Lange J.G., De Alcântara Santos A.C. (2021) Microplastics in shallow coastal areas of Brazil: A review of sources, effects and main solutions pp. 211-221. In Gastescu, P., Bretcan, P. (edit, 2021), *Water resources and wetlands*, 5th International Hybrid Conference Water resources and wetlands, 8-12 September 2021, Tulcea (Romania), p.235
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5th International Hybrid Conference Water resources and wetlands, 8-12 September 2021, Tulcea (Romania)

MICROPLASTICS IN SHALLOW COASTAL AREAS OF BRAZIL: A REVIEW OF SOURCES, EFFECTS AND MAIN SOLUTIONS

Jaciela Gabriele LANGE[1], Alexandre Clistenes DE ALCÂNTARA SANTOS[2]
[1,2]Universidade Estadual de Feira de Santana - UEFS / [1]Master's student in Programa de Pós-Graduação em Ecologia e Evolução, [2]PhD in Ciências Biológicas (Zoologia)
[1,2]Avenida Transnordestina, s/n - Novo Horizonte, CEP 44036-900 - Feira de Santana – Bahia – Brasil. Telefone / FAX: (75) 3161-8790; Email: [1]*jacigablange@hotmail.com*, [2]*alexandreclistenes@gmail.com*

Abstract. The oceans are important sources of food and resources, bearers of great biological diversity and play a fundamental role in regulating the temperature of the planet and in the cycling of nutrients. However, over the past few decades, marine ecosystems have been receiving high amounts of waste, the largest proportion of which is decomposed into smaller particles (<5 mm) called microplastics. Thus, this study reviews the sources, effects and main solutions to reduce microplastic contamination in coastal marine ecosystems on the Brazilian coast. Along the Brazilian coast, in addition to intense urbanization in estuarine areas and bays, port, industrial and tourist exploration activities are developed, which ends up generating numerous problems of pollution and contamination of marine ecosystems by various sources and different types of materials. Among the sources of microplastics in Brazilian marine ecosystems, we can highlight mainly the discharge of untreated sewage in affluents and coastal areas, containing synthetic fibers, microplastics from personal care, hygiene, cleaning and cosmetics products; the inappropriate disposal of plastic waste on the beaches resulting from tourism, recreational and fishing activities; and, industrial and port activities. The main effects caused by microplastics on the Brazilian coast, until now, are related to accidental ingestion by several marine species, causing toxicological effects, due to the adsorption or leaching of contaminants present in the microplastic particles, in addition to other adverse effects, such as hormonal dysfunctions, neurotoxic effects, behavioral and dietary changes, reproductive dysfunction, reduced viability, mobility and even death; the possibility of concentration and transport of different pollutants such as persistent organics; and, with biological risks, in which microorganisms are carried to places where they would not arrive naturally, contributing to the introduction and transport of pathogenic microorganisms or invasive species. Among the main solutions to stop the growth of microplastic contamination in Brazilian coastal ecosystems are environmental education activities to contain the inappropriate disposal of solid waste and the development of research to create bioplastics from renewable sources. So far, there is no effective and economically viable remedy for the removal of microplastics from the oceans and the future consequences of this contamination for marine ecosystems cannot be estimated with precision. Governmental actions are the most urgent, but the awareness and consequently the participation of the whole society in the prevention and combat of marine pollution by microplastics, is fundamental, mainly when we consider the dismantling of the environmental policies of the current Brazilian government.
Keywords: Coastal ecosystems; Environment; Marine waste; Ocean; Plastic; Pollution.

1 INTRODUCTION

The oceans play a key role in the environment and are an important source of resources. In addition, they play an essential role in climate regulation and of the planet's temperature, in nutrient cycling, in the supply of food, housing great biological diversity. Throughout human history the oceans have been important for the development of societies, and even today they serve as a source of food and resources, transport routes, trade and communication between continents (Jeftic et. al., 2009).

