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Recycling Marine Plastic into Clothing Apparel via Global Collaborations

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Abstract: ***According to the United Nations, aquatic pollution affects at least 800 species worldwide, with plastic responsible for up to 80% of the waste. Every minute, up to 13 million metric tonnes of plastic is expected to end up in the ocean, the equivalent of a trash or garbage truck load. Plastic is a design failure; it was never intended to end up in animals' stomachs or at the bottom of the food chain in humans. The fashion industry is a massive contributor to the plastic waste found in the oceans and so it becomes necessary for corporations to take sustainable steps in the direction of reducing Ocean Plastic Pollution. One of the ways to do so would be by recycling ocean plastic into clothes. Our study focuses on analysing global collaborations and suggesting a series of steps for recycling ocean plastic.***
Keywords: Marine Plastic, Recycling, Supply Chain, Plastic Pollution, Polymers

I. INTRODUCTION

Over the past decade, researchers have found evidence to suggest that the plastic material, decomposing in and near oceans, has found its way into marine food chains and has been destroying marine ecosystems at an alarming rate.

The U.S. National Oceanic and Atmospheric Administration (NOAA) sponsored the first global conference on “micro-plastics”, where the attendee countries decided to establish that the fragments of plastic smaller 5 mm would be referred to as micro-plastics. Joel Baker, the organizer of the conference, stated that sources of such small fragments were cosmetic products, body washes and also the eroding of larger plastic debris that are floating in our oceans presently. As these plastic objects are broken down by the elements of nature, the toxic additives, which might have been fed in the production process, are released into the ocean environment. They even harbour persistent organic pollutant such as PCBs and it has been noted that micro plastic particles show million times higher concentration of PCBs than the water surrounding it [1].

According to the United Nations, marine debris affects at least 800 species globally, with plastic accounting for up to 80% of this waste. A report on Primary micro plastics in Ocean stated that currently 300 million tons of plastic are being manufactured annually, and this quantity has increased considerably since 1950, where contrastingly only 1.5 million tons were produced [2]- which is a concerning sign, as plastic is a design failure. Approximately 5.25 trillion plastic particles, weighing over 268,000 tons, float in the five largest convergence zones called gyres. Marine species become entangled or ingest ocean plastic and this causes severe injuries and deaths. The plastic can be degraded in the environment by four mechanisms: photo-degradation, thermo-oxidative degradation, hydrolytic degradation, and biodegradation by microorganisms [3]. Due to ingestion of the decomposed fine particles, plastic becomes a part of our food cycle, threatening food safety and quality. An investigative study published in 2016 by authors Kosuke Tanaka and Hideshige Takada, detected micro-plastics in digestive tracks of 49 out of the 64 Japanese Anchovy (*Engraulis japonicus*) that were sampled. 2.3 pieces were found on an average with the maximum number ranging to 15 pieces per individual (Tanaka K., Takada H., 2016). Majorly polyethylene (52%) or polypropylene (43.3%) were found. 80% of the plastic found were in the size range of 150µm to 1000µm, which is smaller than the estimated size of floating micro-plastics in sea. This could be explained by the subsurface foraging behavior of anchovies. Simply put, their observations confirmed the speculation that micro-plastics have pervaded the marine ecosystem and various food chains. And as we’ve learned already, micro-plastics retain dangerous chemicals and therefore the discovery of their presence in food chains, is a cause of major concern. It is also important to note that lost and discarded gillnets act as silent killers and wreck devastation on fragile marine ecosystems, as they result in over 100,000 ocean mammal deaths every year. A different report noted that the cost of pollution caused by marine debris is somewhere around $13billion [4]

A. World Scenario

Plastic is used in almost every aspect of our life, from supermarket bags and utensils to water bottles and sandwich wraps. However, our search for convenience has gone too far, and we are wasting vital resources and damaging the environment by failing to use plastics efficiently.

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Marine litter is any persistent solid material that has been made or processed and is disposed of or abandoned into the marine environment, whether purposely or unintentionally. To put it another way, it is human-made waste that's dumped into the ocean from land or sea. Seventy-five per cent of plastic garbage that ends up as marine litter is an uncollected waste.

