Single-Use Plastic Legislation and Sustainable Waste Management

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Eric Powell

Spring 2020

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Joshua Earle, Department of Engineering and Society

Single-Use Plastic Legislation and Sustainable Waste Management

Introduction

Single-use plastics are widely prevalent in our society, due largely to the economics behind plastic as a cost-effective packaging solution. However, our society's relationship with single-use plastic has changed since their introduction in the 1950s. The challenge of managing our plastic waste has led to massive amounts of plastic piling up in landfills and oceans, wreaking havoc on the environment (Milbrandt et al., 2022). Recycling has been the answer since the 1990s, promising to turn unusable waste back into perfectly good raw material. Unfortunately, the recycling system has largely failed on the plastics front, and it is nearly impossible to avoid generating plastic waste in today's society. As a result, communities around the world have begun to search for new solutions, many turning towards legislation to regulate the production of single-use plastics. This paper evaluates the role of single-use plastics in society by investigating the drivers behind their prevalence and the effects that single-use plastic legislation has on the system. Understanding how each component of this complicated system affects one another is necessary in order to form a course of action that will prioritize sustainability and the environment.

This paper complements a technical project developing a low-cost near-infrared spectrometer for plastic classification, which would have applications in the sorting of recyclable plastic materials. This technology is included in the scope of this paper, but the focus will be on the larger systematic dynamics and how legislation fits in as a solution for plastic pollution. In this paper I begin by outlining the methods used for answering the research questions, before presenting the results of the research. In the analysis section following the research results, I

synthesize the findings to understand the dynamics of the system surrounding single-use plastics, and specifically how the plastic industry's influence has created a system that fails to sustainably deal with plastic waste. I follow this with a discussion on the role of single-use plastics in a sustainable society, and what future actions should be taken in pursuit of such sustainability. These future actions include further research into recycling technology and possible legislative approaches that could be used to prioritize sustainability.

Methods

In order to understand the various factors influencing the role of single-use plastics in society, I employ actor-network theory as a framework to illustrate the interactions between the relevant groups and technologies. Actor-network theory treats each element of a societal system as an "actor," whether human or inanimate, and uses the relationships between these actors to characterize the system's behavior (Latour, 2002). The main actors are single-use plastics, their manufacturers, legislation, and the recycling system. I also use a public policy methodology to investigate the history of legislation relating to single-use plastics, and determine what effects that legislation has had on the system as a whole. This analysis, combined with a look at the overall environmental impact of single-use plastics, serves to guide a path forward that prioritizes the environment and sustainability. The following section will begin with a look back at the history of single-use plastics and their impact on the environment, before exploring the attempts to solve the problem through recycling and legislation.

Results

The Plastic Industry and Recycling

The single-use plastic industry first began to grow around the 1950s, and global plastic production has increased by an average of 9% per year since (Chen et al., 2021). Single-use plastics make up half of the total plastic production, with single-use packaging applications comprising the highest portion. Single-use plastics affect the environment in a multitude of ways. Firstly, the production of plastic causes a significant release of greenhouse gas emissions (Shen et al., 2020). Once the product has been used, it becomes waste that is either recycled or ends up as pollution in a landfill or ocean. Not only does this waste litter the environment and contribute to harming sea life, but as plastic waste decomposes, it releases more greenhouse gas emissions (Royer et al., 2018). Greenhouse gases refer to gases such as carbon dioxide or methane, which trap heat in the atmosphere and contribute to global warming. The environmental consequences of generating so much plastic waste began to reach the public eye with the help of events such as the garbage barge *Mobro 4000* that floated around the Atlantic Coast for two months in 1987 (Acuff & Kaffine, 2013). This led to recycling programs growing quickly in the 1990s and consumers adopting recycling as part of their waste management routine. In theory, recycling would allow plastic to remain a viable and sustainable solution for applications such as single-use packaging, as the material could be reused rather than ending up as pollution.

However, while recycling has been effective for materials such as paper and metal, the same cannot be said for plastic. A recent study revealed that in 2019, only approximately 5% of plastic waste in the US was recycled, while 86% was landfilled (Milbrandt et al., 2022). Despite the recycling system existing for decades, it has failed to become effective at significantly reducing plastic waste, and this might not be as surprising to the plastic industry as it is for the

general public. An investigation by NPR (National Public Radio) and PBS (Public Broadcasting Service) Frontline showed that the plastic industry was aware that recycling wouldn't be effective at mitigating plastic waste in landfills and the environment. As early as 1974, an industry insider wrote that there was "serious doubt that [recycling plastic] can ever be made viable on an economic basis," yet the industry still pushed for recycling and launched ad campaigns to encourage it (Sullivan, 2020).

