EFFECTIVE SOLUTIONS TO OCEAN PLASTIC POLLUTION

Heirs to Our Oceans

Abstract

Plastic pollution is a serious problem which affects our oceans. Existing "solutions" to this problem, such as current recycling, do not significantly help. A set of four steps -- breaking free from plastic, proper waste management, cleaning upstream, and a circular economy -- is a likely methodology to tackle and solve this problem.

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Effective Solutions to Ocean Plastic Pollution

Introduction

Imagine a lantern fish in the center of the North Pacific Gyre, contemplating colorful "plankton" as its next meal, while in fact, they are microplastic fragments in an assortment of colors.

Picture now a green sea turtle, so bloated and full of plastic bags yet so famished, about to starve to death.

Visualize a Hawaiian monk seal pup, entangled in derelict fishing gear, writhing in agony each time it attempts to break itself free.

A Hawaiian monk seal entangled in derelict fishing gear. Source: New Scientist

Each of these scenarios has one thing in common: ocean plastic pollution.

Plastic pollution is a critical problem worldwide in terms of its long-term and far-reaching impacts on animals and human health. For centuries, coastal populations threw their waste into the ocean, believing that the vast blue could absorb any waste due to its sheer size.

Despite international agreements to stop (MARPOL Annex V), in many places of the world the practice of discarding garbage into the sea is still done today. This idea of "Out of Sight, Out of Mind" is exacerbated by the fact that plastic in the ocean is not easily sighted and therefore, forgotten.

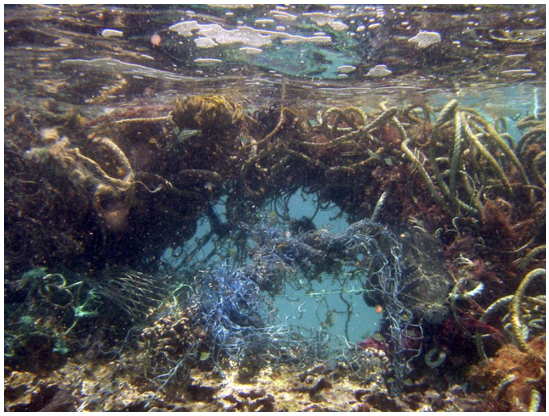
Land is the direct source of approximately 80% of the waste which enters the ocean (Juying et. al., 2016). Plastic often drifts down waterways such as rivers and streams and finally ends up in the ocean. There, plastic breaks apart into microplastics, which are ingested by billions of organisms, eventually deposited on the seafloor or beached.

Plastic pollution washed ashore onto this beach.
Source: Plastic Pollution Coalition

Plastic is harmful to the environment because most types of it do not biodegrade. This means that however small the plastic pieces become, they still remain as plastic. In the ocean, plastic disintegrates into smaller and smaller pieces due to the influence of moving seawater as well as ultraviolet rays from the sun (Eriksen, Cummins). These minuscule pieces of plastic, in turn, are ingested by various animals ranging from seabirds to lantern fish.

Through the influence of ocean currents, there are expanses in the world's oceans where plastic is heavily concentrated, called gyres. There are five gyres in the world: The North and

South Pacific gyres, North and South Atlantic gyres, and the Indian Ocean Gyre. Gyres are also known as garbage patches, wide expanses of garbage in the ocean. However, the latter term has misled many to believe that gyres are floating islands of garbage in the ocean, while in fact, they are akin to "plastic smog" (Eriksen 162, 2017).



An image of the North Pacific Gyre
Source: National Geographic Society

I initially became aware of the plastic pollution problem when I discovered that seabirds were ingesting plastic pieces. Ever since I was four years old, I have been fascinated by the creatures living in the ocean, including sharks and rays. Within a few years, I became passionate about birdwatching. As if it were yesterday, I recall one talk regarding plastic pollution which I attended a few years ago. I learned about the problem regarding seabirds and plastic, and how a variety of discarded plastics affect various other creatures living in the ocean. After doing some basic research to learn more, I was left wondering: *How do we solve the plastic problem?*

Some people believe that plastic pollution can be solved through current recycling strategies and the direct cleanup of litter, but through my learning of plastic pollution I have understood that "solutions" like these do not help solve the pervasive and extensive plastic problem we are facing today.

