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# "Pliable and Easily Shaped": History, harms, and regulations of plastic in the United States

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HISTORY, HARMS, AND REGULATIONS OF PLASTIC IN THE UNITED STATES

BY

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# “PLIABLE AND EASILY SHAPED”:

# HISTORY, HARMS, AND REGULATIONS OF PLASTIC IN THE UNITED STATES

BY

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# DEDICATION

For my mother and father, the people who raised me to be the woman I am today.

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A special thanks to my dearest friend, Sarah Leitner, for listening to spirited tirades about plastic waste and enduring grand ideas for living a cleaner, plastic free life. Further thanks to Rossana Diaz and Joseph Ellis, as well as the friends and family who unknowingly supported me.

ABSTRACT

The majority of plastic exists in a linear economy, wherein a product is developed with raw materials, used, and then discarded. Because there are many applications for plastic in today's society unparalleled by alternative materials, removing all or most plastic use from daily life in the United States is unrealistic. Nevertheless, eliminating single-use plastics and improving recycling are reasonably attainable goals.

This thesis offers a detailed discussion of the origins of plastic, including its discovery, initial applications, and growth in the United States. Against this backdrop, this thesis then examines how various nonhuman animal species and ecosystems have been negatively impacted by excessive human consumption and improper disposal of plastic. Given the ostensibly endless applications for plastic, this thesis concludes by considering how we might discontinue its use at present levels.

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## I. Introduction

Who is responsible for the health and safety of planet Earth? Is it an individual's right to consume whatever he/she wants regardless of the effect on local and global the ecosystems? If so, what role, if any, does an individual play in preventing or reducing environmental degradation? Should corporations be held accountable for producing materials that negatively affect the environment? What is—or should be—the scope and extent of governmental regulations (and their enforcement)? These are questions surrounding the production, use, and disposal of plastic materials in the United States (US).

Plastic, once defined as "pliable and easily shaped," now refers to the vastly developed body of materials. Plastic was first introduced as sustainable and cost-effective alternative solution to hard-to-obtain resources and then became invaluable to the World War II (WWII) effort. Although plastic is now used for countless purposes in nearly every aspect of life, its over-utilization is threatening the integrity of our oceans, endangering wildlife, and causing harm to human health.

Within the past few years, attempts in the US to reduce single-use plastic—such as with plastic bag and straw bans—have garnered substantial media attention. Most stunning was a California municipality's effort to decrease the consumption of plastic straws by proposing up to $1,000 fines and six months in jail for restaurant workers who distributed plastic straws absent a consumer's request (Hafner, 2018). Other states have also begun to express interest in reducing plastic waste and have done so by charging consumers fees or banning plastic bags outright, as well as advertising and encouraging the use of personal reusable bags (Gibbens, 2019). This uptick in the regulation of individual use of certain plastic materials in the US begs the following questions:

1) Why regulate plastic?

2) Who should regulate plastic?

3) How far-reaching should regulations be?

To address these questions, it is necessary to explore the history and current knowledge of plastic and the role it plays in today's world. It is important to know what plastic is, why it can be hazardous to human and non-human animal health and the vitality of the planet, and what alternatives to plastic exist (Plamondon and Sinja, 2017).

The second chapter of this thesis develops a comprehensive understanding of the history, development, and growth of plastic from its inception to the present day. This history includes a cursory overview of the science of plastic, the industry that makes it, and the types and uses of plastic. The third chapter provides an overview of the various harms already propagated by plastic's introduction into the ecosystem and examines additional harms that may unfold in the future. Generally speaking, regulations are enacted after the discovery of a harm; they often reflect a goal of determining the acceptable level of harm and preventing future harm that exceeds those "acceptable" levels. Therefore, a thorough understanding of the known harms propagated by plastic materials and products is necessary to support regulations and determine to what degree plastic may be limited. The fourth chapter examines current plastic regulatory practice in the US with respect to three stages: production, consumption, and disposal/waste management. Each stage considers either federal, state, or municipal regulations or a combination thereof, as there are no overarching plastic regulations. The chapter also notes the presence of state preemption laws, which prohibit municipalities from regulating plastics, thus protecting corporate interests. The concluding chapter reflects on a life-cycle perspective of plastic and contemplates what could be done to reduce harm on the individual and collective levels.

## II. A History of Plastic

### Creation and Discovery

In 1856, Alexander Parks, an English chemist, filed a patent for a synthetic plastic material called "Parkesine" (The Editors of Encyclopaedia Britannica, 2019). Parkes' business partner, at the time, Daniel Spill, patented Xylonite in 1867, which was a more stable improvement on Parkes' material (The Editors of Encyclopaedia Britannica, 2019; 2020). Both of these materials were plant-based synthetic materials that held the qualities of plastic but served no wide-scale practical use.

The history of plastic in the US began in 1863 with a search for an alternative to ivory when a New York billiards company advertised a $10,000 award for anyone who could provide a substitute, which would be less difficult and expensive to source. Inspired by the challenge, John Wesley Hyatt began experimenting with chemical compositions and discovered the process for making celluloid, the first practical synthetic plastic material based on plants (Science History Institute, n.d.; The Editors of Encyclopaedia Britannica, 2019, 2020; Young America films, 1944). Celluloid proved to be a tough, flexible, and moldable material—and resistant to water, oils, and dilute acids—that could be fashioned into a variety of colors and shapes. It became the popular material for many novelty items. While not an adequate substitute for ivory in the production of billiard balls, Hyatt recognized the multi-faceted applicability of plastic material and entered business with his brother using celluloid in the production of embossed checkers and dominoes (Science History Institute, n.d.; The Editors of Encyclopaedia Britannica, 2019, 2020).

