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MICROPLASTICS: TINY STUFF, BIG THREAT TO FRESHWATER ECOSYSTEMS

(Microplásticos: coisas minúsculas, grande ameaça aos ecossistemas de água doce)

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ABSTRACT

Microplastics are tiny plastic particles that we humans produce, and they are constantly moving around our planet. They have become a very serious concern to the environment, because we produce them in huge quantities, and they are very slow to degrade. When microplastics reach freshwater environments, they can pollute drinking water, affect all kinds of life forms, and find their way to our diet. Many international organizations are trying to reduce the use and production of articles like bags, clothes, hygiene products and even toys, that are made of or contain microplastics. Researchers all over the world are looking into ways to degrade microplastics, and to discover new, eco-friendly materials. But there are many things we all can do to help as well. All of us can make a difference to reduce microplastics pollution.

Palavras-chave: *Environmental impact, freshwater pollution, human activities, microplastics.*

RESUMO

Os microplásticos são pequenas partículas de plástico produzidas pelos humanos e que estão em constante movimento pelo nosso planeta. Eles se tornaram uma preocupação muito séria para o meio ambiente, porque nós os produzimos em grandes quantidades e eles são muito lentos para se degradar. Quando os microplásticos atingem ambientes de água doce, eles podem poluir a água potável, afetar todos os tipos de formas de vida e encontrar o caminho para nossa dieta. Muitas organizações internacionais estão tentando reduzir o uso e a produção de artigos como bolsas, roupas, produtos de higiene e até brinquedos, que são feitos ou contêm microplásticos. Pesquisadores de todo o mundo estão procurando maneiras de degradar microplásticos e descobrir novos materiais ecologicamente corretos. Mas há muitas coisas que todos nós podemos fazer para ajudar também. Todos nós podemos fazer a diferença para reduzir a poluição por microplásticos.

Palavras-chave: Impacto ambiental, poluição da água doce, atividades humanas, microplásticos.

INTRODUCTION

Microplastics (MPs) pollution have recently caught attention due to their widespread use in everyday life. But what exactly are microplastics? According to its definition, small pieces or fragments of any type of plastic whose length is between 0.001 and 5 mm. They differ from larger plastic waste like the one we find in plastic bottles. MPs are present in many daily-life products, such as clothes, cosmetics, plastic bags, among others. The most common MP particles are polypropylene (from textile and paper products, plastic parts and packaging), polystyrene (food wrapping and laboratory equipment), polyethylene (plastic bags, wiring, fibers and piping) and polyethylene terephthalate or PET (plastic bottles, food packaging) (LI *et al.*, 2020).

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Plastic is the most common type of marine debris that can be found in aquatic environments. In fact, plastic waste accumulation consists of debris of a wide variety of shapes and sizes, where MPs are among the most abundant (BOYLE e ÖRMECI, 2020). Human activities are mainly responsible for their release to the environment. There are currently two classifications of MPs: first, there are primary MPs, which include fragments or particles that are specifically produced at 5mm in size or less before reaching the environment. Then, there are secondary MPs, which come from the breakdown of larger pieces of plastics through natural processes like weathering, after entering the environment (NG *et al*., 2018; GRGIC *et al*., 2023).

The aim of this short review is to provide a comprehensive overview of the current situation of MPs pollution in freshwater ecosystems that might be useful not only for the scientific community, but also for educators at different levels of education. It focuses on MPs origin and fate in these environments, as well as the life forms that are affected by exposure to these particles. Moreover, remediation technologies are discussed, and simple daily-life sustainable tips are listed to limit MPs intake and impact.

MATERIAL AND METHODS

The search of the scientific production was carried out in specialized databases Scopus®, Google Scholar and ScienceDirect, considering that these are the databases with the greatest coverage, allowing to reduce the bias in the search.

Search parameters

In order to establish the keywords, a primary search was carried out in Google Scholar with the objective of strengthening and identifying the concepts associated with MPs and their impact on freshwater ecosystems, and thus the terms "microplastics", "nanoplastics" and "freshwater" were selected.

