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Study on the environmental impacts of ocean garbage patches and possible solutions

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ABSTRACT

Over the past two decades, unprecedented issues in the oceans, floating garbage patches, have been discovered. There are majorly 5 massive garbage patches floating on the ocean surface, including the biggest Pacific Patch, between Hawaii and California. The garbage patch is an accumulation of trash disposal by industrial production that mainly consists of oil-based plastic. In a recent study from nature.com, it was known that 79,000 tons of plastic are floating in an area spanning 1.6 million square kilometers. The ocean garbage patches can linger on the ocean surface for centuries, posing potential threats to the surrounding environment. Multiple organizations like the Sea Educations Association have carried research in this field by sending ships in the patch, which lay nets, tow and collect the garbage for analysis. This technique has numerous disadvantages as the patch is too large to be monitored by a group of boats. Airplanes can be used to map the patch; however floating plastic can change its position, and thus a piece of more dynamic and real-time equipment is needed for assistance in clean-up. Satellite monitoring proposes another challenge, as a lot of observers have claimed that patches are not visible on satellite imaging (1). Another challenge is the type of plastic. Currently, 65-70% of the dump is mega plastic (>40cm). As plastic is buoyant, it usually is found above 40 m of depth. On exposure of sunlight and SONAR waves, this can turn to micro-plastic, which will be difficult to monitor and clean. Thus, effective cleaning needs to be carried out immediately (2). In this report, I review the impact of the garbage patch on the climate and the environment and aim to investigate and provide suggestions on methods to monitor such patches.

Keywords*— Ocean garbage patch, Micro-plastic, Environment, Ocean surface, Pollution*

1. IMPACT ON THE ENVIRONMENT

1.1 Impact on Natural Processes

Plastics, in particular, can be very harmful to the near-surface marine ecosystem. They might choke the animals: Reports conclude that around one million seabirds and 100,000 marine mammals are killed every year due to plastic ingestion. What's more, the low rate of degradation of plastics allows them to gradually enter the food chain, contaminating the fish with toxins, causing harms to the larger mammals, even humans ourselves. Toxins in plastics are directly linked to cancers, birth defects, immune system problems, and childhood developmental issues in humans; numerous marine species are already on the edge of extinction due to ocean garbage patches. Moreover, when sea expeditions are used to monitor the garbage, the aquatic organisms which are trapped in the nets are dispatched later into non-native waters, and end up being dislocated. Plastics also don't allow the ocean water to properly carry out their work in the natural cycles in the long run, and in turn, disturbs the balance of elements in the environment.

Further impacts of ocean garbage patches include hindering ocean's capacity to act as a carbon sink. This brings one specific species into the picture -- lantern fish, tiny, bioluminescent fish living hundreds of meters beneath the ocean's surface. They are a few inches long but account for over half of the ocean's total fish mass, and are vital to the ocean's ability to store more carbon than do all of the forests on land through a mass migration process than occur in all of the seven seas. Lanternfish ascends nears the ocean surface at night to eat planktons. Planktons use photosynthesis to sequester carbon dioxide, a mechanism that's believed to be responsible for the removal of about half of CO2 produced by the burning of fossil fuels. After lanternfish gorge on those carbon-rich planktons, they descend back down where they deposit their carbon-rich poop. This dynamic allows more carbon to be sequestered by the near-surface planktons, and so on. Lanternfish also help to sequester carbon when eaten by larger fish. This migratory ritual is central to the efficacy of marine environments in reducing human-caused CO2 emissions in the atmosphere by an estimated 20%-35%. However, lanternfish are being harmed by ocean plastic ingestion because floating plastics resemble their plankton diet. This could potentially add to the climate change crisis. (3).

