Plastics, microplastics, and human contamination: A literature review

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ABSTRACT

Plastics are synthetic materials produced through the polymerization of monomers derived from oil or gas. Plastic waste causes several problems, affecting the environment, marine life, biodiversity, and the functioning of ecosystems. Plastic fragments can be ingested by various species, occurring records in the digestive system of various organisms. Microplastics (PMs) include small plastic particles ranging from 1 μm to 5 mm in size and are currently identified as one of the emerging environmental contaminants of greatest concern in aquatic ecosystems, especially in the marine environment. Microplastics can be transported into the body by dermal contact, ingestion, inhalation, and transfer through the food chain. The bioaccumulation of PMs can cause internal and external lesions, ulcers, blockage of the digestive tract, among other lethal and sublethal effects. Microplastics that enter the human body can contain chemicals that cause cancer, DNA mutations, toxic effects on reproduction, hormonal disruption, and affect various organs. Recurrent sources of microplastic for the aquatic system are sewage, drainage systems, tire wear, and plastic waste that is poorly managed or discarded on beaches. Microplastic contamination generates a decrease in fish stocks, influencing populations living in the vicinity of contaminated environments, such as the population living near the ALUMAR Private Use Terminal, São Luís, Maranhão. Therefore, research with microplastics is of fundamental importance for improving the quality of life of the population and the environment and can be associated with several Sustainable Development Goals (SDGs).

Keywords: Environmental pollution, Microplastic pollution, Microplastic contamination.

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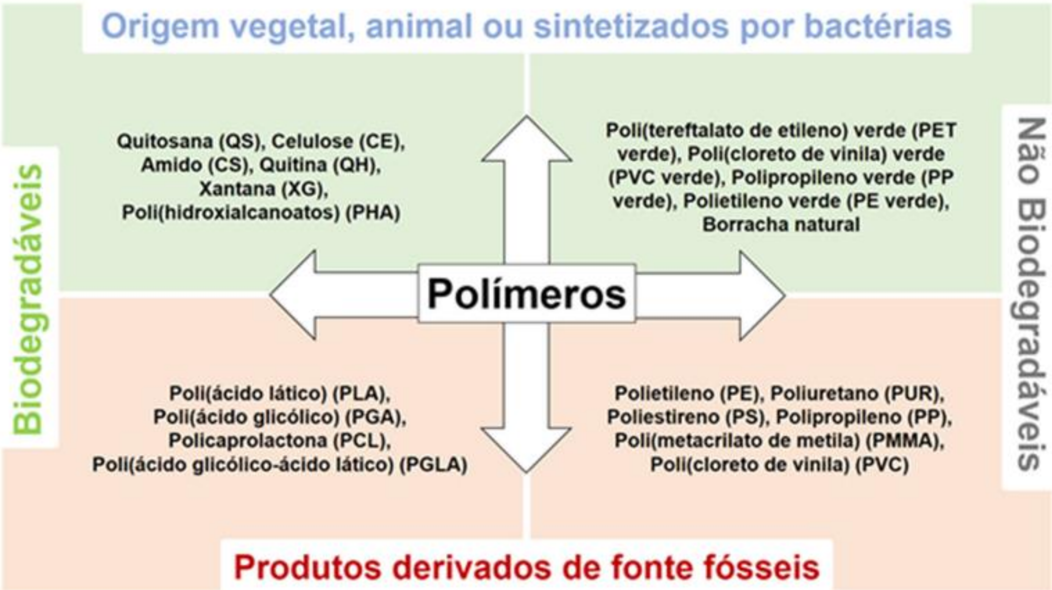
INTRODUCTION

THE USE OF PLASTIC IN THE WORLD

Plastics are synthetic materials produced through the polymerization of monomers derived from oil or gas, often accompanied by the incorporation of various chemical additives aimed at enhancing their properties. These additives contribute to giving plastics a high resistance to corrosion, in addition to significantly reducing their thermal and electrical conductivity (Barnes *et al.*, 2009a).