From the articles thus obtained, we then selected the review articles dating from 2017 or later, in order to obtain the most recent and updated information on the subject matter. We then proceeded to compile the information and organize the text in a way that would be also accessible to non-academic readers, given that our objective was to produce a review article that could be helpful not only for the scientific community, but also for educators at various schooling levels.

Statistical Analysis

Among the articles found applying the search parameters explained, we selected those that were more relevant for our main objective, that is, the presence of MPs in freshwater environments and their impact. The SCOPUS database was selected as the main source. A collection of articles was prepared based on the keywords previously mentioned, and a series of analyses were performed using the tool Analyze Results from the SCOPUS engine.

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RESULTS AND DISCUSSION

MPs in Freshwater Environments

Freshwater environments, that is, rivers, lakes, brooks, wetlands and groundwater, represent 0.02% of the total water in the planet, and they cover about 6% of the Earth surface (SCHLESINGER e BERNHARDT, 2020). However, freshwater is a fundamental resource for the social, economic, and environmental development of human communities, and for maintaining the ecosystems and their biodiversity. These ecosystems provide invaluable services (APOSTOLAKI *et al.*, 2020), such as natural management of floodings, water provision, temperature regulation, water cycling, and human health (SURING, 2020). Some examples of freshwater environments are given in Fig. 01.

(**Source: A.** SALDAÑA-ESCORCIA, 2021; **B.** HEREDIA, 2019; **C. D.** GUILLADE, 2020)

Figure 01: Freshwater ecosystems of Latin America.

Obs.: A = El Gallinazo Wetland, Aguachica (Cesar, Colombia); B = Punta Negra Dam, San Juan Province, Argentina; C = Iberá Wetlands, Argentina; D = Lake Lacar, Argentinian Patagonia.

Origin of MPs and their fate in freshwater environments

MPs can enter the aquatic environment from different sources. The rapid growth of human populations, together with the worldwide shift towards the use of disposable items since the 1950s, have increased the amount of plastic wastes (SUN *et al.*, 2022). Different daily activities such as brushing your teeth with a plastic toothbrush, doing your laundry, unwrapping some crackers, or using certain personal care products, release MPs that end up in urban wastewater. These single-use plastic containers and packages that are deposited in the environment are fragmented and decomposed by different agents, generating MPs (BOYLE e ÖRMECI, 2020).

MPs can enter the aquatic environment directly, from waste such as bottles and bags that are disposed of in bodies of water. But they can also enter indirectly from household or industrial wastewater as seen in Fig. 02 (CAMPBELL *et al.*, 2017), which is disposed of in rivers or lakes, these being the main sinks for MPs (SUN *et al.*, 2022). Wind and rain may also transport MPs deposited in terrestrial environments to different bodies of freshwater. Rivers, in

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turn, can become sources of MPs as they carry waste to other sources such as lakes, ponds and wetlands.

(**Source:** WONG *et al*., 2020)

Figure 02: MPs sources and sinks in freshwater and terrestrial environments.

Effects of MPs on different life forms

Freshwater species, particularly fish, are the most diverse group of animals, and some of the most threatened by MP pollution, together with molluscs such as snails, mussels and clams. This wide range of aquatic life forms play a very important role in building food webs and ecosystem health (TESI *et al*., 2022). There are currently several freshwater species monitoring programs that check on various environmental parameters, such as mean temperature, drought-rain regime and the presence of MPs (TESI *et al*., 2022). It is important to monitor MPs in freshwater ecosystems, because these pollutants affect the health of freshwater species (PARVIN *et al*., 2021).

MPs can build up (accumulate) in the different tissues of fish and other freshwater species, affecting their health in different ways. MPs inhibit an enzyme called acetylcholinesterase (AChE), which is fundamental in the life of animals because it is very important in the transmission of nerve impulses (DING *et al.*, 2018). Similarly, researchers found that the presence of MPs in freshwater species can deform mouthparts and hinder the passage of food, affecting feeding.