Despite the great importance, the oceans have been suffering from anthropic actions in the last decades. Large-scale predatory fishing and pollution have been causing the decline of species, causing ecological imbalances, degrading and threatening collapsing marine ecosystems. Another anthropic activity that is causing large threats in these ecosystems is the pollution of the oceans by plastic.

Plastic has been produced on a large scale worldwide, as it has a high durability, malleability, impermeability, lightness and low cost, replacing materials such as glass, metals and wood, allowing the development of various areas such as engineering and health. In Brazil, more than 11 million tons of plastic are produced at the year, placing the country as the fourth largest producer of plastic waste in the world (Heinrich Böll Stiftung 2020). Thus, it was estimated that in 2018 757,000 tons were recycled of the 3.4 million tonnes of plastic waste generated that year (ABIPLAST 2020).

This rampant consumption of plastic in today's societies is generating a growing concern about waste generation, the increase in marine litter and impacts that can lead to the planet's ecosystems. Plastics, due to wear, undergoing microfragmentation (< 5mm), currently resulting in one of the largest threats to marine life: microplastics. These have been present since the sand from the beaches to deep marine sites (Olivatto et al., 2018; Thompson 2015).

In this study, a review is made, the objective of which is to discuss the main sources and ways of entering microplastics into coastal ecosystems in Brazil, seeking to determine the impact of these particles on the environment. It is intended to discuss strategies for prevention and possible measures to control and mitigate the impacts that can be adopted to address the threat of microplastic pollution.

2 METHODS

An extensive literature review was conducted using databases such as Google Scholar platform and the Mendeley reference manager. For data survey about the country and it's legislation, consultations were held on national government websites. The research keywords included "microplastic, marine pollution, pollution by plastics, Brazilian coast." The database was searched for published studies by 2021. Reference lists of recovered publications have also been checked in order to return to other relevant literature. Ultimately, a total of 39 literatures were addressing topics such as coastal environments, sampling strategies, sample handling procedures and analytical methods for identifying and quantification of microplastics.

3 RESULTS

3.1 Sources of microplastic pollutants

The great fact that contributes to the increase in contamination of the oceans by microplastic is the inappropriate disposal of plastic waste in the environment (Figure 1). The disposal of plastic waste on beaches from tourism and leisure and recreation activities, disposal of plastic materials such as nets, buoys and other materials from the activities of the even of waste discarded on the continent and which are carried through the to the ocean (Barletta et. al., 2019) (Figure 2). Plastic waste, even resistance to degradation and longevity, when discarded in the environment, end up undergoing changes in their physical and chemical properties, becoming fragile and becoming fragmentation due to environmental factors such as UV photodegradation, oxidation, changes in mechanical action, hydrolysis and microbial activity (De Paoli 2008).

Untreated sewage disposed of in streams and tributaries, or even direct in beaches, are relevant for the increase in microplastic pollution in the oceans (Neto et. al., 2019). Agricultural, industrial and port activities also end up contributing to the increased pollution of the oceans with microplastic particles of pellets, which are used as raw materials in various sectors of the industry for the manufacture of materials (Costa and Barletta 2016). These pollutants reach the oceans through the improper disposal of parts of industrial processes and through the loss of material during transport (Mato et. al., 2001; Neto et. al., 2019). An important factor is the ballast water, which is transported from one port to another, where microplastics can be transported translocated from one location to several others on the planet (Matiddi et al., 2017).

Figure 1. Plastic waste present in the sandy strip of Ponta da Ilha beach, Ilha de Itaparica, Bahia – Brazil

Figure 2. Example of the type of waste obtained during ichthyofauna sampling stoneware snow Bahia, Brazil, predominance of plastic (Photo Leonardo Moraes)

Another source of microplastic pollutants in Brazilian marine ecosystems that we can highlight is the discharge of untreated sewage into the tributaries and coastal areas, which end up having the ocean as the final destination. Studies indicate that between 70 and 80% of microplastics that are found in the oceans have been transported to these locations through (Horton et al., 2016).