A major issue with plastic recycling is that it requires a difficult sorting process to separate different types of plastic. Other types of recyclable waste can be sorted through physical methods, such as the use of magnets to separate out metals (Veasey, 1997). However, within the plastics subset there are various types of resins with similar physical properties but different chemical compositions, making them difficult to sort with physical methods. In order for the recycling process to be efficient and economic, recycled resins need to have the same characteristics as the original materials and therefore should not be mixed (Bruno, 2000). Because this is process is difficult, plastic recycling struggles to be economically viable against the alternative—landfills.

The need for automated plastic sorting led to the development of solutions using infrared spectrometry to sort plastics (Vázquez-Guardado et al., 2015). Spectrometry is the measurement of the electromagnetic spectra that is reflected off or transmitted through a material. By using this technique, the type of plastic can be determined by detecting differences in the relative reflectance of that plastic at multiple infrared wavelengths. However, these solutions have not been able to fully solve the problem, as systems are expensive and have limitations such as the number of materials that they are able to distinguish. The technical project accompanying this paper develops a lower-cost, handheld application of spectrometry for plastic classification. This

project explored a tradeoff between the cost of the system and the scope of plastics that could be identified. Lower wavelengths were used for the spectrometry which allowed less expensive parts to be used, however not as many plastics have distinguishable features in the reflectance spectra at these wavelengths. While spectrometry solutions for plastic sorting have advantages and disadvantages, the technology shows promise and similar projects could help make the recycling process more efficient and profitable.

Three of the main actors in this system have been considered so far. First, single-use plastics, which were seen to be the cause of considerable harm to the environment. Next, the plastics industry, which was shown to be the main driving force behind single-use plastics. Finally, the recycling industry, which enabled the public to view single-use plastics to be viewed as a sustainable solution despite being ineffective in its current state to limit the problematic effects of plastic. In the following section I will explore a fourth main actor, legislation, to evaluate how it has affected this system over time.

Single-Use Plastic Legislation

Legislators have a unique position of working under the assumed goal of the public interest, while also being influenced by corporations through actions such as lobbying. As single-use plastics became increasingly prevalent and the environmental consequences fail to be solved by the recycling system, legislators began to search for a different form of solution that directly targets the source of the problem: the production of single-use plastics. A common target for such legislation is plastic bags, which some areas have introduced extra taxes on or banned completely. Plastic bags are especially problematic when it comes to recycling, as while they are recyclable, they must be recycled separately from most curbside recycling streams (*Store Drop-Off - How2Recycle*, n.d.). Consumers then face an extra amount of effort to drop bags off to be

recycled, increasing the likelihood that the bags end up in landfills instead. Plastic bag policy interventions date as far back as 1991, but only started to become more common in the 2000s, and are still very limited in some areas of the world (Xanthos & Walker, 2017). Another major category of plastic-limiting legislation has been bans on microbeads, also a form of single-use plastic, introduced in countries worldwide starting in 2014. There is very limited research on the efficacy of microbead bans, so this paper will focus on plastic bags to explore the impact of plastic-limiting legislation.

In 2002, legislators in Ireland enacted a tax on single-use plastic bags, and this was shown to result in a 90% reduction in plastic bag use, as well as plastic bag litter falling from 5% of the national litter composition to just 0.22% in 2004 (Dikgang et al., 2012). A similar approach was used in South Africa and resulted in a drop in plastic bag use in the short term, but the effect did not continue as it had in Ireland. This was partially due to the tax being too small, as well as insufficient monitoring of plastic bag consumption that made it difficult to create legislation that would change consumer behavior effectively (Xanthos & Walker, 2017).