Another effect present in freshwater ecosystems is in the food chain. Due to their small size and their wide and easy distribution in aquatic environments, MPs can be ingested by organisms at any level of the food chain, harming the affected species, in addition to altering their behavior (MONTOYA-ROSALES *et al*., 2020; YUAN *et al*., 2022). Algae are the first in the food chain to interact with them: MPs block light, making photosynthesis difficult for the algae (JAMES RUBINSIN *et al*., 2020).

MPs can also affect complex organisms such as plants (TESI *et al*., 2022), bivalves, crustaceans, and many varieties of fish. MPs accumulate in the liver, kidneys and intestines of animals that are prey to other animals; these hunters consume the polluted prey and they in turn incorporate the MPs through their diet (EERKES-MEDRANO *et al*., 2015) as illustrated in Fig. 03. If these MPs find their way to a commercial species, like fish or aquatic birds, they can be consumed by humans and even reach unborn babies through their pregnant mothers (DING *et al*., 2018).

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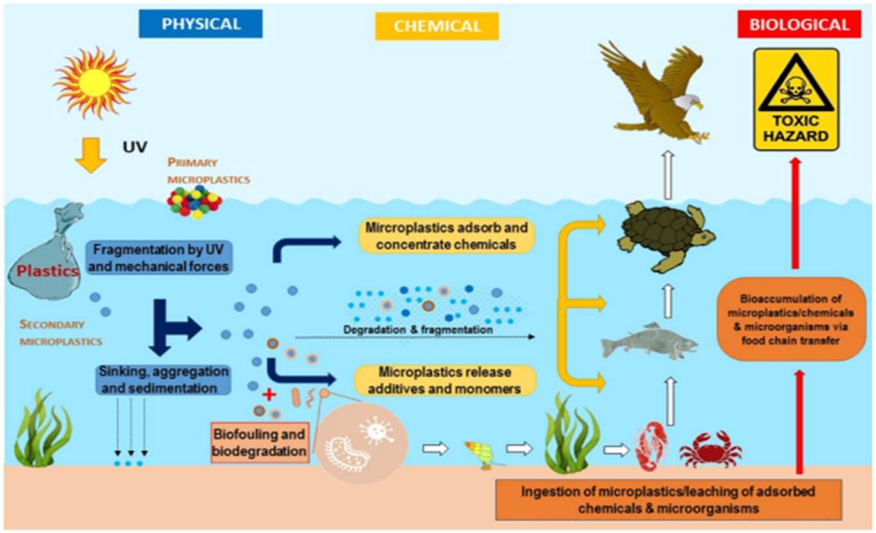

(**Source:** PICO e BARCELO, 2019)

Figure 03: Physical, chemical, and biological processes affecting MPs in the aquatic environment.

The MPs in the human body can affect our hormones, and increase the risk of breast cancer, among other diseases (MEEKER *et al.*, 2009). In high concentrations they can be toxic for the digestive, respiratory, and nervous systems (JEYAVANI *et al*., 2021; XU *et al*., 2022). For this reason, several alternatives are currently being considered to somehow curb the contamination and transport of MPs to freshwater ecosystems through the evaluation and control of river and lake tributaries with a high presence of these pollutants.

Remediation technologies

More efforts need to be made in treating MPs in wastewater treatment plants, because as of today, the recovery of MPs is inefficient, and a great quantity remains as sludge (MIRI *et al*., 2022), and gets discharged to rivers, groundwater, eventually finding its way to drinking water (SUN *et al*., 2022). There are techniques that can remove MPs from water and sediment, and now scientists are looking into how to transform the recovered MPs into fuel (MIRI *et al*., 2022).

Several specialized bacteria have been discovered with the ability to break down different plastics (CHEN *et al.*, 2021). These microorganisms have been found in sites with high MP pollution, such as landfills, or even some that live in the gut of larger animals like worms or moths (JEYAVANI *et al*., 2021). However, microorganisms degrade plastics very slowly, mainly because they need light and oxygen (MIRI *et al.*, 2022). A possible solution to this problem is to bioengineer microorganisms that can biodegrade plastics and can also tolerate extreme environmental conditions, like darkness, low oxygen, etc. Research is needed to match different microorganisms to different plastic polymers and degradation conditions (MIRI *et al*., 2022).