Meanwhile, less than 10 per cent of American plastic waste is recycled, and the U.S. has a 30-year history of shipping half of its recyclable plastic overseas, primarily to China and other developing nations lacking the infrastructure to manage it. That practice was drastically reduced only when China stopped buying plastic scrap in 2018 as a green campaign to clean up its environment. Global trash generation would grow by 70% by 2050, from 2.01 billion tonnes today to 3.4 billion tonnes in 2050. Each year, Australians use 130kg of plastic per person. Only about 12% of that is recycled. Worryingly, up to 130,000 tonnes of plastic will find its way into our waterways and the ocean. According to the report, while China is the world's most significant producer of plastic, the United States is by far the world's largest generator of plastic garbage, producing over 42 million metric tonnes (46 million U.S. tonnes) in 2016. The United States also ranks third among coastal nations regarding litter, illegally deposited rubbish, and other mismanaged waste on its shorelines. Southeast Asia has emerged as a plastic pollution hotspot due to fast urbanization and a growing middle class, which is increasing its consumption of plastic products and packaging due to their convenience and versatility. However, local trash management infrastructure has not kept up, resulting in massive amounts of mismanaged waste. COVID-19 has aggravated the situation by increasing the consumption of masks, sanitizing bottles, and online delivery packaging. When single-use plastic is thrown rather than recovered and recycled, more than 75% of the material value of recyclable plastic is lost in Thailand, the Philippines, and Malaysia, amounting to $6 billion per year. With only 18 to 28 per cent of recyclable plastic collected and recycled in many nations, the majority of plastic packaging trash not only pollutes the environment by polluting beaches and roadsides but its economic worth is also lost. Sub-Saharan Africa and South Asia will grow the fastest, accounting for 35% of worldwide trash generation. The People's Republic of China (China), Indonesia, the Philippines, Thailand, and Vietnam account for more than half of the plastic trash input into the ocean. According to statistical estimates, China not only generates the most plastic (almost 60 million tonnes), but it is also the primary source of worldwide plastic leakage, i.e., plastics that are not adequately handled leak into the environment. According to a recent study, ten rivers account for 88 to 95 per cent of the global load of river-origin unmanaged plastic. Eight of the top ten polluting rivers are in Asia, with the Yellow and Yangtze rivers being the most polluting. Clean-up of beaches and waterways, street sweeping, installation of storm-water capture devices, cleaning and maintenance of storm drains, manual litter clean up, and public anti-littering campaigns to clean up and prevent marine litter cost communities along the West Coast of the United States more than $500 million per year.

1) *Marine Litter's Two Main Sources*

a) Land-based Sources Rivers and other bodies of water are major entry sites for land-based garbage into the marine environment. Littering, dumping, and poor waste management methods are the primary causes of marine litter from land-based sources.

b) Sources from the sea Shipping vessels, ferries and cruise liners, fishing vessels, private vessels, and other industry infrastructure contribute to marine litter from sea-based sources such as cargo, solid waste, and fishing gear. The most common cause of sea-based marine litter is abandoned, lost, or otherwise discarded fishing gear, which can be the most devastating from both an economic and environmental standpoint. Discarding fishing gear causes marine creatures to become entangled, coral reefs and other vital habitats to suffocate, and navigational dangers to safety at sea. Plastic pollution is the most prevalent issue damaging the marine environment. It also endangers the health of the oceans, food safety and quality, human health, coastal tourism, and contributes to climate change.

2) *Effects on the Maritime Environment:* Ingestion, suffocation, and entanglement of hundreds of marine species are marine plastics' most apparent and unpleasant effects. Plastic garbage is mistaken for prey by marine species such as seabirds, whales, fish, and turtles, and the majority of them die of famine as their stomachs fill with plastic debris. They also have lacerations, infections, impaired swimming capacity, and internal damage. Floating plastics also aid in the spread of invasive marine species and germs, causing ecosystem disruption.

3) *Food and Health Ramifications:* Invisible plastic has been found in tap water, beer, and salt and all samples taken from the world's oceans, even the Arctic. Several chemicals used in the manufacture of plastic products are carcinogenic and disrupt the body's endocrine system, producing developmental, reproductive, neurological, and immunological issues in both humans and wildlife. Toxic pollutants can also build up on the surface of plastic products after prolonged exposure to seawater. When marine creatures consume plastic garbage, the toxins enter their digestive systems and build in the food chain over time. The transfer of pollutants between marine organisms and people via seafood eating has been identified as a health risk but has not been thoroughly investigated.

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4) *Climate Change Impact:* Plastic, which is derived from petroleum, also contributes to global warming. When plastic garbage is burned, it emits carbon dioxide into the atmosphere, increasing carbon emissions.
5) *Tourism Effects:* Plastic trash degrades the visual value of tourist attractions, resulting in lower tourism-related income and significant economic expenditures associated with site cleaning and upkeep. Plastic, which is derived from petroleum, also contributes to global warming. When plastic garbage is burned, it emits carbon dioxide into the atmosphere, increasing carbon emissions.

B. Indian Scenario

1) *Aquatic Animals:* In India, marine fishes along the southwest and southeast coasts of almost all the states show signs of plastic ingestion. On analyzing the gut content of commercially important fishes from the beaches of the southeast coast of India, it was revealed that microplastics ingestion was found in 10.1% of the fishes.
2) *Beaches/Sediments:* Researchers have found a significant amount of microplastics on the beaches from different coastal areas in India. In March 2015, right before the Chennai flood and in November 2015, right after it, the microplastic pellets in the surface sediments along the Chennai coast were examined for the source of origin, surface features, distribution, polymer composition and age. Elements of nature such as the wind and surface currents were credited for transporting and depositing these pellets from the sea to the beaches. A similar pattern was observed for the beaches in Goa as well.
3) *Salt:* India is considered a leading producer and exporter of sea salts. Most people consume food products containing commercial salt all their lives. Numerous studies are revealing the presence of microplastics in salts. As per the World Health Organisation (2012) guidelines, a salt intake of up to 5gm salt per day for adults is recommended. An IIT-B study on different brands of Indian sea salts found the presence of the microplastic particles in all the studied eight brands, and the types of M.P.s present were found to be independent of the salt brand and packaging type. The maximum microplastic ingestion for Indians from microplastic contaminated salts was close to 117 micrograms every year. Salt consumption can be considered long-term exposure to the human population and is a primary reason we must deal with the plastic waste in the ocean before they break down into non-retrievable microplastics.
4) *Freshwater, Surface water, Groundwater, Drinking water, Ballast Water:* Vast data exists in the literature on marine microplastics, while concise reports on other water sources. Microplastics were found in the sediments of Vembanad Lake, Kerala and the sediments of river Ganga. The microplastics found in the sediments of river Ganga revealed a strong correlation between microplastics abundance and pollution traits. The sediment samples from different sea beaches revealed different reasons like wind, surface current, fishing, religious activities, recreational activities etc.