Bans on plastic bags have also been introduced, such as in California in 2016 (California, n.d.). A 2019 report on the effects of this legislation showed that in the six months after the ban was enacted "there was an 85% reduction in the number of plastic bags and a 61% reduction in the number of paper bags provided to customers" (Smithline, 2019). The report also identified specific changes and clarifications that could be made to the ban, and recommended establishing enforceable reporting requirements for stores as well as possibly increasing the fee for reusable grocery bags if further incentivization for reuse is needed. A side effect of this legislation was that reducing carryout bags increased the sale of unregulated trash bags, which a study found to counteract 28.5% of the plastic reduction from the policy (Taylor, 2019).

While legislation has been seen to successfully reduce plastic waste, legislation can also be used in favor of plastic bags. Several US states have passed "preemption" bills that prevent local governments from regulating plastic containers and bags (Root, 2019). These bills are often pushed by plastic industry groups and corporate lobbying. Another way that the plastic industry has attempted to defend plastic bags was during the Coronavirus pandemic, when media campaigns were launched that argued reusable grocery bags could be a concern for spreading the virus (Schlegel et al., 2022).

There are also concerns about whether alternatives to plastic packaging could be more harmful to the environment. A report by the Center for Environmental Policy at the Imperial College London and Veolia UK argued that other materials such as aluminum or glass would produce more greenhouse gas emissions if all plastic bottles were replaced by these alternative (Voulvoulis et al., 2020). This indicates that a key factor in reducing emissions is reusability, and legislation that bans single-use plastic would need to consider whether the alternatives are reusable or at least more easily recyclable.

Analysis

In the results of this paper, I showed that there are multiple drivers behind the prevalence of single-use plastics, mainly the corporations producing them, as incentivized by the low cost of plastic packaging compared to other materials. Less obvious is how these corporations are able to influence the role of single-use plastics in society beyond simply manufacturing them. The plastic industry pushes the recycling system as a solution for plastic waste and supports it through ad campaigns to build the image of plastic as a sustainable material. Additionally, plastic

industry groups lobby for preemption laws that prevent other legislation from regulating single-use plastics. The actor-network surrounding single-use plastics is full of interconnected relationships, and the plastic industry has found ways to continue to grow and thrive despite the environmental damage that their products cause. Even with full knowledge of the waste material that is generated and the emissions that are released, the corporations are inherently driven by profit and consistently act in that sole interest.

Our society adopted the recycling system as a solution to the problem of excess waste without needing to significantly change the production systems already in place. This shifted responsibility away from plastic corporations, as their products were then considered sustainable as long as consumers did their part to recycle. The action of throwing a plastic bottle in the recycling bin certainly helps to clear the conscience, knowing that society has a system that will take care of it correctly. However, the recycling system has decidedly not achieved its goal of eliminating plastic waste from the environment. In fact, this is where the plastic producer's interest in the recycling system ends—it only needs to appear to make plastic sustainable, to actually reuse plastic would only reduce demand for the production of new plastic.

The economics of plastic recycling are what fate the system to be so ineffective. There are significant difficulties in sorting plastic considering there are many different types that have very similar physical properties, and the plastics that do get recycled tend to degrade with reuse anyway. Unless plastic recycling can be made profitable, it won't stop plastic waste from littering the environment or releasing greenhouse gases while ever-so-slowly decomposing in landfills and oceans. Advancements in plastic sorting technology show some promise in making the process more efficient, for example the use of infrared spectrometry in automated sorting systems that was explored in my technical project. However, sorting technology is only one part

of the picture and it would be irresponsible to assume at this stage that these advancements will save a system that has failed to recycle even 10% of plastic waste (Milbrandt et al., 2022). This isn't to say that plastic recycling would not still be a component of a future sustainable system, but that there will likely need to be reform on the production side as well.

Governments have begun passing legislation that attempts to reform the use of single-use plastic. However, legislation can be used both to disincentivize the use of plastic or to secure single-use plastic's place in society. This makes legislation a somewhat unique actor in this system—it does not always have a defined objective like the plastic and recycling industries that are motivated by profit, but instead can be influenced by outside actors and their interests. Because of this, I view legislation not simply as a solution to environmental problems, but as a tool that can be used to help form a more sustainable system if the correct motivations are established.