Hyatt's plastic product in the US was more commercially successful than many of its predecessors (The Editors of Encyclopaedia Britannica, 2019). The plastic was capable of being colored by adding dyes or pigments, which produced transparent or opaque colors, respectively, then rolled, sheeted, and pressed into blocks that would be sliced after treatment. These slices could be reheated for molding to any shape and, at room temperature, could be buffed, drilled, planed, polished, sawed, and turned (The Editors of Encyclopaedia Britannica, 2019). Hyatt and his brother obtained their first patent in 1870 and, three years later, registered it under the trade name "Celluloid," which became the plastic polymer's generic name as a number of competing plastics entered the commercial game (The Editors of Encyclopaedia Britannica, 2019). The Hyatt brothers produced celluloid in a variety of generic shapes, which licensed companies would purchase and make into the finished products, including brush handles, combs, eyeglass frames, piano keys, telephones, and toothbrushes. Then, in 1882, scientists found a solvent suitable for diluting celluloid, allowing the material to be formed into a clear, flexible material that was later used as film for still photography and motion pictures (The Editors of Encyclopaedia Britannica, 2020).

While Hyatt's celluloid was synthetic, the molecular chains were based entirely on plant-molecule sequences found in the natural world, which scientists multiplied to lengths not seen in nature. It was not until 1907, that Leo Baekeland created the first fully synthetic plastic later called Bakelite which was created to replace shellac (Young America Films, 1944; Ewing, 2019). The material was soon found to be highly effective as a substitute for other materials because it was durable, heat resistant, inflammable, well-suited to mechanical mass production and could be molded into any shape when heated (The Editors of Encyclopaedia Britannica, 2019; Young America films, 1944). In the 1920s and 1930s, celluloid was being phased out because of its flammability and tendency to crack with age, discolor, and soften under heat. Celluloid replacements included cellulose acetate, Bakelite (mentioned above), and new vinyl polymers (The Editors of Encyclopaedia Britannica, 2019).

## World War II

Prior to WWII, cork was used in great quantities, because, at the time, it was the most flexible material (Ewing, 2019). The plastic industry had become well-established prior to the start of the war for the production of novelty items for the upper classes. Cork was the ideal material for insulation in various items, including bomber gaskets, bomber planes, metal bottle caps and lids (Ewing, 2019). When the war started, the US was concerned because cork was shipped primarily from Europe. Nazi Germany enforced a blockade of the Atlantic Ocean. The result was a restriction on the use of cork for defense and the endorsement of a research and development program which led to the beginning of a nascent plastic industry (Young America Films, 1944; Ewing, 2019). Throughout the war, plastic came to play an integral role in the industrial mass production of instruments used in battle (e.g. body armor, helmet liners, parachutes, plane cockpits, plexiglass plane cockpits, ropes), providing stronger and (seemingly) sustainable alternatives to natural resources (Young America Films, 1944). As a result of its utility in the war effort, plastic was heralded as a miracle material and lifesaver.

After the war, plastic appeared to serve no purpose, leaving workers without jobs and the plastic industry scrambling to find its niche during times of peace (Ewing, 2019). Nylon, for example, used in part in automobile wheels and parachute production, was repurposed for the production of toothbrushes and women's pantyhose. Plexiglass, utilized in place of glass in airplanes became the replacement for automobile windshields (Young America Films, 1944; Ewing, 2019). Indeed, plastic appeared to be everywhere—from Tupperware food containers and plastic food wrap to containers for cleaners, soaps, and various other liquids to Lycra in clothing (spandex). Plastic bags were introduced in 1977 as an alternative to paper bags and, by 1979, more plastic was being produced than steel in the US (Ewing, 2019).

The amount of waste produced by Americans' rate of consumption, increased steadily and, by 1986, there was so much waste in New York City that local landfills were struggling with a lack of space (Hanbury, Weiser, & Howard, 2019). In 1987, the people of Islip, Long Island, were faced with landfill capacity issues: the amount of waste that they had generated exceeded their landfills' capacity. Lowell Harrelson, a businessman, proposed to load the excess waste onto a barge and ship it south along the coast (Hanbury, Weiser, & Howard, 2019). Soon after his proposal, Harrelson leased a barge, named the Mobro 4000, loaded it with waste, and departed for North Carolina to deliver it to a landfill willing to accept the load. Unloading was denied by the landfill, however, because of fear of biohazardous waste from hospitals after a hospital bedpan was found on the barge. This led to denial of the barge at subsequent landfills, leaving the barge floating along the coast for about five months before a solution was reached (Hanbury, Weiser, & Howard, 2019). Eventually, the garbage was incinerated where it had originated, and the residue was sent to the original destination in North Carolina. The Mobro 4000 was a symbol of the growing waste problem in the US. It sparked a sense of individual responsibility for household waste and marked a substantial increase in recycling rates in the 1980s (Hanbury, Weiser, & Howard, 2019).

