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Review

Microplastics Scoping Review of Environmental and Human Exposure Data

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Abstract: Scientific studies of microplastics have expanded since 2015, propelling the topic to the forefront of scientific inquiry. Microplastics are ubiquitous in the environment and pose a potential risk to human health. The purpose of this review is to organize microplastics literature into areas of scientific research, summarize the state of the literature and identify the current data gaps in knowledge to promote a better understanding of human exposure to microplastics and their potential health effects. We searched for published literature from eight databases. Our search focused on three categories: (1) microplastics in the environment, (2) adsorption and absorption of chemicals to microplastics, and (3) human exposure to microplastics in the environment. We screened all abstracts to select articles that focused on microplastics. We then screened the remaining articles using criteria outlined in a questionnaire to identify and assign articles to the three scoping review categories. After screening abstracts, we selected 1186 articles (19%) to thoroughly assess their appropriateness for inclusion in the final review. Of the 1186 articles, 903 (76.1%) belonged to the environmental category, 268 (22.6%) to the adsorption and absorption category, and 16 (1.3%) to the human exposure category. Water was the most frequently studied environmental medium (440 articles). Our assessment resulted in 572 articles selected for the final review. Of the 572 publications, 268 (48.2%) included a geographic component and 110 (19.2%) were the product of literature reviews. We also show that relatively few publications have investigated human health effects associated with exposures to microplastics.

Keywords: scoping review; microplastics; environmental concentration; literature review

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1. Introduction

Plastics have gained immense popularity in industry and modern life since their inception and subsequent mass production in the mid-1950s [1]. The chemical structure of plastics enables the manufacture of useful products such as temperature- and chemical-resistant packaging and sturdy building materials (e.g., polyvinyl chloride [PVC] piping). The hydrophobic property of plastics makes them potential conveyors of dangerous substances such as polychlorinated biphenyls (PCBs) and persistent organic pollutants (POPs). Examples of some of the most common plastics are polyethylene terephthalate (PET), high density polyethylene (HDPE), low density polyethylene (LDPE), PVC, and polypropylene (PP). These plastics are used for a variety of products (e.g., piping, clothing, furniture, electronics, and implants).

As plastics weather in the environment, they fragment into progressively smaller pieces, mainly through physical-chemical breakdown. Plastics can also fragment through microbial degradation. This discovery, combined with the chemical properties of plastic, such as their hydrophobicity and ability to attract other hydrophobic particles, spurred an explosion of research into microplastics, plastic particles smaller than 5 mm, beginning around 2015. A commonly adopted metric for classifying plastics as microplastics is if any dimension (length, width, or height) of the plastics being studied is 5 mm or less [2,3]. Microplastics are also classified by origin as primary or secondary microplastics [4]. Primary microplastics are plastics manufactured with a dimension of 5 mm or less, typical of the textile and pharmaceutical industries. Secondary microplastics are formed through weathering and fragmentation of plastic debris in the environment, such as plastic bags [4]. In the United States, nearly 14.5 million tons of plastic waste including clothes and packaging are produced yearly [5]. Plastics can be dispersed through processes and activities including wastewater and water systems, and farming practices.

The study of microplastics has surged since 2014. Interdisciplinary fields—from biology and chemistry to engineering and exposure sciences—are researching how microplastics are affecting the global environment and the potential threats they can pose to flora and fauna. For this scoping review, we developed a methodology to categorize the microplastic literature and identify knowledge gaps that can be used to advance our understanding of the impact of microplastics in the environment and on human health.

2. Materials and Methods

2.1. Acquiring Articles

Our scoping review methodology employed procedures from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for scoping reviews outlined in the Joanna Briggs Institute Reviewers' Manual 2015 on the methodology for JBI Scoping Reviews [6]. First, we developed the scoping review title, objective, and question. Next, we created a search strategy and inclusion criteria. We modeled our screening and eligibility approaches for abstracts and full articles based on method used in PRISMA Extension for Scoping Reviews: Checklist and Explanation [7]. The screening process involved the development of a novel organizational scheme to identify criteria needed to evaluate the impact of microplastics on human health. Finally, we extracted results from the screening and summarized the findings based on year of publication, publication type, and category (i.e., environmental concentration and media; adsorption and absorption of chemicals of microplastics; human exposure and potential adverse health outcomes).

We partnered with the Stephen B. Thacker Library at the Centers for Disease Control and Prevention to develop a search strategy (Figure 1) and criteria to identify peer-reviewed literature in scholarly publications investigating the relationship between microplastics in the environment and their impact on human health. On 21 January 2020, we conducted a broad search of eight electronic databases (Embase, Medline, Environmental Science Collection, CAB Abstract, GreenFile, Compendex Engineering Village, Scopus, and CINAHL) for a comprehensive compilation of literature on microplastics and human health. The electronic databases search resulted in 6217 articles published between January 1947 and 21 January 2020, after removing 4993 duplicate articles. We excluded non-English papers. Figure 1 displays the total number of articles identified by each database and the number of duplicate abstracts removed from the initial identification stage for acquiring articles. The list of search terms is included in the supplemental material.

