Environmental and Human Exposure Data of Microplastics

Subjects: Environmental Sciences

Contributor: Casillas Gaston, Brian Charles Hubbard, Jana Telfer, Max Zarate-Bermudez, Custodio Muianga, Gregory M. Zarus, Yulia Carroll, April Ellis, Candis M. Hunter

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.

Keywords: microplastics ; environmental concentration ; Exposure

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, 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].

2. Microplastic Surgency

Five hundred and thirty-eight (94%) publications included were published within the period January 2015 through January 2020. 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 [5][6][7].

Starting in the 1960s, plastic production increased annually by approximately 8.7% [8]. Plastics infiltrated multiple sectors, including computing, food preparation, healthcare, and infrastructure [1]. Novel uses for plastics have led to increased production. Plastic pollution has been a major environmental concern, both politically and scientifically.

Plastic pollution has been a major environmental concern, both politically and scientifically [9]. Concern initially centered on macroplastics in the marine environment and their effects, such as plastic ingestion and entanglement of sea turtles [10]. 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 [11]. 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 [11].

3. Areas of Focus in the Screening Methodology

3.1. Water

Measurable concentrations of microplastics have been detected in every ocean, including the Arctic Ocean [12], the North Pacific central gyre [13], the Black Sea [14], and in several major river systems around the world, such as the Amazon River [15]. 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 [16][17]. 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.

3.2. Sediment

Researchers have detected microplastics in land-based ecosystems, including beaches in Brazil [18], Sri Lanka [19], and islands in the Caribbean [20]. Microplastics have been discovered in agricultural fields, where it has been detected in vegetable farmlands [20][21]. The rate of microplastic use in farming increases every year because plastic mulch increases the water efficiency of soil, leading to higher crop yields [21]. 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.

3.3. Atmosphere/Dust

Because of their size, microplastics can mobilize as dust and disperse by wind to other environments [22]. 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 [22]. Synthetic clothing potentially can add to airborne inhalation exposure in the indoor environment [3]. 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. 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.

3.4. Food

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, [23] fisheries in China [24], and estuaries in Florida [25]. Microplastics have been detected in table salt [24][26], bottled mineral water [27], and beer [26]. Studying microplastics in various food sources will continue to yield valuable information for assessing exposure in different diets.

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 [28]. Microplastics are commonly collected from beach and sediment environments using trowels to collect surface sediment samples [29]. 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 [28][30]. Visualization techniques such as physical separation using microscopes, or the naked eye are also used to identify microplastics [28]. 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 [31].

3.6. Microplastics Ingestion

Understanding microplastic ingestion is critical to helping determine human exposure risk and creating risk assessment. This 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) [32], basking sharks, and fin whales [33]. Additionally, microplastics are present in food items, with evidence that all human study subjects tested positive for microplastics in their stool samples [34].

3.7. Geospatial Analysis

Geospatial descriptions help people 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 [35][36][37]. 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 [36]. 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 [38].

3.8. Trophic Transfer

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 [39] and a few described the potential for trophic transfer between crustaceans and fish [40]. Other studies indicate that microplastics do not biomagnify through the trophic levels [41]. 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. 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. [42], 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 [42]. Polypropylene and polyethylene terephthalate were detected in all stool samples from a study conducted by Schwabl et al. [34]. The articles highlight industrial and nonindustrial exposures and the need for more studies of industrial and environmental microplastic exposures. Two objectives 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.

References

1. Miranda, M.N.; Silva, A.M.T.; Pereira, M.F.R. Microplastics in the environment: A DPSIR analysis with focus on the responses. Sci. Total Environ. 2019, 718, 134968.
2. Guven, O.; Gökdağ, K.; Jovanović, B.; Kıdeyş, A.E. Microplastic litter composition of the Turkish territorial waters of the Mediterranean Sea, and its occurrence in the gastrointestinal tract of fish. Environ. Pollut. 2017, 223, 286–294.
3. Stapleton, P.A. Toxicological considerations of nano-sized plastics. Aims Environ. Sci. 2019, 6, 367–378.
4. Piao, M.; Wei Wang, M.; Liu, H.; Feng Chen, Y.; Xia, J. Research on ecotoxicology of microplastics on freshwater aquatic organisms. Environ. Pollut. Bioavailab. 2019, 31, 131–137.
5. U.S. Food and Drug Administration. The Microbead-Free Waters Act: FAQs; U.S. Food and Drug Administration, Ed.; U.S. Food and Drug Administration: Silver Spring, MD, USA, 2021.
6. Pallone, R.F., Jr. H.R. 1321—Microbead-Free Waters Act of 2015; Commerce, H.-E.A., Ed.; Congress: Washington, DC, USA, 2015.
7. Legal Limits on Single-Use Plastics and Microplastics; United Nations Environment Programme: Nairobi, Kenya, 2018.
8. Smith, M.; Love, D.C.; Rochman, C.M.; Neff, R.A. Microplastics in Seafood and the Implications for Human Health. Curr. Environ. Health Rep. 2018, 5, 375–386.