## Plastic Today

Today, plastic permeates all aspects of life including air, food, land, and water. Unfortunately, plastic particles appear in the middle of the world's oceans, including those furthest from human civilization. According to data from a report published by the United Nations Environment Programme (UNEP, 2018), 300 million tons of plastic waste enters the ecosystem every year. Researchers estimate that since the early 1950s, when plastic production skyrocketed, the industry has produced more than 8.3 billion tonnes of plastic, 60% of which has ended up in a landfill or the natural environment (UNEP, 2018). The annual estimates of plastic waste and the lack of recycling demand attention, especially as consumption rates are projected to continue increasing.

Much plastic waste results from the indiscriminate consumption of single-use plastics and a culture of consumption fostered by the convenient availability through superstores and online shopping. As Plamondon and Sinha, authors of *Life Without Plastic* (2017) claim, six of the "absolute worst plastic pollution culprits" include: plastic bags, plastic water bottles, plastic coffee and tea cups and lids (or plastic lined cups), plastic food containers, plastic utensils, and plastic straws. These are consumed in vast quantities on a daily basis, without concern for where they will end up after being thrown into the trash.

## III. Harms of Plastic

The production, use, and improper disposal of plastic presents various harms to the ecosystem and its inhabitants. This chapter describes the negative consequences of plastic production, use, and disposal. While animals and the environment bear the brunt of the harms, human health is affected as well.

### Marine Plastic Pollution

"Marine plastic pollution" refers to the disposal or abandonment of any persistent, manufactured, or processed solid material in the marine and coastal environment (Le Guern, 2018; UNEP, 2018). In addition to the dumping of waste materials along beaches and at sea, littering inland can impact marine and coastal areas because of the movement of water towards the oceans. The detrimental impacts of plastic on the oceans stem from the very same qualities that heralded it a "miracle material" during and after WWII (Le Guern, 2018).

During its emergence as a miracle material, one of the qualities most admired by consumers was its durability. Unfortunately, this means that plastic will not biodegrade. When other materials in the ecosystem break down, they return to base elements that may reenter the natural cycle. A simple example would be an animal dying, decomposing, and become fertilizer for the plant life in the immediate area. In contrast, plastic is incapable of returning to the base components used to create it (Le Guern, 2018). When plastic "breaks down" through a process called "photodegradation," it becomes smaller pieces of plastic referred to as "microplastics," which can be invisible to the human eye.

Plastic's light weight means it is buoyant, resulting in widespread dispersal regardless of where the plastic enters the ecosystem. Even inland litter can make its way to the oceans via various waterways and can pollute areas not frequented or touched by civilization, including secluded beaches and shorelines. Furthermore, plastic's buoyant nature leads to its accumulation in ocean gyres that the media refer to as "garbage patches" (Le Guern, 2009/2018). The first patch was discovered in 1997 by Charles Moore, a California sailor and surfer, while crossing the Pacific Ocean, and it was dubbed the "Great Pacific Garbage Patch" (Parker, 2018). The media claimed these "islands of garbage" were the size of Texas and visible from space in order to sensationalize the issue of plastic litter for readers. In truth, much of the accumulation of plastic in the oceans' gyres are soupy collections of microplastics less than 5mm in size, as well as raft-like agglomerations of bags, bottles, fishing nets, and other large plastics and cannot be seen from satellites in space (Parker, 2018; Le Guern, 2009/2018; Rochman & Browne, 2013). Approximately 10% of overall microplastic waste in the oceans comes from tires, according to a 2017 study published in the *International Journal of Environmental Research and Public Health*; a 2017 report by International Union for Conservation of Nature put the figure at 28% and additional research from *National Geographic* submits that fishing gear comprises 76% of the Great Pacific Garbage Patch (Parker, 2018, Root, 2019).

The long life and mobility of plastic accumulating in the oceans combined with plastic's porous nature, which allows it to absorb toxic substances, rendering it a serious threat to ecosystems around the world (Le Guern, 2018). Plastic debris has the potential to collect or absorb toxic substances from the water in which it is floating (Le Guern, 2018). As plastic moves in the ocean currents, it can act as a carrier, contaminating receiving waters or marine life that mistakenly ingest it as food. As reported by the US Environmental Protection Agency (EPA) (2019), plastic in its various forms and sizes can be found in most habitats, both marine and terrestrial.

**Threats to Marine Life and Wildlife**

The sizes and forms of plastic pose various threats to the health of marine life. Birds, dolphins, fish, seals, turtles, and other animals have consumed or accidentally ingested plastic or have become entangled in and suffocated by shaped plastic materials (Gourmelon, 2015; Le Guern, 2018). Consumption/ingestion can cause nonhuman animals to choke and can impede digestion of food, and various plastics are also known to leak toxic chemicals into their immediate environment (Le Guern, 2009/2018). When consumed/ingested, the leaked toxins may negatively affect the internal organs of the organism. This impact of plastic on wildlife has not gone unnoticed, as evidenced by shocking YouTube videos of biologists painfully removing a four-inch long straw from a sea turtle's nostril and images of decomposing albatross with stomachs full of plastic materials (Daly, 2018).

Extensive research into consumption habits of seabirds provides insight into viable explanations for why seabirds consume plastic materials, as well as potential health risks associated with consumption. Phillips and Waluda (2020) published an analysis of a long time-series spanning 26 years, wherein they documented plastic consumption by seabirds in southern Georgia. Not only did the time-series document reveal the forms and sizes of ingested plastic, but also the ingested plastics' point of origin.