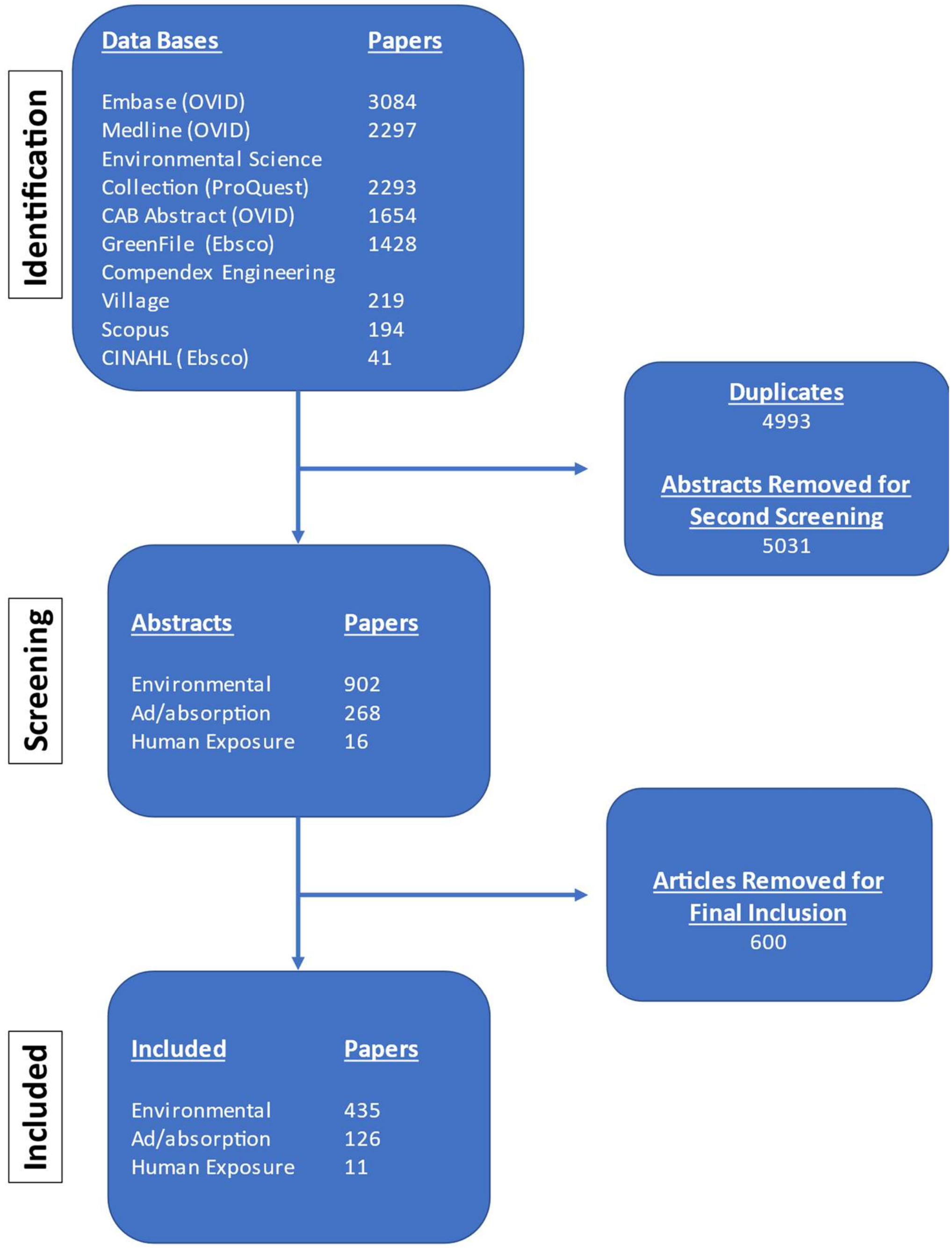

Figure 1. Search strategy.

2.2. Screening Process

We used two key objectives to screen the 6217 abstracts for relevance to the scoping review. The first objective was to determine whether the abstract mentioned microplastics as a central focus of the paper. The second objective was to assign the abstract to one of three broad categories: (1) environmental, (2) adsorption and absorption, or (3) human exposure. In addition to categorizing the literature, we recorded the year and type of publication.

Papers designated for the environmental category focused on microplastics and their concentration or effect in the natural environment. This includes microplastic presence in sediment, aquatic, and atmospheric environments. Papers designated for the adsorption and absorption category focused on chemicals and their ability to absorb microplastics or the ability for chemicals to adsorb to microplastic surfaces. Microplastics can absorb chemicals such as polychlorinated biphenyls and dioxins from sediment and aquatic environments [8]. Papers designated for human exposure category included a focus on microplastics and their interactions specifically within the human body. We excluded 5031 abstracts [81%] of the 6217 through screening. It left 1186 papers to determine their quality for the final selection of papers to be included in this review.

To assess the quality of the papers, ensure their focus on microplastics, and categorized them for future research and systematic review, we developed 12 binary questions for screening of the full articles and assigned a specific point value to each question (Table 1). Question ranking was based on a tiered approach regarding article relevance to human exposures to microplastics and the potential health effects. Questions 1–3 (Tier 1) were each assigned a value of 20 points because these questions are the most critical for determining the potential human exposure and health effects of microplastics. Questions 4–8 (Tier 2) were each assigned a value of 10 points, because they describe the environmental media and context of the microplastics, which are needed to understand potential human exposure sources. Questions 9–12 (Tier 3) were each assigned a value of 5 points. These questions assess the quality of the studies in terms of analytic method, route of exposure, trophic transfer, and geographic context.

Table 1. Questions used to screen the abstracts for inclusion in the scoping review and their associated points.

