# SYMPOSIUM

## RETHINKING THE ENVIRONMENTAL QUALITY OF BRAZILIAN BEACHES: THE INCIDENCE OF MICROPLASTICS AS AN INDICATOR FOR SEA WATER AND SAND QUALITY

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ABSTRACT

Beaches are essential, multidimensional, and dynamic systems of unique importance from social, ecological, and economic points of view. Despite their immense value, the quality of Earth's beaches is being threatened by marine pollution, mostly composed of plastic debris. Specifically, microplastics are a threatening global phenomenon because of their diffusive character. In short, this implies severe potential adverse effects on human health. Therefore, a complete assessment of beaches' environmental quality, including their suitability for swimming, is crucial. However, the main concern

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regarding the environmental quality of beaches worldwide, including the Brazilian coastline, has been traditionally restricted to a set of sanitary and recreational standards. The traditional goal was to guarantee safe public use—mainly to protect human health from direct hazards on the microbiological scale. All the while, the current standards overlook the wide range of immediate negative impacts on marine ecosystems and other indirect hazards of marine pollution on humans, such as the many persistent pollutants accumulating in the ocean for years—microplastics included. This Article questions the adequacy of current testing parameters for determining water quality for Brazilian beaches in order to look at the extent to which the incidence of microplastics can be considered a determining factor when assessing environmental quality. The methodology used is literature review combined with documentary research. Results indicate that it is highly recommended expanding the framework of water quality indicators of Brazilian beaches to include the presence of microplastics as an important factor to be considered in the examination of the environmental quality of these regions, as well as what recently happened in the State of Ceará (Northeast Brazil), where the framework was expanded to legally include the identification of hydrocarbons in seawater and beach sand in response to contamination caused by the environmental disaster of a severe coastal oil spill in 2019.

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## INTRODUCTION

The ocean is the largest component of the Earth's environment; it stabilizes climate, supports life, and ensures human well-being. [1] Coastal ecosystems—including beaches, coral reefs, mangroves, and estuaries—are important spaces in terms of ecological and economical value. These ecosystems play the role of both environmental balance and genetic connection between the ocean and the terrestrial zone. [2] Our planet's coastal zones compose "the ocean belt" that possesses not only an extraordinary biodiversity,[3] acting as sanctuary and breeding ground for various marine species, but also bears a significant burden for the economy of contemporary society. [4]

Despite their value, coastal ecosystems are highly vulnerable environments and have long been adversely affected by human activities. In 2016, the First World Ocean Assessment found that much of the ocean is now seriously degraded, suffering losses in the structure, functionality, and benefits of marine systems.[5] The problems facing the ocean and coastal environment are broad, and include, among others: the climate emergency;[6] ocean acidification;[7] depletion and degradation; high levels of urbanization;[8] the execution of commercial

1. U.N. EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION: UNITED NATIONS DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT (2021-2030), https://en.unesco.org/ocean-decade (last visited Feb. 29, 2020) [hereinafter UNESCO].

2. Icaro Cunha, *Desenvolvimento Sustentável Na Costa Brasileira*, 14 REVISTA GALEGA DE ECONOMÍA 1, 2 (2005).

3. Charles C. Sheppard, *Biodiversity Patterns in Indian Ocean Corals, and Effects of Taxonomic Error in Data*, 7 BIODIVERSITY & CONSERVATION 847, 855 (1998).

4. HEATHER VILES & TOM SPENCER, COASTAL PROBLEMS: GEOMORPHOLOGY, ECOLOGY AND SOCIETY AT THE COAST 9 (Routledge, 1st ed. 1995).

5. U.N. Environment Programme, *World Ocean Assessment Overview*, 11 (2016).

6. O. Hoegh-Guldberg et al., *Coral Reefs Under Rapid Climate Change and Ocean Acidification*, 318 SCI. 1737, 1740 (2007).

7. Scott C. Doney et al., *Ocean Acidification: The Other CO2 Problem*, ANN. REV. MARINE SCI. 169, 172 (2009).

8. Ahana Lakshmi & R. Rajagopalan, *Socio-economic Implications of Coastal Zone Degradation and Their Mitigation: A Case Study from Coastal Villages in India*, 43 OCEAN & COASTAL MGMT. 749 (2000).

activities such as overfishing,[9] tourism,[10] port activities;[11] and last, but not least, intense and increasing pollution levels.[12]

To understand the importance of conserving and protecting the ocean ecosystems, it is necessary to explain the different hazards entailed in this framework. For example, the process of ocean acidification is caused by rising atmospheric carbon dioxide ("CO2"). This increase in CO2 levels is caused primarily by human fossil fuel combustion. Fossil fuel combustion reduces the ocean's pH levels and causes wholesale shifts in seawater carbonate chemistry, which alters the natural cycles of many elements and compounds and poses serious consequences for marine life. Ocean acidification cycle rates will accelerate over this century unless future CO2 emissions are curbed dramatically.[13]

Overfishing and illegal, unreported, and unregulated fishing are some of the other greatest threats to the sustainability of oceans resources. Overfishing and illegal fishing disturb the livelihoods of those who depend upon them—especially for the many small-scale fisheries around the globe. Overfishing is considered one of the most pervasive human disturbances to coastal ecosystems, because it can cause ecological extinction and can severely impact local economies.[14] Despite the international legal framework developed to combat such fishing, this problem is ever-present and increasing.[15]

Studies have shown "that human impacts have depleted [more than] 90% of formerly important species, destroyed [more than] 65% of seagrass and wetland habitat, degraded water quality, and accelerated

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9. Jeremy B. C. Jackson et al., *Historical Overfishing and the Recent Collapse of Coastal Ecosystems*, 293 SCI. 629 (2001).

10. Celso Garcia & Jaume Servera, *Impacts of Tourism Development on Water Demand and Beach Degradation on the Island of Mallorca (Spain)*, 85 GEOGRAFISKA ANNALER 287, 287-88 (2003).

11. C. TROZZI & R. VACCARO, ENVIRONMENTAL IMPACT OF PORT ACTIVITIES (2000).

12. Peter G. Ryan, *A Brief History of Marine Litter Research*, *in* MARINE ANTHROPOGENIC LITTER 1, 16 (2015).

13. Doney, *supra* note 7, at 169.

14. Jackson, *supra* note 9, at 629, 636.

15. United Nations, *SDG 14: Life Below Water*, U.N. SUSTAINABLE DEV. 14, https://www.un.org/sustainabledevelopment/oceans/ (last visited Apr. 13, 2019) [hereinafter *SDG 14*].

species invasions."[16] As the human population grows towards an expected nine billion by 2050, these negative impacts will only increase.[17] Compounding on population growth, projections indicate that 80% of all human activities will be concentrated on the coastal zone before the end of the century.[18]

This alarming scenario caused many problems related to the ocean belt and led to the United Nations proclaiming the next decade (2021-2030), the Decade of Ocean Science for Sustainable Development ("Ocean Decade").[19] The United Nations' main purpose is to raise awareness of the decline in ocean health, and urge the need to reverse the cycle. Its goal can be achieved by gathering ocean stakeholders worldwide behind a common framework built on strong and reliable ocean science that can fully support countries by creating improved conditions for sustainable development of the ocean.[20]

The Ocean Decade campaign illuminates the importance of improving the scientific understanding of the pressures on coastal areas, which is fundamental to ensure science-informed policy responses. It also highlights the potentially irrevocable consequences of marine climate change. Overall, the Ocean Decade campaign illustrates the need to design both local and global mitigation measures based on reliable scientific research.

The launch of the Ocean Decade campaign is not an isolated event; it is a part of a much larger global effort. The U.N. Environmental Programme ("UNEP"), along with numerous other local and international organizations around the world, shares the goal of raising awareness of ocean health decline.[21]

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16. Heike K. Lotze et al., *Depletion, Degradation, and Recovery Potential of Estuaries and Coastal Seas*, 312 SCI. 1806 (2006).

17. UNESCO, *supra* note 1.

18. Nelson Luiz Sambaqui Gruber, Eduardo Guimarães Barboza & Joao L. Nicolodi, *Geografia dos Sistemas Costeira e Oceanográficos: Subsídios para Gestão Integrada da Zona Costeira*, GRAVEL, Jan. 2003, at 81, 82.

19. UNESCO, *supra* note 1.

20. *Id*.

21. *See, e.g.*, SURFRIDER FOUNDATION, https://www.surfrider.org/mission [https://perma.cc/4NNF-N62F] (last visited Apr. 7, 2020); MARINE CONSERVATION INSTITUTE, https://marine-conservation.org/who-we-are/#mission [https://perma.cc/RHZ8-SDT3] (last visited Apr. 7, 2020); OCEAN CONSERVANCY, https://oceanconservancy.org/about/ [https://perma.cc/5KXV-6855] (last visited Apr. 7, 2020); OCEANSWELL, https://oceanswell.org [https://perma.cc/Y9GS-N3EB] (last

On a global perspective, the 2030 Agenda for Sustainable Development ("the Agenda") certainly is the most ambitious environmental step currently. Released by the United Nations in 2015, the Agenda's aim is to improve different fields of human existence using seventeen Sustainable Development Goals ("SDGs"). Each SDG is focused on tackling one specific contemporary problem.[22] SDG 14 - Life Below Water, for example, aims to protect the marine ecosystem by pleading for the conservation and sustainable use of the oceans, seas, and marine resources.[23]

The United Nations has stated the existing policies and treaties related to responsible ocean resource use and protection for marine biodiversity are still largely insufficient to combat hazards such as pollution, overfishing, growing ocean acidification due to climate change, and worsening coastal eutrophication.[24] Billions of people depend on oceans for their livelihood and food, and as the comprehension of the transboundary nature of oceans becomes clearer, the need for increasing the conservation sustainability efforts at all levels grow stronger.

## I. MARINE POLLUTION

Within the broad setting of ocean issues is the important matter of marine pollution. The overwhelming contamination of the seas and ocean by anthropogenic litter is one of the greatest problems in contemporary society. Anthropogenic litter is defined as "'any persistent, manufactured or processed material discarded, disposed of[,] or abandoned in the marine and coastal environment.'"[25] The large-

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visited Apr. 7, 2020); AUSTRALIAN MARINE CONSERVATION SOCIETY, https://www.marineconservation.org.au/about/ [https://perma.cc/8X2W-3MQX] (last visited Apr. 7, 2020); INSTITUTO COMAR, http://institutocomar.org.br/ [https://perma.cc/4H7K-2XF3] (last visited Apr. 7, 2020); PROJETO TAMAR, http://www.tamar.org.br [https://perma.cc/3545-C66Y] (last visited Apr. 7, 2020).

22. *SDG 14*, *supra* note 15.

23. *Id*.

24. *Id*.

25. Sarah Nelms et al., *Marine Anthropogenic Litter on British Beaches: A 10-year Nationwide Assessment Using Citizen Science Data*, 579 SCI. TOTAL ENV'T 1399, 1400 (2017) (citing Emily Hastings & Tavis Potts, *Marine Litter: Progress in Developing an Integrated Policy Approach in Scotland*, 42 MARINE POL'Y 49, 50 (2013)).

scale effects of human pollution on the marine and costal environment is a widely-known and well-documented reality that has been studied since early 1960.[26] Today human pollution in the ocean still represents a powerful threat for the health of the planet, and is one of the biggest challenges facing the global community.

Generally, pollution is any form of contamination that causes a harmful effect upon the organisms in an ecosystem by changing the growth rate and the reproduction of plant or animal species, or interfering with human amenities, comfort, health, or property values.[27] Hence, marine pollution is defined as "the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water, and reduction of amenities."[28]

Sea and ocean pollution originates from four distinct sources. As represented in Figure 1, the largest portion of all pollution comes from the land, either through run-off and discharges (via waterways 44%) or through the atmosphere (33%). Only 12% of all pollution is due to maritime activity and shipping accidents. Dumping of garbage and sewage, as well as offshore drilling and mining, make up for the remaining sources of pollution (10% and 1%, respectively).[29]

26. Ryan, *supra* note 12, at 4.
27. GEERT POTTERS, MARINE POLLUTION 16 (Bookbon ed., 1st ed. 2015).
28. U.N. Convention on the Law of the Sea art. 1.4, Nov. 16 1982, 1833 U.N.T.S. 397.
29. POTTERS, *supra* note 27, at 19.