Seabirds and other marine life which consume plastic mistakenly identify it as food due to similarities in color, shape, and size (Wehle & Coleman, 1983; Philips & Waluda, 2020). Whereas the marine turtle consistently selects plastic bags, mistaking them as their preferred snack—jellyfish—seabirds may consume a variety of different plastics that it confuses for food (Wehle & Coleman, 1983). Direct physical effects of plastic consumption potentially contributing to poor health and potential death in individual seabirds of various species, include blockage of enzyme secretion, partial gut obstruction, suppressed appetite, ulcerations in stomach and intestinal linings, and weight-loss (Wehle & Coleman, 1983; Philips & Waluda, 2020).

In addition to the direct physical threats, plastic poses a potential biological-chemical danger upon ingestion. As mentioned above, plastics release toxic chemicals as they photodegrade and can adsorb toxic substances from polluted waters like a sponge. Once in the stomachs of an organism, the adsorbed toxins can then be transferred from the plastic to the tissues of that organism. Wehle and Coleman (1983) found that plasticizers (additives to reduce brittleness and promote flexibility) and other harmful additives may concentrate in the fatty tissues of seabirds, resulting in eggshell thinning, aberrant behavior, or tissue damage. They surmised that as tissues are mobilized for energy, the toxins may be released in lethal doses.

## Public Health and Economy

The aforementioned detriments plastic litter upon marine-life causes a chain reaction of effects that extend to humans. When humans consume fish, they are ingesting what the fish digested, including any plastic toxins residing within tissues. Furthermore, research shows that microplastics can be found in drinking water from around the world, and even in beer (Kosuth, Mason, & Wattenberg, 2018). Dr. Sherri Mason, professor of chemistry and chair of the Department of Geology and Environmental Sciences at State University of New York at Fredonia, found nearly all major brands of bottled water contain microplastics (Mason, Welch, & Neratko, 2018). The results revealed an average of 325 microplastic particles per liter of bottled water, with the most common polymer type found being polypropylene (PP), and 65% of the plastic particles identified were fragments visible to the naked eye. The data suggest that most of the contamination comes from packaging or the bottling process itself. Nestlé Pure Life and Gerolsteiner had the greatest density of microplastic particles per liter (MPP/L) (Mason et al., 2018).

In another research experiment, Mason and her colleagues found particles in tap water, twelve brands of beer using municipal water from one of the five Laurentian Great Lakes, and twelve brands of sea salt (Kosuth, Mason, & Wattenberg, 2018). All the tested brands of the salt and beer were found to have plastic particles. The studies' results, alongside consumer guidelines, suggested that over 5,800 particles of synthetic debris are ingested by the average person annually (Kosuth, Mason, & Wattenberg, 2018).

The presence of land litter in cities proved to be a serious issue in 1988 in Bangladesh, when plastic bags clogged water drainage systems worsening the impact of flooding, causing several deaths, and leaving two-thirds of the country submerged in water (UNEP, 2018). This example of plastic bags exacerbating natural disasters is but one potential consequence of the mass-consumption and lack of or improper waste management systems. Some question whether this was truly a "natural disaster" or minor flooding which was exacerbated when water drainage was obstructed by plastic bags.

Significant economic impacts also occur when marine debris affects tourism, the fishing industry, and navigation (EPA, 2019b). The areas experiencing the adverse effects of plastic pollution must divert resources and money into resolving the issues. When plastic litter is accumulating in tourist and high foot-traffic locations, such as beaches and parks, there are various economic revenues at risk. Vacationers may look for other places to visit if they perceive a place as visually unappealing or unsanitary, thus decreasing the amount of potential dollars entering the area. Further consequences include the investment of resources to cleaning, maintaining, and advertising the beach to better appeal to tourists.

## IV. Plastic Regulations in the United States

The life cycle of plastic is comprised of three stages: production, consumption, and disposal. For the purposes of this thesis, my discussion of the production stage focuses on the production of plastic materials purchased or utilized by *individual* consumers as opposed to businesses or corporations. The production stage of plastic is where plastic is developed and formed into a marketable product, such as microbeads, packaging, plastic bags, plastic straws, single-use bottles, and Tupperware. For the consumption stage, I center on the use of plastic products by the individual consumer. Finally, for the disposal phase, I examine the disposal of plastic materials. When available, regulations for each phase will be examined.

### Production

The US Congress passed the Microbead-Free Waters Act of 2015 over concerns surrounding the effects of cosmetic-utility microbeads that were being washed down the drain and impacting small fish and other wildlife, who were mistaking the microbeads as food (EPA, 2019b). As of today, this is the only federal law restricting production of a *specific* plastic product.

Much regulation in the plastic production/manufacturing sector on the federal level concerns reductions of hazardous air pollutants emitted as a by-product of manufacturing goods. The Clean Air Act (CAA) of 1970 authorizes the EPA to establish air quality standards in the interest of public health and welfare and to regulate the air emissions of hazardous air pollutants from multiple sources. Under the CAA, states were directed to develop state implementation plans (SIPs), which would apply to industrial sources in their state, making the industries accountable to the state in which they were located (EPA, 2019c). The Clean Water Act (CWA) of 1972, seeks to regulate pollutants released into US waters. A number of programs have been established under the CWA, including wastewater standards for industries, national water quality criteria recommendations for water surface pollutants, and the requirement of a permit to discharge any pollutant from a point source in navigable waters. Thus, the plastic industry is regulated insofar as the manufacturing of plastic must comply with the provisions of the CAA and CWA.