Accordingly, my research paper aims to look at effective and sustainable solutions to the problem of plastic pollution through the methods of (1) breaking free from single-use

plastic, (2) proper waste management, (3) cleaning upstream, and (4) efficient re-design and effective recycling. This paper looks at these specified methods in terms of education and action.

Methodology and Literature Review

To collect information for this research paper, I consulted and interviewed various experts in this field, including Dr. Julia Reisser, Oceanographer working with Ocean Cleanup, Dr. Vasantha Padmanabhan, Professor of Pediatrics as well as Molecular and Integrative Physiology at the University of Michigan, Dr. Marcus Eriksen, Environmental Scientist and co-founder of 5Gyres, and Anna Cummins, Environmental Scientist and co-founder of 5Gyres.

I have researched various scholarly articles regarding this topic of solutions, most notably a World Economic Forum report called *The New Plastics Economy* as well as a United Nations Environment Programme (UNEP) report called *Valuing Plastic*. I cite a significant portion of information for my paper from Junk Raft, Dr. Marcus Eriksen's informative and eye-opening book regarding his adventure across the Pacific atop a raft while talking about plastic pollution.

Of the literature relating to the topic of oceanic plastic pollution I researched:

- More than one-third of the studies were about the raw data regarding plastic pollution (e.g. how much plastic is estimated to be in the ocean based on data collected).
- Almost half of the studies discussed the impact of plastic on marine life.

- There were a few studies about human health regarding plastic substances.
- Most of the remaining studies focused on specific solutions and non-solutions (e.g. recycling, incineration, fuel conversion).
- There are quite a number of data gaps. For example, there needs to be more river data, more human health data, and more field studies of wildlife interactions.

Plastic Entering the Ocean

It is estimated that between 335 million metric tons of plastic products were manufactured worldwide in 2016 (*PlasticsEurope*, 2017). A study from 2015 estimated that between 4.8 and 12.7 million metric tons of plastic entered the ocean in 2010, a liberal estimate (Jambeck et. al., 2015). The latter weight, with the average being 8.75 million metric tons, is equivalent to the weight of almost 3,003 of the largest rocket mankind has ever built, the Saturn V ("What Was the Saturn V?", NASA.gov).

According to Dr. Marcus Eriksen, plastic research scientist and co-founder of 5Gyres, there were approximately 5.25 trillion particles of plastic debris afloat in the ocean, all weighing 269,000 tons (Eriksen et. al., 2014). This is a conservative estimate. The disparity between the amount of plastic entering and the amount of plastic afloat exist due to four probable factors:

- plastic sinking to the seafloor
- plastic washing up on beaches
- plastic ingestion by marine life, and
- nano-fragmentation (Cozar et. al., 2014).

Nano-fragmentation is where plastic breaks into smaller and smaller pieces in the natural environment. Plastic pieces in the ocean are divided into three size classes:

- microplastics, with a diameter smaller than five millimeters,
- mesoplastics, between five and 200 millimeters (20 centimeters), and
- macroplastics, larger than 20 centimeters.

An example of microplastic.
Source: Phys.org

Most of the weight of the plastic in our oceans comes from macroplastics, while microplastics constitute the most plastic pieces (Eriksen et. al., 2014).

Effects on Marine Life

Plastic pollution affects marine life in two main ways: ingestion and entanglement.

Ingestion

A study from 2015 calculated that approximately 59% of all species of seabirds worldwide from 1962 to 2012 had ingested at least one piece of plastic (Wilcox et. al., 2015). Dr.

