Soils	3	36	725
9	Soil pollution	3	35	727
10	Microplastics	3	85	1 290

VOSviewer generates two separate maps for network and overlay display. Both representations utilise a two-dimensional distance-based map that indicates the degree of the objects' associations depending on their distance [45]. Higher distance and vice versa suggest relationships with greater strength. Conversely, a tighter distance indicates a stronger affinity. A label and a circle, the size of which denotes the prominence of the term, are used to identify it. Although various colors signify different sorts of information, the bibliographic mapping for overlay visualization and network visualization is the same. The overlay image depicts the average annual publication of each phrase, while the network visualization depicts keyword cluster groups. The overlay plot demonstrates that the terms in this cluster have trended since 2018. The keywords "degradation" and "bioremediation" trended in 2022 (Figure 2).

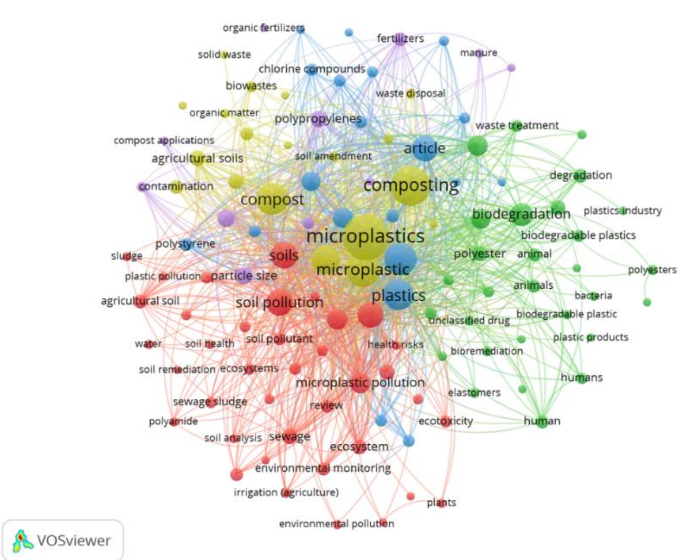

Fig. 1. Representation of the author's keyword network showing co-occurrence.

MPs detection is not only completed on compost yields, but it affects the diversity of microbial communities during composting and cannot be fully decomposed even for up to 10 yr [28, 38]. Composting conventionally has an effect on size but has no effect on reducing the quantity of MPs [46]. Studies on the degradation of MPs polymers have been carried out, proteinase K enzymes showed a faster mixed degradation effect compared to homopolymers with weight loss, but there was an increase in crystallinity and formation of crystalline stereo complexes in the fragmented samples which could limit the degradation after the step which caused the microplastics to persist to longer period, thus, degradation studies in compost are recommended for a minimum of 8 wk to 10 wk [7]. Another recommendation for biodegradation of biodegradable plastic dog litter bags can be 100 % biodegradable in green waste composting in a laboratory composting reactor after 4 wk and 90 d of composting [47].