**Consumption**

There are currently no federal laws in the US restricting the use or purchase of plastics—single-use or otherwise. There are, however, a few states making progress in the movement to restrict and ban single-use plastic items, namely plastic bags, straws and, in some places, foamed plastics. *National Geographic* publishes a special series called "Planet or Plastic?"—a multi-year effort to raise awareness by providing various information and resources. One such article investigated what Gibbens (2019) identified as a "complicated landscape" in plastic legislation. The map from Gibbens' article, reproduced below, categorizes states according to the stage of state legislation regarding preemptions and bans on plastic as of August 2019.

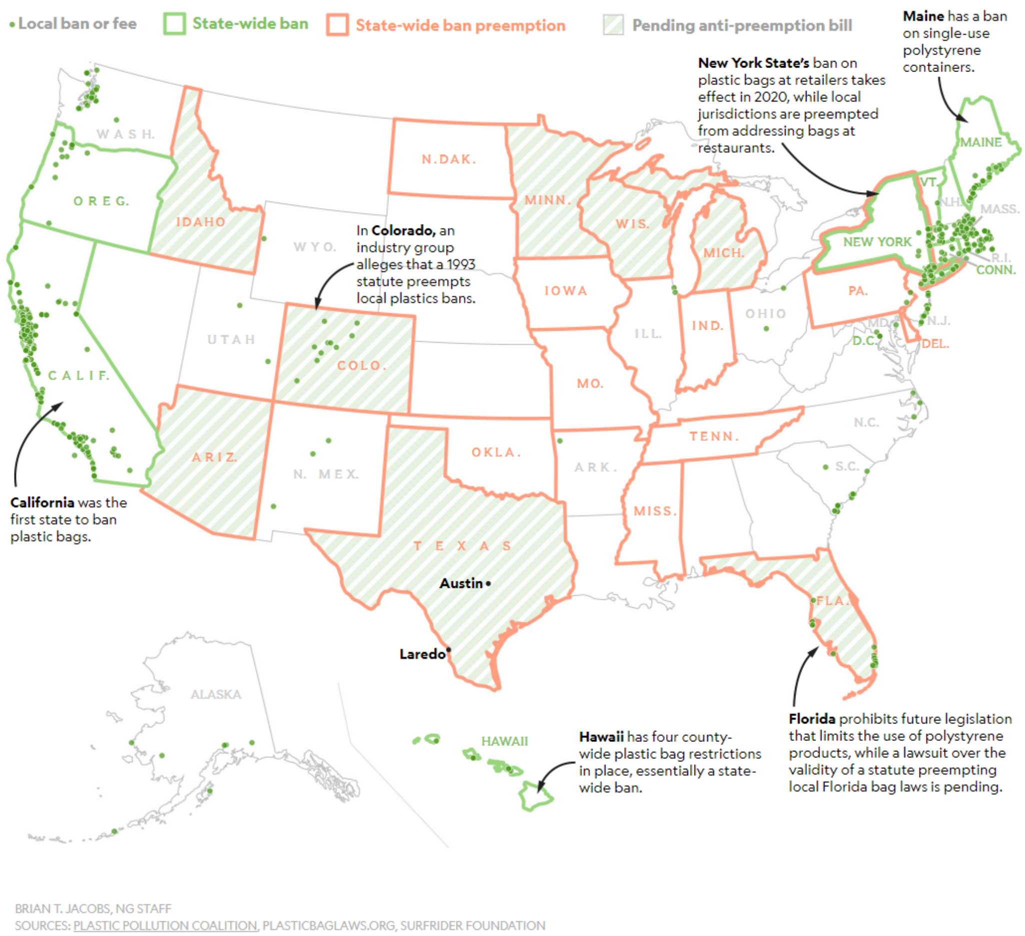


**Figure 1: Source(s): National Geographic; Planet or Plastic? See the Complicated landscape of plastic bans in the US. Sarah Gibbens. August 15, 2019.**

California was the first state to take the initiative to ban plastic bags, and more than 250 local jurisdictions in the state have additional plastic restrictions on items such as straws and foamed plastics (Gibbens, 2019). California lawmakers are discussing the phasing out of all plastic products that are not 100% recyclable in the state; even so, recyclability of plastic according to the resin identification coding (RIC) system (**Table 1** below), and the process of recycling it, are completely different matters, as discussed in the following section of this chapter. At the state level, Hawaii does not ban single-use plastics, but each of its four counties do, essentially rendering it a statewide ban.

Connecticut implemented a statewide ban on the use of plastic bags, causing retailers to switch to paper bags and the promotion of reusable bags. While not all regulations start in small government, much US legislation has roots in local ordinances and municipal regions, moving from grassroots movements to the state and sometimes federal adoption of similar regulations. Many of the campaigns against plastic consumption make appeals to the morals and conscience of consumers. Such appeals serve as a way of assigning responsibility for environmental health to the individual.