3.2 Main effects caused by microplastic pollution

In the marine environment, one of the main effects caused by the pollution of microplastics known to date are related to accidental ingestion by marine species (vertebrates and invertebrates) (Moraes et. al., 2020). The intake of microplastics may also have toxicological effects, as well as other adverse effects, hormonal dysfunctions, neurotoxic effects (Revel et al., 2018), as well as changes in behavioural and eating disorders, reproductive dysfunction, reduced viability, even leading individuals to death (Olivato et. al., 2018). How potential effects caused by microplastic pollution we still have the risks of transport of pollutants and biologicals (Baptista Neto et. al., 2019). Particularly for Brazil, among the studies conducted, cases of microplastic intake are observed by the Marine anemone *Bunodosoma cangicum* (Morais et. al., 2020), by *Centropomus undecimalis* sea bass and *C. mexicanus* (Ferreira et. al., 2019), by anitids with trophic transfer (Gusmão et. al., 2016), mussels (Castro et. al., 2016) and catfish *Cathorops spixii*, *Cathorops agassizii* and *Sciades herzbergii* (Possatto et. al., 2011). Studies has been carried out on the concentration and composition of aromatic hydrocarbons polycyclic (PAHs) in microplastics (Fisner et. al., 2013), colonization of microplastics bacteria and fungi (Baptista Neto et. al., 2019) and concentration of metals in microplastics (Vedolin et. al., 2018), presenting, as results, possible risks to organisms ingesting microplastics containing these substances and/or micro-organisms with potential pathogen.

3.3 Solutions to curb microplastic pollution in the oceans

Among the main solutions that must be adopted by Brazil to contain the growth of microplastic contamination of seas and oceans is the management and sewage and solid waste efficiently (Duis and Coors 2016). Like this as selective waste collection and recycling of plastic materials (Olivatto et. al., 2018).

Environmental education is key to raising awareness among the whole community and individuals concerned about the problem of ocean pollution by microplastics (Bianchini et. al., 2015). Also, changes in consumption habits, opting for the use of returnable packaging, replacing plastic bags with bags reusable, giving preference to products from companies that have care and commitments with the environment in its manufacturing processes, the non-use of plastic bags in stores and supermarkets and the production of products with less material plastic or produced with bioplastics, which are made of fast-to-eat organic materials degradation in the environment (Onen Cinar et. al., 2020). In Brazil, concern about micro-phasing is still insipid, and the main ways of reducing this impact, has been represented by projects from various groups aimed at preserving the environment promoting plastic waste collection groups on several beaches in the country (Cesar 2019), and the adoption of laws to prohibit the use of plastic and plastic bags in supermarkets. Obviously, although not directly related to the actions of impact mitigation under study, actions seeking to reduce the marine litter and the dumping of fresh sewage, indirectly help to reduce the impact of microplastics.

4 DISCUSSION

By the 1980s, around 79 million tonnes of plastic waste per year across the planet (Vasconcelos 2019). In 2016, production reached 396 million tonnes produced and it is estimated that total production could reach by 2025, more than 600 million tonnes of plastic annually, equivalent to a 50% increase compared to that currently produced (Heinrich Böll Stiftung 2020). Of the total produced plastic, it is estimated that more than 8 million tonnes of plastic waste oceans every year (Geyer et. al., 2017).

It is estimated that in Brazil, the amount of plastic waste corresponds to more than 11 million tonnes per year (Heinrich Böll Stiftung 2020), which ultimately contributes, significantly, for the increase and accumulation of microplastic in the oceans, because we are already the the fourth country that produces the most plastic waste in the world, presenting an annual disposal of 1.3 million tons, and only recycling 1.28% of these materials. Thus, 7.7 million tons of plastic waste is destined for landfills and 2.4 million tons will stop in the open (WWF 2019). In this way, with the incorrect disposal of plastic waste, many of these end up being transported to the ocean through the natural water.