Question	Point Value per Question
1. Does the paper focus on microplastics? 2. Does the paper describe human exposures in detail? 3. Does the paper describe a mechanism for microplastic toxicity?	20
4. Does the paper describe the ability for chemicals and/or microorganisms to sorb and/or desorb to/from microplastics? 5. Does the paper describe microplastic behavior in water (oceans, rivers, lakes, glaciers, drinking water, etc.)? 6. Does the paper describe microplastic behavior in sediment/soil? 7. Does the paper describe microplastic behavior in the air/atmosphere/dust? 8. Does the paper describe microplastic behavior in human food and human food sources?	10
9. Does the paper contain a protocol for the collection/isolation of microplastic particles? 10. Does the paper contain evidence of ingestion or uptake (in either animals, humans, or plants)? 11. Does the paper show a geospatial description of microplastics/a geospatial impact of microplastics? 12. Does the paper describe the potential movement of microplastics through different trophic levels?	5

After we reviewed and scored the papers, based on the question ranking, we summed the values for all questions answered in the affirmative. Our research group decided that a paper would provide valuable information pertinent to microplastics and their potential impact on human exposures by earning at least a sum of 50 points. The only way for a paper to achieve a score of 50 points or above was for it to include at least two of the three question tiers. It was difficult for a paper to have every question answered in the affirmative. The final scoping review considered the 572 (48%) manuscripts that had received a point value of 50 or more. We used those manuscripts to understand the status and trends of the microplastic literature.

3. Results

We found that publications on microplastics, most notably journal articles, have increased each year since 2015. Figure 2 illustrates the increase in published reports, by year, from 2010 through 2019, when most of the literature was published. Most of the 572 publications (459 [80%]) included in the scoping review were journal articles. Scientific and critical reviews made up 110 [19%] of the literature included in this review. Only a fraction of the literature was posters (2 [0.35%]) and textbook passages (1 [0.17%]).

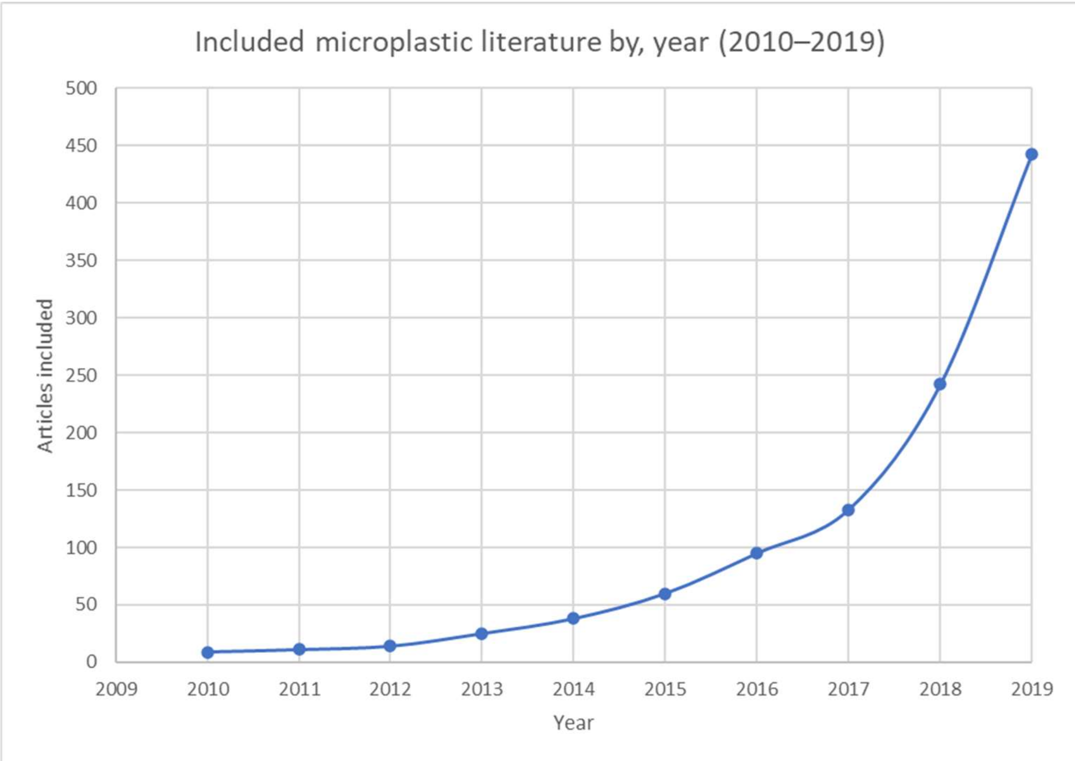

Figure 2. Publications focusing on microplastics by date of publication.

We grouped publications meeting the review criteria into three categories: (1) environmental concentration and media, (2) adsorption and absorption of chemicals to microplastics, and (3) human exposure and the potential adverse health outcomes. In these three categories, the number of publications totaled 435 (76%) for environmental concentration, 126 (22%) for adsorption/absorption, and 11 (2%) for human exposure (Table 2).

Table 2. Categories identified in scoping review, by type of publication.

Category	Journal Articles	Reviews	Posters	Textbook Passage	Total (%) N = 572
Environmental	338	95	1	1	76.05
Adsorption/Absorption	115	11	0	0	22.03
Human exposure	6	4	1	0	1.92
Percentage of total	80.24%	19.23%	0.35%	0.17%	100

Figure 3 displays the sharp increase in published literature on microplastics, especially since 2014. The 2020 data point in the chart only shows literature through 21 January 2020. The literature from January 2020 already exceeds the number of included articles for 2016. This visualization is indicative of a positive trend for the publication of microplastics research.