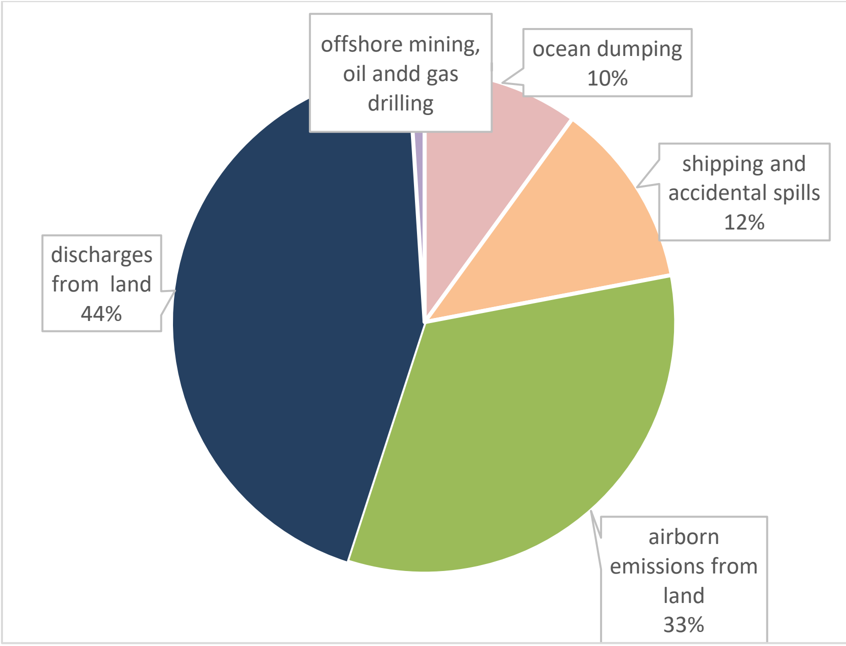


Figure 1: Share of the different sources of pollution into the marine environment (After IMO 2012). Source: Geert Potters, Marine Pollution 19 (2015).

Figure 2: The Citarum River in West Java, Indonesia. Source: http://www.outwardon.com/article/what-lurks-inside-the-worlds-most-polluted-waterways/?utm_source=pinterest&utm_medium=social.

Marine pollutants can cause a wide range of harmful effects, not only to the environment and marine organisms, but also to human health and economies. Detrimental and destructive impacts, such as smother-and-bury coastal ecosystems,[30] carry toxins and excessive nutrients (sediments derived from mining and farming), contaminate coastal swimming areas and sea food (persistent toxins), cause cholera, typhoid and other diseases (pathogens), introduce new marine diseases, and reduce biological diversity (alien species).[31] For example, eutrophication[32] distorts the balance of marine ecosystems. The high levels of nitrogen and phosphorus comes from urban, industrial, and agricultural runoffs that results in "algal blooms" (massive growth of the unicellular algae in the sea).[33] When the algae die, the remaining biomass is mineralized by bacteria that consume so much oxygen that the water beneath these blooms becomes anaerobic and, consequently, suppresses any forms of life.[34]

These pollutants can be classified according to their physicochemical constitution (organic or inorganic); their physical state (solid, drifting solids, gases, or solutes); or their persistence in the environment.[35] Classifying pollutants by persistence in the environment; the more persistent the pollutant in the ocean, the higher the change of life-long effects in the ocean caused by such matter.

30. Consultation prepared for USFWS, Panama City Ecological Services Field Office from Tracy Monegan Rice, Best Management Practices for Shoreline Stabilization to Avoid and Minimize Adverse Environmental Impacts (Nov. 2009) (noting smother-and-bury is when material flows or moves off and covers fragile organisms).

31. POTTERS, *supra* note 27, at 5-6.

32. Patricia M. Glibert et al., *The Role of Eutrophication in the Global Proliferation of Harmful Algal Blooms: New Perspectives and Approaches*, 18 OCEANOGRAPHY 198, 199 (2005) (eutrophication is the pollution of waters by nutrients as "a result of population growth, food production (agriculture, animal operations[,] and aquaculture), and energy production and consumption").

33. POTTERS, *supra* note 27, at 19

34. *Id*.

35. *Id*. at 16.

Pollutants distinguished by their level of persistence in the marine environment can either be biodegradable (i.e., they will be mineralized by bacteria or otherwise assimilated in the metabolism of any of the organisms in the environment) or as dissipating spontaneously, which causes them to lose their damaging nature more rapidly (meaning they will not continue to exist in the ecosystem for a long time).[36]

However, there is a group of conservative, or persistent, pollutants not susceptible to bacterial attack, and is not dissipated easily. Rather, these pollutants are reactive in various ways with plants and animals, causing extensive and long-lasting harmful effects. Examples of these are the heavy metals (mercury, copper, lead, zinc, etc.), radioactive sources, chlorofluorocarbons in the atmosphere, dioxins and pesticides, and, specifically, *plastics*.[37]

Plastics are by far the biggest compound of marine pollution and, lately, have been an intricate and defining issue of our times.[38] Plastic pollution aggregates many complex features that hinder most kinds of mitigation measures. Plastics are a persistent nonpoint source of pollution, meaning they cannot be attributed to a specific location or time, and have a rather diffuse character.[39] Unlike "point source pollution," like a sewage pipe or a leak in an oil drilling platform, plastics can rarely be traced back to a single, identifiable point of origin.[40]

In addition to being a persistent nonpoint source of pollution, plastics contain a wide range of organic contaminants, including polychlorinated biphenyls ("PCBs"), polycyclic aromatic hydrocarbons, petroleum hydrocarbons, organochlorine pesticides (2,2′-bis(p-chlorophenyl)-1,1,1-trichloroethane, hexachlorinated hexanes), polybrominated diphenylethers, alkylphenols, and bisphenol A. Some of these compounds are added to plastic during the manufacturing process, while others are absorbed from the surrounding seawater. [41]

36. *Id*. at 17.
37. *Id*.
38. *Id*. at 183-86.
39. *Id*. at 17.
40. *Id*.
41. Emma L. Teuten et al., *Transport and Release of Chemicals from Plastics to the Environment and to Wildlife*, 364 PHIL., TRANSACTIONS ROYAL SOC'Y B: BIOLOGICAL SCI. 2027, 2027-28 (2009).

The potential to absorb chemical pollutants, like heavy metals and other toxic substances, and transport them to living organisms is called the bioaccumulation capacity.[42] Bioaccumulation capacity means that plastics act as a vector for pollutants to marine life, transferring hazardous chemicals to fish and other marine species.[43] This causes contamination of the food chain with organic persistent pollutants and other toxic substances that are linked to endocrine and reproductive disruption, immune dysfunction, neurobehavioral dysfunction, carcinogenic development,[44] decreased fish population,[45] and reduced species evenness and richness. For as grand an issue as bioaccumulation capacity is regarding plastics, it is even more critical for *microplastics*.[46]

With all those complex features one can begin to understand the magnitude of the problem and the need to address it properly. The next section will investigate marine plastic pollution further.

The history of plastic dates back to the end of the 19th century. It was not until the 1950s, however, that plastic production was intensified, and only in 1987 did concerns about plastic's contaminating

42. *See* Chelsea M. Rochman et al., *Ingested Plastic Transfers Hazardous Chemicals to Fish and Induces Hepatic Stress*, 3 SCI. REP. 1 (Nov. 21, 2013), https://www.nature.com/articles/srep03263.pdf.

43. Linda M. Ziccardi et al., *Microplastics as Vectors for Bioaccumulation of Hydrophobic Organic Chemicals in the Marine Environment: A State-of-the-Science Review*, 35 ENVTL. TOXICOLOGY AND CHEMISTRY 1601, 1667 (2016).

44. *See* L. RITTER ET AL., INT'L PROGRAMME ON CHEM. SAFETY, A REVIEW OF SELECTED PERSISTENT ORGANIC POLLUTANTS: DDT-ALDRIN-DIELDRIN-ENDRIN-CHLORDANE HEPTACHLOR-HEXACHLOROBENZENE-MÏREX-TOXAPHENE POLYCHLORINATED BIPHENYLS DIOXINS AND FURANS 1 (1995).

45. Andrew McKinley & Emma L. Johnston, *Impacts of Contaminant Sources on Marine Fish Abundance and Species Richness: A Review and Meta-Analysis of Evidence from the Field*, 420 MARINE ECOLOGY PROGRESS SERIES 175 (Dec. 16, 2010), https://www.int-res.com/articles/meps2010/420/m420p175.pdf.

46. *See generally* Beatriz Nunes Diógenes, Limites E Possibilidades À Atuação Do Direito Internacional Do Meio Ambiente Na Mitigação Da Poluição Plástica Marinha (2020) (published dissertation, Universidade Federal do Ceará) (on file with author and Biblioteca Universitária, Universidade Federal do Ceará) [hereinafter Diógenes Dissertation]. *See also* U.N. Environment Assembly of the U.N. Environment Programme, *Report of the first meeting of the ad hoc open-ended expert group on marine litter and microplastics*, (June 19, 2018), https://papersmart.unon.org/resolution/uploads/k1801471.pdf [hereinafter UNEP First Meeting Report].

feature begin.[47] Decades after, large amounts of plastic have been entering the oceans, but only recently has the phenomenon of plastic waste accumulation in the marine environment been recognized by the international community as a serious contemporary problem. In 2018, it was the topic of conversation when the UNEP held the first meeting of the ad hoc, open-ended expert group on marine litter and microplastics.[48]

Today, plastic marine pollution is acknowledged as a global phenomenon of transnational proportions and diffuse character.[49] It is estimated that 4.8-12.7 million tons of land-based plastic waste ends up in the ocean each year.[50] Further, a study undertaken by the World Economic Forum and the Ellen MacArthur Foundation estimated that one garbage truck of plastic is thrown into the ocean every minute, with most of it being plastic packaging.[51]

It is estimated that only 14% of global plastic packaging is collected for recycling and only 2% is reused as packaging. In total, $80-$120 billion is lost annually caused by poor packaging waste management.[52]

Recent estimates point out that plastics comprise 90% of the litter accumulated in the ocean surface.[53] It is estimated that by 2025, the oceans will have one ton of plastics to every three tons of fish and by 2050, there will be more plastic than fish per kilo in the ocean.[54]

Another recent study showed that approximately 6300 Megatons ("Mt") of plastic waste had been generated in a global scale by 2015, but only around 9% had been recycled while only 12% was incinerated.

47. Diógenes Dissertation, *supra* note 46, at 25.

48. *See* UNEP First Meeting Report, *supra* note 46.

49. *See generally* Jenna R. Jambeck et al., *Plastic Waste Inputs from Land into the Ocean*, 347 SCI. 695 (2015).

50. *Id*. at 768.

51. James Pennington, *Every minute, one garbage truck of plastic is dumped into our oceans. This has to stop*, WORLD ECON. F. (Oct. 27, 2016), https://www.weforum.org/agenda/2016/10/every-minute-one-garbage-truck-of-plastic-is-dumped-into-our-oceans/.

52. *Id*.

53. *Overview on Marine Plastic Litter and Microplastics*, BASEL CONVENTION, http://www.basel.int/Implementation/MarinePlasticLitterandMicroplastics/Overview/tabid/6068/Default.aspx (last visited Apr. 11, 2019).

54. Sean Dixon et al., *The Big Apple's Tiny Problem: A Legal Analysis of the Microplastic Problem in the N.Y./N.J. Harbor*, 22 ROGER WILLIAMS U.L. REV. 385, 386 (2017).