II. UNDERSTANDING PLASTIC

A. Polymers

Polymers are materials made of repeating units called monomers. They can be classified based on whether the polymerization can be reversed or not. Thermosetting plastics become infusible once set and it is hard to recycle them. On the other hand, thermoplastics undergo single stage polymerization and only form linear chains- this allows recycling and reprocessing.

B. Thermoplastic Polyurethane (TPU)

TPU is a thermoplastic elastomer which is a linear block made up of soft and hard segments. The hard segment can either be an aromatic compound or an aliphatic compound based on the qualities required in the end product. For instance, aromatic hard segments are usually used, but if the product's primary requirement is a specific colour and clarity retention in sunlight, then aliphatic hard segments are preferred. Aromatic TPU has isocyanates such as Methylene diphenyl diisocyanate (MDI), while aliphatic TPU has hydrogenated MDI. These isocyanates, when combined with short-chain diols, result in hard blockchains. The soft segment is usually either polyether-type or polyester-type and is chosen based on the requirement as well. For example, polyether-based TPU has its application in wet environments. Polyester based TPU, on the other hand, is used when oil/hydrocarbon resistance is a priority. Different combinations of hard and soft segments give the properties offered by TPU a wide range. The unique structure contributes to high resilience, resistance to abrasions, impact, and the weather. It offers flexibility without the use of plasticizers.

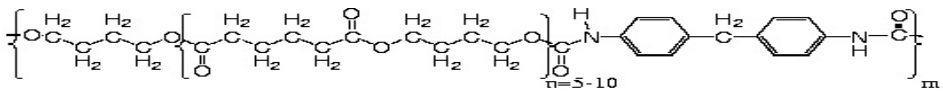


Fig. 1. Structure of TPU

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A study conducted on the recycling of TPU reveals that on constant reprocessing (recycling), the degradation of the complex and soft segments takes place at different rates and is mass-dependent. The remarkable conclusion from this study was that performance of a fabric produced from TPU that has been recycled eight times was similar to that produced from TPU that has only been recycled once. [16]

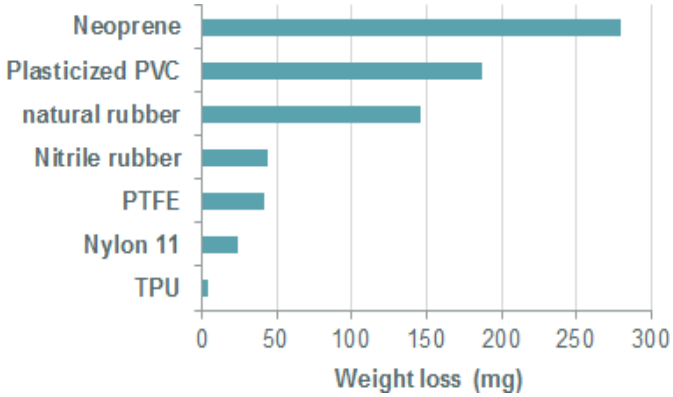


Fig. 2. Test Results for [16]

To establish a basic understanding of the other plastic waste materials found on the coastline, we shall also look at plastic bottles and the polymers used in manufacturing them. The number mentioned within the recycling symbol is called the SPI code and is used to distinguish the different plastics.

1) PET- Polyethylene Terephthalate

Plastic bottles made of this polymer are used as water/beverage bottles.

a) A thermoplastic polymer whose opacity can be tweaked according to its material composition.
b) It is produced from petroleum hydrocarbons via a reaction between ethylene glycol and terephthalic acid.
c) PET waste, aka "post-consumer PET", is sorted based on opacity or colour or origin (the corporation within which it was produced- in case it needs to be sent back to the manufacturers for recycling), following which it is sent to material recovering facilities.
d) The accumulated waste is then cleaned via hot and cold washing and subsequently through acidic water to ensure no dirt gets left behind before recycling.
e) The waste undergoes treatment- i.e. crushing the bottles into small PET flakes. These are then used as raw materials for a variety of different recycled products.

2) P.E.- Polyethylene: High-density polyethene is used to make detergent bottles, while low-density polyethene is used to make squeeze bottles (ketchup bottles)

a) It consists of a single monomer, ethylene and is therefore classified as a homopolymer.
b) LDPE is amorphous, which explains its ductility, while HDPE is crystalline, accounting for its higher rigidity.
c) Because of its internal structure, HDPE is more robust than PET and can be recycled/reused safely.
d) Therefore, LDPE has the simplest structure and is easy to produce into plastic bags but not as easy to recycle.

3) V/PVC- Polyvinyl Chloride

a) One of the oldest plastics
b) Initially is very rigid but becomes flexible on the addition of plasticizers.
c) PVC plastic contains harmful chemicals and is therefore not used in storing edible substances.
d) They are mainly recycled into flooring or panelling.