9. Worm, B.; Lotze, H.K.; Jubinville, I.; Wilcox, C.; Jambeck, J. Plastic as a Persistent Marine Pollutant. Annu. Rev. Environ. Resour. 2017, 42, 1–26.
10. Ivar do Sul, J.A.; Santos, I.R.; Friedrich, A.C.; Matthiensen, A.; Fillmann, G. Plastic pollution at a sea turtle conservation area in NE Brazil: Contrasting developed and undeveloped beaches. Estuaries Coasts 2011, 34, 814–823.
11. Rao, B.M. Microplastics in the aquatic environment: Implications for post-harvest fish quality. Indian J. Fish. 2019, 66, 142–152.
12. Avio, C.G.; Gorbi, S.; Regoli, F. Plastics and microplastics in the oceans: From emerging pollutants to emerged threat. Mar. Environ. Res. 2017, 128, 2–11.
13. Cole, M.; Lindeque, P.; Halsband, C.; Galloway, T.S. Microplastics as contaminants in the marine environment: A review. Mar. Pollut. Bull. 2011, 62, 2588–2597.
14. Aytan, U.; Valente, A.; Senturk, Y.; Usta, R.; Sahin, F.B.E.; Mazlum, R.E.; Agirbas, E. First evaluation of neustonic microplastics in Black Sea waters. Mar. Environ. Res. 2016, 119, 22–30.
15. Souza e Silva Pegado, T.D.; Schmid, K.; Winemiller, K.O.; Chelazzi, D.; Cincinelli, A.; Dei, L.; Giarrizzo, T. First evidence of microplastic ingestion by fishes from the Amazon River estuary. Mar. Pollut. Bull. 2018, 133, 814–821.
16. Doris Klingelhofer, M.B.; Quarcoo, D.; Bruggmann, D.; Groneberg, D.A. Research landscape of a global environmental challenge: Microplastics. Water Res. 2019, 170, 115358.
17. Rachel, M.; Sorensen, B.J. From nanoplastic to microplastic: A bibliometric analysis on the presence of plastic particles in the environment. Mar. Pollut. Bull. 2020, 163, 111926.
18. Alves, V.E.N.; Figueiredo, G.M. Microplastic in the sediments of a highly eutrophic tropical estuary. Mar. Pollut. Bull. 2019, 146, 326–335.
19. Bimali Koongolla, J.; Andrady, A.; Kumara, P.T.P.; Gangabadage, C. Evidence of microplastics pollution in coastal beaches and waters in southern Sri Lanka. Mar. Pollut. Bull. 2018, 137, 277–284.
20. Acosta-Coley, I.; Mendez-Cuadro, D.; Rodriguez-Cavallo, E.; de la Rosa, J.; Olivero-Verbel, J. Trace elements in microplastics in Cartagena: A hotspot for plastic pollution at the Caribbean. Mar. Pollut. Bull. 2019, 139, 402.
21. Zhang, M.; Zhao, Y.; Qin, X.; Jia, W.; Chai, L.; Huang, M.; Huang, Y. Microplastics from mulching film is a distinct habitat for bacteria in farmland soil. Sci. Total Environ. 2019, 688, 470–478.
22. Toussaint, B.; Raffael, B.; Angers-Loustau, A.; Gilliland, D.; Kestens, V.; Petrillo, M.; Rio-Echevarria, I.M.; Van den Eede, G. Review of micro- and nanoplastic contamination in the food chain. Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess. 2019, 36, 639–673.
23. Zhu, J.; Zhang, Q.; Li, Y.; Tan, S.; Kang, Z.; Yu, X.; Lan, W.; Cai, L.; Wang, J.; Shi, H. Microplastic pollution in the Maowei Sea, a typical mariculture bay of China. Sci. Total Environ. 2019, 658, 62–68.
24. Yang, D.; Shi, H.; Li, L.; Li, J.; Jabeen, K.; Kolandhasamy, P. Microplastic Pollution in Table Salts from China. Environ. Sci. Technol. 2015, 49, 13622–13627.
25. Waite, H.R.; Donnelly, M.J.; Walters, L.J. Quantity and types of microplastics in the organic tissues of the eastern oyster Crassostrea virginica and Atlantic mud crab Panopeus herbstii from a Florida estuary. Mar. Pollut. Bull. 2018, 129, 179–185.
26. Kosuth, M.; Mason, S.A.; Wattenberg, E.V. Anthropogenic contamination of tap water, beer, and sea salt. PLoS ONE 2018, 13, e0194970.
27. Welle, F.; Franz, R. Microplastic in bottled natural mineral water—Literature review and considerations on exposure and risk assessment. Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess. 2018, 35, 2482–2492.
28. Rezania, S.; Park, J.; Din, M.F.M.; Taib, S.M.; Talaiekhozani, A.; Yadav, K.K.; Kamyab, H. Microplastics pollution in different aquatic environments and biota: A review of recent studies. Mar. Pollut. Bull. 2018, 133, 191–208.
29. Mathalon, A.; Hill, P. Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Mar. Pollut. Bull. 2014, 81, 69–79.
30. Zhang, S.; Wang, J.; Liu, X.; Qu, F.; Wang, X.; Wang, X.; Li, Y.; Sun, Y. Microplastics in the environment: A review of analytical methods, distribution, and biological effects. TrAC Trends Anal. Chem. 2019, 111, 62–72.
31. Shen, M.; Zhang, Y.; Zhu, Y.; Song, B.; Zeng, G.; Hu, D.; Wen, X.; Ren, W. Recent advances in toxicological research of nanoplastics in the environment: A review. Environ. Pollut. 2019, 252, 511–521.
32. Amelineau, F.; Bonnet, D.; Heitz, O.; Mortreux, V.; Harding, A.M.; Karnovsky, N.; Walkusz, W.; Fort, J.; Grémillet, D. Microplastic pollution in the Greenland Sea: Background levels and selective contamination of planktivorous diving seabirds. Environ. Pollut. 2016, 219, 1131–1139.