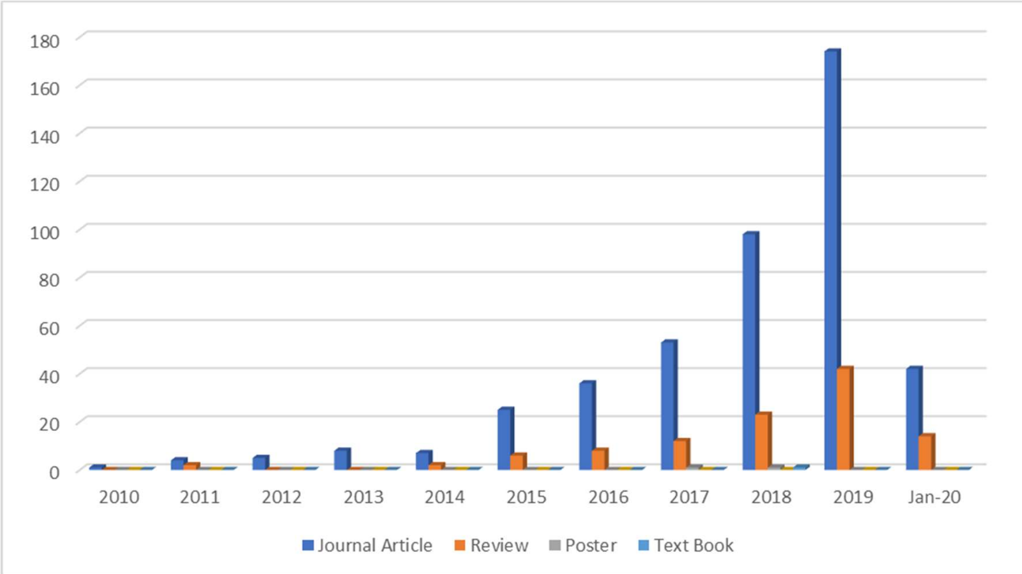

Figure 3. Total literature by category and year for included articles, 2010–January 2020.

3.1. Environmental Literature

The environmental category predominated in this scoping review (Table 2). Almost all literature identified and categorized as environmental was either a journal article (338 [78%]) or an environmental scientific or critical review (95 [22%]). Among the literature categorized as environmental, 81% were published during 2017–2019.

Among scientific publications, Figure 4 shows 430 (99%) were included in the scoping review and placed in the environmental category. These publications focused primarily on microplastics. The remaining four (1%) addressed microplastics and other pollutants, including macroplastics. Of the 435 publications, 49 (11%) described human exposures to microplastics, and 179 (41%) described a mechanism or potential mechanism of toxicity in organisms.

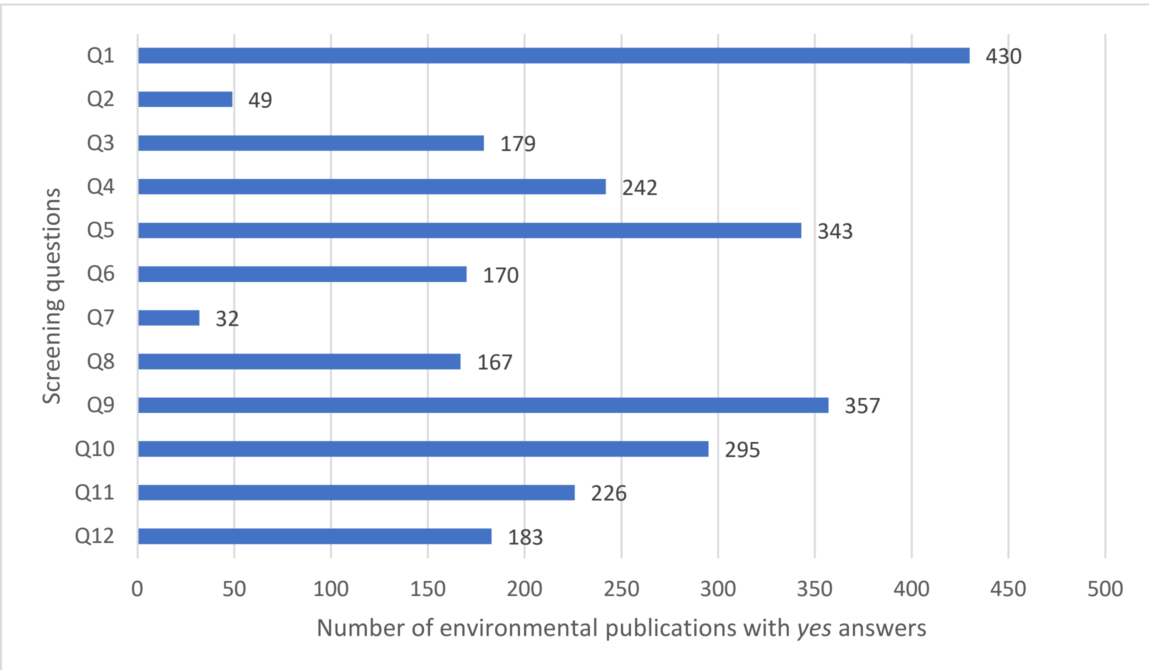

Figure 4. Displays the number of publications in the environmental category that correspond with "yes" per each screening questions (n = 435).

