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Microplastics, environment, and human health. A global review

Microplásticos, ambiente y salud humana. Una revisión a nivel global

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RESUMEN

In the world, microplastics represent a growing environmental concern due to their resistance and consequent contamination of ecosystems. This review resorted to the ScienceDirect platform as a database to analyze the topic in the environment context and the human being, using the systematic literature review methodology, specifically research articles, with the search equations <micropastics> AND <aquatic>, <microplastics> AND <soil>, <microplastics> AND <human health> between 2018 and 2023. Based on the literature review, a total of 11 795 articles were obtained between research (9814) and review (1981); regarding microplastics in the water, the search yielded a total of 5504 writings; in the case of soils, 3900 articles were found, and regarding human health, 4848 documents. It was identified that the contamination of this compound in the soil factor decreases water retention and contaminates aquifers; it also causes negative impacts on marine ecosystems since one of the origins of microplastics is the secondary one, which degrades large plastic objects in the sea, such as bags, bottles, fishing nets, and releases into the environment different additives such as heavy metals, phthalates, among others, affecting the environment, the aquatic biota but also the respiratory and digestive system of people; therefore, there is a need for further research on the presence and possible effects of microplastics in soil, water, and human beings.

KEYWORDS: microplastics, environment, water, soil, human health

ABSTRACT

En el mundo, los microplásticos representan una preocupación ambiental cada vez mayor debido a su resistencia y la consecuente contaminación de los ecosistemas. Esta revisión acudió a la plataforma ScienceDirect como base de datos para analizar el tema en el contexto ambiental y el ser humano, utilizando la metodología de revisión sistemática de la literatura, específicamente artículos de investigación, con las ecuaciones de búsqueda <microplastics> AND <aquatic>, <microplastics> AND <soil>, <microplastics> AND <human health> entre 2018 y 2023. Con base en la revisión bibliográfica se obtuvo un total de 11 795 artículos entre investigación (9814) y revisión (1981); respecto a la presencia de microplásticos en el agua, la búsqueda arrojó un total de 5.504 escritos; en el caso de suelos, se hallaron 3.900 artículos, y en cuanto a la salud humana, 4.848 documentos. Se identificó que la contaminación de este compuesto en el suelo disminuye la retención y la contaminación de acuíferos; también origina impactos negativos en ecosistemas marinos debido a uno de los orígenes de los microplásticos es el secundario, el cual se genera de la degradación de grandes objetos de plástico en el mar, como bolsas de plástico, botellas, redes de pesca, los cuales liberan al medio los diferentes aditivos que estos los componen como son metales pesado, ftalatos, entre otros, estos terminan afectando no solo la biota acuática sino también el sistema respiratorio y digestivo de las personas; por lo cual se evidencia la necesidad de realizar más investigaciones respecto a la presencia y posibles efectos de los microplásticos en el agua, suelo y el ser humano.

PALABRAS CLAVE: microplásticos, ambiente, agua, suelo, salud humana

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Introduction

Microplastics comprise small particles that do not exceed 5 mm in diameter. As a result of the degradation of larger plastics, they can be found in many everyday products such as packaging, clothing, personal care articles, materials, and industrial waste (Bollaín & Vicente, 2019; Matos et al., 2022). They entail a global environmental problem because they are present in places such as the ocean, soil, and air (Laborda et al., 2021; Paul et al., 2020). Over time, these residues accumulate in the environment, harming wildlife, ecosystems, and humans (Iannacone et al., 2022).

Coastal areas are subject to direct environmental pressures such as population growth (10% of humanity lives on the coast), tourism, ports, maritime traffic, or fish farms, which emit complex mixtures of pollutants, including plastic; there are also indirect inputs through river discharges and atmospheric deposition (Llorca et al., 2020). Currently, it is estimated that there are trillions of microplastics in the oceans, and their quantities increasing; in addition, they have been found in drinking water sources, such as rivers, lakes, and aquifers (Vidal et al., 2021), then, marine fauna can ingest them and transfer them to the human food chain where they act as vectors of chemical contaminants and cause the release of toxic materials into the environment, reduction of digestive enzyme activity, damage to absorption function, pulmonary problems and others, which raises concerns about possible effects on human health (Bollaín & Vicente, 2019; Liu et al., 2019; Yin et al., 2023).