The percentage of plastic accumulated in landfills or the natural environment was 79%.[55]

There are many reasons that can explain why the plastic marine pollution is a larger problem than other pollution. First, two inherent characteristics of plastic—its durability and versatility—make it appealing as a product and challenging for the environment. Plastics are "inexpensive, lightweight, strong, durable, corrosion-resistant materials, with high thermal and electrical insulation properties."[56] Seemingly indispensable in modern society, plastics are one of the most useful and important materials in modern society, helping to make a vast array of products that bring medical and technological advances, energy savings, and numerous other societal benefits.[57] Unfortunately, plastics are also a perverse feature of modern industrial civilization; almost all the plastic ever created still exists, untied and unstoppable, in our environment.[58]

Because plastic pollution sources are dispersed, an unquantifiable amount of plastic debris exists in the ocean. Plastic enters the ocean through a variety of pathways—most of them coming from land-based sources—such as: poorly-managed municipal landfills (waste dumps) located on the coast; riverine transport of waste from landfills along rivers and other inland waterways; discharges of untreated municipal sewage and storm water (including occasional overflows); industrial facilities (solid waste from landfills and untreated waste water); and tourist activities.[59] Plastic also comes from sea-based sources, such as merchant shipping; ferries and cruise liners; aquaculture installations;

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55. Roland Geyer et al., *Production, Use, and Fate of All Plastics Ever Made*, SCI. ADVANCES, Jul. 19, 2017, at 1, https://advances.sciencemag.org/content/3/7/e1700782/tab-pdf.

56. Richard C. Thompson et al., *Plastics, the Environment and Human Health: Current Consensus and Future Trends*, 364 PHIL. TRANSACTIONS ROYAL SOC'Y B 2153, 2154 (2009), http://www.royalsocietypublishing.org/doi/10.1098/rstb.2009.0053.

57. *See* Anthony L. Andrady & Mike A. Neal, *Applications and Societal Benefits of Plastics*, 364 PHIL. TRANSACTIONS ROYAL SOC'Y B 1977, 1980 (2009), https://royalsocietypublishing.org/doi/10.1098/rstb.2008.0304.

58. Elizabeth Mendenhall, *Oceans of Plastic: A Research Agenda to Propel Policy Development*, 96 MARINE POL'Y 291, 292 (2018)

59. UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), MARINE LITTER: AN ANALYTICAL OVERVIEW 5 (2005), https://wedocs.unep.org/handle/20.500.11822/8348 [hereinafter UNEP].

fishing vessels; military fleets and research vessels; and offshore oil and gas platforms.[60]

Although it can be argued that there are "no direct estimates of plastic input to the ocean,"[61] and frequently cited global estimates are not supported by robust data,[62] land-based sources (especially rivers) are deemed to be the major contributor of marine plastic debris.[63] In 2005, UNEP estimated that over 80% of marine litter comes from land-based sources.[64]

Two-thirds of this plastic ends up on the seabed, while the rest floats on, or under, the ocean surface.[65] These plastics can travel over great distances on ocean currents, polluting shorelines and accumulating in massive mid-ocean gyres, such as the "North Pacific Gyre," which has been nicknamed the "Plastic Vortex" or the "Great Pacific Garbage Patch."[66] The "North Pacific Gyre" is considered one of the prime examples of the extraterritorial proportion of marine pollution because it is the largest accumulation of marine litter in an oceanic zone and composed primarily of plastic waste.[67]

Another pervasive feature of plastic is its transboundary nature. This nature results in high costs to countries and communities that are far from the debris' origin.[68] Once the plastic is released into the natural environment, the debris spreads easily and can negatively affect communities that did not generate them.[69] Plastic's transboundary nature can be understood as the ecological injustice feature of the global

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60. *Id*.

61. MICHAEL NIAOUNAKIS, MANAGEMENT OF MARINE PLASTIC DEBRIS: PREVENTION, RECYCLING, AND WASTE MANAGEMENT 10 (David Jackson ed., 2017).

62. Mendenhall, *supra* note 58, at 292.

63. *Id*.

64. UNEP, *supra* note 59, at 19.

65. *Id*. at 4.

66. L. Lebreton et al., *Evidence that the Great Pacific Garbage Patch is Rapidly Accumulating Plastic*, SCI. REP., Mar. 22, 2018, at 1, https://www.nature.com/articles/s41598-018-22939-w.pdf.

67. *Id*.

68. PETER DAUVERGNE, THE SHADOWS OF CONSUMPTION: CONSEQUENCES FOR THE GLOBAL ENVIRONMENT 16 (2010) (explaining how the costs of rising consumption, particularly in wealthy countries, disproportionately fall on the disenfranchised populations of the world).

69. *Id*.

plastic trade. In other words, the ecological impacts of wealthy people's overconsumption can be transfer to other parts of the world, generally affecting low-income and underprivileged people in a process called "ecological shadows of consumption."[70]

The aggregate environmental impact of one country's domestic consumption, and the avoidance of its own environmental problems, is directly related to the export of plastic waste to countries with low standards of recycling and management. The "distancing of waste" deflects the environmental costs of excessive consumption in places like Europe and North America to countries with developing economies, especially in Asia.[71]

The effects and costs of this persistence are devastating. Plastic debris not only disrupts the normal functioning of ocean ecosystems, but also negatively affect societies and their economies through hindering shipping, fishing, aquaculture, tourism, and recreation.

The ecological damage starts with plastic manufacturing. Plastic manufacturing uses non-renewable resources, such as oil, and releases greenhouse gases into the atmosphere, which contribute to climate change.[72] "Approximately 4% of oil production is used as feedstock and another 4% is used to fuel the plastic manufacturing process as well as other resources such as natural gas, water, and chemicals."[73] Extracting and processing these raw materials into plastic feedstock generates carbon emissions amongst pollutants.[74]

Plastic litter in the ocean can drastically kill, injure, and harm marine wildlife. According to decades of records, a large amount of marine species (sea birds, turtles, mammals, and others) deaths are caused by entanglement and suffocation of plastic debris, mostly by abandoned, lost, or otherwise discarded fishing gear from commercial

70. *Id*.

71. *See* Jennifer Clapp, *The Distancing of Waste: Overconsumption in a Global Economy*, *in* CONFRONTING CONSUMPTION 155, 166 (Tom Princen et al. eds., 2002) (explaining the relationship between the ability of richer countries to push off waste and poorer countries' acceptance of that waste).

72. *See* Richard C. Thompson et al., *supra* note 56, at 2153 (describing the use of fossil fuels in plastics manufacturing).

73. United Nations Environment Programme, *Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry*, at 16 (2014), http://wedocs.unep.org/handle/20.500.11822/9238.

74. *Id*.

fishing boats.[75] Other items such as plastic bags and plastic strapping for packages strangle and kill marine animals. Further, these marine animals can also ingest the plastics.

Entanglement in and ingestion of marine debris can be fatal, but can also have a range of sub-lethal consequences such as compromising the ability to capture and digest food, altering sense of hunger, hindering escape from predators, jeopardizing reproduction and decreasing body condition, and compromising locomotion (including migration).[76] Ingestion, particularly of microplastics, is also of concern as it could provide a pathway for transport of harmful chemicals into the food chain.[77]

In 2014, the UNEP and the Secretariat of the Convention on Biological Diversity revealed that all known species of sea turtles (about half of all species of marine mammals) and one-fifth of all species of sea birds were affected by entanglement or ingestion of marine debris[78] (and a more recent study showed higher numbers: 66% of all species of marine mammals and 50% of all species of seabirds).[79] The impact frequency varied depending on the type of debris ("over 80% of the impacts were associated with plastic debris while paper, glass[,] and metal accounted for less than 2%").[80] The study also revealed that there has been a 40% increase in the number of species reported to be affected by ingestion and entanglement between 1997 and 2012.[81]

Furthermore, plastic waste found in the marine environment can leach chemicals into the environment as well as attract and transfer hazardous chemicals from the ocean to wildlife. "For example, plastic waste in the Pacific Gyre has become contaminated" with Persistent

75. GRAEME MACFADYEN, TIM HUNTINGTON & ROD CAPPELL, ABANDONED, LOST OR OTHERWISE DISCARDED FISHING GEAR 35-38 (2009).

76. Secretariat of the Convention on Biological Diversity, *Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions*, at 19 (2014), https://www.cbd.int/doc/publications/cbd-ts-67-en.pdf.

77. *Id*.

78. *Id*. at 9.

79. Susanne Kühn et al., *Deleterious Effects of Litter on Marine Life, in* MARINE ANTHROPOGENIC LITTER 75, 75 (Melanie Bergmann et al., eds., 2015).

80. Secretariat of the Convention on Biological Diversity, *supra* note 76, at 9.

81. *Id*.

Bioaccumulative Toxic Pollutants ("PBTs").[82] "PBTs are toxic to humans and marine organisms," and pose a risk to the marine environment because they resist degradation, persist for years or even decades, and have "been shown to accumulate at various trophic levels through the food chain."[83]

*Figure 3: Dead albatross with plastic inside its carcass. Source: https://coastalcare.org/educate/pollution/.*

The U.S. Environmental Protection Agency confirms that, "[e]ven at low concentrations, PBTs can be insidious in the environment due to their ability to biomagnify up the food chain, leading to toxic effects at higher trophic levels even though ambient concentrations are well below toxic thresholds."[84] Further, "[t]he subset of PBTs known as [P]ersistent [O]rganic [P]ollutants ([“]POPs[“]) are especially persistent, bioaccumulative, and toxic (such as DDT, dioxins, and PCBs)."[85] Due to its chemical characteristics, plastic absorbs PBTs present in the ocean and, when ingested by marine life, can cause harmful effects and potentially threaten human health through food chain contamination.[86]

82. United Nations Environment Programme, *supra* note 73, at 18.

83. U.S. Environmental Protection Agency, *Toxicological Threats of Plastic*, ENVTL. PROTECTION AGENCY (2015), https://www.epa.gov/trash-free-waters/toxicological-threats-plastic (last visited Apr. 15, 2020).

84. *Id*.

85. *Id*.

86. Rochman, *supra* note 42, at 4.

*Figure 4: Seal entangled by fishing net. Source: https://www.sealsitters.org/dangerous_waters/marine_debris.html.*

The socio-economic impacts of marine debris are also extensive and overwhelmingly negative, causing (or contributing to) economic losses to many human activities. It is clear that environmental degradation of beaches could lead to loss of income from tourism (e.g., loss of income for hotels, restaurants, bathing resorts, general commerce, etc.). For instance, the Asia-Pacific Economic Cooperation estimates that the cost of marine debris to the tourism, fishing, and shipping industries was approximately $1.3 billion in that region alone.[87]

Cleaning the coastline is another economic factor that should be taken into consideration, especially for local communities that may depend on the aesthetic quality of recreational water areas.[88] In addition, the health care costs connected to beach litter is an economic harm that mostly burdens local municipalities.[89]

As public awareness of marine pollution increases, voluntary beach cleaning initiatives by civil society groups also expand. These initiatives can generate the false belief that it is possible to clean

87. A. MCILGORM, H.F. CAMPBELL & MICHAEL J. RULE, UNDERSTANDING THE ECONOMIC BENEFITS AND COSTS OF CONTROLLING MARINE DEBRIS IN THE APEC REGION (MRC 02/2007) vii (2009).

88. JAMIE BARTRAM & GARETH REES, MONITORING BATHING WATERS: A PRACTICAL GUIDE TO THE DESIGN AND IMPLEMENTATION OF ASSESSMENTS AND MONITORING PROGRAMMES 162 (Jamie Bartram and Gareth Rees trans., E & FN Spon 1999); *see also* WORLD HEALTH ORGANIZATION, GUIDELINES FOR SAFE RECREATIONAL WATER ENVIRONMENTS 162 (2003).

89. BARTRAM & REES, *supra* note 88, at 162.

beaches and oceans through collective effort. Nevertheless, the harsh reality is that community cleanings have little ability to reduce marine pollution, especially microplastic contamination.

Valuing Plastic, a UNEP-supported report produced by the Plastic Disclosure Project and Trucost, says that marine plastic debris costs "approximately US$13 billion per year in environmental damage to marine ecosystems. This includes financial losses incurred by fisheries and tourism as well as time spent cleaning up beaches."[90] Furthermore, the report reveals that "[t]he total natural capital cost of plastic used in the consumer goods industry is estimated to be more than US$75 billion per year."[91] These costs result from a range of environmental factors including loss of valuable resources "when plastic waste is sent to landfill rather than being recycled," air pollution caused by incinerating plastic and "greenhouse gas emissions released from producing plastic feedstock."[92]

While it is well-evidenced that plastic negatively impacts many marine life and economic activities, there is still poor understanding of the totality of its effects and the resultant impact on ecosystem "services," which, "in turn, is bearing on human wellbeing, society, and the economy."[93] This is especially true when it comes to microplastics.