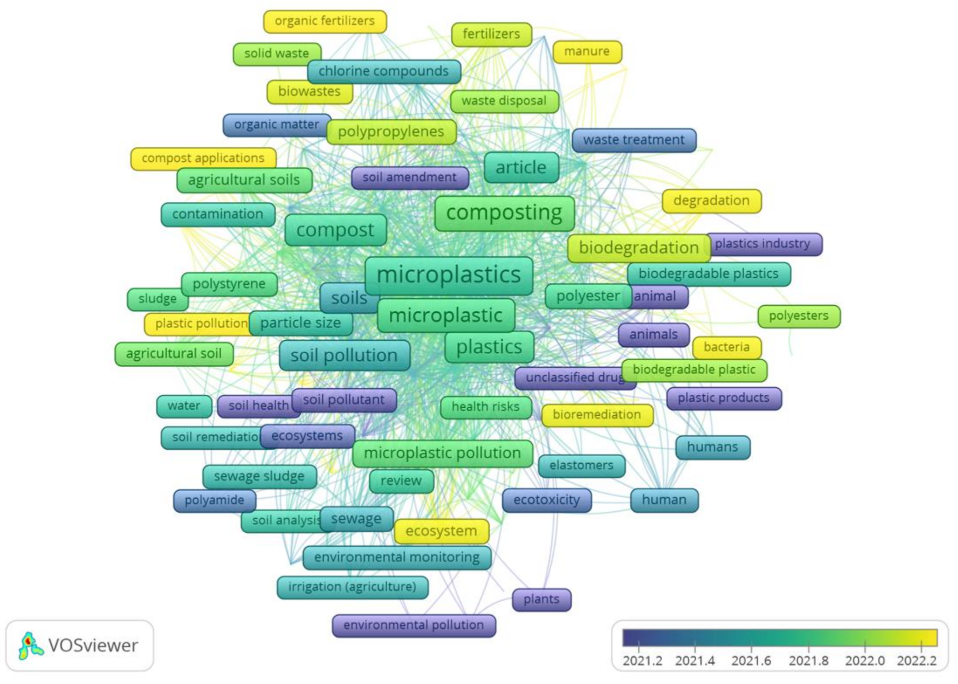

Fig. 2. Keyword's overlay visualization of co-occurrence based on average publications per 2018 to 2023. Keywords with different colors differ in their emergence.

The ability of MPs in the environment to have severe impacts, such as the development of metal toxicity in plant organisms and causing contamination of animals and humans through the food chain [8, 35, 48]. Worldwide regulations on compost, which are used as amendments in agriculture, have thresholds ranging from 2 mm to 15 mm for requirements related to MPs. MPs that passes the threshold filter is considered to be assimilated with compost [49]. The study of MPs in sewage sludge compost was carried out using the Fourier Transform Micro-infrared (μ-FTIR) spectrometry method. The results clearly show that the amount of MPs in the soil shows a close correlation with the rate of application of slurry-based fertilizers. The total abundance of MPs was 545.9 items kg^{-1} and 87.6 items kg^{-1} in the soil after annual amendments with 30 t ha^{-1} and 15 t ha^{-1} compost sludge, which was significantly higher than without compost application. Mud compost can act as a carrier of MPs into the soil and then enter the soil biota and in turn affect the distribution of MPs in the environment [37]. In addition to using the (μ-FTIR) method, MPs can also be detected by the Near-infrared (NIR) Spectroscopy method, MPs can be detected in model samples with a mass fraction of 1 mg g^{-1} and PS based packaging materials with a particle size of < 1 mm contained in compost or soil with high natural organic matter content (> 10 % determined by burn loss) [50]. Another study found that there was potential for MPs found in compost made from plastic bags made from plastic films combined with food waste, but this study did not specifically analyze the number of particles contained in the compost [51]. A recent study found that polyurethane (PU) is recyclable and its waste management is particularly relevant given the increasing concern about plastic pollution and the occurrence of MP in the environment, an almost quantitative degradation in compost was observed at 45 °C in 3 mo, whereas at 58 °C, a higher temperature was observed, specified by ASTM D6400, complete degradation takes only 35 d which is much faster than compostable polymers [52]. Another finding found that manure biochar (MBC) was shown to increase the biodegradation of Polyhydroxyalkanoate (PHA) MPs and increase carbon loss and oxygen loading during thermophilic composting [53].

3.4 Geographical mapping and international collaboration

The 43-country participated in the study on MPs in compost. Table 5 displays the most prolific nations, which got a total of 1 505 citations. These 111 articles were created by their respective writers. The most productive country is China, followed by Germany, the United States, Australia, and Spain. China were the most cited countries, representing 26.32 % of the total citations. Given the significant investments made over the past 5 yr, research MPs in compost is booming in China and Germany. To make a difference in the world, it is vital to invest in education, entrepreneurship, translational research, manufacturing infrastructure, and a mental shift among government officials [54].

In terms of funding, the establishment of scientific and technological infrastructure, and the development of human skill sets, the governments of China and India play a crucial role in building transportation packaging fruit research capability. Since 2013, it has invested in packaging fruit as a separate field of study. The National Natural Science Foundation of China (NSFC) has raised its funding budget to 33×10^9 yuan ($5.2 × 10^9) in 2022, up 6.8 % over last year [55].

Table 5. Most cited and productive countries.

Number	Country	Documents	Citations
1	China	24	1 505
2	Germany	17	858
3	United States	13	926
4	Australia	9	795
5	Spain	9	490
6	Italy	7	253
7	France	5	170
8	United Kingdom	5	357
9	Poland	4	31
10	India	3	332

Frequently in scientific policy is the notion that collaborative research offers a range of benefits and should, therefore, increase research output. Knowledge and technique sharing, idea exchange, resource pooling, sharing expensive instruments, boosting visibility and recognition, and accelerating research progress are regularly cited among the many benefits of research collaboration in the literature [56]. Out of the 43 countries, only five had at least 11 co-authored documents. The overall strength of the co-authorship ties with other nations was computed for each of the 11 countries. As seen in Figure 3, the nations with the strongest overall linkages were chosen. China was found to possess the most intensive research connections.

