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Communication

Garbage Patches and Their Environmental Implications in a Plastisphere

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Abstract: This Communication reports on the increases in the sizes of garbage patches, and their environmental implications, outlining the dimensions of what is a growing problem connected with the "plastisphere". The paper presents some data on the distribution of garbage patches in the world's oceans and makes some predictions on future growth, which is partly associated with the future increases in worldwide plastics production. The findings demonstrate that the size of the main garbage patches is increasing, posing a threat to the environment and marine life. The paper urges for better plastic waste management to prevent it from reaching the oceans, along with concerted actions in respect of plastic collection and cleaning up the oceans, which may include new technological solutions.

Keywords: garbage patches; ocean pollution; gyres; plastic waste

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1. Introduction

Garbage patches refer to large areas in the ocean where garbage and debris accumulate. These patches are formed by gyres, ocean currents that help in the circulation of ocean waters around the planet. Apart from circulating ocean waters, they also transport marine debris, especially solid waste from coastal areas [1].

There are six main influential gyres, namely, the North Atlantic Gyre, the South Atlantic Gyre, the East Pacific Gyre, the North Pacific Gyre, the South Pacific Gyre, and the Indian Ocean Gyre. Garbage patches exist inside these gyres [2]. Due to the scope of the problem, they are herewith introduced.

These six gyres have a significant impact on the ocean. The big six help drive the so-called oceanic conveyor belt that helps circulate ocean waters around the globe. Apart from circulating ocean waters, they're also drawing in the pollution that we release in coastal areas, known as marine debris.

Figure 1 provides a schematic overview of the gyres in the world.

The world´s largest garbage patch is the Great Pacific garbage patch which is located in the North Pacific gyre. The estimated area of the patch is 1.6 million km^2. This is roughly three times the size of France [3,4]. Currently, an estimated 80,000 tons of debris make up the large mass [4], which is equivalent to 50 kg/km^2 or 50 mg/m^2. Studies have indicated that more than 75% of the garbage found in the area was of debris greater than 5 cm in size. Furthermore, at least 46% of garbage was found to be from fishing nets and gear. Additionally, microplastics accounted for a substantial portion of the total plastic-related garbage. The pollution in the area appears to be increasing at a faster rate than in surrounding sites [3].

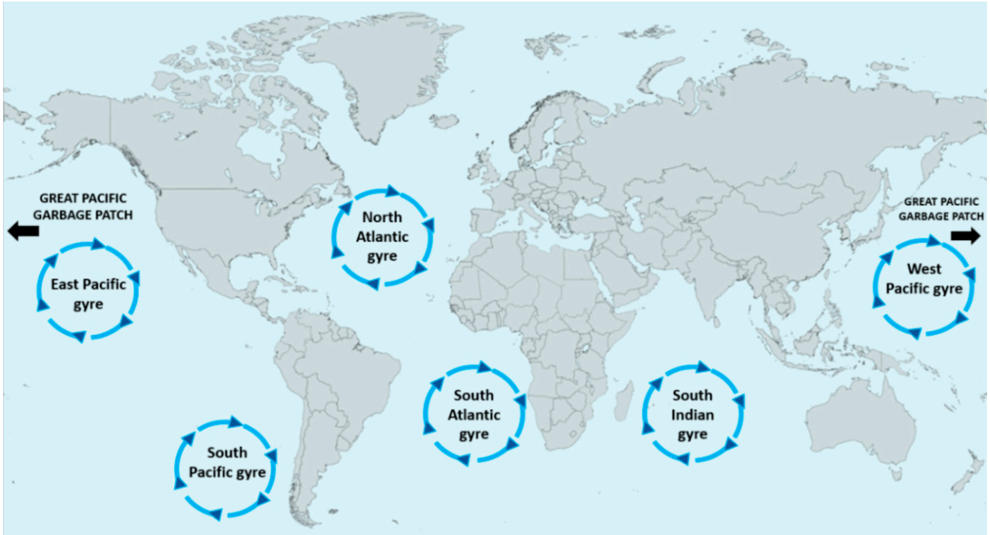

Figure 1. Schematic overview of the main gyres.

The South Pacific garbage patch located in the South Pacific gyres is estimated to cover around 2.6 million km^2 [5]. The debris is concentrated toward the center of the gyre rather than the edges. Furthermore, due to the increased fishing activity in the area, the debris had a large amount of fishing lines and nets. Since these materials have broken down into smaller fractions, the trash is predominantly made of microplastics [5].