The global problem involves the production and final disposal of plastic products and requires attention from industry, governments, and consumers (Tomaz & de Oliveira, 2020). Some of the practices that help mitigate this problem include the adoption of recycling and the reduced use of single-use plastics; this is why most countries have banned them in personal care products, and technologies are being developed to filter microplastics from water and reduce their release into the environment (de Carvalho et al., 2021). They have also been detected in food, mainly in protein products consumed by marine and inland fauna, which proves the impact they can have on the health of fish and seafood consumers (Franco-Herrera et al., 2022; Guan et al., 2023; Yin et al., 2023). Therefore, this review focuses on the potential consequences of microplastics in aquatic environments, soil, and human health and on possible methods for quantifying microplastics to identify these structures.

Methodology

As part of this research, microplastics and their impact on environmental pollution, human health, and food have been studied extensively. Several studies have been assessed and analyzed to understand comprehensively the subject. It constitutes a review research since it analyzes problems related to scientific knowledge, making them susceptible to further application. This exploratory study seeks to collect and record the facts of reality without the researcher needing to formulate direct questions or use technical means (Gómez et al., 2015; Puerto et al., 2020). The bibliographic survey on this topic was based on the collection of research articles published in recognized databases during the last five years as of 2018.

The method used focuses on the systematic review of the literature (Petersen et al., 2008), where an articulated process is linked to the research topic; it starts with the definition of research questions: how are microplastics contextualized in the world, how do microplastics affect the aquatic environment and soil, how do microplastics affect human health? After defining the research questions, search patterns are generated with the following keywords: microplastics, water, and human health. For the search equations, the Boolean operator AND is used as follows:

- Microplastics AND aquatic
- Microplastics AND soil
- Microplastics AND human health

Searching in the ScienceDirect database, we generate inclusion and exclusion criteria:

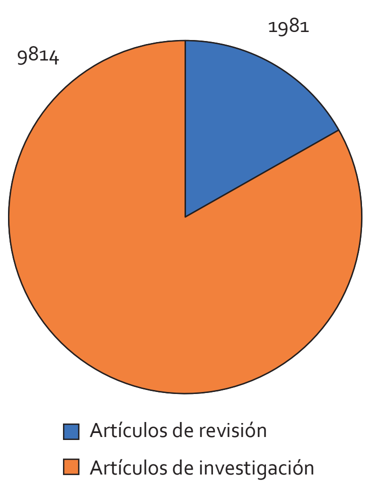
- Inclusion criteria: (a) the article should mention studies on microplastics in the country or abroad; (b) the article should include at least one effect of microplastics on the environment; and (c) the article should mention at least one consequence of microplastics on human health.

§ Exclusion criteria: (a) graduate theses, technical guides, and technical reports; (b) publications before 2015; (c) publication unavailable in digital format; and (d) review articles. The scientometric analysis was applied to classify and extract the information, with indicators such as year of publication or number of annual publications to analyze the specific content (Gómez et al., 2016; Monsalve et al., 2020).

Results

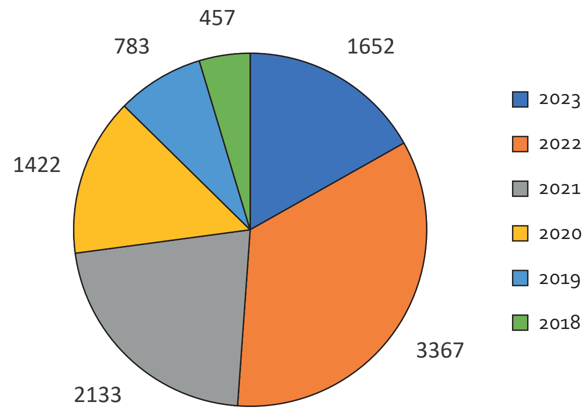
After searching for the word microplastics in ScienceDirect, a total of 11 795 articles were obtained, of which 1981 correspond to review articles and 9814 are research articles published between the years 2018 and 2023, with a higher number of publications for 2022 and 34.31 % (3367 articles), followed by 2021 with 21.73 % (2133 articles), and for 2023 16.83 % (1652 articles), which shows more research in the last three years on microplastics in the world; Perhaps due to the growth of studies focused on demonstrating that plastics generate smaller particles that may have implications or presence in different environments such as water, soil, food and in humans, with consequences for health. This issue is growing as concern about these structures is also increasing (Figure 1 and Figure 2).