As legislation has found an increasing role in societies around the world, cases such as the Ireland study have shown that it can be effective in significantly reducing the amount of plastic usage and litter (Dikgang et al., 2012). However, this legislation and resulting effect was limited to a specific type of plastic waste: plastic bags. This is the case in many plastic-limiting policies, whether they focus on plastic bags or another type of single-use plastic such as microbeads, legislation requires a very specific scope and targets applications of single-use plastic that are easiest to regulate. While legislation has the potential to be effective, there are various factors that can influence its success, such as whether there is sufficient monitoring of plastic waste to evaluate possible approaches to policy. Additionally, we need to consider the side-effects of limiting single-use plastics, for example how a study on California's legislation found increased consumption of trash bags when plastic grocery bags were banned (Taylor,

2019). While this didn't completely counteract the benefits of the California policy, it highlights the importance of considering the alternatives to single-use plastics.

Alternatives to single-use plastics can include other materials that are either more easily recyclable such as paper straws, or more reusable such as metal water bottles (Fetner & Miller, 2021). The most suitable alternative varies on a case-by-case basis considering how widely the applications of single-use plastics range. Some products may not even have a viable non-plastic alternative yet. In cases where plastic needs to be used we would need to evaluate whether the specific type of plastic being used is as cooperative as possible with the recycling system. Another consideration when finding alternatives to single-use plastics is ensuring that physically disabled communities are not overlooked if they rely on a specific plastic product. For example, bans on plastic straws have been criticized for unequally effecting those who need flexible plastic straws due to physical conditions (Jenks & Obringer, 2020). Legislation banning specific applications of single-use plastics is certainly susceptible to this type of unintended effect, and this points towards the need for reforming the system as a whole to incentivize sustainability while keeping availability of products that are physically required for some communities.

The implementation of legislation can vary substantially, changing the effect it has on the system. Two similar approaches I looked at in this paper were single-use plastic bans and taxes, which were both seen to be successful in some cases. However, each approach has its own set of advantages and disadvantages, and the most effective path would vary for different areas of the world. For example, a tax on plastic bags requires the tax to be set at an appropriate amount for the specific economy, and there needs to be a way to monitor plastic bag usage to ensure the policy is working and evaluate whether the tax should be adjusted. A ban simplifies the economics of the policy, but risks having more significant side-effects like plastic straw bans had

on some disabled communities. In either case, it is critical that legislators address this issue on behalf of the environment, rather than helping the plastic industry with preemption laws. Corporate interest is not in sustainability, so if their influence over legislation continues to grow, the general population will be left with very little potential for action in reducing plastic waste and pollution. In the following section I will discuss future courses of action that could reform this system towards sustainability as well as identifying areas that require further research.

Discussion

The network surrounding single-use plastics is not an environmentally sustainable one, and we have seen that deliberate changes are needed to solve the problems of pollution that only grow worse each year. Legislation shows promise as the main avenue for making these changes, as the recycling system is unable and unwilling to work at the level necessary for sustainability when it comes to single-use plastics. However, plastic recycling will still need to be a part of the solution, and could certainly be successful if the system were reformed with the limitations of plastic recycling in mind.

We should use legislation to directly limit as much unnecessary plastic usage as possible to reduce the amount of waste that the recycling system is responsible for. Additionally, the system should incentivize plastics that are easier to recycle over those that degrade quickly and aren't as suitable for reuse. In this paper I have shown that legislation can be complicated to implement and alternatives for single-use plastic are the key factor in what applications are suitable for regulation. One should not imagine a sustainable system as one with zero single-use plastic production, but instead as one where we have greatly reduced the production of single-use

plastics to a point where the recycling system can profitably handle the waste. We should

continually pursue advancements in plastic sorting technology in order to make the recycling

system more capable to deal with society's waste, however this approach would likely not be

sufficient to overcome the economic barriers of recycling on its own.

It is possible that we could use legislation to provide extra incentives for recycling or to

establish taxes on new plastic production in order to motivate a more circular system. While the

introduction of recycling created the appearance of consumer responsibility, it is the plastic

producers who should be held accountable for the environmental effects of their products. The

main motivation for companies using single-use plastic packaging is the low cost, so reducing

the profitability of single-use plastic production is necessary in order to reform the system for

sustainability.

More research is required in evaluating the effectiveness of single-use plastic limiting

policies because there are many varying factors across different implementations. For example,

one study highlighted the lack of research on the effects of microbead bans (Xanthos & Walker,

2017). We will need continual evaluation of policies not only to ensure that they are being

followed but to guide future courses of action and discover any side-effects that were not

originally considered. This entails establishing sufficient methods for monitoring both plastic

production and plastic recycling to keep track of how much waste is generated and where it ends

up.