Two hundred and forty-two (56%) of the environmental publications included descriptions of chemical adsorption and absorption to microplastics. Most publications in the environmental category addressed microplastics in water (343 [79%]), followed by microplastics in sediment (170 [39%]), food (167 [38%]), and air or dust (32 [7%]).

A majority (357 [82%]) of the environmental publications focused on sampling and microplastics collection protocols and methods used to isolate microplastics. More than half (226 [52%]) of the included publications contained a geospatial description of source, such as oceans, rivers, lakes, and both human inhabited land settings (e.g., cities, farmlands, park grounds) and uninhabited land settings (e.g., beaches, deserts, mountains). Among the environmental publications, 295 (68%) examined evidence of microplastics ingestion associated with animals, plants, and microscopic organisms. Our data show that 183 (42%) of the environmental publications considered the potential for microplastics to accumulate through trophic transfer in the food chain.

3.2. Adsorption/Absorption Literature

The screening methodology placed 126 publications in the adsorption and absorption category. Of those, 115 (91%) were journal articles and the remaining 11 (9%) were scientific or critical reviews. As in the environmental category, the adsorption and absorption publications primarily were published during 2017–2019.

Figure 5 shows the number of publications that met the inclusion criteria in the adsorption/absorption category. Of those 126 publications, 124 (98%) focused strictly on microplastics; 19 (15%) focused on microplastics and human exposure and 48 (38%) either showed or predicted a mechanism for toxicity via microplastic exposure.

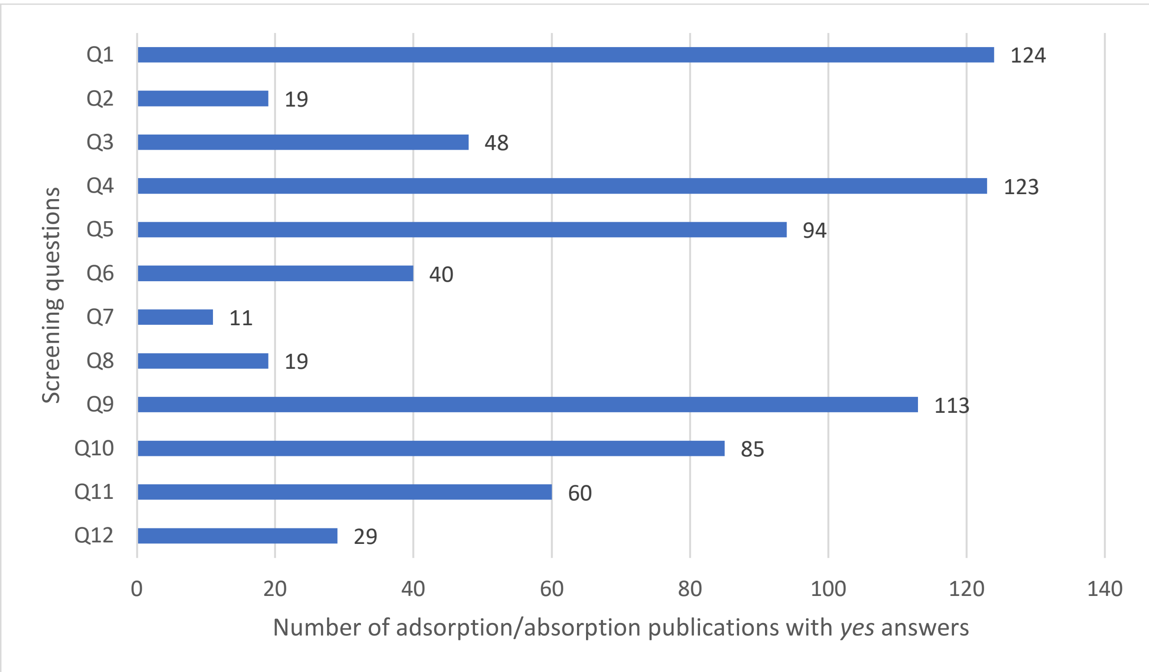

Figure 5. Displays the number of publications in the adsorption/absorption category that correspond with "yes" per each screening questions (n = 126).

In this third category, 123 (98%) of the papers explored adsorption/absorption of chemicals to microplastics. Among the 126 publications, 94 (75%) focused on the water environment, followed by sediment 40 (32%), 19 (15%) considered food, and 11 (9%) considered dust and air, with some overlap.

Within the adsorption/absorption category, 113 (90%) of the publications contained specific protocols on collection, isolation, and detection of microplastics (questions 9–12). Among the 126 publications in this category, 85 (68%) displayed evidence relating to detection of microplastics after ingestion. Nearly half (60 [48%]) of the publications discussed or extrapolated the geospatial concentrations of microplastics. Nearly a quarter (29 [23%]) of included publications indicated evidence of trophic transfer between organisms.

3.3. Human Exposure Literature

The final category examines human exposure. This category contained the fewest publications—only 11—, of which six (56%) were journal articles, four (36%) were reviews, and one (9%) was a poster. All publications included in this category were published after 2017.

Figure 6 shows the scoring for the 11 publications that met the inclusion criteria in the human exposure category. Among those publications, 10 (91%) concentrated on human exposure and five (46%) also investigated or described a mechanism for toxicity. Four (36%) publications described adsorption and absorption of chemicals to microplastic surfaces, three (27%) focused on microplastics in water, three (27%) studied microplastics in food, and one (9%) described microplastics in air and dust.