Figure 1. Review and research articles



Note: Source: authors

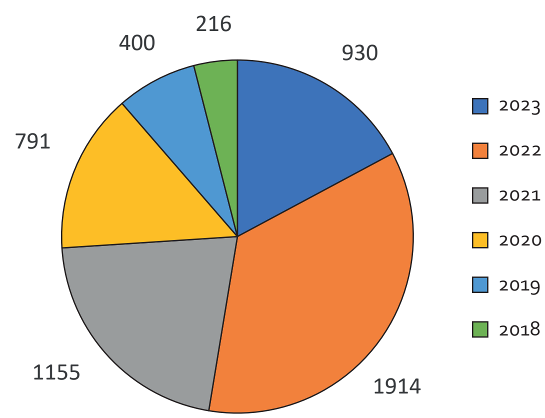
Figure 2. Research articles per year



Note: Source: authors

Regarding the results obtained from the search equations <microplastics> AND <aquatic>, 5504 research articles were obtained, of which 2022 shows the highest number of publications with 1914 articles, representing 45.41% of the total number of texts published for the ScienceDirect database, followed by 2021 and 2023 with 1155 and 930 articles, covering 21.37% and 17.20% respectively; thus it can be inferred that for just the first quarter of 2023 there is a large amount of information on microplastics and aquatic environments, as shown in Figure 3.

Figure 3. Articles per year about microplastic contamination in water

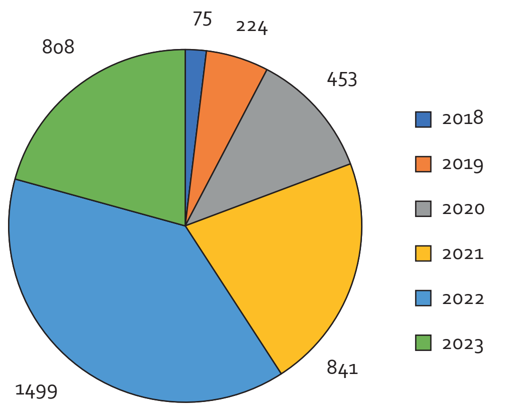


Note: Source: authors

For the search equation <microplastics> AND <soil>, 3900 research articles were obtained, of which the highest number of publications occurred in 2022 with 1499 articles, representing 38.44% of the total number of papers published in

ScienceDirect, followed by 2021 and 2023 with 841 and 808 articles, representing 21.56% and 20.72% respectively as can be seen in Figure 4.

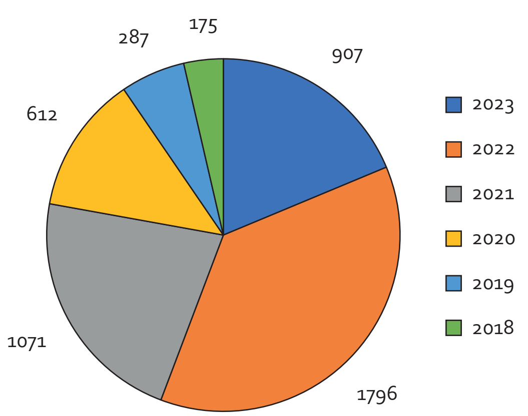
Figure 4. Research articles about microplastic contamination in soil



Note: Source: authors

For the search equation <microplastics> AND <human health>, 4848 research articles were identified, with the highest number of publications for 2022 and 1796 articles, representing 37.05% of the total manuscripts published for the ScienceDirect database, followed by 2021 and 2023 with 1071 and 907 articles, representing 22.09% and 18.71% respectively as illustrated in Figure 5.