França *et al.* (2022) advocates other ways of classifying polymers, such as relating their origin and properties in the context of whether or not they are biodegradable (Figure 1). Polymers from non-renewable sources are those that derive from resources that do not form or renew themselves in a short period, such as the example of commercial materials made of polystyrene (PS), Polyethylene (PE) and Polypropylene (PP).

Figure 1. Types of polymers and their potential for biodegradation



Fonte: França *et al.* (2022)

Currently, plastics are identified as one of the emerging types of environmental contaminants of greatest concern in aquatic ecosystems, especially in the marine environment (Alvarez *et al.*, 2020; Ribeiro, 2022; Hernandes, 2023). In 2010, between 4.8 and 12.7 million tons of plastic waste from the continent were discharged into the ocean, representing 1 to 4% of the estimated total volume of waste generated that year and 2 to 6% of the total waste disposed of (Jambeck *et al.*, 2015; Mizoguchi, 2019).

According to Eriksen *et al.* (2014), approximately 5 trillion pieces of plastic are floating in the oceans, being dispersed by sea currents. One of the consequences of this situation is the formation of the Great Pacific Garbage Patch (GPLP), an area where it is estimated that there are 79 thousand tons of plastic waste in an extension of 1.6 million km² (Mizoguchi, 2019).

The Brazilian Government's National Plan to Combat Litter at Sea (Brazil, 2019) points out that approximately 80% of the garbage present in the oceans consists mainly of plastics, cigarette filters, rubber, metals, glass, textiles and paper, which originate on the continents. This suggests that the problem of solid waste is intrinsically linked to the poor management of these materials.

The growing use of plastic was driven by the COVID-19 pandemic, a period that was marked by the exacerbated consumption of single-use plastic materials, such as masks, gloves, syringes used in vaccination, packaging, and delivery utensils (Tardim; Almada, 2022)

To mitigate the impact of plastic on the environment, several measures have been explored for decades, such as the 4R strategy, which includes reduction, reuse, recycling and recovery (Klemeš *et al.*, 2020). Reduction implies a series of tactics aimed at reducing the consumption of single-use plastic products by the population and companies, and this approach has been implemented for years as part of environmental policies in many countries (Fletcher, 2023).

According to the UN (2023), plastic waste implies several problems for the environment, causing impacts on marine life ranging from physical or chemical damage to individual animals, to broader effects on biodiversity and the functioning of ecosystems.

Plastic fragments have been discovered in the digestive systems of aquatic organisms, including all species of sea turtles and nearly half of the seabird species and marine mammals surveyed (Jambeck *et al.*, 2015; Nelms *et al.*, 2016; Gall, 2015; Claro *et al.*, 2019; Almeida *et al.*, 2023) . This material poses a high risk, as they disintegrate over time into smaller sizes, known as microplastics and nanoplastics, which can have significant adverse impacts (Araujo, 2022).

MICROPLASTICS

Plastics can be classified for size into macroplastic and microplastic. It is distinguished as macroplastic when it has a size greater than 25 mm, which is the cause of visual pollution (Derraik, 2002; Gregory, 2009, Heip *et al.*, 2009). Macroplastic, when available in the environment, is exposed to ultraviolet radiation, temperature, oxidation, biodegradation, chemical agents and physical abrasion, and can generate smaller particles, microplastics (Athapaththu *et al.*, 2020).

Microplastics include all small plastic particles ranging from 1 µm to 5 mm in size (Cold; Nash, 2019). Because they have a very small size, they are considered bioavailable, that is, available for the accidental or intentional incorporation of an organism (Elías, 2015). They represent a large group of polluters that are made of different materials and can come in different sizes, shapes, and colors (Kiliç *et al.*, 2022).

According to Chart 1, it is possible to identify the problems of plastics and their subdivisions, including their detection and examples found in the sea.