Pieces of plastic found inside the gut of a fish caught on the JUNK raft.
Source: Dr. Marcus Eriksen

Julia Reisser of The Ocean Cleanup stated that 100% of the deceased beached turtles from the La Plata region of Brazil which were surveyed and dissected had plastic inside their digestive tract. In fact, some were bloated with plastic to the point where they became positively buoyant before starving to death (Reisser). In a study from 2011, 35% of the lantern fish, one of the most numerous types of small fish ("Lantern fish", 2008), collected from manta trawls off the North Pacific Gyre had ingested plastic, averaging 2.1 pieces of microplastic per fish (Boerger et. al., 2010).

This whale was entangled at the tail flipper.
Source: NOAA

Entanglement

Between 1997-2009, 132 bottlenose dolphins were reported entangled or with ingested fishery-related gear and other types of debris statewide" (2014 NOAA Marine Debris Program Report 3-6). Pinnipeds, such as seals and sea lions, are prone to entanglement in discarded longline fishing gear and fishing nets. In the case of the Hawaiian monk seal, a critically endangered pinniped, entanglement climbed from 0.1% in 1990 to 0.7% in 2004 (2014 NOAA Marine Debris Program Report 3-6). The upsurge in entanglement rose 7 times within 14 years, despite the MARPOL Annex V shipping agreement which eliminated garbage dumping from ships at sea. Therefore, these debris must have come directly from land ("Prevention of Pollution by Garbage from Ships", 2018).

Entanglement not only affects small and medium-size sea creatures, but also the gigantic ones. The same source stated that the "best estimate for a marine debris entanglement rate [of North Atlantic right whales] over the 30-year period [1980-2009] would be 4.2%" (2014 NOAA Marine Debris Program Report 3-6).

Toxicity

Certain kinds of plastic contain additives to make them more sturdy or tensile. These additives can include toxic chemicals such as Bisphenol A (BPA), an endocrine-disrupting chemical. A University of Michigan that capitalized on National Health and Nutrition Examination Survey (NHANES) biomonitoring data found a positive correlation between urinary BPA levels and childhood obesity (Eng et. al., 2013). Phthalates, chemicals used to soften and make many types of plastic more elastic, are "reasonably anticipated to be a human carcinogen" by the National Toxicology Program ("Tox Town - Phthalates", 2017). According to a study done by Dr. Chelsea Rochman of the University of Toronto, many varieties of plastic absorb chemical pollutants from the ocean water, along with initially having toxins in the plastic substance itself (Rochman et. al., 2013).

When a fish ingests microplastic, the toxins inside the piece of plastic accumulate in the body of the fish. When a predator ingests many of those fish, they inadvertently consume all the toxins inside not just one, but multiple fish, which results in an even higher concentration of toxins in the predator's body tissues. This effect is called bioaccumulation. This bioaccumulation effect is exactly what happens to fish that ingest mercury, according to Scientific American ("How Does Mercury Get Into Fish?").

As this cycle continues, predator after predator progressively ingests a greater concentration of toxins. After some point in the food web, fish that are often consumed by humans are inevitably affected, making plastic toxicity a human health hazard. According to a study from 2015, approximately a quarter of fish sampled in Californian and Indonesian fish markets had plastic inside their gut (Rochman et. al., 2015).

Existing Non-Solutions


Oil is where plastic begins life.
Source: Wikimedia Commons

It is a well-known fact that plastic is made from the hydrocarbon gas liquid (HGL) polymers of petroleum ("How Much Oil Is Used to Make Plastic?", 2017). According to *The New Plastics Economy*, around six percent of oil was used to make plastic in 2013. Roughly half of this was used for the components of plastic, and another half was used for the process of manufacturing plastic. If the current trends and growth rates continue, this statistic may reach 20% of oil around 2050 (*The New Plastics Economy*, 2016).