## II. THE MICROPLASTIC PHENOMENON

"By the end of the 1980s, most [effects] of marine litter were reasonably well understood," but "[r]esearch was largely limited to monitoring trends in litter to assess the effectiveness of mitigation measures."[94] This reality persisted until the last decade, when concern about microplastics, coupled with the discovery of alarming densities of small plastic particles in the North Pacific "garbage patch" (and other

90. JULIE RAYNAUD, VALUING PLASTIC: THE BUSINESS CASE FOR MEASURING, MANAGING AND DISCLOSING PLASTIC USE IN THE CONSUMER GOODS INDUSTRY 7 (James Richens & Andrew Russell eds., 2014).

91. *Id*. at 7.

92. *Id*.

93. Nicola J. Beaumont et al., *Global Ecological, Social and Economic Impacts of Marine Plastic*, 142 MARINE POLLUTION BULL. 189 (2019).

94. Ryan, *supra* note 12, at 1.

mid-ocean gyres), shifted public attention and forced researchers to seek better methods for understanding the plastic phenomenon.[95]

Primary microplastics comprise as much as one-quarter of annual marine plastic pollution.[96] The two largest sources of primary microplastics are washing of synthetic clothes (e.g., polyester and nylon) and the wear-and-tear of synthetic rubber tires, which together account for two-thirds of the primary microplastic now flowing into the oceans.[97] Also, products containing plastic microbeads (e.g., cleansers and exfoliants in toothpaste and facewash) have contributed 1-2% of the primary microplastic pollution of the oceans.[98]

Microplastics are currently present throughout the ocean, from the surface to the deepest and most distant areas, and cannot be removed because they cover vast volumes of water.[99] They are now documented in all marine environments, from coastlines to the open ocean,[100] the sea surface to the sea floor,[101] deep-sea sediments,[102] Arctic sea ice,[103]

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95. *Id*. at 19.

96. *See* JULIEN BOUCHER & DAMIEN FRIOT, PRIMARY MICROPLASTICS IN THE OCEANS: A GLOBAL EVALUATION OF SOURCES 5 (Carl Gustaf Lundin and João Matos de Sousa trans., 2017; *see also* Lebreton, *supra* note 66, at 13; Alice A. Horton et al., *Microplastics in Freshwater and Terrestrial Environments: Evaluating the Current Understanding to Identify the Knowledge Gaps and Future Research Priorities*, 586 SCI. TOTAL ENV'T 127, 128 (2017).

97. BOUCHER & FRIOT, *supra* note 96, at 21

98. *Id*.

99. Melanie Bergmann et al., *High Quantities of Microplastic in Arctic Deep-Sea Sediments from the HAUSGARTEN Observatory*, 51 ENVTL. SCI. & TECH. 11000 (2017), https://doi.org/10.1021/acs.est.7b03331 (noting microplastics are being found in the Polar Regions and on the seabed).

100. David K. A. Barnes et al., *Accumulation and Fragmentation of Plastic Debris in Global Environments*, 364 PHIL. TRANSACTIONS ROYAL SOC'Y B 1985 (2009).

101. Kyra Schlining et al., *Debris in the Deep: Using a 22-year Video Annotation Database to Survey Marine Litter in Monterey Canyon, Central California, USA*, 79 DEEP-SEA RES. I 96 (2013), http://www.sciencedirect.com/science/article/pii/S0967063713001039.

102. Lucy C. Woodall et al., *The Deep Sea is a Major Sink for Microplastic Debris*, 1 ROYAL SOC'Y OPEN SCI. 1 (2018).

103. Rachel W. Obbard et al., *Global Warming Releases Microplastic Legacy Frozen in Arctic Sea Ice*, 2 EARTH'S FUTURE 315, 318 (2014), https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2014EF000240.

fresh water,[104] and in the atmosphere.[105] Microplastics have also been found recently in tap and bottled water, as well as in seafood and table salt.[106]

The now ubiquitous contamination of marine microplastics causes concern, especially because the nature and extent of its ecological impacts (and on human health as well) are largely unknown. Also, there is an extensive lack of data regarding the global presence, sizes, and frequencies of microplastics, which can inhibit additional policies and undermine stronger regulation efforts.

Nevertheless, increasingly reliable data is gradually revealing the negative impacts microplastics have on the marine ecosystem, and potential adverse effects these pollutants have on human health. The effects observed by scientists demonstrate that microplastics can have serious ecological consequences, with potential to affect marine species at all levels of their biological organization, altering the expression of genes, interfering with the formation of cells and tissues, damaging reproduction and development, and altering the way species work and behave.[107]

Microplastics, like all plastics, can both absorb and leach chemicals, including persistent organic pollutants, as mentioned above. Recent laboratory research has shown that microplastic acts as a conduit for chemical additives and pollutants, including those intentionally added during the manufacturing process, but also other contaminants dispersed in the marine environment (e.g., POPs).[108] Such additives and pollutants, which have the characteristic of bioaccumulation, can reach the circulatory system of marine animals, causing toxicological

104. Martin Wagner & Scott Lambert, *Microplastics Are Contaminants of Emerging Concern in Freshwater Environments: An Overview*, *in* FRESHWATER MICROPLASTICS: EMERGING ENVIRONMENTAL CONTAMINANTS? 1, 5 (2018).

105. Johnny Gasperi et al., *Microplastics in Air: Are We Breathing it in?*, 1 CURRENT OP. IN ENVTL. SCI. & HEALTH 1, 2 (2018), http://www.sciencedirect.com/science/article/pii/S2468584417300119.

106. Peter Dauvergne, *Why is the Global Governance of Plastic Failing the Oceans?*, 51 GLOB. ENVTL. CHANGE 22, 24 (2018).

107. Chelsea M. Rochman et al., *The Ecological Impacts of Marine Debris: Unraveling the Demonstrated Evidence from What is Perceived*, 97 ECOLOGY 302, 304 (2016).

108. Dauvergne, *supra* note 106.

effects[109] and contaminating the food chain.[110] This makes microplastic an emerging problem for "food security, food safety and, consequently, for human health."[111]

Laboratory investigations have provided evidence that additives used in the life cycle of plastics "may be involved in endocrine" and "reproductive immune [dysfunction], neurobehavioral and developmental disorders, and cancer."[112] Based on several years of monitoring some of the additives incorporated into plastic, exponentially increasing levels have been observed in breast milk, and it was found that the main route of human exposure is through food.[113] In addition, exposure to plastic additives also impacts the public budget, as disease treatment costs are often paid by states. [114]

Also, lack of transparency in production chains makes it difficult to provide useful information to consumers about plastics. Moreover, the risks to human health are not adequately reflected in legal frameworks at international and regional level.[115]

One group of scientists argue that the global mismanagement of plastic waste is similar to other POPs "silent spring" on land fifty years

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109. Mark Anthony Browne et al., *Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity*, 23 CURRENT BIOLOGY 2388 (2013), https://linkinghub.elsevier.com/retrieve/pii/S0960982213012530.

110. Delilah Lithner, Åke Larsson & Göran Dave, *Environmental and Health Hazard Ranking and Assessment of Plastic Polymers Based on Chemical Composition*, 409 SCI. TOTAL ENV'T 3309, 3321-23 (2011) (discussing the nature of additives and how they are distributed through the environment).

111. Luís Gabriel Antão Barboza et al., *Marine Microplastic Debris: An Emerging Issue for Food Security, Food Safety and Human Health*, 133 MARINE POLLUTION BULL. 336, 345 (2018).

112. RITTER ET AL., *supra* note 44, at 1.

113. Per Ola Darnerud et al., *Polybrominated Diphenyl Ethers: Occurrence, Dietary Exposure, and Toxicology*, 109 ENVTL. HEALTH PERSP. 49, 54-56 (2001), https://ehp.niehs.nih.gov/doi/10.1289/ehp.01109s149.

114. Leonardo Trasande et al., *Estimating Burden and Disease Costs of Exposure to Endocrine-Disrupting Chemicals in the European Union*, 100 J. CLINICAL ENDOCRINOLOGY & METABOLISM 1245, 1251 (2015), https://academic.oup.com/jcem/article-lookup/doi/10.1210/jc.2014-4324 (exposure to endocrine disrupting chemicals has been estimated at € 119 billion in disease burden and costs for the European Union).

115. *Id*. at 1046.

ago (e.g., DDT and PCBs).[116] "POPs are defined under the Stockholm Convention on Persistent Organic Pollutants . . . as potentially harmful organic compounds that resist environmental degradation through chemical, biological, and photolytic processes."[117] Parties to the Stockholm Convention are required to restrict, prohibit, or eliminate the intentional production and use of chemicals listed in Annexes A and B, and to reduce or eliminate release of chemicals from the unintended production of chemicals listed in Annex C to the Convention.[118]

Although plastics are not listed in the Stockholm Convention as a POP, some of the additives used by the plastic industry in its manufacturing process *are* POPs, and the Convention provides measures to reduce or eliminate the releases of waste containing POPs.[119] The chemicals relevant to plastic listed in the Stockholm Convention include: (1) polychlorinated biphenyls (PCBs), which are often detected in high concentration in marine plastic waste due to their adhesive property; (2) polybrominated diphenyl ethers (pentaBDE and commercial octaBDE), used as a flame retardant; and (3) perfluorooctane sulfonic acid (PFOS), used as an additive in some plastic products.[120]

Yet, scientists argued that plastic, *itself*, fulfills some criteria for POPs, considering that "they are organic substances; they persist and accumulate in the environment and in organisms over long periods of time; and they can cause a wide range of sub-lethal and lethal effects, including the complex toxicology of micrometer- to nanometer-sized plastic particles coming to light recently."[121] Hence, the scientists' consideration implies that plastic is much more dangerous than originally thought, and it deserves a more careful treatment and attention than what is currently being given today.

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116. Boris Worm et al., *Plastic as a Persistent Marine Pollutant*, 42 ANN. REV. 1, 21 (2017), http://www.annualreviews.org/doi/10.1146/annurev-environ-102016-060700.

117. *Id*. at 3.

118. *Overview*, UNITED NATIONS ENVIRONMENT PROGRAMME, http://www.pops.int/TheConvention/Overview/tabid/3351/Default.aspx (last visited Apr 13, 2019).

119. Diógenes Dissertation, *supra* note 46, at 59.

120. *Id*.

121. Worm et al., *supra* note 116, at 3.

In fact, listening to public and scientists appeal, the recent May 2019 Conference of the Parties of the Basel, Rotterdam, and Stockholm Conventions reached several significant results in combatting marine plastic pollution.[122] The Parties approved an amendment to the Basel Convention to include some plastic waste in its legally-binding structure, which could make global plastic trade more transparent and better regulated. As the decision is very recent, it is too early to evaluate its results.[123]

Because of the wide range of associated problems, "[p]lastic pollution has now become widely recognized as a major environmental burden . . . particularly in the oceans where the biophysical breakdown of plastics is prolonged . . . , effects on wildlife are severe . . . , and options for removal are very limited. . . ."[124]

When thinking about the impacts of plastic pollution on the marine environments, society must acknowledge that it provides a wealth of ecosystem services, including many social and cultural benefits, including recreational spaces and opportunities to develop human well-being and even spiritual enhancement.[125] This reality is especially true when it comes to beaches—which have a central role in our social lives.

Actually, beach environments are susceptible to all the negative effects of marine plastic debris, including the social, ecological, and economic costs discussed above. In fact, the threats caused by plastic pollution have the capacity to affect the supply of the "beach ecosystem services," significantly impact the wellbeing of humans across the globe,[126] and jeopardize the economic and ecological value of the beach environment framework, including its role as a singular source for biodiversity maintenance, ecological balance, and human food and income.

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122. *Summary of the Meetings of the Conferences of the Parties to the Basel, Rotterdam and Stockholm Conventions: 29 April – 10 May 2019*, 15 EARTH NEGOT. BULL. 269 (May 13, 2019), https://enb.iisd.org/download/pdf/enb15269e.pdf.

123. Diógenes Dissertation, *supra* note 46, at 59.

124. Worm et al., *supra* note 116, at 2.

125. Beaumont, *supra* note 93, at 189.

126. *Id*.