4) P.P.- Polypropylene

a) It is sturdy and can stand high temperatures.
b) Used to make Tupperware, car parts, thermal vests, etc.
c) It gets recycled to produce heavy-duty items

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5) *P.S.- Polystyrene*

Also known as Styrofoam

a) Used in making disposable cups and dinnerware, packing materials, etc.

b) Similar to P.P., it is hard to recycle even though some recycling plants may accept it

6) *Misc. Plastics:* These plastics are used everywhere but are considered unsafe because of the toxic chemical called bisphenol A or BPA. They are hard to recycle as they do not break down easily.

III. CASE STUDIES

As a part of reviewing existing technology, we examined different instances of recycling and reusing marine plastic in fashion products. Our first case study focused on the collaboration between Adidas and Parley.

A. Adidas x Parley

1) *Studying the Process of Production of the Ultraboost:* Parley claims that it uses plastic from 11 recycled water bottles for every pair of shoes it produces. These water bottles are mainly collected in coastal areas such as the Maldives and then shipped to Taiwan to be processed into textile fibres. Far Eastern New Century (FENC) Corp is the name of the supplier of Parley and Adidas in Taiwan. FENC not only has a fibre bottle recycling rate of about 95%, which is the highest in the world, but is also a leader in textile dyes. Bottles dumped in the ocean are being made into high-quality shoes thanks to the joint efforts of Adidas, Parley, and FENC. According to Parley, the target of one million pairs of shoes was met, which means that in 2017, Adidas and Parley recovered and recycled eleven million water bottles. Upon obtaining by FENC, these water bottles are transformed into textile fibres used in Ultraboosts, such as recycled polyester and polystyrene, and, perhaps most importantly, thermoplastic polyurethane. Unlike conventional plastic textiles, made from petroleum and are therefore not environmentally friendly, the polyester used in the Adidas X Parley Ultraboosts is recycled. Plastic water bottles, also known as "PET bottles", are used instead of petroleum as a raw material. These 'PET' bottles are mainly collected from the oceans. PET bottles are sterilized before being compressed and crushed into tiny plastic chips, which is how recycled polyester is made. These chips are then heated and spun into long strands of yarn using a spinneret. The yarn is then woven into spools and crimped to give it a woolly texture before being dyed and knitted into the fabric used to manufacture shoes. The upper part, which covers the top of one's foot, is recycled polyester in the Ultraboost. The rigid insert that extends under the wearer's heel is called a heel counter, and according to an Adidas supplier called "Framas", it is composed of 50% recycled polystyrene from food packaging. They produce 110 million heel counters annually and prevent 1,500 tons of waste from ending up in landfills. On the other hand, traditional counters are usually made of new materials (unprocessed materials), such as thermoplastic rubber and polystyrene. The environmental benefits of recycled marine plastics outweigh the benefits of using virgin materials, but the concern of durability remains. A study conducted in 2004 by Kobe University in Japan found that recycled polyester fibres are more prone to fatigue than new fabrics. However, the analysis ignores the advantages of recycled materials and the growing urgency to combat plastic pollution, rapidly degrading our oceans. The ocean and our atmosphere benefit tremendously from using these resources, but they can also benefit us, the consumers. Thermoplastic polyurethane is perhaps the most significant recycled plastic material in the Ultraboost, and as we have studied before, it has various benefits. Due to its high energy absorption and lightness, the Ultraboost outsole uses bead foaming technology, utilizing recycled TPU. The same recycled plastic is used in the other parts of the shoe, and the technology is named "Infinergy" after its inventor, a German sports goods manufacturer. There are many advantages to using thermoplastic polyurethane; this material is solid and can withstand all temperatures, but the main advantage is the relatively low density of the bead foam while simultaneously having a very flexible texture. In the initial step in the high-tech thermoplastic polyurethane manufacturing process, a mixture of polymer and gas must be produced. Following this, the nucleation of cells occurs, and the nuclei that are produced work as centres of growth for the cell [24]. The cells continue to grow until they reach the desired size. The cells are stabilized by a sharp drop in temperature and prevent further expansion. Each bead is expanded by using a blowing agent. These particles are expanded in the mould and stick together to achieve the desired shape, bypassing the mould through hot steam. Made from recycled water bottles, these TPU soles are not only heat-resistant, lightweight, flexible and energy-absorbing, but also fully biodegradable. By adding a digestive enzyme called protease, the sole can be decomposed entirely in 36 hours. There is much scope for more research in this direction. TPU is also used in Adidas' recent prototype called Futurecraft Bio fabric. With the TPU outsole, this fabric can be used in new