In Brazil, less than half of the municipalities, which corresponds to 49.9%, still dump various solid waste into dumps, which are irregular and illegal deposits, which are generally in the open, presenting a high risk of environmental contamination, in respect of Article 47 of Law No. 12,305 on the National Solid Waste Policy (Brazil 2010), which defines that "the disposal of solid waste or directly into water or in natura bodies in the open." In addition, on average 17.8 million Brazilians do not have access to residential solid waste collection and only 3.85% of the collected waste is recycled (SELURB 2019).

Single-use packaging, such as plastic bags and canudos, deserves attention especially, because of every 400 million tons of plastic produced each year in the world, 158 million tonnes are destined for packaging manufacturing (Heinrich Böll Stiftung 2020). Thus, the Brazilian states of Rio de Janeiro, The Federal District, Espírito Santo and Goiás, already have their own legislation to ban the use of plastic bags. Already in relation to the rejection of plastic canudos, the states of Rio de Janeiro, Distrito Federal, Espírito Santo, Maranhão, Rio Grande do Norte, Santa Catarina and São Paulo adopted legislation (Table 01).

Table 01 - Legislation on the control of the use of bags and canudos plastics in The Brazilian states.

FEDERATION UNITY	LEGISLATION TO CONTROL THE USE OF	
	plastic bags	**plastic straws**
Distrito Federal (DF)	Lei Nº 6.322, de 10 de Julho de 2019 - Provides for the prohibition on the distribution or sale of plastic bags and regulates the distribution and sale of biodegradable or biocompostable bags to consumers, in all commercial establishments in the Federal District, and makes other provisions. (Distrito Federal 2019[a])	Lei Nº 6.266, de 29 de Janeiro de 2019 - Provides for the obligation of commercial establishments to use straw and glass made with biodegradable products in the form mentioned. (Distrito Federal 2019b)
Espírito Santo (ES)	Lei Nº 11.101, de 09 de Janeiro de 2020 – Provides for the distribution of plastic bags to consumers by commercial establishments, in the form specified. (Espírito Santo 2020)	Lei Nº 10.942, de 04 de Dezembro de 2018 – Prohibits commercial establishments, within the scope of the State, from marketing and providing their customers with disposable plastic straws and or similar materials. (Espirito Santo 2018)
Goiás (GO)	Lei Nº 16.268, de 29 de Maio de 2008 - Deals with the use of biodegradable plastic bags for packaging products and goods to be used in commercial establishments. (Goiás 2008)	-
Maranhão (MA)	-	Lei Nº 11.014, de 24 de Abril de 2019 - Vetoes the sale and use of plastic straws. (Maranhão 2019)
Rio de Janeiro (RJ)	Lei Nº 8.006, de 25 de Junho de 2018 - Provides for the replacement and collection of plastic bags in commercial establishments located in the State of Rio de Janeiro, as a way of making them available to the recycling cycle and protection of the Rio de Janeiro environment. (Rio de Janeiro 2018)	Lei Nº 6.458, de 8 de Janeiro de 2019 - It obliges restaurants, bars, snack bars, beach huts, street vendors and the like authorized by the Municipality to use and supply straws manufactured exclusively with biodegradable and or recyclable material individually and hermetically packaged with similar material. (Rio de Janeiro 2019)
Rio Grande do Norte(RN)	-	Lei Nº 10.439, de 16 de Outubro de 2018 - Prohibits the use of plastic straws, except biodegradable ones, in restaurants, bars, kiosks, street vendors, hotels and the like within the State of Rio Grande do Norte. (Rio Grande do Norte 2018)
Santa Catarina (SC)	-	Lei Nº 17.727, de 13 de Maio de 2019 - Provides for the duty of commercial establishments and mobile services to use straws manufactured with biodegradable, recyclable or sterilizable and reusable products, in the State of Santa Catarina. (Santa Catarina 2019)
São Paulo (SP)	-	Lei Nº 17.110, de 12 de Julho de 2019 - Prohibits the supply of straws made of plastic material in the State and provides other measures. (São Paulo 2019)

In the oceans, several factors can influence the distribution of pollutants microplastics, such as tributaries, winds, turbulence caused by maritime traffic and ocean currents, which can be transported over long distances, reaching even remote locations of the planet (From the South et. al., 2014). However, they generally presente concentration close to its polluting sources (Cole et. al., 2011).