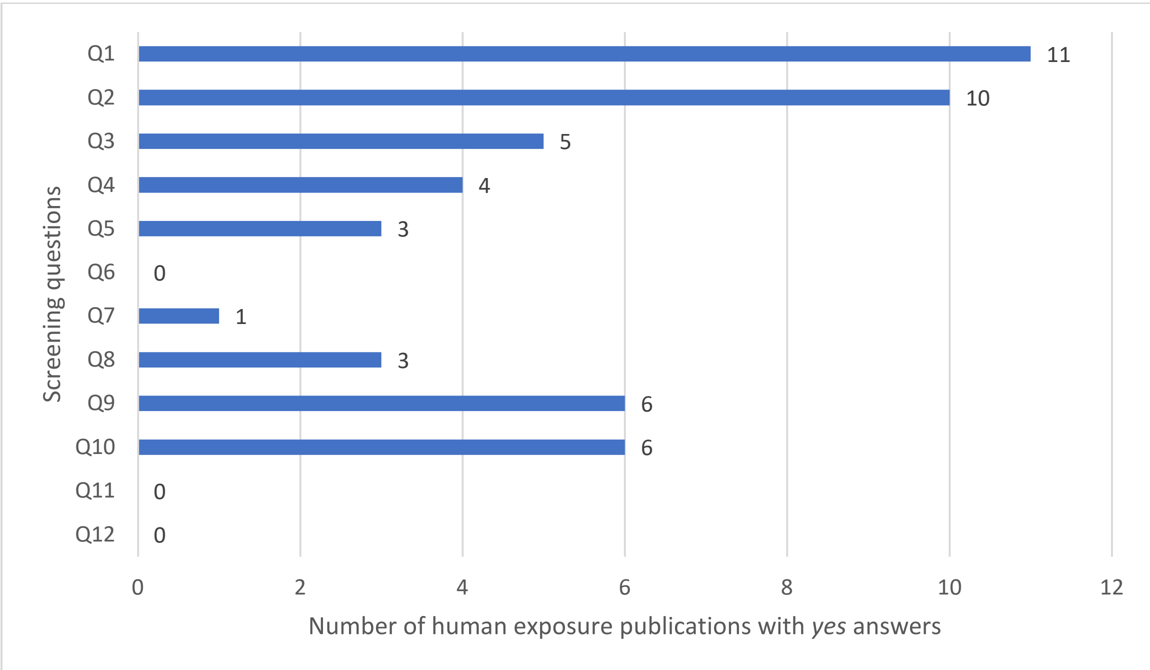

Figure 6. Displays the number of publications in the human exposure category that correspond with "yes" per each screening questions (n = 11).

Six (55%) publications included in the human exposure category described specific protocols for collection, detection, or isolation of microplastics. A different set of six (55%) publications described detection of microplastics after ingestion. Literature in this category did not address geospatial considerations or trophic transfer of microplastics.

4. Discussion

4.1. Microplastic Surgency

Five hundred and thirty-eight (94%) publications included in this scoping review were published within the period January 2015 through January 2020. There are many reasons for the recent microplastics publication boom in the scientific community. The development of modern technologies, such as dynamic light scattering, Raman spectroscopy, transmission electron microscopy, hyperspectral microscopy, and mass- or size-based particle counters, have allowed for the identification, characterization, and study of small particles such as microplastics [3]. Along with these advances in technology, environmental and political groups have made marked investments to invigorate the study of microplastics and bring them to the attention of the public [9–11].

Starting in the 1960s, plastic production increased annually by approximately 8.7% [12]. Plastics infiltrated multiple sectors, including computing, food preparation, healthcare, and infrastructure [1]. Novel uses for plastics have led to increased production. Understanding how plastics have permeated the environment has increased concerns about potential exposures and related harms. These concerns have triggered microplastic surveillance in the environment from a variety of institutions [13].

Plastic pollution has been a major environmental concern, both politically and scientifically [13]. Concern initially centered on macroplastics in the marine environment and their effects, such as plastic ingestion and entanglement of sea turtles [14]. However, the focus expanded rapidly upon the discovery that plastics were breaking down into smaller microplastics. Instead of breaking down into environmentally usable carbon, macroplastics were becoming smaller microplastics that retained their relatively inert chemical properties [15]. This discovery—coupled with the fact that the hydrophobic nature persists as plastics break down into their microplastic constituents—concerned scientists. Hydrophobicity allows harmful hydrophobic chemicals to adsorb to the plastics, and eventually enter the food chain leading to potential human exposure at the end of that chain. This process has spurred an international inquiry into microplastics [15].

4.2. Human Exposure Category

The first stage of the abstract screening process identified 16 (1.3%) papers to be placed in the human exposure category, one of the main objectives for the scoping review. Only 11 of the articles were included in the final scoping review. In 2019, five published research articles dealt with human exposure, a possible indicator that research might be trending toward human exposure investigations. Articles such as that by Zarus et al. [16], describe a variety of human exposures to microplastics, specifically showing particular organ targets. According to Zarus et al. there is sufficient characterization to demonstrate that elements of exposure exist in both the lungs and immune systems. There is also emerging evidence of characterization of exposure in the neurologic, gastrointestinal, and hepatic systems [16]. Polypropylene and polyethylene terephthalate were detected in all stool samples from a study conducted by Schwabl et al. [17]. The articles highlight industrial and nonindustrial exposures and the need for more studies of industrial and environmental microplastic exposures. Two objectives for conducting this scoping review were to identify research trends and to identify accomplishments related to the assessment and quantification of human exposure to microplastics. The authors intend to use this information to develop next steps related to assessing and quantifying human exposure.