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Adidas shoes to make them more environmentally friendly. To shield the energy-absorbing ocean plastics, the TPU outsole is made of beads and encased in rubber. Continental, an Adidas affiliate and manufacturer, deal with the production of rubber. Continental creates a high-quality encasing for the outsole for the Ultraboost. Even though they make both natural and synthetic rubbers (both of which use crude oil as a primary raw material), the rubber used in the outsole of Ultraboosts is 100% natural and is called "Stretchweb." Natural rubber is derived from rubber trees and is environmentally friendly. Synthetic rubbers take a long time to degrade and often end up in landfills. Continental does this by using environmentally friendly fabrics to create a high-grip, high-energy-absorbing outsole. A TPU "Torsion device bar" is also found on the Ultraboost's outsole. This technology is designed to relieve pressure on the middle of the foot by allowing the heel and forefoot to travel independently. Finally, the most remarkable about the Adidas x Parley Ultraboosts is that these recycled materials were used without compromising the product's consistency. The industry-leading 'BOOST' technology is an example of this as the outsole is made of recycled thermoplastic urethane, which is biodegradable and has a natural rubber grip. The shoe upper is recycled polyester, and the heel counter is made of recycled ocean plastic. The use of both of these products together leads to the creation of a more environmentally friendly shoe. Adidas and Parley are making a difference in sneaker sustainability and recycled plastic use by using these approaches. Not only that, but they have also designed and manufactured one of the most technologically advanced and environmentally friendly sneakers available.

2) *Supply Chain Analysis:* Although this project has successfully converted plastic ocean waste into fully functional shoes over the years, it is essential to question whether the emissions from the production process counter the apparent environmental benefits. Adidas claims to have prevented 2,810 tons of plastic from reaching the oceans. Moreover, each item in the Parley collection is made from at least 75% intercepted marine trash. It is important to note that production using recycled polyester yarn has more benefits than using virgin materials, as recycled polyester uses fewer chemicals and raw materials while also helping in reducing plastic pollution. These benefits are not apparent but play a vital role in making the process of production greener. FENC, the Taiwan based corporation, was revealed to face two significant problems during the initial stages of production. First, the contamination of PET bottles collected from the oceans was quite different from the domestic waste they were earlier used to dealing with. They were equipped with an entire supply chain ranging from recycling to spinning fibres to weaving fabrics, but ocean waste was something they had never treated prior to this collaboration. Under different circumstances, contaminated waste from the ocean would have been classified as second-grade raw material. However, this was eventually overcome to some extent, and accommodations were made within the supply chain to account for processing cleaner raw waste materials- and although it is not quite up to the level of a typically recycled PET bottle- it is still a considerable feat. Another implication of ocean contamination meant the up-cycled fabric could only be dyed in a limited range of colours. The second major problem was the transportation of ocean waste from beaches in the Maldives to the processing unit in Taiwan. Prior to this, there was no proper recovery system in the Maldives. Usually, the collector would be expected to condense PET into bricks and efficiently transport over 20 tons of waste, but only eight tons were received on the arrival of the first shipment. This situation arose because the Maldives had never treated PET bottles from the ocean before, and a subsidiary of FENC, called Oriental Resources Development Limited, had to step in. They managed to set up recovery stations in twelve islands near the Maldives, which helped reduce transport and production costs, and treatment in Taiwan became much more accessible. As one can infer from the previously stated instances, the primary reason for hindrances in production was the lack of proper infrastructure required to convert plastic waste from the oceans. Both were technical issues that arose from the fact that recycling marine trash had never been done before. Once an efficient setup is built, CO2 emissions would not be a significant concern. Moreover, via this project, Adidas and Parley have managed to create and update the world's first supply chain for up-cycled marine waste, which is constantly under a green microscope, i.e. focuses on sustainable fashion and industry choices. The outcome of this project was not just the shoe but an entire ideology that is expected to shape sustainability in fashion for the better. As the supply chain continues to develop and production accelerates, there will be less virgin plastic demand, reduced CO2 emissions and increased awareness of the issue. They have also expanded their collection network to places other than the Maldives like the Dominican Republic and Sri Lanka, thereby preventing increased plastic pollution in the Indian Ocean and the Caribbean Sea. The rapid production increase, i.e. 1 million pairs in 2017, 5 million pairs in 2018, 11 million pairs in 2019, and the planned estimate of 15 million pairs in 2020, can only indicate that this has been a very successful project and can be implemented on an even larger scale, by the development of green supply chains all around the world.

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B. The Ocean Cleanup Sunglasses

1) *Introduction:* In his independently published book, Boyan Slat talked about the feasibility of 'The Ocean Cleanup Array, a unique method to collect copious amounts of plastic debris from the famous accumulation region called the Great Pacific Garbage Patch (GPGC). He founded a non-profit organization called "The Ocean Cleanup" in 2013, which currently implements his ideology and collects mismanaged plastic waste from the GPGC, also known as the Pacific trash vortex, located in the central North Pacific Ocean. The first actual implementation, after years of modelling and research, was carried out in 2018. This system provided much insight but could not effectively catch plastic and had to return to the shore prematurely because of structural failure. Utilizing previous research and analyzing the inadequacies in System 001, a new cleanup system was developed called System 001/B. It was launched, and collected plastic which was then brought to the shore, and the project went into its valorization stage: the recycling phase. A significant aim has always been to convert the collected plastic into a durable product and fund further expeditions by selling the product above. Moreover, the plastic debris collected in 2019 from System 001/B, which included a large volume of fishing nets, was pooled to the shores of Vancouver and then later transported to Rotterdam in the Netherlands for the process of recycling. The contents were sorted, cleaned and then shredded into shards. These were then further processed to form small pellets, which were used to make the final product.