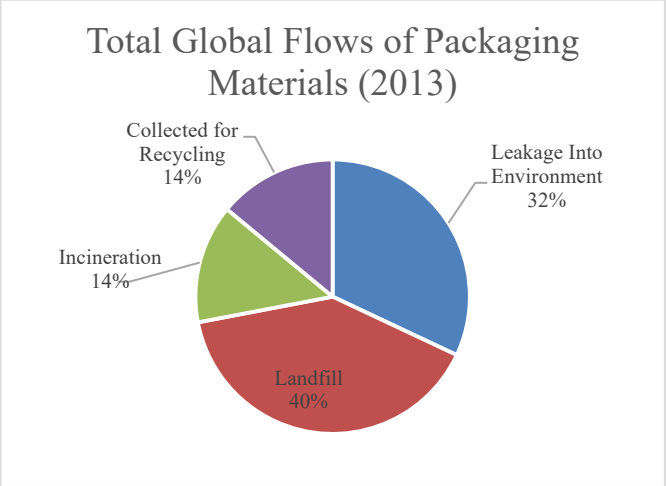
There are many proposed solutions to the plastic waste problem, but only some are effective. The proposed solutions which turn out to be ineffective are called non-solutions. Here

are the four most common non-solutions which are promoted and used today, enabling customers to continue buying and using single-use plastic:

1. Current Method of Recycling,
2. Plant-Based Plastic,
3. Incineration, and,
4. Plastic to Fuel Conversion.

Recycling

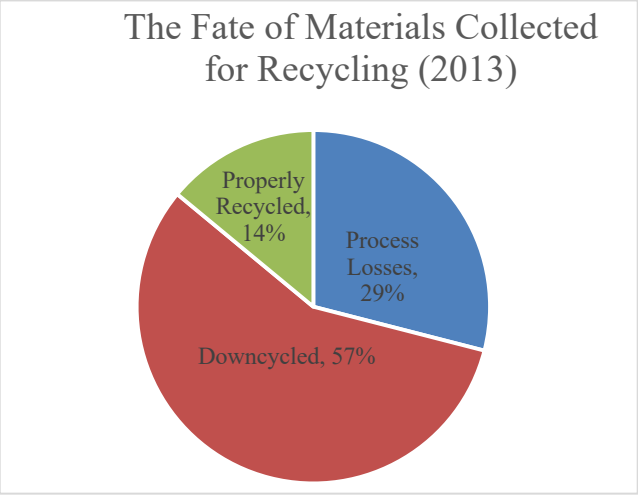
My first learning was that the current method of recycling is not an effective solution to plastic pollution. Current recycling is not as simple as it seems; plastic in recycling bins seldom turn into a same or similar product. Rather, the product typically turns into something of lower value, called down-cycling.



According to *The New Plastics Economy*, only 14% of *global* plastic packaging waste, one of the largest categories of waste, was collected for recycling in the same year.

Of the 14% of global packaging waste that was collected for recycling in 2013, 29% of was lost in the inefficient process of recycling. 57%, was down-cycled. 14% was recycled into something of similar value.

Relating to all plastic packaging, this means that 2% of total global plastic packaging waste, was fully recycled (*The New Plastics Economy*, 2016).



Source: The New Plastics Economy

Plant-Based Plastic

Some people claim that to reduce our dependency on oil-based plastic, the ideal choice would be to use "eco-friendly" plant-based plastic. The BAN (Better Alternatives Now) List 2.0 states the problems associated with plant-based plastic.


Plant-based plastics like these might be innovative, but not all types biodegrade in the natural environment.
Source: Solid Waste and Recycling

1. First, plant-based plastic is defined as plastic made from plant sugar, but most of these maintain the same chemical structure as regular fossil-fuel based plastic, and therefore are not biodegradable.
2. Second, some plant-based plastics are supplemented with oil-based plastic.
3. Finally, "biodegradable" plastics do not decompose in all environments as a true plant would. For example, PLA alternatives only biodegrades in an industrial compost facility, but not a marine environment. On the other hand,

PHA alternatives, which is non-toxic, does biodegrades in a marine environment (Allen et. al., 2018).