## III. BEACH ENVIRONMENTAL QUALITY

Beach environments are essential, "multidimensional systems, in which natural and human subsystems operate in continuous, dynamic, and complex relationships."[127] Beaches "form the single largest interface between the sea and the land"[128] and their unique ecological attributes include a vast range of ecosystem goods and services, such as their habitats and biodiversity; geobiochemical transformations and linkages (especially nutrient cycling and water filtration); and many others.[129]

Beach environments make up the economic base for many communities around the globe that rely on beach health to provide for their families and to ensure their income. Multiple workers and economies depend either directly or indirectly on the well-being and sustainable management of beaches, mostly because many commercial activities like fishing and tourism need beaches to be healthy and well-functioning.[130]

Besides their obvious ecological and economical value, beaches also provide an important social space for cultural connections and recreational opportunities. As a natural place for socio-cultural activities, beaches play a meaningful social role by providing a happy environment that not only encourages social gatherings, but also fosters respect for public spaces while creating a sense of collectivity.[131] To summarize, beaches have strategical importance from the ecological, economic, and social perspectives.

Despite the inherent value, the world's coastlines, which are dominated by sandy shores, are highly vulnerable to anthropogenic

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127. Seweryn Zielinski & Camilo Botero, *Are Eco-Labels Sustainable? Beach Certification Schemes in Latin America and the Caribbean*, 23 J. SUSTAINABLE TOURISM 10, 1550–1572 (Aug. 27, 2015), https://doi.org/10.1080/09669582.2015.1047376.

128. T.A. Schlacher et al., *Open-Coast Sandy Beaches and Coastal Dunes*, *in* COASTAL CONSERVATION 38 (Brooke Maslo & Julie L. Lockwood eds., 2014).

129. *Id*.

130. *Id*. at 39.

131. Rodney J. James, *From Beaches to Beach Environments: Linking the Ecology, Human-Use and Management of Beaches in Australia*, 43 OCEAN & COASTAL MGMT. 495, 496 (2000); *see also* Worm et. al., *supra* note 116; Zielinski & Botero, *supra* note 127.

pressures that act at multiple temporal and spatial scales, translating into ecological, economic, and social impacts that are manifested across several dimensions. It is not an overstatement to say that "today almost every beach on every coastline is threatened by human activities."[132]

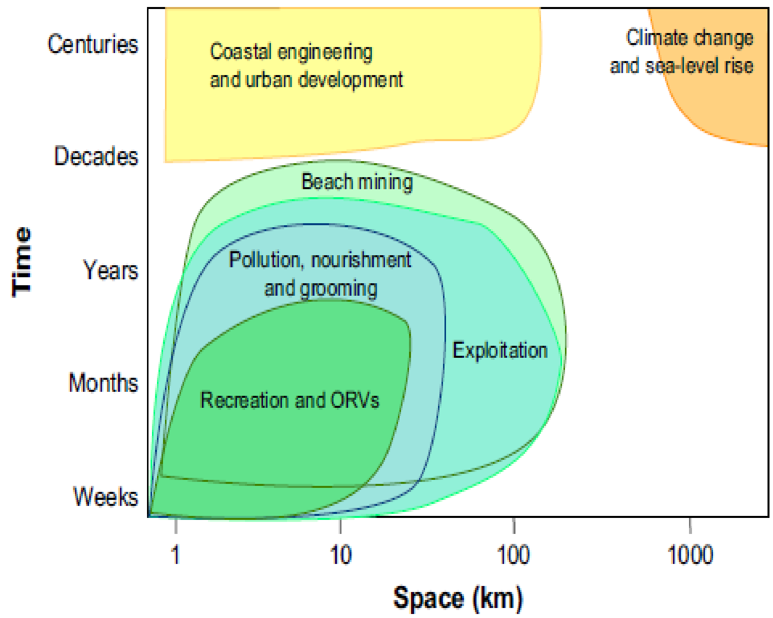


*Figure 5. Conceptual model and schematic diagram showing the relative spatio-temporal scales in which different factors reviewed here generally operate on sandy beach macrofaunal communities. Boxes/envelopes indicate the potential extent of individual impacts in space and time with the lower curve reflecting the lower limit of impacts in time and space, whereas the upper curve reflects the corresponding maximum. Shorter term impacts (i.e., weeks to months) tend to be pulse disturbances and effects are generally expected to last for shorter time periods, since sandy-beach species are adapted to severe physical disturbances (e.g., storms). However, the temporal extent of impacts from the anthropogenic pressures depicted here could be drastically altered if the intensity of the disturbance is increased and/or its timing*

132. Omar Defeo et al., *Threats to Sandy Beach Ecosystems: A Review*, 81 ESTUARINE, COASTAL & SHELF SCI. 1 (Jan. 1, 2009), http://www.sciencedirect.com/science/article/pii/S0272771408003752.

*is more protracted. Under such circumstances, sandy beach habitats could become unsuitable for supporting macrofaunal communities and the ecosystem services they provide in the medium or long term. Source: Omar Defeo et al., Threats to Sandy Beach Ecosystems: A Review, 81 Estuarine, Coastal & Shelf Sci. 1, 1–12 (Jan. 1, 2009), http://www.sciencedirect.com/science/article/pii/S0272771408003752 .pdf.*

The scales of anthropogenic stressors threatening the environmental quality of beaches around the globe (Fig. 1) encompass multiple orders of magnitude in both time and space.[133] These stressors can have both little localized effects (e.g., litter from recreational activities) and a truly global reach (e.g., sea-level rise, climate change, and marine pollution).

As evidenced above, marine pollution (mostly composed of plastic debris) is one type of anthropogenic threat to the world's beaches with truly global reach. This type of pollution strongly impacts beach quality, either by corrupting its ecological role and weakening its ecosystem—or by discouraging its recreational use and causing diseases in beachgoers, as well as hampering economic activities such as fishing and tourism.

Thus, from all points of view, the negative impact of pollution on beaches demonstrates environmental, as well as social and economic, issues.

133. *Id*.

*Figure 6: Polluted sandy beach. Retrieved from:* https://coastalcare.org/2009/11/plastic-pollution/.

For decades, many strategies have been proposed to respond to the anthropogenic pressures on the world's coast and to the growing need for increased environmental quality of beaches. These strategies encompass a number of Coastal Planning and Management Schemes[134] (e.g., Integrated Coastal Management[135] and Marine Spatial

134. *See generally* ROBERT KAY & JAQUELINE ALDER, COASTAL PLANNING AND MANAGEMENT (1998).

135. *See generally* BILIANA CICIN-SAIN ET AL., INTEGRATED COASTAL AND OCEAN MANAGEMENT: CONCEPTS AND PRACTICES (1998).

Planning),[136] but especially Beach Management Programs (e.g., Beach Certification Schemes and Environmental/Quality Management Systems[137]), among others.

Methods to undertake marine debris surveys have also been discussed for decades.[138] Marine debris monitoring programs, for example, can provide information on the types, quantities, and distribution of marine debris and grant insight into problems and threats associated with an area. They "can also increase public awareness of the condition of coastlines," "assess the effectiveness of legislation and coastal management policies," and "explore public health issues related to marine debris."[139]

Despite these existing efforts, the main concern regarding the quality of beaches has been public health standards. Traditionally, sanitary and recreational standards aimed to protect public health—mainly to ensure that the waters are suitable for bathing and the sand is safe for human-contact. Historically, fecal coliforms and Escherichia coli ("E. coli") have been used as bathing water suitability indicators.[140]

"Coliforms, particularly of the species E. coli, have been used as an indicator of water quality . . . since the 19th century."[141] There are some divergent views over the use of coliform groups, but these organisms are widely-employed as a water quality indicator in marine environments.[142]

Hence, the marine pollution aspects considered in beach quality assessments make reference primarily to the direct hazards for human health, but show a strong tendency to overlook the wide range of

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136. Fanny Douvere, *The Importance of Marine Spatial Planning in Advancing Ecosystem-Based Sea Use Management*, 32 MARINE POL'Y 5, 762-771 (Sept. 2008), http://www.sciencedirect.com/science/article/pii/S0308597X0800064X.

137. *See generally* Zielinski & Botero, *supra* note 127.

138. *See generally* BARTRAM & REES, *supra* note 88.

139. GUIDELINES FOR SAFE RECREATIONAL WATER ENVIRONMENTS, 163 (World Health Organization ed., 2003), http://www.who.int/water_sanitation_health/publications/srwe1/en/.

140. David Gray, *Qualitative Review of Epidemiology Studies*, *in* REGIONAL BEACH PROGRAM CONFERENCE—1999 PROCEEDINGS: US ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF WATER, EPA 43-45 (Feb. 2000).

141. Oscarina V. Sousa et al., *Specificity of a Defined Substrate Method Used to Monitor Balneability of Tropical Coastal Waters Impacted by Polluted Stormwater*, 8 J. WATER HEALTH 543 (Sept. 1, 2010).

142. Gray, *supra* note 140, at 43-45.

immediate negative impacts on marine ecosystems and the other indirect hazards of marine pollution on humans, such as the many persistent pollutants and similar contaminants accumulating in the ocean for years—plastics included.

The preference for instant human health care rather than a holistic perspective of the marine environment is evidenced by the content of The Guidelines for Safe Recreational Water Environments, developed by the World Health Organization ("WHO"), which provide an overview of the hazards that may be encountered during recreational water use, "including hazards leading to drowning and injury, water quality, exposure to heat, cold and sunlight, and dangerous aquatic organisms."[143]

"With regard to coastal water quality," the WHO guidelines "address fecal pollution, free-living microorganisms, freshwater algae, marine algae, and chemical aspects."[144] But when it comes to plastics, it is only considered as an *aesthetic* issue, even though the report says that "the sampling program[] should be representative of the range of conditions in the recreational water environment while it is being used."[145]

Consequently, persistent marine pollutants (plastics additives and even plastic itself, for example) are not yet considered a hazard worth to be added in its water quality standard, at least not to its recreational waters standards.[146] Overlooking plastic is reasonable because the argument for considering plastic as a persistent pollutant is still debated by scientists on the international community and is not yet accepted entirely even though its notorious evidence.[147]

An argument can be made that although "aesthetic issues play an important role in the public perception of a recreational water area,"[148] which can be of significant importance especially for communities dependent on tourism, are far from the most pressing side effects of the marine plastic pollution.

143. GUIDELINES FOR SAFE RECREATIONAL WATER ENVIRONMENTS, *supra* note 139, at ix.

144. *Id*.

145. *Id*. at 82, 196.

146. *Id*.

147. *See generally* Worm et al., *supra* note 116.

148. GUIDELINES FOR SAFE RECREATIONAL WATER ENVIRONMENTS, *supra* note 139, at 159.

Chemical contaminants in recreational waters (including persistent pollutants like heavy metals and plastics additives) comprise another factor to be considered since WHO guidelines state that it "does not seem to represent a serious health risk for recreational water users, and in most cases the concentration of chemical contaminants will be below drinking-water guideline values."[149] It is important to underscore that the guidelines do not consider plastic to be a chemical contaminant, but only as a type of marine litter labelled as an aesthetic issue.[150]

The report states, in general, the potential risks from chemical contamination of recreational waters, apart from toxins produced by marine and freshwater cyanobacteria and algae, marine animals or other exceptional circumstances, are minimal compared to the potential risks from other hazards like drowning, sun, heat and fecal pollution. According to the WHO guidelines, "it is unlikely that water users will come into contact with sufficiently high concentrations of most contaminants to cause adverse effects following a single exposure."[151] Or even with repeated exposure.

> Even repeated (chronic) exposure is unlikely to result in adverse effects at concentrations of contaminants typically found in water and with the exposure patterns of most recreational water users. However, it remains important to ensure that chemical hazards and any potential human health risks associated with them are recognized and controlled and that users can be reassured as to their personal safety.[152]

Note that when it comes to chemical contaminants, the WHO guidelines prioritize exposure as "one of the key issues in determining the risk of toxic effects from chemicals in recreational waters", meaning the human care aspect of the guideline is focused on only the immediate side effects of exposure linked to surface contact ("including skin, eyes and mucous membranes, inhalation, and ingestion").[153]

Even though the guidelines argue that "in assessing the risk from a particular contaminant, the frequency, extent and likelihood of

149. *Id*. at 170.
150. *Id*. at 159.
151. *Id*. at 169.
152. *Id*. at 169-170.
153. *Id*. at 168.

exposure are important parts of the evaluation"[154] the medium and long-term effects of persistent contaminants are not considered by the guidelines for assessing the quality of recreational waters, and, equally, the care for the marine ecosystem as a whole and unique environment.