It is interesting to examine preemption laws (laws preventing local bans on plastic) and bans on plastic in **Figure 1** in comparison to state and legislative political party compositions. The National Conference of State Legislatures provides data on which parties control each state's legislature: Republican, Democratic, and "divided" or "split" (between Democratic and Republican). Aside from Nebraska, every state has a bicameral legislature, consisting of two separate legislative chambers or houses. In the majority of US states, the smaller chamber is referred to as the Senate (the upper house) and the larger chamber as the House of Representatives. A party has legislative control when it holds both chambers within a state and is "divided" or "split" when chambers are held by different parties. In order to have state control, the party must hold both legislative chambers and the governorship.

The data for 2019 are dated August 26, 2019, which coincided favorably with the information gathered from *National Geographic* in the map of states' plastic legislation (**Figure 1**, August 15, 2019). State-wide bans on the consumption of plastic material(s) are present in eight states; six states are held by Democrats, and two are divided between Democrat and Republican (NCSL, 2019). The eighteen states with preemption laws preventing municipalities from passing legislature banning plastic materials are held primarily by the Republican political party (Legis. Control 14/18; Gov. Party 11/18; State Control 11/18). Meanwhile, those states that have passed some form of plastic regulation or ban are primarily Democratic (Legis. Control 7/7; Gov. Party 6/7; State Control 6/7).

**Disposal**

As mentioned above, plastic does not biodegrade and it presents various harms for the inhabitants of ecosystems, as well as the economy and human health. Thus, there is a debate as to how to manage the plastic waste properly, effectively, and ethically. In many cases, plastic waste is sent to landfills or disposed of improperly (i.e., it is littered), with a slim 8.4 percent (3.0 million tons) recycling rate in 2017 (EPA, 2019d). At one time, the ocean was considered a massive landfill and countries would ship various types of waste, including plastic and chemical waste, to the middle of the ocean, where it would be dumped (EPA, 2020).

In 1988, the Society of Plastics Industry (SPI) developed the voluntary plastic RIC system, noted above, to address an increasing need of recycling programs in communities due to rising rates in waste. In 2008, SPI began working with ASTM International, an international standards organization, formerly known as American Society for Testing and Materials, to ensure that progressive developments in the plastic industry were updated in the RIC system. While the RIC system was intended for use in the recycling industry, today, the system is utilized by municipalities and various entities managing the end-of-life of plastics (ASTM, 2018). The RIC system was developed to identify resin content rather than recyclability, and consists of six categories of plastic resins, and a seventh category to include outliers as seen in **Table 1**.

**Table 1. System of Coding Plastic Resins.**

| Resin Code | Description | Packaging Applications |
|---|---|---|
| 1<br>PET | **Polyethylene (PET, PETE)**<br>**Aka. Polyester** | Beverage bottles, food jars (e.g., jams, jellies, peanut butter), microwaveable trays, and oven-able films.<br>**Non-Packaging Applications**: carpet, engineering moldings films, monofilament, strapping, and textiles. |
| 2<br>HDPE | **High-Density Polyethylene (HDPE)** | Bags for cereal box liners, grocery, and retail. Bottles for cosmetics, dish and laundry detergents, household cleaners, juice, milk, and shampoo.<br>**Non-Packaging Applications:** Injection molding, reusable shipping containers. |
| 3<br>PVC | **Polyvinyl Chloride (PVC, Vinyl)** | Flexible packaging (bags for bedding and medical, deli and meat wrap, shrink wrap, and tamper resistance). Rigid packaging (blister packs, clamshells).<br>**Non-Packaging Applications:** Flexible applications (medical blood bags, medical tubing, and wire insulation). Used as/for/in rigid applications (decking, fencing, pipe, railing, siding, window frames). |
| 4<br>LDPE | **Low-Density Polyethylene (LDPE)** | Bags for bread, dry cleaning, newspapers, fresh produce, frozen foods, and household garbage; shrink wrap and stretch film; coatings for paper milk cartons and hot and cold beverage cups; container lids, squeezable bottles (e.g., honey and mustard), toys.<br>**Non-Packaging Applications:** Used as/for/in injection molding applications, adhesives and sealants, and wire and cable coverings. |

**Table 2. System of Coding Plastic Resins (continued).**

| Resin Code | Description | Packaging Applications |
|---|---|---|
| 5<br>PP | **Polypropylene (PP)** | Containers for deli foods, margarine, takeout meals, and yogurt; medicine bottles; bottle caps and closures; bottles for catsup (Ketchup) and syrup.<br><br>**Non-Packaging Applications:** Used as/for/in fibers, appliances, and consumer products, including durable applications such as automotive and carpeting. |
| 6<br>PS | **Polystyrene (PS)** | Food service items (cups, cutlery, bowls, hinged takeout containers, meat and poultry trays, plates, and rigid food containers such as yogurt). *These items may be made with foamed or non-foamed PS.<br><br>Protective foam packaging for electronics, furniture, and other delicate items; packing peanuts, known as “loose fill”; compact disc cases and aspirin bottles.<br><br>**Non-Packaging Applications:** Used as/for/in agriculture trays, building insulation, cable spools, coat hangers, electronic housings, video cassette cartridges, and medical products and toys. |
| 7<br>Other | **Other** | Three- and five- gallon reusable water bottles, some citrus juice and catsup bottles, oven-baking bags, barrier layers, and custom packaging. |

**Source(s): Sinha, J. & Plamondon, C. (2017). Life Without Plastic**

The most commonly accepted RIC designations are one, three, and seven (Sinha & Plamondon, 2017), and as part of ongoing efforts by ASTM International, assigned task groups are striving to expand identification of materials currently designated as “other” in the RIC system. This can further assist consumers, manufacturers, and recycling programs in increasing the amount of plastic recycled properly.