Table 1. Garbage at sea: Detectability

Garbage in the Sea: detectability and examples	**Garbage in the Sea: sizes**					
	Size	Nano (< 1 nm)	Micro (< 5 mm)	Meso (< 2.5 cm)	Macro (< 1 m)	Mega (≥ 1 m)
	Detection/Method of Identification	Need for special detection methods, since smaller particles are not detected by microscopes.	It often needs microscopes and instrumentation to confirm that it is plastic; Larger items: visible/identifiable With the naked eye.	Visible/identifiable to the naked eye.	Visible/identifiable to the naked eye.	Visible/identifiable to the naked eye.
	Examples of Garbage at Sea	Nanofibers from clothing; rubber powder tire wear; nanoparticles in products. They have not yet been detected as litter due to technical limitations.	Microbeads in personal care products; fragmentation of existing products (plastic); polystyrene; plastic from shipyards; particles of incineration waste.	Bottle caps; filters and cigarette butts; plastic pellets; waste carried by the wind or carried by storms.	Beverage bottles and cans; plastic bags; food packaging; other packaging; disposable cutlery; beer seals; fishing lines, floats and buoys; Tires; Tubes; Balloons; toys; textile.	Abandoned fishing nets and traps; Strings; Boats; plastic films; polyvinyl chloride (PVC) from construction activities.

Source: Watkins and Brink (2017).

Plastic and microplastic pollution are global problems and their introduction into the aquatic environment can occur from various anthropogenic sources. According to Zhou (2020) and Khalid *et al.* (2021), the most recurrent sources of microplastic to the aquatic system are sewage, municipal drainage systems, tire wear, poorly managed plastic waste or even discarded on beaches.

Some microplastics are absorbed by the body in the form of small pellets, which are small granules of plastics that constitute the main way in which plastic resins are produced and marketed (Nobre and Sousa, 2022). They constitute raw material in the manufacturing industries, originating the most varied objects, which are produced after their melting and molding of the final product (Manzano, 2009) or in cosmetics (Fendall; Sewell, 2009). They can also be released by accidental spillage, such as virgin plastic granules (Barnes *et al.*, 2009b; Elías, 2015).

Microplastics are plastic particles smaller than 5mm, they are classified into two forms: primary and secondary. Martins (2023) points out that the primers come from the transformation processes of polymers or products from the detachment of materials containing polymers and their arrival in the environment can be voluntary (disposal) or involuntary (abrasion of polymeric items). According to Montagner (2021), these are materials used in the formulation of cosmetics such as glitter, personal hygiene products (scrubs, soaps, and toothpastes) and also in pellet format, the configuration of plastic raw material.

Secondary plastics, on the other hand, originate from the fragmentation of larger plastics such as plastic bags, bottles, fishing nets and agricultural activities, such as the application of sewage sludge, vinyl coatings (Nizzetto *et al.*, 2016; Miloloža *et al.*, 2022). In freshwater environments, primary sources of PMs such as textiles and cosmetics, electronic equipment, tire abrasion through driving, city dust, road construction, and marine lining are reported (Rezania *et al.*, 2018; Prokicet al., 2019; Miloloža *et al.*, 2021).

MPs draw attention from all over the world due to their chronic contamination. Kiliçet al., (2022), states that microplastics have become a major concern for aquatic environments due to their intense concentration. Microplastics are ubiquitous in the environment and are currently classified as emerging contaminants (Montagner, 2021). The potential risks to living beings, as well as the levels of contamination in different environmental compartments, need to be better elucidated, so this new class has been the focus of research worldwide.

In view of these sources of contamination, Brahney (2020) estimates that the amount of plastic waste in the environment will reach 11 billion tons by 2025, most of which will be in the aquatic environment.

CONSUMPTION OF MICROPLASTICS AND SDGS

Although most studies have been directed to macroplastics over the last decades, there is currently a greater concern with smaller plastics, which due to their long permanence in the aquatic environment constitutes a growing risk of exposure to toxic agents for the biota.