According to the WHO guidelines, the standard criterion for verifying the "health" (quality) of recreational water is the microbial colimetry test (percentage of Fecal Coliforms).[155] "The initial classification is based upon the combination of evidence that includes the degree of influence of (human) fecal material (by sanitary inspection of beach and water catchment) alongside counts of suitable fecal index bacteria (a microbial quality assessment)."[156]

Note that:

> information to be collected during sanitary inspections should cover at least the three most important sources of human fecal contamination of recreational water environments for public health purposes: sewage; riverine discharges (where the river is a receiving water for sewage discharges and is either used directly for recreation or discharges near a coastal or lake area used for recreation); and bather contamination, including excreta.[157]

The results of the "sanitary inspection and the microbial water quality assessment can be combined to give a five-level classification for recreational water environments: very good, good, fair, poor, and very poor."[158] "Following initial classification, the guidelines propose that all categories of recreational water environment should be subject to an annual sanitary inspection (to determine whether pollution sources have changed) and continued water quality monitoring."[159]

The WHO guidelines are intended to be used as the basis for developing international and national approaches (including standards and regulations) to control the potential health risks that may be encountered in recreational water environments, as well as provide a framework for local decision-making. The guidelines also highlighted

154. *Id*.
155. *Id*. at 56.
156. *Id*. at xxii.
157. *Id*.
158. *Id*. at xxiii.
159. *Id*.

that the "guideline values should be interpreted or modified in light of regional and/or local factors."[160] "Such factors can include the nature and seriousness of local endemic illness, population behavior, exposure patterns, and sociocultural, economic, environmental, and technical aspects, as well as competing health risk from other diseases that are not associated with recreational water."[161]

Regardless of the WHO guidelines, public and private actors have defined criteria for assessing the quality of their beaches. For instance, many Beaches Environmental Assessments and Programs, such as the reports on bathing water quality produced by the European Environment Agency and the Technical Resources about Beaches provided by the U.S. Environmental Protection Agency's ("EPA"), have created their own standards. Both have similar purposes, which include providing water quality standards and indicators, data and reports about beach health, tools to evaluate, and manage beach health, among others.[162] The central aim, however, is to reduce the risk of diseases, specifically to beachgoers who come in contact with the recreational waters, and the standard measurement criteria is the colimetry test.[163]

To illustrate, according to the Natural Resources Defense Council, the violation of public health standards at American beaches is mostly caused by bacteria carried in raw sewage, animal waste, and storm water runoff that can make people sick after the primary contact. Although victims often do not "attribute their condition to exposure to contaminated water, since they may not realize that their rashes, stomach flu, hepatitis, or other illnesses were caused by swimming in polluted water."[164]

The overall takeaway is that beach quality has customarily been concentrated on the service offered to *users*,[165] and the general focus of

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160. *Id*. at xxii.

161. *Id*.

162. *Our Work: Water Pollution: Improve Beach Water Quality*, NRDC, https://www.nrdc.org/issues/improve-beach-water-quality (last visited May 1, 2020).

163. *Id*.

164. *Id*. ("The U.S. Environmental Protection Agency estimates that up to 3.5 million people a year become ill from contact with sewer overflows.").

165. Rafael Sardá et al., *Towards a New Integrated Beach Management System: The Ecosystem-Based Management System for Beaches*, 118 OCEAN & COASTAL MGMT. 167, 168 (2015),

many beach programs and schemes is commonly oriented to safeguarding recreational *human* use of beaches (mainly to guarantee safe water for swimming), while largely ignoring or overlooking the ecological processes and functions of beaches—including the effects of the plastic phenomenon.

Clearly, this problem requires a higher standard of assessing the quality of beach waters and environmentally-sustainable management of coastal areas is required to address this problem. This conception must acknowledge that beaches are multidimensional environmental systems rather than unidimensional physical systems or recreational playgrounds.[166]

The discussion involving the health and quality of beach ecosystem is even more important and problematic on developing coastal countries with intense economic activities on their beaches and poor waste management schemes, which is the case in Brazil.

## IV. BRAZILIAN BEACH ENVIRONMENTAL QUALITY

Brazil is a huge coastal country. It has approximately 7500 kilometers of Atlantic coastline and a high population density on the seafront.[167] The ten largest cities in the country are located in Brazil's coastline, which add up to twenty-five million citizens. Brazil's coastline is known for its many breath-taking sandy beaches and warm water temperature.[168]

Many traditional communities and local businesses depend on the maintenance of the environmental quality of beaches. Several human activities and industries, such as tourism, artisanal fisheries, nautical sports, and aquaculture, are highly dependent on the beaches' natural resources. Thus, beaches play a fundamental role generating regional

http://www.sciencedirect.com/science/article/pii/S0964569115002100 (last visited Apr 26, 2020).

166. James, *supra* note 131.

167. *Brazil*, Nations Online, https://www.nationsonline.org/oneworld/brazil.htm (last visited Jun. 24, 2020).

168. *See* Cal Fussman, *Beauty and the Beach*, WASH. POST (Mar. 16, 1987), https://www.washingtonpost.com/archive/lifestyle/magazine/1987/03/15/beauty-and-the-beach/bdff84da-f4e9-48c9-baaf-8aba64a96905/. (One beach in particular, Jericoacoara, was selected by The Washington Post as one of the Top Ten most beautiful beaches in the world).

development and income for the Brazilian population. The Northeast of Brazil, in particular, has both "unique demographic features, such as a dense population distribution in the coastal zones (10 of 11 state capitals are located along the coast), and natural characteristics (owing to the diversity of the tropical ecosystems in this region)."[169]

Nevertheless, Brazil, like many developing countries, has a long history of beach mismanagement. The coast is commonly damaged by anthropogenic hazards like inadequate solid waste management and failures in sewage treatment networks.[170] Thus, monitoring the quality of coastal waters is an essential measure to ensure not only the safety of recreational beach-goers, but to guarantee the maintenance of important economic activities.

In Brazil, resolutions 20/86 and 274/00 of Conselho Nacional do Meio Ambiente established the classification of bodies of water according to use. These resolutions establish the following indicators for saline water intended for recreation: floating materials; oils and greases; substances that produce odor or turbidity; artificial dyes; substances that form objectionable deposits; fecal coliforms; DBO-5; biochemical oxygen demand (BOD); organic debris (OD); dissolved oxygen (DO); pH; and potential for hydrogen and potentially harmful substances.[171]

Despite the various indicators, the "balneability" (parameters for to determine the suitability for bathing) of Brazilian beaches is historically determined by the amount of bacteria in the coliform group present in the water (Escherichia coli and/or Enterococci).[172] Legislation established that seawater is appropriate for recreational use when 80% or more of the samples collected at the same location during the preceding five weeks contain on the average less than 1,000

169. Marcelo de Oliveira Soares et al., *Oil Spill in South Atlantic (Brazil): Environmental and Governmental Disaster*, 115 MARINE POL'Y 103879, 103882 (2020).

170. Navarro Ferronato & Vincenzo Torretta, *Waste Mismanagement in Developing Countries: A Review of Global Issues*, 16 INT'L J. ENVT'L. RES. & PUB. HEALTH 1060, 1084 (2019).

171. Resolution No. 274/00, de 29 de Noviembre de 2000, DIARIO OFICIAL DA UNIAO [D.O.U.] de 18.1.2001 (Braz.); Resolution No. 357/05 de 17 de Marzo de 2005, DIARIO OFICIAL DA UNIAO [D.O.U.] de 18.3.2005 (Braz.) (promulgated Resolution 20/86).

172. Sousa et al., *supra* note 141, at 545.

thermotolerant coliforms or 800 E. coli, or 100 enterococcus per 100 milliliters. "Seawater is deemed unsuitable if this requirement is not met or if the last sample collected contains over 2,500 thermotolerant coliforms or 2,000 *E. coli*[,] or 400 enterococcus per 100 [milliliters]."[173]

Consequently, the assessment of Brazil's beach quality emphasize the microbiological scope related to sanitary issues regarding sewage and human hazards connected only to the primary contact with the water (adverse health outcome associated with exposure to fecal-contaminated recreational water, being the most common enteric illness).

This survey of the sanitary conditions of waters and beach sands is very important, since contamination represents potential risks for users. However, it is necessary to point out that there are other criteria that must be considered in the macro scope. The environmental quality of a beach must take into account not only the presence of fecal coliforms, but also the broad spectrum of human activities that impact its ecosystem.

For example, extraordinary events, such as oil spills and epidemic outbreaks of waterborne illnesses, may temporarily make the beach unsuitable for swimming and be considered, even provisionally, as an indicator in beaches environmental quality assessments.

That was the case with the ecological tragedy that happened in Brazil in 2019, when large amounts of dense crude oil washed the beaches of Brazil's tropical coast. The disaster affected more than 980 beaches in nine Northeastern states and two Southeastern states, spanning along more than 3000 kilometers of the Brazilian coastline, from Maranhão to Rio de Janeiro. The oil was even observed along the Amazon coast. Experts stated that this oil spill is "the most extensive and severe environmental disaster ever recorded in Brazilian history, in the South Atlantic basin, and in tropical coastal regions worldwide."[174]

The source of the oil was investigated by the Brazilian Navy and other governmental authorities, but no answer was found. The oil could have originated from illegal oil dumping (intentional discharge); an accidental release from a vessel navigating offshore; leakage from a wreck, either old or new; or an extraction platform. Nevertheless, "[t]he

173. *Id*. (italics original).

174. Soares et al., *supra* note 169, at 103879-80.

procedure to the identification of the oil origin is unclear and few details have been publicized."[175]

A group of Brazilian scientists said that, "[t]he management of this disaster is more challenging than that of a typical oil spill because the dense crude oil is not observed on the ocean surface; it only appears when it washes up in coastal zones such as sandy beaches and intertidal reefs."[176] "Moreover[,] . . . the spread of the oil reached a continental scale along the Brazilian coastline.[177]

175. *Id*. at 103880.
176. *Id*.
177. *Id*.

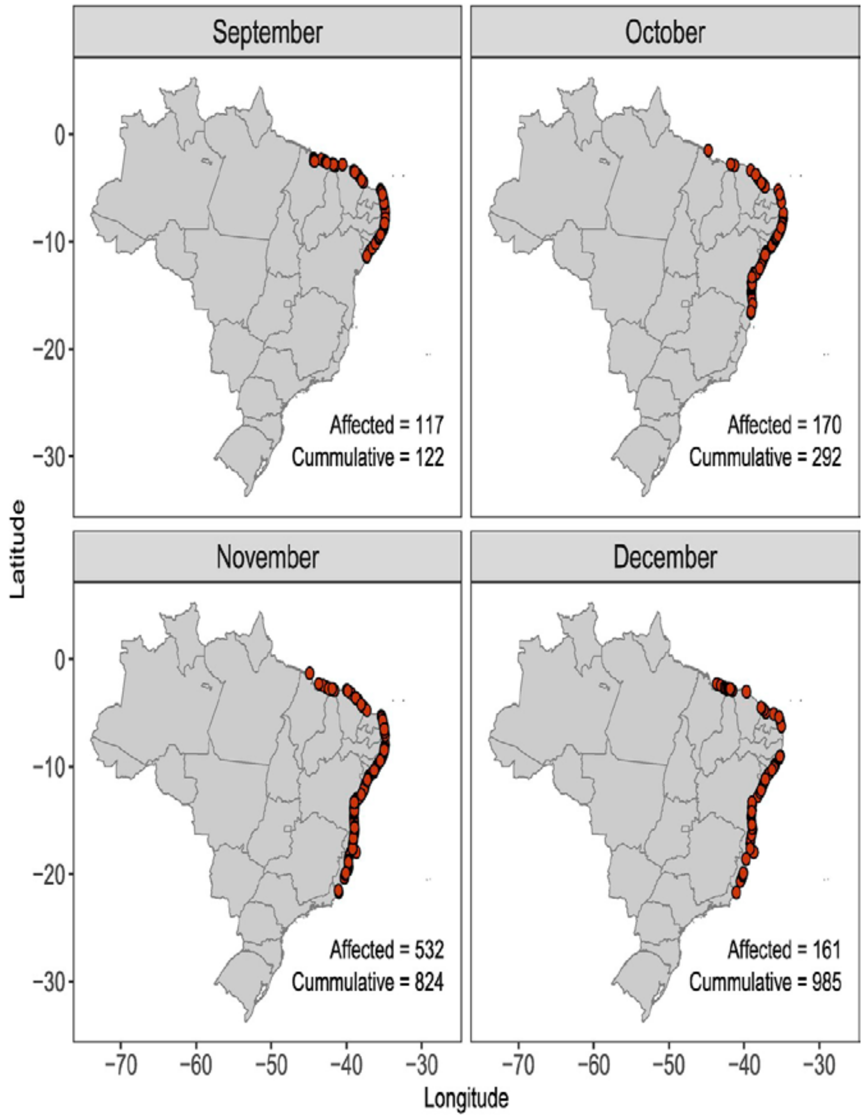


*Figure 7: Most extensive oil spill disaster ever recorded in the South Atlantic (Brazil). Temporal evolution of the impacted sites between September, October, November, and December (2019). Retrieved from* https://www.researchgate.net/publication/339212504_Oil_spill_in_South_Atlantic_Brazil_Environmental_and_governmental_disaster.