Of all the possible techniques and technologies available to eliminate MPs from the environment, the most promising is bioremediation. Simply put, microbial degradation of MPs consists of three steps: 1) large polymers (plastic chains) are broken down into smaller polymers; 2) microbes produce and release enzymes that break down smaller polymers into

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olygomers, dimers or monomers (the smallest parts of a plastic chain), and 3) microbes ingest and break down these smaller parts into carbon dioxide, methane, nitrogen, and water (JEYAVANI *et al*., 2021), very small molecules which can return safely to the environment.

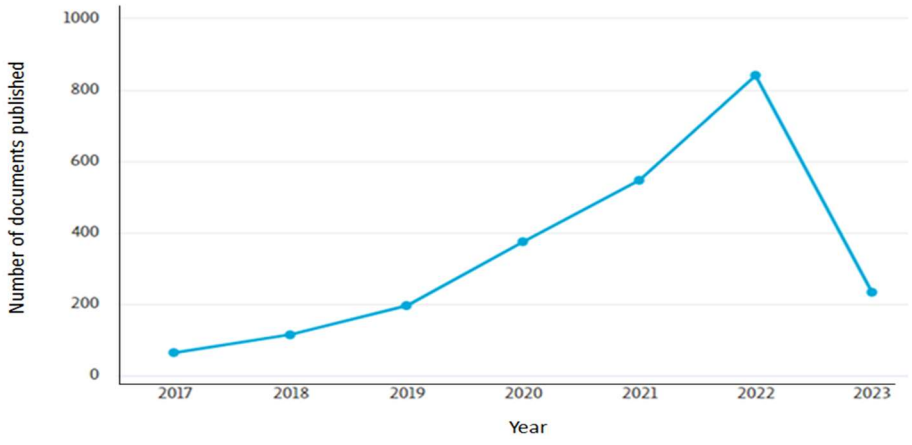
Different approaches to dealing with MPs

Many countries and organizations have established policies aiming to reduce the emission of MPs to the environment. Chief among these is the restriction of single-use plastic items like plastic bags in Australia, several EU countries, the USA, China, many African and Latin American countries (CHEN *et al.*, 2021; JEYAVANI *et al*., 2021). The EU has set the goal that all plastic products should be reusable and recyclable by 2030 (BOYLE e ÖRMECI, 2020). Another important measure is to stop manufacturing personal care products that contain plastic microbeads (Canada, Australia, several EU countries, the USA and many Asian and Latin American countries (BOYLE e ÖRMECI, 2020; CHEN *et al*., 2021; JEYAVANI *et al*., 2021). Several countries have pledged to transition from the use of traditional plastics to recyclable plastics.

There has been progress in recent years on the development of biodegradable plastics: plastics that are made from renewable materials such as starch, cellulose, and lignin. These materials are vegetable in origin, and therefore are safe for the environment (CHEN *et al*., 2021). Bioplastics are being developed for several purposes, such as packaging, electronics, textiles, toys, and medical products (MIRI *et al*., 2022), and are very promising replacements to traditional plastics. The downside is that the production and degradation of bioplastics is quite expensive, and so research is needed to come up with cheaper processes (CHEN *et al*., 2021).

MPs are a growing concern in the scientific community

We compiled data on the growing interest and increasing trend in scientific articles published on MPs and their direct and indirect impact. There has been an exponential growth in the number of scientific publications from the year 2017, as shown in Fig. 04, with an approximately 90% increase over a 6-year period, clearly reflecting the significant impact of MPs on the environment, and the need to find solutions to this issue.



(**Source:** SCOPUS, 2023)

Figure 04: Analysis of annual publications on MPs pollution in freshwater environments. Index of annual publications.