Microplastic pollution has become an emerging global environmental issue. A growing body of evidence indicates that microplastics have been detected in the aquatic environment, atmosphere, biota, and even in humans, raising concerns for food safety and human health (Zhang *et al.*, 2022).

Many studies and official records indicate that microplastic contamination in marine ecosystems is mainly caused by river and terrestrial sources (Gasperi *et al.*, 2014). Transported from the aquatic environment or resulting from the decomposition of larger plastic debris (Cole *et al.*, 2011), microplastics represent the most abundant and dangerous fraction of marine plastic pollution (Eriksen *et al.*, 2014). The physical properties of particles, hydrodynamic conditions, and biofouling influence the fate of microplastics and their effects on marine ecosystems (Kowalski; Reichardt; Waniek, 2016; Kaiser; Kowalsky; Waniek, 2017).

This pollutant, when discarded into the environment, becomes bioavailable to organisms. Microplastics can be transported into the body by direct contact, i.e., dermal contact, ingestion, inhalation, and transfer through the food chain (Samandra *et al.*, 2022). Islam (2022), states that the bioaccumulation of PMs can cause internal and external lesions, ulcers, blockage of the digestive tract, among other lethal and sublethal effects. Approximately 74,000 to 113,000 microplastics enter the human body annually through caloric intake and inhalation (Mak, 2020; Caixeta., 2022).

Even with few reports on their impact on humans, direct contact with these polymers can trigger several diseases. Wright and Kelly (2017) warn that many of the HOCs are highly toxic, resulting in endocrine disruptions, carcinogenic, mutagenic and immunotoxic effects in the human body.

As pointed out by the UN (2023), the totality of the impact on human health has not yet been fully understood, since research is at an early stage. However, Almeida (2021) warns that microplastics can contain harmful chemicals that, when incorporated into the human body, can cause cancer, DNA mutations, toxic effects on reproduction, hormonal disruption, and mainly affect internal organs such as the liver, kidneys, heart, nervous system, and reproductive system.

In view of this scenario, goals were established to control and mitigate global contamination, an initiative that began in 2015 with the 2030 Agenda for Sustainable Development. This agenda comprises the 17 Sustainable Development Goals (SDGs), which cover 19 targets and 230 indicators to be achieved over 15 years. Its main objective is to encourage the participation and cooperation of the 193 Member States of the UN General Assembly on issues of environmental, economic and social importance (UN, 2015).

When considering research with microplastics, with the objective of improving the quality of life of man and the environment, the objectives that can be associated are: SDG 2, SDG 3, SDG 5, SDG 6, SDG 11, SDG 12 and SDG 14 (Chart 1).

Table 1. Objectives and targets associated with the sustainable development of the coastal zone.

ODS	OBJECTIVE	GOALS
2. Zero hunger and sustainable agriculture	end hunger, achieve food security and improved nutrition, and promote sustainable agriculture.	**2.1:** By 2030, end hunger and ensure access for all people, in particular the poor and people in vulnerable situations, including children, to safe, nutritious and sufficient food all year round.
3. Health and Wellness	ensure healthy lives and promote well-being for all people, at all ages.	**3.9:** By 2030, substantially reduce the number of deaths and illnesses caused by hazardous chemicals and pollution and contamination of air, water, and soil.
		3.c: Substantially increase health financing and the recruitment, development, training and retention of health workers in developing countries, especially in least developed countries and small island developing states.
		3.d: Strengthen the capacity of all countries, in particular developing countries, to warn, reduce risk and manage national and global health risks.
		3.1: By 2030, reduce the global maternal mortality rate to less than 70 per 100,000 live births.
5. Gender Equality	Achieving Gender Equality and Empowering All Women and Girls	**5.5:** Ensure the full and effective participation of women and equal opportunities for leadership at all levels of decision-making in political, economic and public life.
		5.c: Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and empowerment of all women and girls at all levels.
11. Sustainable Cities and Communities	Making Cities and Human Settlements Inclusive, Safe, Resilient, and Sustainable	**11.1:** By 2030, ensure access for all people to adequate and safe housing and basic services, as well as to significantly improve public transport, with particular attention to the needs of people in vulnerable situations.
		11.3: By 2030, increase inclusive and sustainable urbanization, and capacity for participatory, integrated, and sustainable planning and management of human settlements in all countries.
		11.6: By 2030, reduce the per capita negative environmental impact of cities, including by paying special attention to air quality and management of municipal and other waste.
12. Sustainable Consumption and Production	Ensure sustainable consumption and production patterns	**12.1:** Implement the Ten-Year Programme Plan on Sustainable Production and Consumption, with all countries taking action, and developed countries taking the lead, taking into account the development and capacities of developing countries.
		12.2: By 2030, achieve sustainable management and efficient use of natural resources.
14. Life on Water	Conserving and Sustainably Using the Oceans, Seas and Marine	**14.1**: By 2025, prevent and significantly reduce marine pollution of all kinds, especially from land-based activities, including marine debris and nutrient pollution.