1.2 Impact on aquatic life

As seaborne plastics mainly circulate around the Pacific, Indian, and Atlantic gyres, they indirectly affect marine wildlife. Wildlife is injured due to entanglement or ingestion of the plastics. Specifically, the article examines three impacted species: autopsies show that ingested plastic and tar are the primary culprits of stress and non-natural death for sea turtles; plastic has also been found to block the passage of female eggs; studies show that cetaceans will sink to the bottom of the ocean if plastics continue to cause unnatural deaths; and plastic swallowed by birds, and passed on to their offspring, can damage their digestive systems.

Fig. 1: Pacific garbage patch

In addition, plastic is increasingly becoming an active medium for invasive species. The hard surfaces of plastics are now found to be alternative materials for invasive species -- like mollusks, barnacles, and algae -- to attach. Additional major garbage patches other than the Great Pacific Patch-- the South Pacific Subtropical Gyre, the North and South Atlantic Subtropical Gyre, and the Indian Ocean Subtropical Gyre -- were discovered by scientists that contain just as much plastic. Over the decades, as the economic development advanced, the rate of waste disposal into the ocean increased, and the problem became unprecedentedly severe. Currently, around 12.7 million tons of plastic waste is washed into the ocean every year. The United Nations Environment Programme estimates there could be as many as 51 trillion micro-plastic particles in the oceans already. (4)

Fig. 2: NOAA's Office of response and restoration

2. MONITORING SYSTEMS

2.1 Current system

The garbage patch monitoring programs have basically used evidence gathered by sailors, or surveys conducted by airplanes. So far, Ekam pumping in subtropical gyres governs the formation of the patches. However, this theory doesn't predict the timescales of patch formation from debris entering at coastal margins or how eddy mixing can counteract the accumulation of debris. "Knowing how fast coastal debris reaches the different garbage patches, as well as how leaky these patches are in time, can help inform monitoring efforts for the coming decades." (Erik Van Sebille, Matthew H England and Gary Froyland) (5)

2.2 A new approach

In order to monitor the patch, a method that takes into account the dynamic nature of the plastic position in the ocean needs to be considered. The Ocean Clean Up Foundation conducted surveys using trawls and aerial imagery. The aerial imagery used RGB cameras which produced geo-referenced mosaics every second. These plains took data from a height of approximately 400 m and also monitored the wind speed and surface temperature variations. These were run through computer simulations and a mathematical model was created by combining the readings of the aerial imagery and surface trawl observations.

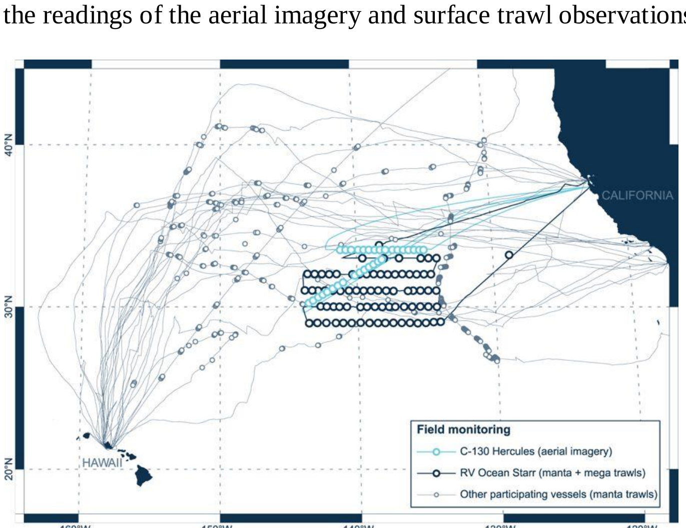

Fig. 3: Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic

2.3 The mathematical model

The organization modeled the movement of particles and micro plastics by taking a number of affecting factors into consideration: sea surface currents, Stokes drift, and wind speed. Stokes drift here would assume plastic particles as almost spheres in the massive ocean (infinite compared to the size of the plastic particles). Assuming vortices and nets form tube-like structures for these to flow, we can apply $F = 6\pi\mu rv$ where F is the force driving a particle in an infinitely long tube (hypothetical in this case) of radius r, v is the velocity of the fluid and μ is its viscosity.