2) *Process of Plastic Collection:* The garbage patch is present in an ever-revolving vortex which causes shifting regions of high concentration of plastic. Using a computational model, the project predicts the position of these hotspots and a cleanup system is positioned accordingly. The basic ideology behind the retention of plastic is creating a false shoreline(a sort of physical barrier) upon which plastic washes upon. A relative speed difference is maintained between the plastic and cleanup system. The wingspan of the system, speed and direction are monitored according to the requirement and are sustained by the deployed vessels. The plastic debris then washes up on the false "shoreline" called the retention zone. Once the system is filled, the back of the retention zone is pulled back up on board. It is sealed, detached from the system, and the contents are emptied on the ship/vessel. The retention zone is then put back in the ocean, and the process of cleaning up continues. As the containers on the ship get filled, they are brought back to the shore for processing and converting into products.

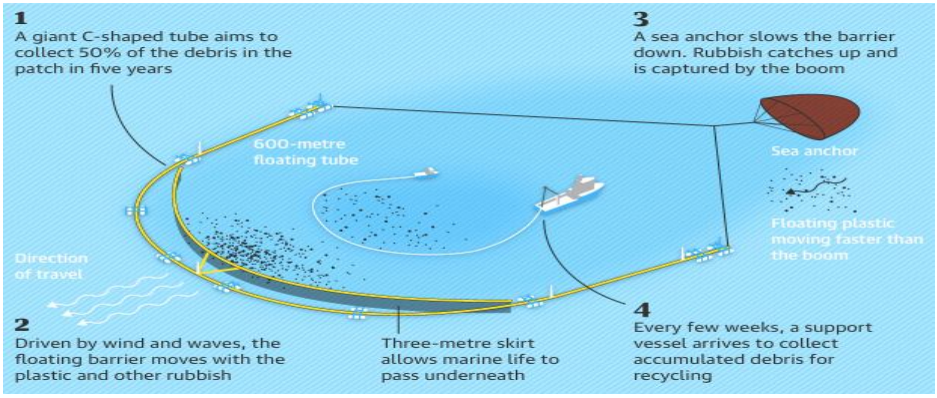


Fig. 3. Ocean Cleanup System Design from [18]

3) *The Making of the Sunglasses:* The CEO and Founder of The Ocean Cleanup stated that their product out of the collected plastic was designed in California by Yves Behar. It was produced in Italy by a company called Safilo and sold for USD 199; all proceeds go to fund the operation of the plastic collection even further.

C. Other Notable Endeavours

G-Star RAW, Parley for the Oceans, Bionic Yarn and Pharrell Williams resulted in denim and apparel made of recycled ocean plastic. The first collection contained 33% recycled plastic, but as it serves to be a long term collaboration, the main goal would be to include more and more recycled plastic. The first line used 10 tons of recycled ocean plastic and was available in stores on September 1, 2014. The company has since moved on and made other more sustainable strides. An athleisure brand called the Girlfriend Collective has been putting out leggings made from recycled plastic bottles, 25 to be precise. They have also launched a collection made from recycled fishing nets, contributing to corporations utilizing recycled ocean plastic. Another attempt to deal with ocean pollution was made by the U.K. based company called GANT. They started the "Beacons Project", which had them team up with Mediterranean fishermen. The plastic caught by these fishermen while fishing was collected to upcycle into button-down shirts.

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IV. OUR LEARNINGS

Studying various global collaborations helped us analyze their supply chains and the problems some faced while dealing with ocean plastic. The solid conclusion drawn from our analysis seems to be that such a setup is possible when companies and the government consciously choose to put in the effort needed. The initial efforts should be implementing a plastic collection drive that is not a one-time expedition but a more regulated and periodically carried out task. If the supply chain has to be set up within the Indian Subcontinent and the target location for marine plastic sourcing is the Indian Ocean Garbage Patch, then the first step would be to monitor where the debris hotspots are. The Sea Education Association (SEA) has been researching garbage patches for 25 years. Mathematical and Physical models of these garbage patches can be drawn up to estimate the hotspot's location. Using one such model, called the Maximenko model, a paper estimated that the amount of plastic debris in the Indian Ocean was equal to 2185 tons[17]. Once a high concentration spot is found, a system, such as the one suggested in the Ocean Cleanup project, can be set up. This would ease out the plastic collection process, and we would not have to depend on manual labour. We could even implement the ideology used in the Gant project and collect all the plastic caught in the fishing nets of the fishermen in India instead of having them throw it back in the waterways. After the collection step, we would have to focus on transporting plastic waste to the processing plant in the most effective way, one with the most diminutive carbon footprint. We could take inspiration from the Adidas x Parley collaboration and set up plants near the ocean, where the plastic collected can be compressed into blocks and make transportation more accessible. After large quantities are transported effectively in one trip, our focus would shift to processing the collected plastic. Many of the plastic processing plants are not equipped with the technology needed to process ocean plastic which is often contaminated. Therefore a wise step would be to fund research and instate the needed chemical treatment machines. Crossing the barrier of ocean contamination will lead us to the essential part of the production process: recycling.

As all the above studies have shown us, the plastic is first cleaned and broken into shards. These shards are then processed in different ways to form fine yarn by spinning or to form soles of shoes through the chemical process of nucleation in polymers. A similar procedure can be followed for any endeavour that may be calibrated to produce fashion from ocean plastic in India. We have included a flowchart based on our learnings.