33. Fossi, M.C.; Coppola, D.; Baini, M.; Giannetti, M.; Guerranti, C.; Marsili, L.; Panti, C.; de Sabata, E.; Clò, S. Large filter feeding marine organisms as indicators of microplastic in the pelagic environment: The case studies of the Mediterranean basking shark (Cetorhinus maximus) and fin whale (Balaenoptera physalus). Mar. Environ. Res. 2014, 100, 17–24.
34. Schwabl, P.; Köppel, S.; Königshofer, P.; Bucsics, T.; Trauner, M.; Reiberger, T.; Liebmann, B. Detection of Various Microplastics in Human Stool: A Prospective Case Series. Ann. Intern. Med. 2019, 171, 453–457.
35. Kazour, M.; Jemaa, S.; El Rakwe, M.; Duflos, G.; Hermabassiere, L.; Dehaut, A.; Le Bihanic, F.; Cachot, J.; Cornille, V.; Rabhi, K.; et al. Juvenile fish caging as a tool for assessing microplastics contamination in estuarine fish nursery grounds. Environ. Sci. Pollut. Res. 2018, 15, 15.
36. Ory, N.; Chagnon, C.; Felix, F.; Fernández, C.; Ferreira, J.L.; Gallardo, C.; Ordóñez, O.G.; Henostroza, A.; Laaz, E.; Mizraji, R.; et al. Low prevalence of microplastic contamination in planktivorous fish species from the southeast Pacific Ocean. Mar. Pollut. Bull. 2018, 127, 211–216.
37. Tsang, Y.Y.; Mak, C.; Liebich, C.; Lam, S.; Sze, E.T.-P.; Chan, K. Microplastic pollution in the marine waters and sediments of Hong Kong. Mar. Pollut. Bull. 2017, 115, 20–28.
38. Colton, J.B., Jr.; Knapp, F.D.; Burns, B.R. Plastic particles in surface waters of the Northwestern Atlantic. Science 1974, 185, 491–497.
39. Zhao, S.; Ward, J.E.; Danley, M.; Mincer, T.J. Field-Based Evidence for Microplastic in Marine Aggregates and Mussels: Implications for Trophic Transfer. Environ. Sci. Technol. 2018, 52, 11038.
40. Zhang, F.; Wang, X.; Xu, J.; Zhu, L.; Peng, G.; Xu, P.; Li, D. Food-web transfer of microplastics between wild caught fish and crustaceans in East China Sea. Mar. Pollut. Bull. 2019, 146, 173.
41. Walkinshaw, C.; Lindeque, P.K.; Thompson, R.; Tolhurst, T.; Cole, M. Microplastics and seafood: Lower trophic organisms at highest risk of contamination. Ecotoxicol. Environ. Saf. 2020, 190, 110066.
42. Zarus, G.; Custodio, M.; Hunter, C.; Pappas, S. A review of data for quantifying human exposure to micro and nanoplastics and potential health risks. Sci. Total Environ. 2021, 756, 144010.