	Resources for Sustainable Development	**14.3:** Minimise and address the impacts of ocean acidification, including through scientific cooperation at regional and global levels.

Source: Modified from United Nations Brazil (2023).

THE RIVERSIDE POPULATION AND THE CONSUMPTION OF CONTAMINATED LOCAL FISHERIES

As disclosed by the United Nations (UN) in its report on "World Environment Day" 2023, it is estimated that annually between 19 and 23 million tons of plastic waste are dumped into lakes, rivers, and seas. This amount is roughly equivalent to the combined weight of 2200 Eiffel Towers, which has opened the door to the contamination of fish species around the world.

According to Ory *et al.*, (2018), the fishing and aquaculture industry has been affected by the reduction in the number of organisms and species, generating economic and ecological losses. Direct and constant contact with MPs generates a decrease in the fishing stock, influencing the population that survives in the surroundings of contaminated environments, as occurs with the population that lives in the vicinity of the ALUMAR Private Use Terminal, São Luís, Maranhão.

Silva (2012) stated that ALUMAR's facilities attracted workers and land grabbers and that, from the 70s onwards, the occupation intensified. Cavalcante (2016) defines the area of this complex as a stronghold for the conservation of the main ecosystems that still encompasses a system of life of traditional peoples, that is, artisanal fishermen and agroextractivists.

Thus, the consumption of fish contaminated by microplastics in the area of influence of ALUMAR's TUP may be carried out by the surrounding community, causing great concern, since according to Santos (2015), about 58% of this population does not have access or has difficulty accessing health services.

REFERENCES

1. Almeida, M. A. A. L. S. (2021). *Análise semiquantitativa de microplásticos na água de torneira na cidade de Brasília - Distrito Federal* (Tese de Doutorado). Universidade de Brasília, Brasília.

2. Almeida, M. A., Silva, I. C. A., Vieira, A. A., & Maia, A. C. R. (2023). Plásticos nos ambientes marinhos: uma real ameaça à vida dos mamíferos marinhos. In *Jornada Científica e Tecnológica e Simpósio de Pós-Graduação do IFSULDEMINAS, 15, 12*. Anais [...]. Muzambinho: IFSULDEMINAS. Disponível em: https://josif.ifsuldeminas.edu.br/ojs/index.php/anais/article/view/1652/585 Acesso em: 17 de junho de 2024.

3. Alvarez, L. D. G., Jesus, F. B., Costa, A. P. L., Bastos, L. E. F., Sousa, D. A. M., & Silva, D. G. (2020). Efeitos dos microplásticos no meio ambiente: um macroproblema emergente. *RECyT,* (33), 100-107.