The Indian Ocean garbage patch is located within the Indian Ocean gyre. Currently, the patch is estimated to extend between 2.1 to 5.0 million km^2 [6]. The gyre passes the southern tip of Africa. Therefore, plastics and debris accumulating there are carried by currents into the South Atlantic Ocean. The brief accumulation near the coast of South Africa, before it is transported by the currents, threatens the local marine life. It has been reported that the patch contributes greatly to the death of sea turtles, evidenced by many of them washing up on shore with plastic in their stomachs and intestines. Due to counter current flow of water and the constant movement of trash, scientists describe that garbage patch as a disappearing area [7], being at least one not very likely to increase in its size, according to computer models.

The North Atlantic garbage patch, which hosts the largest patch in the region, located at the North Atlantic gyre, was first discovered in 1976. The exact size remains unknown. However, there are estimates that it spans over hundreds of kilometers. There is limited information about this particular patch in comparison to the more famous North Pacific garbage patch. However, there are estimates that suggest that roughly 200,000 pieces of debris are found per square kilometer [8].

The South Atlantic Plastic gyre hosts the smallest of the five garbage patches. The size is approximately 0.7 million km^2 [6]. Recent studies suggest that bottles originating from Asia are the biggest source of debris located in this area. More specifically, bottles stranded from Asia on the inhabitable Tristan da Cunha archipelago are considered to be the main feeder to the garbage patch. This is mainly attributed to ships dumping such bottles in the ocean [9].

The central parts of the garbage patches are characterized by a higher density, having most of the weight, when compared with the boundaries, which are less dense. Attempts to quantify the mass of the patches thus tend to focus on the central parts.

It should be stated that it is rather complex to define the size of the garbage patches exactly since the trash constantly changes its position due to ocean currents and winds. Since spring 2020, a new element has been added to the debris: used face masks.

Figure 2 describes some of the components of garbage patches.

Figure 2. Overview of some of the components of garbage patches.

This is a review study, which attempts to provide an overview of the trends related to marine plastic pollution, taking into account the paucity of precise data related to increases in the sizes of the gyres.

2. Trends from the Literature

This paper uses a review of the literature and a description of the environmental impacts of plastics on the marine environment. As far as the literature on garbage patches is concerned, it is rather limited when compared with the overall literature on waste. This is because research and practical projects on oceans are logistically more difficult to perform than works on land. Moreover, it is noticeable that the literature on the management of garbage patches is even more limited. Table 1 offers an overview of the literature on some of the garbage patches in the period 2010–2020.

Table 1. Overview of the literature on the different garbage patches.

Name of Patch	Title of Article	Scope	Reference
North Pacific Garbage Patch	The Dirt on Ocean Garbage Patches	Provides an early overview of the Great Pacific Garbage patch and its contents.	[10]
	Reduce the Plastic Debris: A Model Research on the Great Pacific Ocean Garbage Patch	Assessment of plastic debris in the patch and designing of models that may help reduce the plastic content in the future.	[11]
	Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic	Summarizes the latest evidence of plastic constituents found in the patch.	[3]
	First evidence of plastic fallout from the North Pacific Garbage Patch	Details the correlation between plastic fallout at sea level and at the deeper levels.	[12]
North Atlantic Garbage Patch	Plastic Accumulation in the North Atlantic Sub-tropical Gyre	Provides early evidence of the plastic found in the North Atlantic gyre and the accumulation associated with the garbage patch.	[13]
	The vertical distribution of buoyant plastics at sea: an observational study in the North Atlantic Gyre	Provides information about the distribution of microplastics in the water column of the ocean.	[14]
	Plastics in the North Atlantic garbage patch: A boat-microbe for hitchhikers and plastic degraders	Summarizes the micro-organisms found on the surface of the patch.	[15]
	Transition paths of marine debris and the stability of the garbage patches	Assesses possible pathways of marine debris that lead to different gyres, including the North Atlantic gyre.	[16]