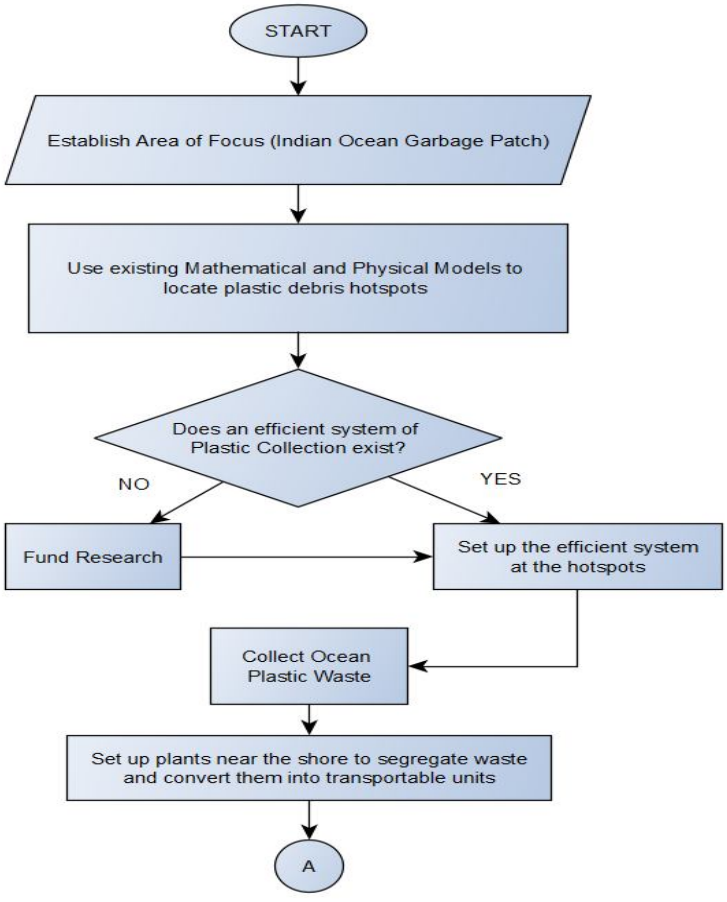


Fig. 4. Part One of Our Suggested Flowchart

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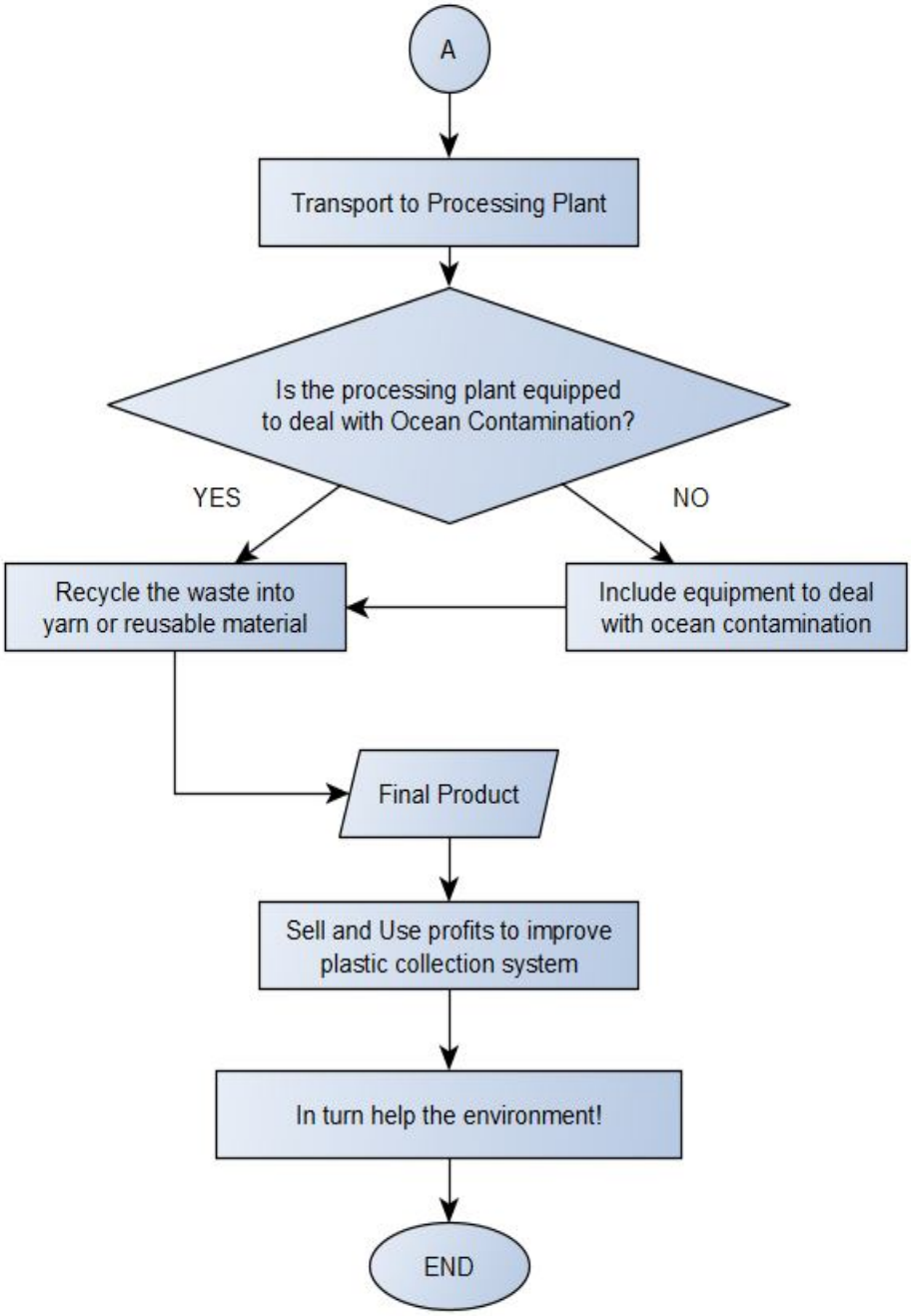