4. Araujo, D. G. (2022). *Avaliação dos efeitos de pellets e polímeros, oxi-biodegradável e hidrossolúvel, em ambientes marinhos utilizando sedimento marcado e mexilhões da espécie Mytella charruana* (Dissertação de Mestrado). Universidade de São Paulo, São Paulo.

5. Athapaththua, A. M. A. I. K., Thusharia, G. G. N., Diasa, P. C. B., Abeygunawardenaa, A. P., Egodauyanana, K. P. U. T., Liyanagea, N. P. P., Pitawalab, H. M. J. C., & Senevirathnaa, J. D. M. (2020). Plastics in surface water of southern coastal belt of Sri Lanka (Northern Indian Ocean): Distribution and characterization by FTIR. *Marine Pollution Bulletin, 161,* 111750.

6. Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009a). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B, 364,* 1985–1998.

7. Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009b). Our plastic age. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1526), 1973-1976.

8. Brahney, J., Hallerud, M., Heim, E., Hahnenberger, M., & Sukumaran, S. (2020). Plastic rain in protected areas of the United States. *Science, 368*(6496), 1257-1260.

9. Brasil. Ministério do Meio Ambiente. (2019). *Agenda Nacional de Qualidade Ambiental Urbana: Plano de Combate ao Lixo no Mar* [recurso eletrônico]. Brasília, DF: MMA.

10. Brink, P. T., Kettunen, M., & Watkins, E. (2017). *Expert group on green and circular economy in the outermost regions: Final report.* For DG Regional and Urban Policy, European Commission.

11. Caixeta, D., & Morais, E. (2022). Panorama mundial de produção de plástico e estratégias de degradação. *Enciclopedia Biosfera, 19*(39).

12. Cavalcante, L. P. A. (2016). *Estudo da qualidade físico-química e microbiológica das águas do rio dos cachorros na comunidade do taim* (Trabalho de Conclusão de Curso). Universidade Federal do Maranhão, São Luís.

13. Claro, F., Fossi, M. C., Ioakeimidis, C., Baini, M., Lusher, A. L., McFee, W., & Algani, F. (2019). Tools and constraints in monitoring interactions between marine litter and megafauna: Insights from case studies around the world. *Marine Pollution Bulletin, 141*(1), 47-160.

14. Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: a review. *Marine Pollution Bulletin, 62*(12), 2588-2597.

15. Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin, 44*(9), 842-852.

16. Elías, R. (2015). Mar del plástico: una revisión del plástico en el mar. *Revista de Investigación y Desarrollo Pesquero,* (27), 83-105.

17. Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borrero, J. C., Galgani, F., Ryan, P. G., & Reisser, J. (2014). Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *PLoS One, 9*(12), e111913.

18. Fendall, L. S., & Sewell, M. A. (2009). Contributing to marine pollution by washing your face: microplastics in facial cleansers. *Marine Pollution Bulletin, 58*(8), 1225-1228.

19. Fletcher, S., March, A. L. A., Roberts, K., Shirian, Y., Canals, L. M., Cairns, A., Lefort, P., Meso, A., Raine, A. D., Smagadi, A., Stone, S., Tonda, E., Fuente, J., Koskella, J., Bove, A. T., Boon, E., & Bass, A. (2023). *Turning off the Tap: How the world can end plastic pollution and create a circular economy.* United Nations Environment Programme.

20. França, D., Chiregato, C. G., Ulrich, G. D., Veloso, H. B., Messa, L. L., Angelo, L. M., Pereira, T. S., & Faez, R. (2022). As faces do plástico: uma proposta de aula sobre sustentabilidade. *Revista Quím. Nova Escola, 43*(3), 277-286.

21. Frias, J. P. G. L., & Nash, R. (2019). Microplastics: Finding a consensus on the definition. *Marine Pollution Bulletin, 138,* 145-147.

22. Gall, S. C., & Thompson, R. C. (2015). The impact of debris on marine life. *Marine Pollution Bulletin, 92*(1), 170-179.