Rochman, Browne, and colleagues (2013) present an argument for classifying plastic waste as hazardous, which would allow the EPA to act through the Comprehensive Environmental Response, Compensation, and Liability Act (known as "CERCLA", or the Superfund). Under CERCLA 42 U.S.C. §9601 et seq. (1980), the government funds the cleanup of orphaned hazardous waste sites when liability cannot be determined. When liability of the hazardous waste site is identifiable, the EPA is granted power to seek responsible parties and assure cooperation in cleanup (EPA, 2019). If classified as hazardous, the plastic debris/waste already filling the oceans and other sites of accumulation within the US jurisdiction would be susceptible to action by the EPA through CERCLA (Rochman & Browne, 2013). While CERCLA does not address plastic directly, it provides a potential avenue to waste management of plastic threatening the ecosystem post-degradation.

*Recycling Policies*

The EPA prepared a draft proposal of federal regulations that extend producer responsibility when it comes to the recycling of its own products (EPA, 2019b). This is due to the US's lack of efficient recycling programs, which are managed currently at state and municipal levels of government.

As alluded to above, recycling programs and regulations vary from state to state as there are is no federal oversight for the practice. Recycling is highly dependent upon the availability and convenience of programs within municipalities, as well as individual consumer recycling habits and knowledge. Many plastic materials/products are officially recyclable, but the local recycling programs may not have the means (equipment or finances) to recycle specific items. Recycling programs are responsible for the collection of a variety of materials including plastic, as well as cardboard, glass, metals, and paper (Lexington, KY Recycling). Common household recycling policies for glass, metals and plastics include curbside recycling, drop-off recycling, deposit-refund systems (bottle bills), and marginal pricing for household waste. Again, the recycling methods and acceptable materials are dependent on the local recycling center's capabilities.

In addition to relying on the municipality's ability to process recycled materials, recycling is heavily dependent upon individual consumers' ability and willingness to partake in the responsibility. In 2014, Nixon and Saphores published their study on the efficiency of household recycling policies across the country. According to Nixon and Saphores (2014), the most important determinants of household recycling is an individual's attitude towards recycling. If individuals view recycling as inconvenient or that the added effort bears little impact, recycling habits are likely to decrease. Thus, omitting perceived recycling obstacles and highlighting the benefits and any moral consideration may positively affect household recycling (Nixon and Saphores, 2014).

*Recycling Programs*

There are two main collection methods employed by municipalities for recyclable materials: curbside pick-up and drop-off locations. The increased convenience of curbside pickup is more likely to encourage individuals and households to recycle, as there is less hassle involved (Nixon and Saphores, 2014). Interestingly, drop-off locations are more common in rural areas and, according to the data from Nixon and Saphores (2014) study, rural residents are more likely to recycle than their urban and suburban counterparts (2014). Nixon and Saphores (2014) do not explain *why* rural residents are more likely to recycle, having collected only quantitative data that they recycle at higher rates. One could speculate that the increased likelihood of rural residents to recycle over their urban counterparts may be a product of the intimacy many rural residents have with the environment, which may encourage increased feelings of responsibility or action to keep the environment clean and healthy.

Outside municipal recycling programs, a collection of environmentally-conscious businesses and organizations provide alternative recycling locations and service that can accept recyclable materials the municipality may not be able to accept or process. The recycling center of Lexington, Kentucky, offers curbside recycling for the following items: aluminum and steel cans, dry cardboard, glass bottles and jars, and plastic screw-top bottles and jugs. Comparatively, Whole Foods Marketplace partners with a handful of organizations to expand customers' ability to recycle. The store, located in the Summit at Fritz Farm, accepts clean, dry recyclables including aluminum cans, cardboard, corks, and papyrus greeting cards, electronic waste, glass, paper and magazines, and plastic materials with resin codes #1-5 and #7. While the Lexington-Fayette Recycling Center accepts some of the same materials, individuals can increase the amount of waste they recycle through services offered through cooperative organizations operating outside of municipal or state services.

Additional approaches to encouraging recycling, as well as waste reduction, include market-based instruments, such as deposit-refund programs and unit-based pricing. Deposit-refund programs require consumers to pay a deposit that can be returned when the recyclable product is recycled appropriately. Unit-based pricing programs charge individuals for the disposal of their trash, but this program could lead to illegal dumping of waste, thus causing more harm than good (Nixon and Saphores, 2014; Viscusi et al 2013).

*Consumer Responsibility*

Recycling at the level of the individual consumer must be learned and become habit in order for the process to be effective. The attitudes, beliefs, knowledge, and norms of individuals are of importance when considering the likelihood of individuals to commit to recycle regularly. The first steps toward consumer responsibility in the purchase and management of plastics is a thorough consumer education regarding the items and materials (Fisk, 1973; Dauvergne, 2018).

If people do not know or believe the extent of harm propagated by plastic, understand how to recycle, or care about the effects of plastic because changing their current practices would be inconvenient, they are less likely to recycle. Knowledge of recycling programs (e.g. what materials are accepted, where to recycle) and environmental concerns surrounding plastic have a positive correlation with the inclination to recycle in the US (Nixon and Saphores, 2014). The most effective factor to encourage recycling of any materials is to make the act more convenient (Nixon and Saphores, 2014). The more convenient and less complicated the act of recycling is for the consumer, the more willing the individual will be to partake in it. This could be anything from not insisting upon the organization of recycling (e.g., identifying specific RIC codes, separating glass from other recyclables), to where recycling takes place (i.e. curbside bins, recycling drop-offs).