The total consequences of this massive crude oil spill is still unknown, but scientists attested that the spill has "certainly damaged the structure and function of tropical marine ecosystems, having toxic effects on the organisms therein."[178] The oil spill affected more than fifty-five of Marine Protected Areas ("MPAs") (part of the National System of Nature Conservation Units, Federal Law 9985/2000), which are uniquely important to the health of the coastal environment.[179] MPAs contribute to the maintenance of the many marine ecosystem goods and services (e.g., "food provision; biodiversity maintenance; nutrient cycling; reproduction and nursery areas; and leisure, recreation, and cultural inspiration").[180]

The social and economic costs are innumerable, but the effects on tourism, fishing, and extraction activities in traditional and artisanal communities are undoubted ("[i]nitial estimates indicate that [more than] 159,000 fishers distributed along the Northeast coast have been affected").[181] Additionally, this oil spill, like any chemical contaminant waste in the marine environment, "has repercussions for public health owing to the contamination of water, sediments, and seafood, and it may have long-term negative effects on the food security of vulnerable communities in northeastern Brazil."[182] Moreover, the ecological, social, and economic impacts may have been amplified by governmental inertia and considerable budget cuts for public policies.[183]

According to specialists, this oil spill disaster is unique because:

> [(]1) the characteristics of the oil spill; [(]2) the characteristics of the affected region in tropical Brazil; [(]3) the significant number of protected areas (>55) and tropical ecosystems affected by the oil; and [(]4) the absence of measures and/or flaws in the measures taken by the federal government to address this environmental and social emergency.[184]

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178. Soares et al., *supra* note 169, at 103879.
179. Robert Costanza et al., *Changes in the Global Value of Ecosystem Services*, 26 GLOBAL ENVTL. CHANGE 152, 156 (2014).
180. Soares et al., *supra* note 169, at 103880.
181. *Id*.
182. *Id*. at 103881.
183. *Id*. at 103882.
184. *Id*. at 103881.

Specialists also highlight the importance and urgent need for "conducting research on chemical contaminants and their ecotoxicological effects at different biological levels of organization, e.g., species, community, and ecosystem levels."[185] This emphasis resonates very much in regards to the plastic phenomenon in the ocean.

In fact, it is quite significant how closely this oil spill catastrophe mirrors the wide range environmental side effects of marine plastic pollution and specially microplastics. Even though the oil spill is a single and extraordinary event, while the microplastics phenomenon is ongoing, their negative impacts will both probably be experienced for a long time. In addition, both have sources that are difficult or impossible to determine. Also, both types of pollution have unsettling magnitudes of ecotoxicological effects, which means they might reach different levels of biological organization, and may cause indefinite and widespread long-term repercussions.

In response to the oil spill disaster and in recognition of the possible health risks for human contact with the oil existing in sandy beaches, the State of Ceará (Northeast Brazil) decided to expand its current legal parameters currently used to assess bathing waters to include the identification of hydrocarbons in seawater and beach sand.[186] The weekly "balneability bulletin," provided by the Superintendência Estadual do Meio Ambiente, which was traditionally limited to a microbiological exam, was amplified to include a new physical-chemical parameter that can identify the occurrence of hydrocarbons (a substance that is indicative of the presence oil traces in the sea water, fishing, or catching shellfish and crustaceans).[187]

The expansion of the "balneability" indicators to incorporate a new beach quality parameter based on a physical-chemical aspect indicate that, in some circumstances, it may be necessary to question the classification of a recreational water environment and maybe include other indicators when needed. Thus, where there is reason to believe that the existing guidelines no longer complies with changed reality, it

185. *Id*. at 103884.

186. Semace ampliará boletim de balneabilidade, SEMACE: SUPERINTENDÊNCIA ESTADUAL DO MEIO AMBIENTE (Dec. 12, 2019, 12:57 PM), https://www.semace.ce.gov.br/2019/11/12/semace-ampliara-boletim-de-balneabilidade/.

187. *Id*.

maybe the time to re-evaluate the traditional set of parameters and rethink what kind of environmental quality assessment is needed.

The improvement of standards due to this resolution demonstrates that it is also possible to question the adequacy of such a system to the current reality of high rates of plastics and microplastics contamination in oceans and Brazilian beaches.

Brazil's recycling rate is less than four percent.[188] This rate is no surprise when taking in to account that Brazil has a long history of inadequate solid waste management and serious failures in sewage treatment networks.[189]

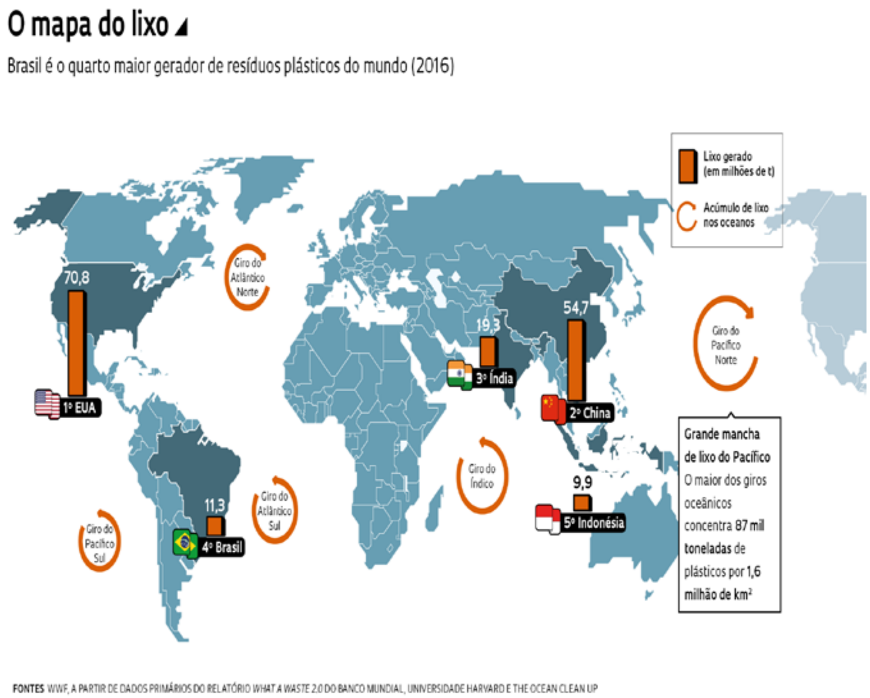


*Figure 8: the plastic waste map. Retrieved from https://www.comprasustentavel.com.br/lixo-plastico.html.*

For instance, about 90% of Brazil's coastal population lives in cities, where 45% of the population still does not have access to

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188. *Maioria das cidades brasileiras mantém depósitos de lixo sem tratamento*, GLOBO (Feb. 8, 2018, 9:10 PM), https://g1.globo.com/jornal-nacional/noticia/2018/08/02/maioria-das-cidades-brasileiras-mantem-depositos-de-lixo-sem-tratamento.ghtml.

189. Ferronato & Torretta, *supra* note 170, at 1075.

adequate sewage service.[190] Only 43% of the Brazilian citizens are served by a waste collective system (collection network and sewage treatment plant); 12%, by septic tank (individual solution); 18% have their sewage collected, but not treated; and 27% do not have any waste assistance at all.[191]

When it comes to plastic pollution, Brazil, much like all coastal countries, is adversely affected. Marine debris investigations in South America have occurred since the 1970s,[192] the same decade the first evidence of microplastics fragments in the environment was reported.[193]

Over the last few years, microplastic studies in the world increase every year, especially in regards to Brazil. In a recent literature review, scientists collected data on microplastic pollution in Brazilian aquatic ecosystems and found that the Brazilian Northeast and Southeast were the most studied areas and the investigation of microplastics were mostly associated with biota (46% of studies), with only one study conducted in a freshwater environment.[194] The review highlighted that few places were monitored and that "[d]etermining the trends and abundances at local level in different environmental scenarios and regions of Brazil is fundamental in the search for mitigating measures. . . ."[195]

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190. Andrea Verdélio, *No Brasil, 45% da população ainda não têm acesso a serviço adequado de esgoto*, AGÊNCIA BRASIL (Sept. 25, 2017, 5:45 AM), https://agenciabrasil.ebc.com.br/geral/noticia/2017-09/no-brasil-45-da-populacao-ainda-nao-tem-acesso-servico-adequado-de-esgoto.

191. *Id*.

192. *See generally* Juliana Assunção Ivar do Sul & Monica F. Costa, *Marine Debris Review for Latin America and the Wider Caribbean Region: From the 1970s Until Now, and Where Do We Go from Here?*, 54 MARINE POLLUTION BULL. 1087 (2007).

193. Edward J. Carpenter & K.L. Smith Jr., *Plastics on the Sargasso Sea Surface*, SCI., Mar. 17, 1972, at 1240.

194. Rebeca Oliveira Castro, Melanie Lopes da Silva & Fábio Vieira de Araújo, *Review on Microplastic Studies in Brazilian Aquatic Ecosystems*, 165 OCEAN & COASTAL MGMT. 385, 386–87 (2018).

195. *Id*. at 397.

The records demonstrate the presence of microplastic along the Brazilian Atlantic coast and several impacts to marine biota.[196] Marine mammals, seabirds, turtles, and benthic invertebrates can be severely impacted by marine debris via entanglement and/or ingestion. Along the Brazilian coast, several turtle species were found with plastic debris in their gastrointestinal tracts, even in the most important sea turtle nesting beaches in Brazil (Costa dos Coqueiros, Bahia State).[197]

A recent study showed that Brazilian estuarine fauna is exposed to chronic plastic pollution.[198] Three catfish species were investigated in a tropical estuary of the Brazilian Northeast after their accidental ingestion of plastic marine debris.[199] It was discovered that all three species had ingested plastics.[200]

Another study evaluated the contamination by microplastics in mussels cultivated in Jurujuba Cove, Niterói, Rio de Janiero.[201] The results showed a high concentration of microplastics in both rain and dry seasons with diversity of colors, types and sizes.[202] The scientists suggested that the presence of microplastics was probably due to a high and constant load of effluent that this area receives as well as mussel farming in the area, which uses many plastic materials.[203]

The only freshwater Brazilian study concerning microplastics pollution discovered that a common freshwater fish heavily consumed by humans in semi-arid regions of South America have been massively contaminated. The study showed "that 83% of the fish had plastic debris inside the gut, the highest frequency reported for a fish species so

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196. *See* Juliana Assunção Ivar do Sul et al., *Plastic Pollution at a Sea Turtle Conservation Area in NE Brazil: Contrasting Developed and Undeveloped Beaches*, 34 ESTUARIES & COASTS 814 (2011).

197. *Id*.

198. *See generally* Fernanda E. Possatto et al., *Plastic Debris Ingestion by Marine Catfish: An Unexpected Fisheries Impact*, 62 MARINE POLLUTION BULL. 1098 (2011) http://www.sciencedirect.com/science/article/pii/S0025326X11000567 (last visited May 10, 2020).