23. Gasperi, J., Dris, R., Bonin, T., Rocher, V., & Tassin, B. (2014). Assessment of floating plastic debris in surface water along the Seine River. *Environmental Pollution, 195,* 163-166.

24. Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1526).

25. Heip, C., Hummel, H., Avesaath, P. V., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, T. J., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, J. P., Gasol, J. M., Gooday, A., Harder, J., ... Nash, R. (2009). *Marine biodiversity and ecosystem functioning.* Dublin: Printbase.

26. Hernandes, C. C. G. (2023). *COVID e meio ambiente: levantamento bibliográfico de aspectos ambientais no contexto da pandemia* (Trabalho de Conclusão de Curso). Universidade Estadual Paulista, São Paulo.

27. Islam, T., Li, Y., Rob, M. M., & Cheng, H. (2022). Microplastic pollution in Bangladesh: research and management needs. *Environmental Pollution, 308,* 119697.

28. Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science, 347*(6223), 768-771.

29. Kaiser, D., Kowalski, N., & Waniek, J. J. (2017). Effects of biofouling on the sinking behavior of microplastics. *Environmental Research Letters, 12*(12), 124003.

30. Khalid, N., Aqeel, M., Norman, A., Hashem, M., Mostafa, Y. S., Alhaithloul, H. A. S., & Alghanem, S. M. (2021). Linking effects of microplastics to ecological impacts in marine environments. *Chemosphere, 264*, 128541.

31. Kılıç, E., Yücel, N., & Şahutoğlu, S. M. (2022). First record of microplastic occurrence at the commercial fish from Orontes River. *Environmental Pollution, 307*, 119576.

32. Klemeš, J. J., Fan, Y. V., Tan, R. R., & Jiang, P. (2020). Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. *Renewable and Sustainable Energy Reviews, 127*, 109883.

33. Kowalski, N., Reichardt, A. M., & Waniek, J. J. (2016). Sinking rates of microplastics and potential implications of their alteration by physical, biological, and chemical factors. *Marine Pollution Bulletin, 109*(1), 310-319.

34. Mak, C. W., Tsang, Y. Y., Leung, M. M. L., Fang, J. K. H., & Chan, K. M. (2020). Microplastics from effluents of sewage treatment works and stormwater discharging into the Victoria Harbor, Hong Kong. *Marine Pollution Bulletin, 157*, 111181.

35. Manzano, A. B. (2009). *Distribuição, taxa de entrada, composição química e identificação de fontes de grânulos plásticos na Enseada de Santos, SP, Brasil* (Dissertação de Mestrado). Universidade de São Paulo, São Paulo.

36. Martins, G. R., Rodrigues, E. J. R., & Tavares, M. I. B. (2023). Revisão da literatura sobre os eventos de degradação e adsorção em microplásticos primários e secundários. *CIS-Conjecturas Inter Studies, 23*(1), 368-390.

37. Miloloža, M., Bule, K., Ukić, Š., Cvetnić, M., Bolanča, T., Kušić, H., Bulatović, V. O., & Grgić, D. K. (2021). Ecotoxicological determination of microplastic toxicity on algae *Chlorella* sp.: Response surface modeling approach. *Water, Air, & Soil Pollution, 232*(1), 1-16.

38. Miloloža, M., Cvetnić, M., Grgić, D. K., Bulatović, V. O., Ukić, S., Rogošić, M., Dionysiou, D. D., Kušić, H., & Bolanča, T. (2022). Biotreatment strategies for the removal of microplastics from freshwater systems: A review. *Environmental Chemistry Letters, 20*(2), 1377-1402.

39. Mizoguchi, I. H. (2019). *Os desafios do plástico e cenários para o futuro* (Trabalho de Conclusão de Curso). Universidade Federal do Rio Grande do Sul, Porto Alegre.

40. Montagner, C. C., Dias, M. A., Paiva, E. M., & Vidal, C. (2021). Microplastics: Environmental occurrence and analytical challenges. *Química Nova, 44*, 1328-1352.