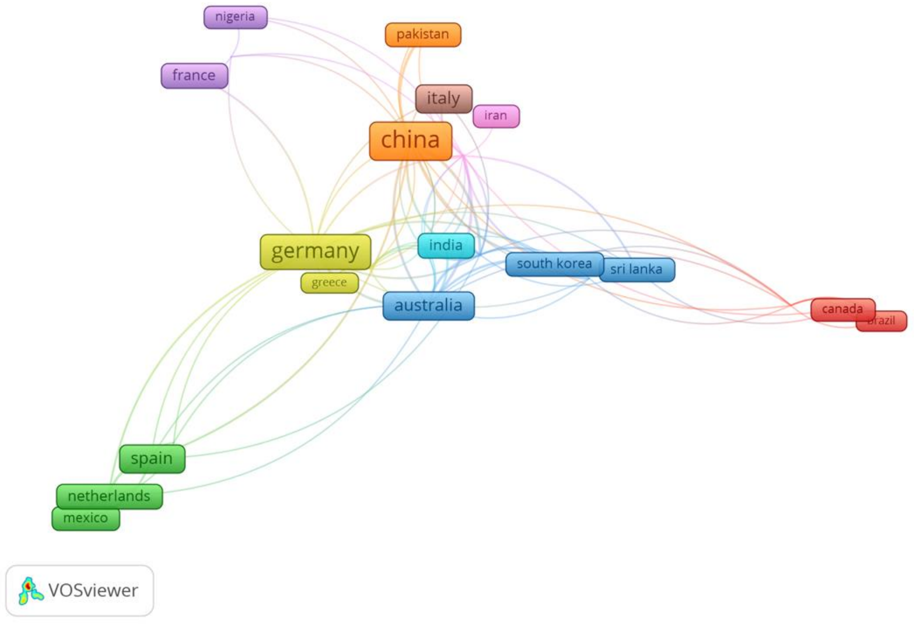

Fig. 3. VOSviewer visualization of research collaboration based on co-authorship. Circles represent the number of co-authored documents.

4 Conclusions and perspectives

To the evolution and extension of this body of knowledge and to forecast its future path, the present study analyzed Scopus-indexed research publications on microplastic in compost from 2018 to 2022 using VOSviewer software and Scopus Analytics. A total of 111 journal articles (n = 77) and conference papers (n = 3) were extracted. The number of research documents published by 111 authors was steadily increasing annually. China is the leading country in the number of publications and research collaborations. The current results offset global scientific efforts on microplastic contamination in compost and inform that there is potential for compost to be a carrier of microplastic contaminants in plants.

Organic farming is playing an increasingly important role in providing people with nutrients, especially in developing and developed countries. Similar to other environmental systems, organic farming systems are also polluted by microplastics. MPs were detected in compost (organic waste, manure, and biosolids) and soils from organic farming systems in abundance in the same order as those from conventional farming. The analysis shows that the main source of MPs in organic farming is the use of compost. Reducing and recycling plastic waste dumped in agricultural areas can be a viable way to reduce MPs pollution in organic farming systems, but inputs from other pathways are more difficult to control. Studies show that MPs in compost can affect the health of soil organisms and the functioning of agricultural ecosystems. However, the risk of MPs sourced from compost in agricultural environments remains uncertain, and more evidence is needed to fully address this topic.

Consumption of agricultural products is not the primary pathway for human exposure to MPs, but the authors suggest that further research is needed.

MPs in compost as emerging pollutants have attracted research attention over the past 5 yr. Field investigations and laboratory experiments have contributed to knowledge about the number, characteristics, types of polymers, effects on soil, and potential effects of MPs in crop cultivation systems. However, more work is needed to understand the true risks of microplastics in the application of compost to agricultural systems to help guide decision-making by the public and government. In the future, toxicological research methodologies for microplastics in compost should be refined to produce more environmentally relevant information and to better reveal the mechanism of action. Further analytical methods should be developed to measure MPs in small-sized compost. Further research efforts should focus on evaluating the impact of microplastic compost applied to plants. MPs as vectors of pollutants and other pathogens should also receive further research attention. Emergency measures should be developed to prevent the possible adverse effects of microplastics on plants and human health.

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Declaration of competing interest. The authors declare no known competing interests that could have influenced the work reported in this paper.

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