The organization started from identical particle releases and eventually added combinations of interactions of particles of different shapes and sizes. They also considered atmospheric drag. As they'd taken into consideration the wind speed, the drag coefficient could be calculated. Thus, the effect of atmospheric drag: Fdrag = cv^2 where c is the coefficient of inertial atmospheric drag (calculated by taking into account wind speed, direction, and size of the interacting particle) and v is the speed with which the particle was drifting with respect to the surface.

Once they created a model based on many physical factors including the ones mentioned above, they collected data on windage coefficients and ocean currents over the past two decades. They calculated wave-induced Stokes drift amplitude for different combinations. They formulated the following model (6):

Divide the screen into n cells so that the weight of material s in the total area is αs and the percentage of that particle is δi,s. So, concentration in cell I would be:

$$\delta_i = \sum_s \alpha_s \delta_{i,s}$$

2.4 Monitoring using Global Drifters Program

Using a well-developed system of the Global Drifters Program, which tracks activities in the ocean using satellite controlled buoys, can be more efficient. This method was recently used for monitoring in some unprecedented models, and not only did it improve the mapping in the five already reported patches by incorporating the garbage flowing towards it from the coast, but it also predicted a sixth developing patch in the Barents Sea. (7)

This method suggests dividing the surface of the Earth into a grid and then summing the probabilities of the movements in the ocean debris, as determined by buoys, which are floating objects connected to satellites that were originally used to monitor salinity of oceans and help direct boats. They have been deployed since the 1980s, and have an organized network (app. 85 % of the ocean surface is known to have coverage).

The method works in the following steps. Plastics and other floating debris are carried by winds and currents and then stay at confined regions. The method includes observation of the buoy sensors (both with and without drifters) that are capable to measure data including the sea surface temperature over a window and transmit the sensor data to Polar Orbiting Environmental Satellites that obtain a global coverage. Tracer accumulation will be observed after releasing the surface drifters to detect the direction of marine debris in the open ocean. A probability of movements in the grids would be created, and the probability equation would be used to sum and find the movement of garbage.

A recent execution of this method has shown some significant results and predictions over the next few years which can be useful. For instance, it shows that the garbage patch in the Southern Indian Ocean will eventually merge with the one in the Atlantic, and a new patch will develop in the Barents Sea. (8)

3. CONCLUSION

One of the most efficient ways to clean the ocean garbage patches is to replace oil-based plastics with a biodegradable plastic that can be broken down by microorganisms. The exact type of bioplastic on what we are focusing on is PLA (polylactic acid) which is made from starch (mostly corn), cassava or sugarcane. This is the best option since it is both carbon-neutral and edible, and it has no effect on marine life. (9)

Other suggested solutions have included cleaning up ocean shores. However, we see that these practices have been carried out since the 1980s, and the majority of the accumulation has happened over the past two decades. So, while it is a good practice to clean the shores, it doesn't really help in preventing the formation of these patches.

For proper monitoring and modeling of ocean debris, we suggest taking readings at buoys through satellites and then using probability theory for figuring out the current impacted region and the regions with the risk of developing new patches. In the areas where debris is present, we suggest trawls be used to physically examine the properties of the debris. Then, aerial imaging can be used with RGB cameras and SWIR imagers to figure what kind of garbage is present and where. Appropriate arrangements can then be made to clear plastic or non-plastic debris, either on the surface or below it. (10)(11)

The currently proposed methods to clean the oceans includes huge floating nets held in place by giant tubes. These would sweep the ocean, like a rope sweeps the cricket field, and transfer the waste to nearby ships, which would visit every six to eight weeks. The nets have been designed such that the fish can escape through them. This idea has been proposed by the Dutch scientist Boyan Slat, who raised $2.2 million for this project through crowd funding. We suggest using ocean currents to control the flow of these tubes and nets so that there is a minimization of fossil fuel usage. (12)

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