41. Nelms, S. E., Duncan, E. M., Broderick, A. C., Galloway, T. S., Godfrey, M. H., Hamann, M., Lindeque, P. K., & Dudley, B. J. (2016). Plastic and marine turtles: A review and call for research. *ICES Journal of Marine Science, 73*(2), 165-181.

42. Nizzetto, L., Futter, M., & Langaas, S. (2016). Are agricultural soils dumps for microplastics of urban origin? *Environmental Science & Technology, 50*(20), 10777-10779.

43. Nobre, A., & Sousa, D. (2022). Microplásticos: um mega problema. *Correio do Minho, 10*, 23.

44. ONU Brasil - Organização das Nações Unidas do Brasil. (2023). *Os Objetivos de Desenvolvimento Sustentável*. Brasília, DF. Disponível em: https://brasil.un.org/pt-br/sdgs. Acesso em: 14 de abril de 2024.

45. ONU - Organização das Nações Unidas. (2023). *Dia do meio ambiente: Solutions to plastic pollution*. Disponível em: https://www.un.org/en/observances/environment-day. Acesso em: 23 de maio de 2024.

46. ONU - Organização das Nações Unidas. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development; Resolution Adopted by the General Assembly on 25 September 2015*.

47. Ory, N. C., Gallardo, C., Lenz, M., & Thiel, M. (2018). Capture, swallowing, and egestion of microplastics by a planktivorous juvenile fish. *Environmental Pollution, 240*, 566-573.

48. Prokić, M. D., Radovanović, T. B., Gavrić, J. P., & Faggio, C. (2019). Ecotoxicological effects of microplastics: Examination of biomarkers, current state and future perspectives. *TrAC Trends in Analytical Chemistry, 111*, 37-46.

49. Rezania, S., Park, J., Din, M. F. M., Taib, S. M., Talaiekhozani, A., Yadav, K. K., & Kamyab, H. (2018). Microplastics pollution in different aquatic environments and biota: A review of recent studies. *Marine Pollution Bulletin, 133*, 191-208.

50. Ribeiro, R. F. C. (2022). *Efeitos de nanoplásticos, isoladamente e em mistura com dicromato de potássio, no crescimento da microalga Chlorella vulgaris* (Dissertação de Mestrado). Universidade do Porto, Porto.

51. Samandra, S., Johnston, J. M., Jaeger, J. E., Symons, B., Xie, S., Currell, M., Ellis, A. V., & Clarke, B. O. (2022). Microplastic contamination of an unconfined groundwater aquifer in Victoria, Australia. *Science of the Total Environment, 802*, 149727.

52. Santos, D. C. C. (2015). *Bacia Hidrográfica do Rio Dos Cachorros: População, Saúde e Ambiente* (Dissertação de Mestrado). Universidade Federal do Maranhão, São Luís.

53. Silva, P. R. M. E. (2012). *Estudo da potabilidade das águas dos poços artesianos, cacimba e caixas d'água com levantamento sócio-econômico e ambiental da comunidade do Taim*. Universidade Federal do Maranhão, São Luís.

54. Tardim, A. C. C., & Almada, E. V. C. (2022). O impacto da pandemia de COVID-19 na geração de resíduos sólidos. *Meio Ambiente (Brasil), 4*(2).

55. Wright, S. L., & Kelly, F. J. (2017). Plastic and human health: A micro issue? *Environmental Science & Technology, 51*(12), 6634-6647.

56. Zhang, Y., Wu, H., Xu, L., Liu, H., & An, L. (2022). Promising indicators for monitoring microplastic pollution. *Marine Pollution Bulletin, 182*, 113952.

57. Zhou, G., Wang, Q., Zhang, J., Li, Q., Wang, Y., Wang, M., & Huang, X. (2020). Distribution and characteristics of microplastics in urban waters of seven cities in the Tuojiang River basin, China. *Environmental Research, 189*, 109893.