Figure 5. Research articles per year about microplastics on human health



Note: Source: authors

Discussion

Microplastics and environment

Microplastic particles can be found in many matrixes, including soil and water. The microplastics in the soil are of increasing concern due to their potential impact on the environment and health, as some organisms can ingest them and, through the food chain, end up in the human body (Luo et al., 2023). Microplastics in soils can come from different sources, such as waste caused by plastic mulch used in agriculture (Yang et al., 2023), application of compost from municipal solid waste and sewage sludge (Huerta et al., 2023), greenhouse structures (Kumar & Sheela, 2021) and road dust (Surendran et al., 2023). Microplastics can be produced from fragments, films, fibers, foams, granules, or polymeric components and are characterized by persisting in soil for years (Gong et al., 2019). Once in the soil, microplastics affect the biotic and abiotic structure and contaminate aquifers in the long term (Singh et al., 2023).

It has been shown that the accumulation of microplastics has harmful effects on soil physical properties such as bulk density and aggregate stability, with more influence in clay soils (Wang, C., et al., 2023), as it can reduce water and nutrient holding capacity (Zhang et al., 2023). In addition, it can affect soil biota because the tiny size and low density of the particles allow them to enter the organisms of many species that perceive them as food; ingestion is harmful and even lethal because they have been shown to decrease the abundance of this macrofauna and microfauna in Tang et al., 2023; Shen et al., 2023). To reduce the presence of microplastics in the soil, it is advisable to implement practices such as regenerative agriculture techniques which focus on restoring the quality and fertility of degraded soils, the reduction of Pesticides do not generate microplastics, the use of wastewater treatment systems with synthetic fiber filters, the application of microplastic purification methods using the enzymatic hydrolysis method (Mbachu et al., 2021), the use of biodegradation methods through mealworm (*Tenebrio molitor*) (Peng et al., 2023), the disposition of previously isolated and analyzed polymer-degrading bacteria (*B. subtilis V8, P. aminophilus B14-, P. putida C 2 5, P. aeruginosa V1* and *A. calcoaceticus V4*) (Pathak & Navneet, 2023) and bioremediation processes (Rad et al., 2022).

Microplastic pollution in the marine ecosystem increases the concern: by 2030, 53 million metric tons of plastic waste are expected to reach aquatic ecosystems (Borrell et al., 2020). This problem is widespread due to the capacity of microplastics to remain in the environment and the transfer of these particles through the food chain, as microplastics of different sizes have been found in seawater, rivers and ponds, sediments, plankton, and fish (Qaiser et al., 2023). In the latter, it complicates feeding behavior (Yagi et al., 2022), as ingestion affects animal health, affectation in the composition of intestinal microorganisms, accumulates toxins, and changes behavior. Microplastics also contain chemical contaminants such as masks (used to prevent SARS-CoV-2 virus transmission), which release significant amounts of heavy metals and toxic chemicals (Li et al., 2022), affecting marine life. Microplastic pollution in marine environments has been assessed through aquatic drones that facilitate sampling (Pasquier et al., 2022) and clean-up processes in the most affected areas. It is necessary to deepen studies on efficient organisms that filter microplastics like the Virginian oyster Crassostrea virginica to reduce the amount of this material in water. In addition, applying filtering techniques via fluorescence has shown enormous utility (Liu et al., 2021).