The Brazilian coast is to the west of the Atlantic Ocean, with an extension of 8,698 km, with an area of approximately 388,000 km², where thirteen of the seventeen capitals of the coastal states are located on the seafront, concentrating higher population density. In coast, in addition to areas of intense urbanization in estuarine areas and bays, are industrial port and large-scale tourism exploration activities, which generates numerous problems from the point of view of environmental management due to pollution and contamination of marine ecosystems from different sources by different and types of materials (Ministry of the Environment 2010), including microplastics.

The lack of proper collection and treatment of sewage is one of the major problems environment faced by the country, given that more than half of the sewage generated is not treated and is played directly into the wild, being carried through the tributaries to the ocean. Only less than 43% of all sewage generated in the country daily is collected and treated (National Water Agency 2017).

Some more recent studies on microplastics in coastal areas of the Brazil presented synthetic fibers (Macieira et. al., 2021) and pellets (Gorman et. al., 2020; Ribeiro and Dos Santos 2020), probably from personal care products, hygiene, cleaning and cosmetics, which end up being discarded in domestic sewers. Other commercial product that deserves attention is glitter, which is composed of microparticles of polychloride (PVC) or ethylene polyephthalate (PET), which are widely used in school glues, make-up and clothing, costumes, props and allegories by the schools of samba and revelers during the carnival festivities in Brazil (Lucio et. al., 2019). Despite of many debates about contamination of the environment by glitter, this is still being produced and used without restrictions in the country.

Since 2016, in the Brazilian plenary, the approval of the draft federal law PL 6528/2016, which "prohibits the handling, manufacture, import and marketing, throughout the national territory, of personal care products, cosmetics and containing the intentional addition of plastic microspheres" (Brazil 2016). However, the bill is being processed in the Chamber of Deputies and is Commission of Constitution Justice and Citizenship (CCJ).

The textile industry also makes use of plastic microfibers in the production of which are released in the washing procedure of these tissues, which are released domestic sewage or near water courses, with the ocean as the destination for (Browne et al. 2011). By 2019, the number of formal textile companies was 25.5 million 1,000 throughout the country (ABIT - Brazilian Textile and Clothing Industry Association 2020).

Another sector that ends up generating microplastics is agriculture, which consumes 6.5 million tons of plastic in the world annually, making use of plastic materials agricultural insums, for conditioning and storage of production and others (Heinrich Böll Stiftung 2020). Thus, we highlight that Brazil corroborates the generation of microplastics, also through agriculture, given that the country is currently a of the highest agricultural potentials, being one of the largest soybean producers in the world, with 124.845 million tons produced in 2020 (EMBRAPA 2020).

Diagnosing the sources of origin of microplastics that contaminate the oceans is challenging. Given that these materials can travel thousands of miles per hydrodynamic means of transport, taking into account its physical and low density chemicals, arriving at beaches, mangroves and estuaries, and remaining long periods in the marine environment (Barletta et. al., 2019).

When present, microplastics present as their main problem the ingestion of of it. Because they are small in size, microplastics are easily ingested aquatic organisms belonging to different trophic levels. The intake of microplastics may cause obstruction of the digestive tract, presenting a feeling of satiety and causing malnutrition, stress and endocrine changes, compromising the rates of growth and reproduction of individuals (Olivatto et. al., 2018).