Fig. 5. Part Two of Our Suggested Flowchart

V. CONCLUSION

It is essential to understand that the fashion industry is a massive contributor to the plastic waste found in the oceans. With microfibers accumulating with every wash to the plastic waste collected during production, all aspects of the fashion industry are, to a significant extent, responsible for the plastic pollution described in the chapters above. As a result, the fashion industry needs to take up greener practices and walk down a more sustainable path. This thought led to form the basis of our paper on how sustainable supply chains should be set up to collect plastic waste from oceans to turn them into clothing apparel.

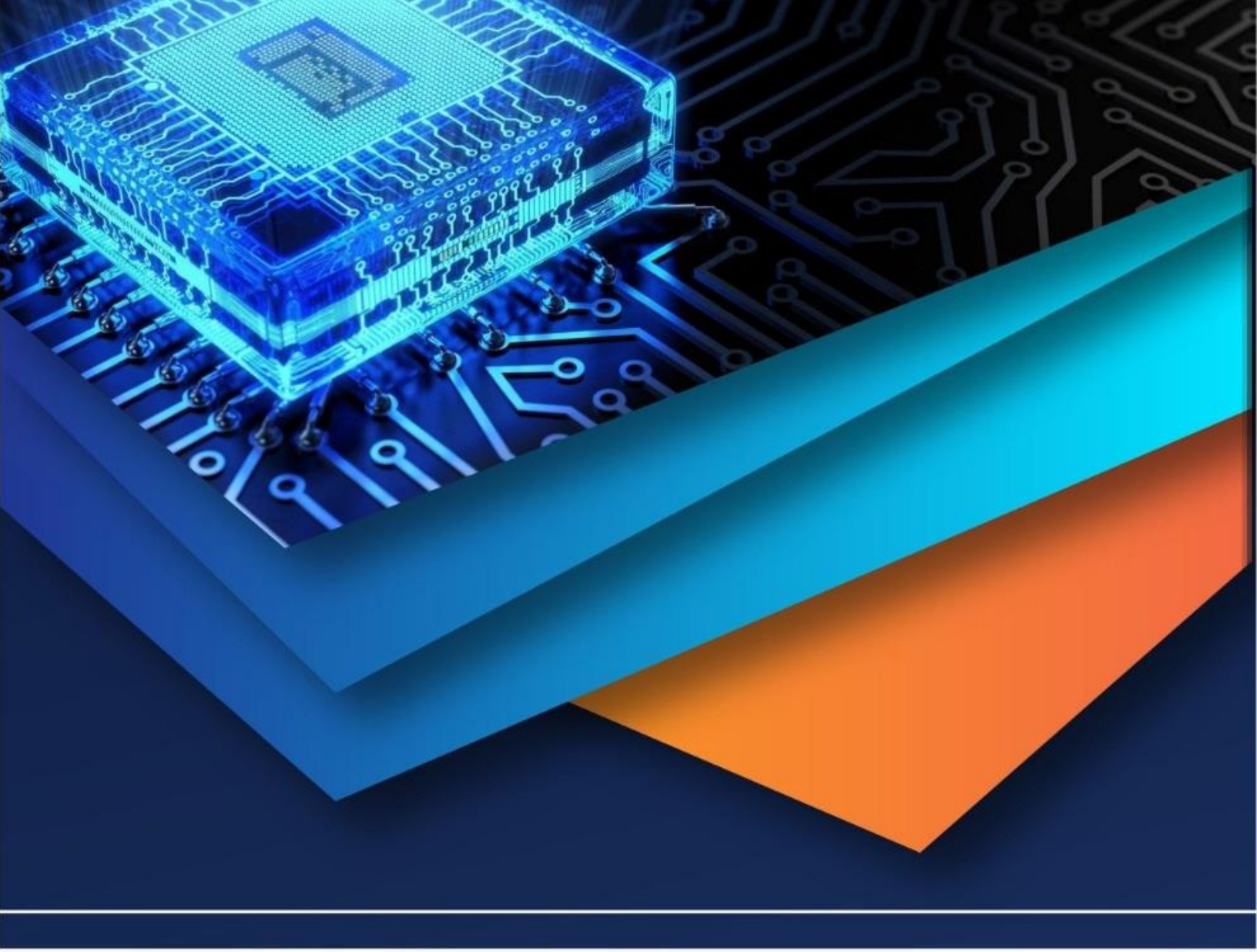
In our paper, we have successfully suggested setting up a sustainable chain in the form of a flowchart and have studied various collaborations and efforts on the part of global corporations to create a greener and more environment-friendly fashion industry.

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