4.3. Areas of Focus in the Screening Methodology

4.3.1. Water

Measurable concentrations of microplastics have been detected in every ocean, including the Arctic Ocean [18], the North Pacific central gyre [19], the Black Sea [20], and in several major river systems around the world, such as the Amazon River [21]. Microplastics absorption and adsorption properties in water have been studied more extensively than in any other media in the scoping review, with 94 [75%] of publications included in the absorption/adsorption category investigating microplastics in water. Water has been the main environmental medium of study of other review articles on microplastic literature [22,23]. In our review, 440 [77%] of included publications examined microplastics in water. The pervasiveness of microplastics in water has implications for flora and fauna and for several worldwide industries. Over the past 5 years, scientists have developed a clearer understanding of microplastic presence in water. Microplastics have been observed in plastic mineral water bottles because of mechanical breakdown especially in the cap and neck of the bottle [24]. There is evidence showing microplastics both in the sludge of urban wastewater treatment plants and after anaerobic digestion and centrifugation indicating a potential source for microplastics to enter the aquatic environment [25]. However, additional research is necessary, including broader investigations of other exposure mechanisms which will lead to a more holistic understanding of microplastics in the environment.

4.3.2. Sediment

Researchers have detected microplastics in land-based ecosystems, including beaches in Brazil [26], Sri Lanka [27], and islands in the Caribbean [28]. Microplastics have been discovered in agricultural fields, where it has been detected in vegetable farmlands [28,29]. The rate of microplastic use in farming increases every year because plastic mulch increases the water efficiency of soil, leading to higher crop yields [29]. This practice shows little sign of letting up and reinforces the case for further research into the potential for human exposure to microplastics through ingestion of farmed products. Studies have described microplastics in urban environments in major cities such as Paris, France, where they have been identified in wastewater, atmospheric fallout, and surface water [30]. Additionally, polyester and cotton microfibers in wastewater from washing machines have been detected [30,31].

4.3.3. Atmosphere/Dust

Because of their size, microplastics can mobilize as dust and disperse by wind to other environments [32]. Dris et al. indicate between 29 and 280 particles m^{-2} day^{-1} for microplastic and microparticle atmospheric fallout. Atmospheric or airborne microplastics have been documented to remain in the lungs of people working in indoor industries such as textile factories [32]. Synthetic clothing potentially can add to airborne inhalation exposure in the indoor environment [3]. The detection of microplastics in certain industries and within the home is an indication that future research should include more airborne studies to determine the threat to humans of airborne microplastics exposure.

4.3.4. Food

In this review, 33% of publications focused on microplastics in food and food sources. Food should be closely monitored with respect to new potential threats to human safety. The pervasiveness of microplastics in the water environment, as discussed above, has led to several studies focusing on the commercial fish market. Microplastics have been identified in fisheries in the Maowei Sea, [33] fisheries in China [34], and estuaries in Florida [35]. Microplastics have been detected in table salt [34,36], bottled mineral water [37], and beer [36]. Microplastics ability to absorb chemicals from the environment such as PCBs and dioxins and adsorb to potential food items makes exposure to microplastics through food a potential danger to health [8]. Studying microplastics in various food sources will continue to yield valuable information for assessing exposure in different diets.

4.3.5. Measuring Protocol

The majority of included papers (83%) described protocols for gathering, isolating, and quantifying microplastics. Microplastics usually are collected from water surfaces such as lakes and oceans using fine mesh or plankton nets [38]. Microplastics are commonly collected from beach and sediment environments using trowels to collect surface sediment samples [39]. Raman, micro-Raman, micro-Fourier-transform infrared spectroscopy, and macroscopic dimensioned near infrared in combination with chemometrics and hyperspectral imaging technology are used to identify microplastics [38,40]. Visualization techniques such as physical separation using microscopes, or the naked eye are also used to identify microplastics [38]. The future of microplastics detection and understanding is advancing as innovations in spectroscopy and other scientific fields, allowing scientists to study plastics at the nano level [41].

4.3.6. Microplastics Ingestion

A variety of exposure routes (e.g., skin, inhalation, and ingestion) have been considered in describing toxicity. Understanding microplastic ingestion is critical to helping determine human exposure risk and creating risk assessment. This scoping review reveals that very little literature exists on human ingestion and exposure, but the scoping review did yield work addressing ingestion across the trophic range. Literature shows evidence of microplastic ingestion in higher trophic level organisms, including the auk (an arctic sea bird) [42], basking sharks, and fin whales [43]. Additionally, microplastics are present in food items, with evidence that all human study subjects tested positive for microplastics in their stool samples [17].

Toxicity resulting from ingestion of microplastics is important to quantify and understand. Several adverse outcomes have been shown to occur after ingestion, such as physical mechanical blockage of the intestines [44], liver toxicity [3], endocrine disruption [3], neurotoxicity [3,45], and several downstream immunologic and cellular effects [45]. Microplastics have been shown to adsorb pyrene, a model for polycyclic aromatic hydrocarbons. In marine mussels, microplastic accumulation occurred in the hemolymph, gills, and digestive tissues [45]. Toxicity has been shown in marine rotifers ingesting microplastics, displaying synergistic effects between microplastics and environmental persistent organic pollutants [46]. Research should continue to examine the effects on microplastics after ingested to better understand potential mechanisms of toxicity.