Table 1. *Cont.*

Name of Patch	Title of Article	Scope	Reference
South Pacific Garbage Patch	Origin, dynamics, and evolution of ocean garbage patches from observed surface drifters	Describes changes associated with the size of different garbage patches, including the South Pacific patch.	[17]
	Plastic pollution in the South Pacific subtropical gyre	Details the average abundance and mass of plastic particles found in the patch.	[18]
	Expedition finds South Pacific plastic patch bigger than India	Details the size and constituents of the patch following an assessment study.	[5]
	Double trouble in the South Pacific subtropical gyre: Increased plasticingestion by fish in the oceanic accumulation zone	The study found significant increases in plastic ingestion by fish in the area, which is harmful to consumers.	[19]
South Atlantic Garbage Patch	The Garbage Patch in The Oceans: The Problem and Possible Solutions	Provides an overview of the patch, including surface area and density of particles.	[20]
	Litter survey detects the South Atlantic 'garbage patch'	A study discovered the litter constituents of the patch, as well as how far it extends.	[21]
	Marine debris in Trindade Island, a remote island of the South Atlantic	Evidence shows that the pollution found within the gyre and patch negatively affects the flora and fauna of the island located on the edge of the gyre.	[22]
	Rapid increase in Asian bottles in the South Atlantic Ocean indicates major debris inputs from ships	The study found that bottle pollution from ships contributes greatly to the increased size of the patch.	[9]
Indian Ocean Garbage Patch	Origin, dynamics, and evolution of ocean garbage patches from observed surface drifters	Describes changes associated with the size of the South Indian garbage patch and other evolutions.	[17]
	Role of Indian Ocean Dynamics on Accumulation of Buoyant Debris	Assesses the factors that influence accumulation at the garbage patch, including different currents.	[23]
	The transport and fate of marine plastics in South Africa and adjacent oceans	Details South Africa's contribution to waste in the Indian ocean that may potentially feed the gyre and patch.	[24]
	Plastics in the Indian Ocean: Sources, fate, distribution and impacts	Describes the outcomes for plastics in the Indian ocean, including feeding the gyre and leakage to other gyres.	[25]

There is a noticeable need for more literature on aspects related to microplastics, which make up for a substantial part of the garbage patches. The wide presence of plastics in the aquatic environment has led to the coining of the term "plastisphere", a term used to assess the influences of plastic and microplastics on microbes [26], also meaning that a novel type of substrate for river and marine micro-organisms is evolving [27].

3. The Environmental Problems Caused by Garbage Patches

Apart from posing a threat to shipping and potential damage to vessels, there are various environmental problems associated with garbage patches, as summarized in Table 2.

The environmental problems are complemented by the challenges garbage patches pose to tourism since a considerable portion of the debris reach beaches and make them less attractive to tourists. Moreover, there are some potential health problems associated with garbage patches. There is, for instance, a potential risk related to the consumption of seafood with microplastics to human health and air contamination by microplastics spread through the air from sea debris [1].

In terms of future trends, the increases seen in global plastic production, which totalize in 2019 around 368 million metric tons worldwide [28], are a reason for concern. The global cumulative production of plastic is expected to reach 34 billion metric tons by 2050 [29], meaning that garbage patches are expected to grow in the future. Table 3 provides an estimate of their growth at the annual growth rate of 2.5% based on current trends.

Table 2. Some of the environmental problems posed by garbage patches.

Problem	Potential Impacts
Entanglement of marine life	Marine life is caught and trapped in the debris, especially larger species
Ghost fishing	Fishing through lost nets that are not recovered
Ingestion of debris	Plastic and other debris mistakenly eaten by bird/fish as food
Transport of foreign species	Ocean currents transport plant/animal species from one area to the other, away from their natural habitat, with the risk of invasive ones
Water contamination	Ocean currents may transport chemicals deriving from the decomposition of debris, which may impact sea fauna/flora

Table 3. Estimates of the growth of garbage patches *.

	2013	2023	2063
North Pacific Ocean	964.0	1234.0	3313.4
North Atlantic Ocean	564.7	722.9	1941.0
Indian Ocean	591.3	756.9	2032.4
South Atlantic Ocean	127.8	163.6	439.3
South Pacific Ocean	210.2	269.1	722.5

* g $\times$ 10^2 tones, annual growth rate of 2.5%. Source: Authors' estimations based on [30].

An increase of 2.5% is presented as a conservative estimate based on previous trends. Increases in marine plastic pollution are higher in Asia than in North America, but the problem is cumulative and current growths in plastic production and consumption suggest the sizes of the gyres may increase and not decrease.

This trend suggests that immediate action is needed, to reduce the flow of debris to the world´s oceans.

4. Conclusions

The garbage patches represent a major environmental problem, with wide-ranging implications not only to the marine fauna and flora, but also to the physical environment.

It is therefore important that concerted action is undertaken so as to address the problem in respect of collecting them and clean up the oceans. This entails, in turn, better management of land-based solid waste as a whole, and plastic waste in particular, so that they do not reach the oceans in the first place. Moreover, the test and deployment of new technologies to collect and process marine plastic, especially microplastics, is needed, a task which needs to mobilize substantial amounts of money to cover the associated costs.

A further reason for concern is the fact that, whereas EU countries have imposed bans on some types of plastic products, most countries in Asia, Latin America, and Africa have no such restrictions in place. This trend suggests that, apart from technological solutions, clear policies to regulate plastic production and consumption are needed so that the world is better able to cope with what is, without doubt, a growing problem.

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