Microplastics, when ingested by marine organisms, can cause damage to the irreparable due to adsorption of various pollutants that end up adhering to the microplastics, such as persistent organics and metals, or through the leaching of chemical additives that are used in the manufacture of the polymer matrix of the (Olivatto et. al., 2018). These additives can achieve their diffusion coefficient and into the environment or be absorbed by the organism that ingested it, and may be cause intoxication and hormonal dysfunctions (Olivatto et. al., 2018; Revel et al., 2018). It is notepoint that contamination by the ingestion of microplastics can also occur through trophic transfer (Ferreira 2019).

In view of the distances and hydrodynamic transport of microplastics, these may present biological risks, in which micro-organisms are carried in their surfaces to places where they would not reach naturally. In this way, microplastics may contribute to the introduction and transport of pathogenic microorganisms or (Baptista Neto et. al., 2019), threatening the native species of certain locations.

Campaigns such as Clean Seas, launched in 2017 by the United Nations united nations, which aims to carry out actions to contain the entry of plastic waste into the ocean (UN 2018), and March for the Oceans (WWF 2018), which had its first edition in 2018 in Rio de Janeiro, promoted playful actions with the aim of raising awareness among society in the protection of the marine environment, combating pollution of beaches and seas. In parallel with the actions of campaigns to replace and reduce the use of packaging for the Senate Bill No. 92 of 2018, which provides for the replacement of biodegradable, within 10 years, utensils made of plastic as trays, plates, cutlery and disposable cups, but the processing of this Project is also since 2019 (Brazil 2018). Even considering that actions like these are of great relevance to contain the increase in microplastic pollution in the oceans, only a part of the society has been mobilized.

The most relevant points to curb the increase in microplastic pollution in the oceans are the changes in consumption habits and the replacement of plastics in the bioplastics produced through renewable raw materials. In Brazil, research on the production of bioplastics manufactured from sugarcane bagasse (Teles et. al., 2011), a plant species widely grown in the country of sweet potato starch (Del Vecchio et. al., 2020) and corn starch (Silva et. al., 2020) had satisfactory results in the possibility of replacing plastic materials manufactured today, especially those single-use packaging.

It is essential to carry out practical actions of governments, together with society's initiatives to alleviate the problems caused by the pollution of microplastic in the oceans. In this way, we believe that, punctual actions at the local level can be addressed more efficiently and carefully by putting municipalities ahead of the combating marine pollution by plastic and presenting a synergistic effect on the mitigation of impact of microplastics on Brazilian coastal ecosystems.

5 CONCLUSIONS

It is indisputable that microplastics are abundant in marine ecosystems and their real ecological impacts are not yet fully known is constituting a subject that is still being studied and debated by the scientific community. To date there is currently no technical and economically viable remediation for the withdrawal of microplastics of the seas and oceans and we still cannot accurately estimate what the consequences of this contamination for marine ecosystems.

Research and studies are still needed to estimate effects and long and short-term consequences. Studies on microplastics in Brazil are still and limited analyses in tidal zones, due to the ease of access to these locations, lacking, mainly studies in areas of open ocean.

Brazilian society needs, arguably and swiftly, to review its consumption patterns of plastic materials. Only with a broad change in habits of consumption will be possible to curb the increase in contamination of the oceans by microplastics, however, even by reducing the level of these pollutants in the oceans, efficient methods need to be be created for the depollution of this material. The current scenario of lack and/or mismanagement of plastic solid waste and the absence of sewage treatment should be reversed as as soon as possible. Government actions are the most urgent, but awareness and consequently the participation of the whole society in the prevention and combating of microplastics, is essential, especially when considering the dismantling of the environmental policies of the current Brazilian government.

ACKNOWLEDGEMENTS

This work is part of the master's thesis of PPGECoEvol at the Universidade Estadual de Feira de Santana (UEFS), funded by the Fundação de Amparo à Pesquisa do Estado da Bahia (FAPESB).

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