## V. Discussion and Conclusion

Today, plastic takes many forms and there are the seemingly endless applications and areas where it is used. Consider the difference between extended-use and single-use. These identifications refer to the manufacturer's intended use of products by consumers. Single-use plastic is intended to serve one function for a single, limited time and is then to be discarded via recycling or waste. Extended-use plastic is supposed to be used for prolonged periods of time, requiring replacement only when broken or worn beyond use. Examples of extended-use plastics could include car parts, reusable plastic bottles, toothbrushes, and various appliances. Once a reusable plastic needs replacement, the material may be discarded, recycled or, when accepted, returned to the manufacturer.

Knowing the present extent of harm caused by plastics in ecosystems and the adverse effects upon wildlife begs the question: why is plastic available for mass consumption in the form of single-use plastics? One of the greatest hurdles for plastic reduction is the deeply ingrained plastic culture wherein plastic use and consumption is part of the daily lives of the average person in the US. The plastic industry turned plastic from a novelty to a perceived necessity for consumers—all at the expense of planetary health. Furthermore, items that were once passed down as heirlooms, such as fountain pens and precious China sets were replaced with plastics that are now thrown away. The utility, price and accepted risks of plastic use are often provided as reasons for continued use. In addition, the perceived recyclability of plastics provides consumers with the impression that the plastic they consume will not cause any of the known harms associated with plastic waste.

The health of the planet is critical to the existence of every human and nonhuman animal. Arguably, humans hold more responsibility for maintaining the health of the planet than other forms of life due simply to the collective negative impact by humans in the last century alone. Unofficially, the Anthropocene is the current geological age in which human activity has greatly altered the environment and climate (National Geographic, 2019). It is within the power of governments to affect the practices of many individuals under their authority. If governments were to limit the production of plastic to essential products, such as those in the medical field, or to those products that are not so easily replaced or discontinued, plastic pollution and its adverse impacts would be reduced.

The use of plastic by individuals increases during times of crisis, as the COVID-19 pandemic has demonstrated. The use of items, such as hand sanitizers, household cleaning supplies, masks, plastic gloves, sanitary wipes, and toilet paper was so high that stores and warehouses were out of stock for weeks. Consumption of these items which are either plastic (gloves, masks) or have plastic packaging (cleaning supplies, hand sanitizers) was essential to the continued health and well-being of individuals. This lends credence to the continued use of many plastic materials in both single-use and extended use forms. Even so, there are viable alternatives to plastic that are deemed less preferable as they require more effort on part of the consumer or user of the product. Alternatives include metal or glass beverage bottles and food containers, metal straws, paper straws, and various hygiene products (e.g., body wash, conditioner, oils shampoo) in paper wrapped bars or metal or glass containers. These plastic alternatives require individuals to be mindful. Rather than buying drinks in plastic bottles and throwing the bottles into waste bins when finished, there are the added steps of remembering to clean them after use.

As noted at the outset, this thesis stated that the majority of plastic exists in a linear economy, wherein it is produced with raw materials, used, and then thrown away, ending up in landfills and the oceans. Comparably, in a circular economy, the materials would continuously reenter the cycle or be reused, without waste. While there are various recycling programs across the US, run primarily by local governments, current levels of recycling are miniscule and ineffective. Even so, many applications for plastic are unparalleled by alternative materials making it unreasonable to strive for complete removal of plastics from society. While the removal of plastic from society is currently beyond the realm of possibility, the control over *what forms* plastic takes, *where it is distributed* and *how it is consumed* is a significantly more attainable goal for the US.

A relatively short-term goal the US government could set would be the elimination of single-use plastics. An alternative to the plastic bags, which are used to bag fresh vegetables, fruits, and the like, arereusable cloth material bags. There is an adjustment period where consumers must train themselves to bring their reusable bags along for grocery or market trips. The US could take the next step and end production of the following single-use plastics: foamed plastics, plastic bags, packaging, straws, and beverage bottles.

The history of plastic, including its role in WWII and why plastic became so important during that time, is largely unknown to the general public. During WWII, mass production of war materials was necessary, and few resources were easily available. When the war ended, factories already equipped for producing plastic materials and products made the industrial application of plastic for the public a simple step. Today, plastic is used often without knowledge about or concern for many harms it has on planetary health. Nonhuman animals are suffering as a result of plastic pollution, and humans experience the ill effects as microplastics invade water and food sources. Potentially the greatest issue in the US is misinformation about the plastic recyclability and the common misnomer that the RIC symbols indicate that the product is recyclable at *all* recycling centers. Some states and municipalities are beginning to make progress in the reduction of single-use plastics in an effort to end plastic use where there are attainable alternatives. Preemption laws preventing the banning of plastic demonstrates resistance to regulations curbing plastic use by consumers.

Future research might investigate potential correlation between state political partition and the likelihood of a state to enact preemption laws on banning plastic. The education of consumers, beginning with information offered in this thesis, and the continued growth in regulations for plastic use in the US, are two ways to decrease harms caused by plastic through reductions in production and consumption.

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