Incineration

In the world, there are some incineration plants that burn plastic to dispose of it, and some which convert waste-to-energy. The Global Alliance for Incinerator Alternatives (GAIA) has determined that waste-to-energy incinerators are inefficient and ineffective. Though older incinerators run at "efficiency rates of 19-27%", a study in the United Kingdom determined that new incinerators are even less efficient (The Viability of Advanced Thermal Treatment in the UK, 2004). GAIA has also determined that waste-to-energy incineration is "not renewable energy—and it takes investments away from real renewable energy solutions", but instead contributes to climate change (*Facts About Waste-to-Energy Incinerators*, 2018).

In addition to being ineffective and contributing to climate change, the incineration of plastic is unhealthy for humans as plastics contain toxins and burning them is even considered a human health hazard. The documentary *A Plastic Ocean* showcases people on Fiji burn plastic because they cannot afford kerosene to cook their food. This leads to lung problems in those individuals (*A Plastic Ocean*). As Stiv Wilson, an environmentalist who documents stories regarding plastic pollution noted in his talk, Chinese districts near Beijing builds incineration plants at their borders to meet air quality tests, allowing the burning plastic fumes to drift downwards into a neighboring district (Wilson, personal communication, 2017).

Plastic-To-Fuel Conversion

A relatively new idea, plastic-to-fuel conversion is the chemical process of converting plastic into petroleum and its byproducts. Though it is innovative, plastic-to-fuel conversion is not a potent solution for two reasons. First, the existing technology needed to effectively and efficiently convert plastic into fuel is not fully developed. Second, though it is a possible idea for the plastic already out there in the ocean, heavily investing in plastic to fuel conversion could mean the production of more plastic, just for the sake of fuel conversion. This in turn would release more greenhouse gases into the air.

Effective Solutions

I believe the four-step process outlined below is one of the many effective methods to tackle plastic pollution. In order to solve the problem, one must stop the flow of all plastic, manage and clean up existing waste, and then invest in renewable technological solutions.

1. Break Free Movement,
2. Proper Waste Management,
3. Cleaning Upstream, and,
4. Circular Economy.

Break-Free Movement

The first step is the break-free movement, which is to break free from all single-use plastic. This is crucial for two reasons. First, by ceasing our use of single-use plastic, we can globally reduce our consumption and as a result our waste of plastics. Second, our current recycling and waste management practices cannot keep up with the increase in single-use plastics, and the usage of such plastic would be adding onto the burden of an already ineffective recycling and waste management system. Ocean capital cost is a vital measure that stresses the importance of the break-free movement.

The report *Valuing Plastic* defines ocean capital cost is a certain action's annual fiscal cost on the ocean, including the monetary gain and/or loss regarding ecosystems, tourism, anti-littering efforts and fisheries in or near the ocean. For example, if an arbitrary fishing company sells approximately $1M of fish produce (assets) while damaging the ecosystem for approximately $4M (liabilities), the ocean capital cost would be $3M per year. The soft drinks sector, including bottled water, had the third highest annual ocean capital cost between $1 and $2 billion in 2015. The total ocean capital cost in the whole consumer goods sector during the same year was estimated to be over $13 billion per year. This implies that the soft drinks sector was responsible for approximately one-tenth of the consumer good sectors' ocean capital cost. (*Valuing Plastic* 10-14, 2014).

One simple solution to the immense environmental cost of plastic pollution is to bring a reusable bottle to fill at a drink station, avoiding any single-use plastic bottle. However, this move to reusable bottles will require a bit of education or maybe even an educational campaign

for **all** communities as well as integrating effective plastic pollution solution education in schools, from preschool to university.

Proper Waste Management

The second step is proper waste management. As much plastic we clean up, more will be produced. According to Junk Raft, many West Coast U.S. businesses have shipped their plastic waste to China. This is because landfills here in the United States charged the businesses for bringing their plastic waste, whereas China took it for free. Since China placed the "Green Fence" and does not allow our plastic trash to be imported anymore, the U.S. ships this plastic to third-world nations, leading to health hazards for people in those nations (Eriksen 82-85, 2017).