199. *Id*. at 1099.

200. *Id*. at 1098.

201. *See generally* Rebeca Oliveira Castro et al., *Evaluation of Microplastics in Jurujuba Cove, Niterói, RJ, Brazil, an Area of Mussels Farming*, 110 MARINE POLLUTION BULL. 555 (2016).

202. *Id*.

203. *Id*.

far."[204] This study also observed that fish at the urbanized sections of the river consumed more microplastics, "and that the ingestion of microplastics was negatively correlated with the diversity of other food items in the gut of individual fish."[205]

The results of this study suggest that urbanization is a major factor contributing to the pollution of freshwater environments by microplastics. These results show that further research is needed to evaluate the risk posed to humans by the consumption of freshwater fish that have ingested microplastics.[206]

Despite the suggestion that urbanized areas are more susceptible to microplastic pollution, areas far from urbanization are also not exempt from microplastic presence. An analysis of the sediments of the beaches of Fernando de Noronha emphasized that despite being isolated, the archipelago is not free of plastic pollution.[207]

Microplastic has even reached the remote and uninhabited island of Atol das Rocas, an important Brazilian Biological Reserve, which "is on the route of tourist ships, sailboats, fishing boats and ships merchants."[208] The research reported that "the manufactured items were transported by ocean, mainly by the South Equatorial Current," and that the origin of the products could come both from vessels, and from the archipelago of Fernando de Noronha, which is affected by the same ocean current.[209]

The research indicates that the presence of microplastics in Brazilian waters poses a risk to biodiversity and human health. Considering that urbanization is one of the main factors related to microplastics pollution in freshwater environments,[210] and contamination of the coastlines by sewage of both domestic and

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204. *See* Jacqueline Santos Silva-Cavalcanti et al., *Microplastics Ingestion by a Common Tropical Freshwater Fishing Resource*, 221 ENVTL. POLLUTION 218 (2017).

205. *Id*.

206. *Id*.

207. *See generally* Marcelo de Oliveira Soares et al., *Atol das Rocas (Atlântico Sul Equatorial): Um caso de Lixo Marinho em Áreas Remotas*, 11 REVISTA DA GESTÃO COSTEIRA INTEGRADA 149 (2011).

208. *Id*. at 151.

209. *Id*.

210. Jacqueline Santos Silva-Cavalcanti et al., *Microplastics Ingestion by a Common Tropical Freshwater Fishing Resource*, 221 ENVTL. POLLUTION 218, 224 (2017).

industrial origin is a major public health and economic concern in Brazil, and, finally, taking into account that current standard for measuring water quality in the coastal area of Brazil excludes other harmful pollutants (hydrocarbons), it is suggested that microplastics surveys should complement "balneability" parameters and be considered a determining factor when assessing beaches environmental quality in Brazil.

## V. UPGRADING BEACH QUALITY ASSESSMENT: USING MICROPLASTIC AS AN INDICATOR FOR SEA WATER QUALITY IN BRAZILIAN BEACHES

The contamination of Brazilian water environments by microplastic is gradually being revealed by increasingly reliable data that has proved the far-reaching impacts of microplastics. A recent study showed an increase in Brazilian publications on microplastics in 2015, which may reflect the increase in publications on microplastics from 2013 in the global scale.[211]

The microplastic phenomenon, however, is still largely overlooked by public policies and unreported in the Brazilian coast, with few studies evaluating the presence and effects of microplastics. Additionally, despite the increase in publications about microplastics in 2015 and 2016, a rapid decrease in the number of publications was observed in 2017, probably an aftermath of the Brazilian political and economic crisis that was intensified by large, successive budget cuts in science since that year.[212]

To better understand this microplastic phenomenon, estimate the contamination level, and discern and identify microplastic sources, more quantitative data on the abundance of microplastics in the Brazilian environment is needed. "Determining the trends and abundances at local level in different environmental scenarios and regions of Brazil is fundamental" to stimulate mitigation measures.[213]

One important issue regarding sampling and collecting data on microplastic presence is disagreement over the definition and

211. Luís Gabriel Antão Barboza & Barbara Carolina Garcia Gimenez, *Microplastics in the Marine Environment: Current Trends and Future Perspectives*, 97 MARINE POLLUTION BULL. 5, 6 (2015).

212. Castro et al., *supra* note 201, at 386.

213. *Id*. at 397.

categorization of plastic materials.[214] In fact, different definitions for plastic exist and are accepted in their respective fields. Some definitions are used by industry while others are used by branches of science, such as chemistry and marine sciences. These definitions can be slightly divergent, but they all share the central idea that plastic is a solid matter material made of polymers that can be shaped.[215]

Regarding the definition, scientists disagree about which materials should be included in the term "plastic" and under what criteria this definition should be constructed.[216] For instance, some studies consider regenerated cellulose as plastic, while others point out that the opposite can be argued.[217] In the standard developed by the International Standardization Organization, rubber is not considered plastic, although several research point out the waste of rubber tires as an important component of microplastic pollution, constituting a stealthy source of plastic pollution in the environment.[218]

There are also disagreements regarding the criteria for categorizing plastic. A commonly used categorization system is one that divides plastic based on particle size, using the prefixes mega, macro, meso, micro, and nano. But there is also no consensus on this classification. The point of departure for the definition is the broad understanding in environmental science about the general properties of microplastics: microplastics are synthetic materials, and consist of solid particles that are smaller than five millimeters.[219] Additionally, microplastics are insoluble in water and not degradable. [220]

The inquiries that surround the microplastic definition encompass concerns over its chemical composition (e.g., should elastomers

214. Nanna B. Hartmann et al., *Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris*, 53 ENVTL. SCI. TECH. 1039, 1042 (2019).

215. ANJA VERSCHOOR, NAT'L INST. FOR PUB. HEALTH, TOWARDS A DEFINITION OF MICROPLASTICS: CONSIDERATIONS FOR THE SPECIFICATION OF PHYSICO-CHEMICAL PROPERTIES (RIVM LETTER REPORT 2015-0116) 13 (2015).

216. Hartmann et al., *supra* note 214, at 1042.

217. *Id*. at 1040.

218. Pieter Jan Kole et al., *Wear and Tear of Tyres: A Stealthy Source of Microplastics in the Environment*, 14 INT'L J. ENVTL. RES. & PUB. HEALTH 1265, 1283 (2017).

219. VERSCHOOR, *supra* note 215, at 11.

220. *Id*.

(rubber) and organic-inorganic hybrid polymers (for example silicone) be considered as potential source of microplastics?); concerns over its solid state (e.g., should semi-solids be considered as microplastics? Or are melting point and vapor pressure suitable parameters to define the solid state of plastics, or should other visco-elastic properties be considered?); concerns over its size (e.g., is there a need for a lower size boundary? Or is there a need for a seamless connection with nano-materials definition? Or is it opportune to harmonize the size limits with analytical equipment and detection limits?); and, finally, concerns about its persistence (e.g., is adoption of REACH criteria for persistence feasible? Or which tests can be done to study the degradability of microplastics?[221]).

Whether through an argument of necessity or convenience, it is clear that the adoption of a concept provides legal certainty and allows for more consistent monitoring of trends in microplastic pollution and a more transparent assessment of the effects of political measures. The construction of these definitions can be considered a prerequisite to ensure the adequacy of socio-economic assessments and applications of mitigation measures.[222]

It is also understood that standardizing of measurement methods is an important step in making research results more reliable and would make it easier to compare the results of different studies carried out in Brazil and in the world. Standardization should be done in an "efficient and simplified way that allows the study and the monitoring in places with different financial resources, structure[,] and access to the materials."[223] This would allow countries like Brazil, which often lack laboratory supplies and commonly struggle with budget constraints, to conduct scientific research.

Therefore, now that there is a pressing need for more robust, quantitative information about the quantity, frequency of occurrence, type, and size of microplastics in Brazilian environments, the presence of microplastic as a "balneability" should be used as an indicator.

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221. *See, e.g.*, EUROPEAN CHEMICALS AGENCY, GUIDANCE ON INFORMATION REQUIREMENTS AND CHEMICAL SAFETY ASSESSMENT, PART C: PBT/VPBT ASSESSMENT 15-17 (2017) (discussing REACH criteria for persistence, bioaccumulation, and toxicity in marine environment and estuaries).

222. VERSCHOOR, *supra* note 215, at 11.

223. Castro et al., *supra* note 201, at 397.

This way, more data could help determine the consequences of microplastic pollution to wildlife and human health, and ultimately, the ecosystem. Thus, establishing a frequent program researching microplastic occurrence in beach waters and sands could serve as a database for the competent bodies to act and take preventive measures. It could also raise public awareness and encourage citizens and tourists to adopt more sustainable behaviors.

Additionally, the vast and diffuse effects of the many compounds of beach pollution, that have been neglected in regular bulletins for Brazilian beaches, have to be publicly acknowledged, as the restricted comprehension of a beach environment can be highly dangerous to humans, because the value of a beach goes far beyond its recreational function.

Moreover, better evaluations on the quality of beaches must go beyond the certification that their waters are suitable for bathing. Further, the importance of quality must be promoted and the gap between the reduced recreational approach and ecological necessities of beaches must be properly addressed.

Conclusion

Beach environments are essential, multidimensional, and dynamic systems of unique social, ecological, and economic importance. They provide important social spaces for cultural connections and recreation.

Unfortunately, the quality of world's beaches has been threatened by marine pollution—mostly composed of plastic debris, especially microplastics. This transnational phenomenon negatively impacts the marine ecosystem and has severe adverse effects on human health.

The vast and diffuse effects of beach pollution have been neglected in regular bulletins for Brazilian beaches. Moreover, the microplastic phenomenon has been overlooked and unreported in Brazilian coast.

As demonstrated above, when it comes to the quality assessment of Brazilian beaches, human well-being has been valued more than broader ecological, environmental, economic, and social scopes of beaches. And even with regard human well-being, evaluation of beaches has been restricted to health issues linked to bacterial contamination. This narrow view disregards other relevant health issues, like side effects from chemical contact or even mental health issues triggered from general pollution.

The emphasis on microbiological aspects in assessing beach quality, including the WHO guideline for recreational waters, demonstrates how important bathing indicators are for public health. Yet, this perspective turns a blind eye toward the ecological level. It overlooks the fact that such indicators can point to environmental imbalances that can have a great public cost (social, economic, and environmental), and that negative effects can be previously identified with a smarter use of "balneability" parameters.

This was the concern behind the expansion of the "balneability" indicators in the State of Ceará in response to the oil spill disaster to prevent the health risks for beach users. The need to question the current classifications arose because of the change in the circumstances of the recreational water environment. The "balneability bulletin" then incorporated a new beach quality parameter based on a physical-chemical exam aiming to identify hydrocarbons in sea water and sand.

This paradigm shift suggests that existing standards must improve to respond to contemporary issues that no longer can be ignored. The microplastic phenomenon worldwide is indicative that the traditional set of parameters for beach environmental quality need to be revised to go beyond evaluating the recreational aspects. A more comprehensive approach needs to be promoted to account for the environmental quality of beaches.

Studies must consider not only the presence of fecal coliforms, but the broad spectrum of human activities that impact its ecosystem, plastics included. Microplastic pollution is widespread in marine ecosystems. This major threat to biodiversity and human health poses many risks, including a potential food security problem.

Thus, it is highly recommended that the framework of beach quality indicators of Brazilian beaches be expanded to include the presence of microplastics as an important factor in the examining the environmental quality. The expanded criteria will help collect more data to determine the consequences of microplastic pollution to wildlife and human health, and ultimately, the ecosystem. Also, establishing a frequent program of microplastic occurrence in beach waters and sands could serve as a database for competent bodies to take preventive measures, raise public awareness, and encourage individuals to adopt more sustainable behaviors.

There are limitations in the lack of consensus on the definition and categorization of both plastics and microplastics, limitations regarding the risks associated with human health, food security and ecosystems. There are also difficulties in implementation due to budget constraints.

Despite the uncertainties over the effects of plastic pollution, there is enough evidence for public policy makers and the general community to recognize the hazards of microplastic pollution and take a precautionary and/or anti-catastrophe approach.