Microplastics and their influence on human health

Humans are not exempt from the impact of microplastic pollution, as they depend on ocean fish and their surrounding ecosystems as a source of protein (Huang et al., 2022; Vital et al., 2021; Yang et al., 2022). Human consumption of seafood is among the most common ways microplastics enter the body (Cox et al., 2019). Microplastics have been detected in the human placenta (Ragusa et al., 2021), lungs (Amato et al., 2021), feces (Schwabl et al., 2019), and colon (Ibrahim et al., 2021). While research on measurements of internal exposure of plastic particles in human body fluids and tissues and their impacts is still low, studying the possible exposure paths to understand and minimize them in humans is recommended (Mahu et al., 2023). Relevant examples include the case of the US diet by Cox et al. (2019), who assessed the number of microplastic particles in commonly consumed foods about their recommended daily intake and explored the eventual inhalation of microplastics. Drinking water sources may include them according to the rough assessment of 15% of Americans' caloric intake; the researchers estimated that annual microplastic consumption ranges from 39 000 to 52 000 particles depending on age and sex, and increases to 74 000 and 121 000 when inhalation is considered, and people who meet their recommended water intake only through bottled sources would ingest an additional 90 000 microplastics per year, compared to 4000 microplastics for those who consume only tap water. On the other hand, in Nigeria, microplastics were detected in 160 fish species analyzed and a total of 5744 microplastics were counted with an average of 39.65 ± 5.67 particles per fish, identifying six types of microplastics based on shape: microbeads, fragments, burnt film, fibers, granules and threads. Microspheres were found to be the most abundant and fibers the scarcest in fish intestines. It was also identified that 15% of microplastics were found more frequently in demersal fish than in pelagic fish (>100 μm). The guts studied have the potential to translocate from fish gut barriers to muscle, so when ingested by humans they can become fixed in tissues or organs (Mahu et al., 2023).

In Hong Kong, the risks associated with the consumption of wild clams were assessed using the polymer risk index, and the results pointed to a medium degree of risk, with exposure to microplastics through this food being unavoidable and posing a potential threat to human health (Wing et al., 2023). Among Pacific Island nations (Tutuila and American Samoa), microplastics were found to be unevenly distributed in the marine environment, with the highest concentrations detected in marine mollusks, ranging from 15 to 17 particles per organism, most of which corresponded to microfibers identified as polyethylene terephthalate. Based on estimated invertebrate consumption rates, the risk of adverse human health impacts would be low (Wing et al., 2023). In evaluating the concentrations of microplastics in *Oreochromis niloticus*, widely consumed in Mexico, Martínez-Tavera et al. (2021) stated that the presence of microplastics in fish from a highly contaminated region is not only governed by their bioavailability but also by the physiological characteristics of the organism.

In human food consumption, microplastics have been detected in drinking water sources, such as tap and bottled water (Koelmans et al., 2019), also in more than 120 brands of salts worldwide (Zhang et al., 2020), it has also been reported in human feces (Schwabl et al., 2019). Samples with Polyethylene terephthalate and polypropylene indicate consumption of microplastics from various food sources (Walkinshaw et al., 2020). Another source of exposure other than food is air since humans could inhale approximately 272 particles/day, with consequences for the lungs, and the micro size turns them more toxic to neurons (Joseph et al., 2023; Liu et al., 2019). On the other hand, exposure to microplastics causes cellular toxicity by cellular oxidative stress. Exposure to microplastics reduces lipid digestion due to the formation of microplastic oil droplets and inhibits enzyme activity during the digestion process (Wang, Z., et al., 2023; Tan et al., 2020).

"Hua et al. (2022) made a 3D model of cortical spheroids of the human forebrain, which mimics the early development of the human cerebral cortex and found that, depending on its size and concentration, polystyrene can negatively affect tissue development.". Senathirajah et al. (2021) estimated that, worldwide, humans may ingest 0.1 to 5 g of microplastics per week through various exposure pathways. Determining an ingestion rate is critical for assessing health risks from microplastic ingestion. These findings will contribute to decreasing the future risk to human health; however, more research is still needed to understand the whole effects of microplastics, and Yang et al. (2022) propose five urgent perspectives and implications for future microplastic research:

1) To develop standardized terminology and research methods.
2) To strengthen the governance of microplastic contamination.
3) To explore innovative strategies and technologies.
4) To engage people and change behavior.
5) To adopt a transdisciplinary approach.

While more research is still needed to understand the microplastic effects on health, efforts to reduce their amount in the environment and limit human exposure are crucial. These could include reducing or avoiding single-use plastics, opting for personal care products that do not contain microplastics, and increasing waste management and recycling.