China's "Green Fence" program in action. Source: Hangzhou Weekly

If the United States has a low-cost waste management system that effectively handles plastic, similar to a system in the Philippines, which includes daily waste collection, cleanups, and recycling, there would be many positive results (Wilson, personal communication, 2017). For one, the output of plastic into the waterways and oceans would be significantly reduced. Further, plastics would not be shipped to third-world nations, as many of those nations already have enough of their own plastic to handle.

Cleaning Waste Upstream

The third step is cleaning waste upstream. The very reason oceanic cleanups do not entirely help solve the plastic waste problem is because it is estimated that 80% of marine debris originates from land, while the remaining 20% comes from ships and boats on the sea. What should be implemented is the prevention of plastics from entering waterways, which in turn flow to the ocean. This can be done by holding water and beach cleanups to prevent waste from going into the ocean.

Circular Economy

The final step is the adoption of a circular economy, a principle where products would be effectively recycled, and their components reconstructed into another product of similar value. *The New Plastics Economy* report states that approximately 95% of plastic packaging is lost to the economy after a single use, and $80-$120 billion is wasted in this process (*The New Plastics Economy* 12, 2016). As well as a conservation solution, the circular economy is an excellent way to improve the global economic model.

The reason that plastic companies, and, by association, the petrochemical and oil companies, are not following these steps is because their revenues would be negatively impacted. If the same plastic was used to make many products over and over again, there would be no need to maintain a virgin plastic feedstock based on oil. The oil companies, first, would see a great reduction in their demand if proper recycling was implemented. Second, the plastic companies would see a reduction in the price of plastic, as secondhand plastic would be cheaper than virgin plastic. And finally, with these new systems, people would view plastic as a limited resource, and instead place their faith in reusable alternatives, possibly trying to sparingly use plastic. This,

in turn, would reduce demand even more for plastic products. All of these reductions in demand would prove damaging to the petrochemical, oil, and plastic industries as we know them today.

This is especially important for our generation because we need to understand that plastic is a limited resource and therefore help implement a circular economy to not keep draining the planet's resources.

Analysis of Solutions

The Disruptive Innovation Festival (DIF) is a project organized by the Ellen MacArthur Foundation, one of the world leaders in promoting and pursuing effective solutions to plastic pollution. According to the Harvard Business Review, disruptive innovation "describes a process whereby a smaller company with fewer resources is able to successfully challenge established incumbent businesses" (Christensen et. al., 2016).

Effective disruptive innovation regarding our environment should consist of three criteria:

- Clean Energy, or the usage of renewable energy such as solar, wind, or hydropower,
- Cradle-to-Cradle Material Bank, which means that a product would either be broken apart into its components, or safety returned back to the biosphere, and, finally,
- Effective Systems, which are systems that efficiently and effectively get jobs done.

I chose to look at the four effective solutions I have mentioned previously (the break-free movement, proper waste management, cleaning upstream, and the circular economy) through the criteria of successful environmental disruptive innovations.

Analysis

Firstly, while the break-free movement is not a step of disruptive innovation in and of itself, it indirectly impacts how effective systems can be used such that, when successful, it is meant to cut the amount of plastic flow into the collection, sorting, and recycling centers, thereby improving efficiency and speed. This is done by ceasing the use of most or even all single-use plastic. Additionally, a break-free movement reduces the burden we place on the fossil fuel industry to manufacture plastic.

Secondly, proper waste management and cleaning upstream can both be considered the third step of disruptive innovation, effective systems. This is because both are meant to greatly improve the plastic collection rates (and thereby management and recycling) as well as significantly lowering the rates of plastic flowing into waterways. This improves systems as a whole.

Finally, the circular economy can be considered the second step of disruptive innovation, the material bank. The purpose of the circular economy is exactly this; it aims to create new products using materials from the end of their life cycle. In fact, the circular economy needs all three criteria to thrive: it needs clean energy because it must constantly take apart and create new products, a material bank (discussed above), and it needs efficient systems such as effective recycling for it to work.