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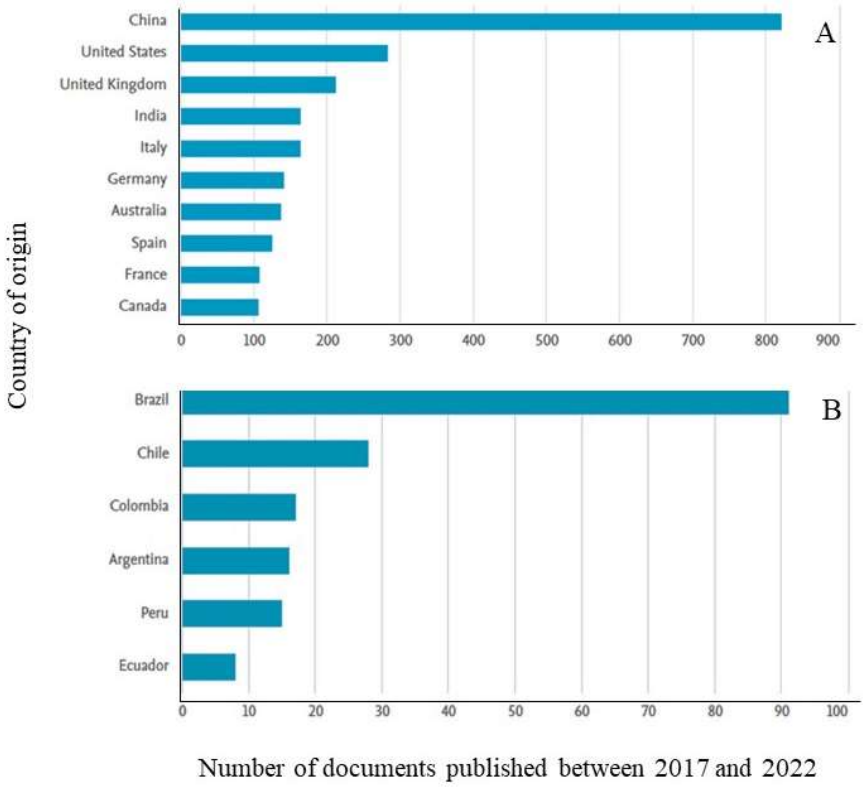
We also sorted the publications by country of origin, both worldwide (Fig. 05A) and within Latin America (Fig. 05B). From this analysis it was clear that China is by far the country that produces more research publications on MPs in freshwater environments, with more than 800 research papers published in the last 6 years, followed by the USA and the UK. Similarly, Brazil is overwhelmingly prolific within Latin America compared to the other countries in the region, with more than 90 research papers over the 6-year period analyzed, followed by Chile, Colombia, Argentina and Peru. These countries show a promising increase in both the published work and the growing concern about MPs pollution, as well as the need to find solutions to local situations of contamination.



(**Source:** SCOPUS, 2023)

Figure 05: Relationship between number of publications in leading countries in MP research worldwide (A) and within Latin America (B).

CONCLUSIONS

Current studies of MPs include sources, distribution, toxicity and identification. These particles are mainly detected and identified in water and soil environments. However, there is still a need to fully investigate the prevalence of MPs in terrestrial and freshwater ecosystems, in comparison with the marine ecosystem. Studies regarding fate and transport show that the migration of MPs is complex, as there are many environmental processes that take place. In addition, negative effects are focused on their toxicity on animals and humans and transfer via

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food chains. This short review will hopefully contribute to deepen the understanding of MPs pollution in freshwater environments, as it addresses the state of the art and the challenges to take up in order to overcome this problem, from citizens to governments.

In spite of this, there are small changes in our daily habits that can reduce contamination by MPs. There are several things everyone can do to help the situation regarding microplastics. You can carry your own cloth bag when you go shopping. You can ask for boxes or paper bags at the supermarket to carry your purchases. Avoid using plastic cutlery and disposable trays when having lunch or dinner, especially at cafeterias or dining courts. Make it a habit to carry your own water bottle or canteen. Turn on your washing machine only when it is full to capacity. Whenever possible, try to replace everyday plastic items with others made of environmentally safer materials, such as wood, natural fibers, etc. Throw away plastic waste in the correct recycling bin. And always remember the three Rs: Reduce, Reuse and Recycle.

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