Methods for quantification of microplastics

Quantification is the counting and categorizing of microplastics according to their size, color, and polymer type (Möller et al., 2020). When using a microscope for optically counting microplastics, accuracy can be a limitation; therefore, the chemical structure of the polymers is fundamental to ensure precision (Sun et al., 2019); microscopy and spectroscopy make it possible to improve the accuracy of optical counting. Authors such as Zhang et al. (2018) suggested a method to identify soil polymers. After density separation with water, the residues in the supernatant are examined by comparing previous microscopic images. There are other particle-based techniques used for identifying microplastics, such as pyrolysis-gas chromatography-mass spectrometry and thermal extraction-desorption-gas chromatography-mass spectrometry (Rose et al., 2023). Another methodology involves gas chromatography-mass spectrometry with thermal extraction desorption (Dümichen et al., 2017) for rapid sample analysis but destructive. Vibrational spectroscopy, such as Raman or FTIR, is usually used for analyzing microplastics. Their spectra are employed to identify various types of plastics compared to a spectral library (Corradini et al., 2019). Raman microspectroscopy identifies microplastics with a pixel resolution of up to 500 nm (Lv et al., 2020), while micro-FTIR spectroscopy identifies particles from 10 to 500 μm (Möller et al., 2020) and defines an ideal procedure for analyzing sediment samples. To determine the chemical compositions of plastic particles, energy dispersive X-ray spectroscopy (EDS) is considered a good option; however, its regular access is complicated, as detection requires more time and costs. Proton nuclear magnetic resonance spectroscopy can analyze samples quantitatively and qualitatively containing polyethylene particles; it is a new method to analyze microplastics, regardless of size (Peez et al., 2019). Finally, depending on the need for microplastics' analysis or determination of size, shape, color, and morphology, the described methods can be used separately or combined.

Conclusions

Based on the literature review of the ScienceDirect database for 2018-2023 and the search for the word *microplastics*, a total of 11 795 articles —9814 research and 1981 review— were retrieved, the majority published in 2022 with 3367 articles, followed by 2021 with 21.7 % (2133) and 2023 with 16.8% (1652). Regarding *microplastics in aquatic ecosystems*, the search yielded 5504 articles, corresponding to 56% of the total, of which 45.4% (1914 articles) were published in 2022, followed by 2021 with 21.3% (1155) and 2023 with 17.2% (930). The search *microplastics in soil* revealed a total of 3900 articles, of which 2022 shows the highest number of publications with 38.4% corresponding to 1499 articles, followed by 2021 with 21.56% (841) and 2023 with 20.7% (808). The search for *microplastics in human health* listed 4848 articles, the majority published in 2022 with 1796 corresponding to 37%, followed by 2021 with 1071 and 2023 with 907 articles. This review shows a higher number of publications in the last 3 years due to the implications of microplastics on the aquatic ecosystem, the soil matrix, and human health.

Microplastics in soil have been proven to contaminate groundwater in the long term, affect bulk density and the stability of soil aggregates by reducing water and nutrient holding capacity, and damage soil biota because their ingestion is harmful and even lethal to some organisms.

Pollution of the marine ecosystem by microplastics is an increasingly studied problem, as it has been identified that ingestion of particles by marine species causes clogging of their digestive tracts, accumulation of toxins, and changes in behavior; it is also reported that microplastics can release significant amounts of heavy metals and toxic chemicals that weaken marine and human health.

Daily, humans are exposed to microplastics: they could inhale up to 272 particles/day from indoor air, leading to lung damage and neuronal intoxication; likewise, microplastics would be found in food in direct exposure because they inhibit enzymatic activity during the digestion process; they can also affect the development of embryonic brain-like tissue in spheroids of the forebrain, as they occur in environmental factors with neurotoxicity. Consequently, further studies are required to research the microplastic load in soil, water, and humans and the possible effects on organisms.

Conflictos de interés:

No existen conflictos de interés asociados al presente artículo

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