Education and Action

Education is an important and preceding stop to all of these solutions. Through misinformation, most people either do not understand or worse have misunderstood the complexity of the plastic problem. A good example was the incorrect reporting that a gyre is a "floating island the size of Texas", leading most to believe that an island made of plastic was floating on the ocean. Rather, it is akin to seeing plastic smog on the water, due to the microplastic content. The incorrect reporting has led most people to believe that the ocean is easy to clean up while it is not.

Most people also mistakenly believe that recycling is an adequate solution. Many corporations that manufacture and use plastic, especially the American Chemistry Council (ACC), have denied their responsibility by displaying the current model of recycling as a solution while it is not. The Earth Island Institute stated, concerning the addition ACC-endorsed statements regarding plastic into the curriculum of high school students in California, that the association "also pushed to include more about plastic bag recycling", despite its ineffectiveness (Westervelt, 2011).

It is important to note that levels of plastic waste disclosure for companies in the consumer product sector are very poor. According to *Valuing Plastic*, the highest sector had an 88% disclosure rate while the lowest was at 0% (*Valuing Plastic* 10-14, 2014).

The main problem with the massive amounts of plastics in our natural environment, no matter how much we clean it up, is the lack of corporate responsibility. One system which works

is the German water bottle system (even though it is still considered single-use plastic): bottles are placed under the responsibility of their manufacturers, using a barcode with all the information. From there, they are effectively recycled in German plants (James, 2017).

What Can You Do?

Individuals

As an individual, there are many day-to-day solutions one can participate in:

- **First and foremost, educate yourself and others about this problem.**
- Avoid single-use plastic, including straws, utensils, water bottles, bags, and to-go containers including polystyrene hot-cup lids. Go reusable.
- Buy in bulk to avoid plastic packaging as much as possible and bring your own cloth bags to grocery stores to avoid using their plastic bags.
- Join and support organizations such as Heirs to Our Oceans, Plastic Pollution Coalition, 5Gyres, and Story of Stuff. These organizations actively participate in the education and empowerment of youth and adults with regards to the ocean, marine life, plastic pollution, and the connections between them.

Bring reusable utensils wherever you go!
Source: MightyNest

These organizations provide opportunities to take action, ranging from beach cleanups to signing a petition.

Small Business

Educate and urge small businesses to help make changes in the way they operate. For example, one could urge a local café or restaurant to stop using plastic straws and utensils. This business could possibly serve as a model for others, eventually giving other businesses the pressure and incentive to change.

Industry

With industry, the process of change is much more difficult than when concerning a small business. Industry, especially the plastic production industry, need to practice policy-driven extended producer responsibility or EPR. This means that the companies are responsible for what they produce through its full life cycle. For example, a company making plastic bottles would be responsible for its production, usage, disposal, and recovery. This practice involves a great amount of policy change to pressure industry to comply with the new rules and regulations. The German system of placing water bottles under the responsibility of their manufacturers is an example of EPR (Eriksen 88-89, 2017).

Government

This leads to the need to urge our lawmakers, both state and federal, to propose, endorse, and support bills that protect our planet's and our health. In due course, these laws will force government agencies and corporations to follow new procedures that work toward bettering our planet for future generations.

Action

Do what you can to help with this crisis, as it affects every single person on this blue planet, including you. This crisis must be addressed right now because the effects are becoming more disastrous. One estimate states that in 2050, there might be more plastic than fish in the ocean by weight (*The New Plastics Economy*, 2016). This would mean multiple devastating consequences for both the Earth's land and oceans, and humanity would be directly affected by it.

However, if we all join together and work towards effectively solving plastic pollution, humanity could end up with a zero-waste world where efficacy and efficiency are the pillars of civilization, and therefore we would be able to live at ease and in harmony with the environment. We would achieve an existence where we live at ease and in harmony with the environment. Our generation needs to take steps toward that goal.

Heirs to Our Oceans is inspiring the next generation of environmental leaders.

www.heirstoouroceans.org

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