4.3.7. Geospatial Analysis

Geospatial descriptions help us understand how microplastics mobilize and settle in a variety of environments. Geospatial analysis can come in the form of displaying specific latitude and longitude of sample collections in a study [47–49]. Geospatial analysis using overlayed pie charts can display proportions of microplastics relative to important factors affecting human exposure through consumption, such as fishing and fish-based diets. Studies have used pie charts to show the location in the ocean where microplastics were sampled and where fish that eat plankton live and were caught. These spatial analyses show that certain fish that support seafaring economies are also located in areas contaminated with microplastics. This highlights the increased potential for exposures to microplastics among those societies consuming these fish regularly [48]. Geospatial analysis described within the scoping review also displayed concentrations of microplastics in freshwater systems around the world [50]. Geospatial analysis can prove to be a critical aspect of understanding microplastics in the environment. These tools can allow researchers to track the mobilization of plastics across large areas to better understand how the movement and sequestration of plastics can affect human health [51].

4.3.8. Trophic Transfer

A trophic level for an organism represents that organism's hierarchical position relative to other organisms in that ecosystem. The base trophic levels include primary producers, such as plants. Higher levels include more and more complex predators, leading to the highest trophic level—the peak predator. The trophic transfer of microplastics is the ability for microplastics to move through the food web from lower trophic levels to higher trophic levels. Relatively few studies delve into trophic transfer in the environment. Literature identified in the scoping review used mussels as a model to illustrate the potential for trophic transfer [52] and a few described the potential for trophic transfer between crustaceans and fish [53]. Other studies indicate that microplastics do not biomagnify through the trophic levels [54]. Whether trophic transfer of microplastics is occurring remains unclear. More research is needed to understand the effects on human exposure to microplastics associated with consumption of animals and plants throughout the trophic levels.

4.4. Unexpected Discoveries and Limitations

When conducting the scoping review, we discovered some surprises. An initial finding was the lengthy time for study completion; reading and sorting the 1186 publications proved to be an almost year-long endeavor. Because microplastics comprise a relatively novel dataset for a scoping review, our methodology proved particularly useful for abstracting literature about microplastics. This type of scoping review and abstraction process could prove even more time-consuming if applied to other fields of research, where the literature base is in the tens of thousands to hundreds of thousands. This two-stage abstraction methodology is most useful for smaller sets of literature.

Some screening questions in the methodology were better predictors of a publication remaining in the final scoping review. This was intentional because we weighted screening questions based on their importance for including robust scientific literature that addressed microplastics. However, some questions, for example those related to air exposure (Q7) and human health exposure (Q2), made up only a small percentage of the publications included in the final review. Only 44 (8%) of the papers had some focus on Q7. The inclusion of Q7 helped us to develop a grouping of papers describing microplastics in air and dust that was useful for understanding inhalation exposures. We used Q2 to include publications that addressed human exposures to microplastics, the main objective of this scoping review. The review identified 78 (14%) publications that addressed human health exposure. The relatively few publications investigating human health exposure associated with microplastics indicates a lack of studies focusing on this topic.

This review was not without limitations. As noted above, the timeline for completion was quite lengthy, showing that this methodology might not be practical for larger topics that have more literature to consider.

4.5. Utility of the Organization Provided by This Methodology

Our goal in this scoping review was to increase our understanding of microplastics and their potential adverse health outcomes related to human exposure. To accomplish this, we settled on a two-stage screening methodology incorporating inclusion criteria to organize relevant literature into useful categories. The screening questions helped us assess and categorize information to reveal trends in the literature.

The second screening of the microplastics literature reduced the final count of publications by 50%. The specificity of the screening questions produced this significant reduction. This screening process can be repeated in the future, for updates to the literature contained in the current microplastics database as research continues to be published.

The research regarding microplastics is novel, but the trend of publications per year is significantly increasing. To show the substantial growth of microplastics research, we used our search criteria to identify new papers for the period from January 2020 to September 2022. This search identified 2917 new scientific articles. These articles have not been screened or included in this scoping review. The majority of the included research centered on microplastics in the environment. Publications in areas such as absorption and adsorption of a variety of chemicals to and from microplastics are increasing and were the second most common category of research in this review. Human exposure to microplastics was the category with the fewest papers, a category with opportunities for further research to better understand the human health effects from exposure to microplastics. This scoping review provides a methodology for organization and understanding the current state of microplastics research and highlights areas for future research.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/microplastics2010006/s1.

Author Contributions: G.C.—lead author, conceptualization, methodology, analysis, curation, writing original draft and review and editing, visualization. B.C.H.—project supervisor, writing—review and editing. J.T.—methodology, writing—review and editing. M.Z.-B.—conceptualization, methodology, analysis, writing—review and editing. C.M.—analysis, writing—review and editing.

G.M.Z.—methodology, writing—review and editing. Y.C.—conceptualization, analysis, writing—review and editing. A.E.—conceptualization, methodology, analysis. C.M.H.—lead principal investigator, conceptualization, analysis, curation, writing original draft and review and editing. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Not applicable.

Data Availability Statement: The specific search criteria used to create the original literature database is in the supplemental data. All the literature that we included in this scoping review is cited in the references section. The literature that was not cited in this scoping review is contained in an EndNote™ database.

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Conflicts of Interest: The authors declare no conflict of interest.

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