Further research on alternatives to single-use plastic is also necessary, including cost-

benefit analysis to understand how the system would act with and without legislation. This

includes research into suitable alternatives to plastic products that are generally relied upon by

disabled communities to ensure accessibility is maintained. Finally, research into a more efficient

plastic recycling process is needed to make the technology more profitable and sustainable. Research into these areas as well as the increased use of legislation in the forms explored by this paper could contribute to a more sustainable system—one that minimizes environmental damage from plastic waste by establishing accountability for the plastic industry and motivating the prioritization of using recycled plastics and plastic alternatives.

Bibliography

Acuff, K., & Kaffine, D. T. (2013). Greenhouse gas emissions, waste and recycling policy.

Journal of Environmental Economics and Management, *65*(1), 74–86.

https://doi.org/10.1016/j.jeem.2012.05.003

Bruno, E. A. (2000). *Automated Sorting of Plastics for Recycling*.

California, S. of. (n.d.). *Single-Use Carryout Bag Ban (SB 270)*. CalRecycle Home Page.

Retrieved October 12, 2022, from https://calrecycle.ca.gov/plastics/carryoutbags/

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production,

usage, disposal, and adverse impacts. *Science of The Total Environment*, *752*, 141772.

https://doi.org/10.1016/j.scitotenv.2020.141772

Dikgang, J., Leiman, A., & Visser, M. (2012). Analysis of the plastic-bag levy in South Africa.

Resources, Conservation and Recycling, *66*, 59–65.

https://doi.org/10.1016/j.resconrec.2012.06.009

Fetner, H., & Miller, S. A. (2021). Environmental payback periods of reusable alternatives to

single-use plastic kitchenware products. *The International Journal of Life Cycle

Assessment*, *26*(8), 1521–1537. https://doi.org/10.1007/s11367-021-01946-6

Jenks, A. B., & Obringer, K. M. (2020). The poverty of plastics bans: Environmentalism's win is

a loss for disabled people. *Critical Social Policy*, *40*(1), 151–161.

https://doi.org/10.1177/0261018319868362

Latour, B. (2002). *Aramis, or the love of technology* (C. Porter, Trans.; 4. printing). Harvard

University Press.

Milbrandt, A., Coney, K., Badgett, A., & Beckham, G. T. (2022). Quantification and evaluation

of plastic waste in the United States. *Resources, Conservation and Recycling*, *183*,

106363. https://doi.org/10.1016/j.resconrec.2022.106363

Root, T. (2019, May 16). *Inside the long war to protect plastic*. Center for Public Integrity.

    http://publicintegrity.org/environment/pollution/pushing-plastic/inside-the-long-war-to-

    protect-plastic/

Royer, S.-J., Ferrón, S., Wilson, S. T., & Karl, D. M. (2018). Production of methane and

    ethylene from plastic in the environment. *PLOS ONE*, *13*(8), e0200574.

    https://doi.org/10.1371/journal.pone.0200574

Schlegel, I., Cray, C., Hocevar, J., Melges, K., & Pinsky, D. (2022). *The Making of an Echo

    Chamber: How the plastic industry exploited anxiety about COVID-19 to attack reusable

    bags*. 21.

Shen, M., Huang, W., Chen, M., Song, B., Zeng, G., & Zhang, Y. (2020). (Micro)plastic crisis:

    Un-ignorable contribution to global greenhouse gas emissions and climate change.

    Journal of Cleaner Production, *254*, 120138.

    https://doi.org/10.1016/j.jclepro.2020.120138

Smithline, S. (2019). *SB 270 Report to the Legislature*. California Department of Resources

    Recycling and Recovery.

Store Drop-Off—How2Recycle. (n.d.). Retrieved February 13, 2023, from

    https://how2recycle.info/sdo

Sullivan, L. (2020, September 11). How Big Oil Misled The Public Into Believing Plastic Would

    Be Recycled. *NPR*. https://www.npr.org/2020/09/11/897692090/how-big-oil-misled-the-

    public-into-believing-plastic-would-be-recycled

Taylor, R. L. C. (2019). Bag leakage: The effect of disposable carryout bag regulations on

    unregulated bags. *Journal of Environmental Economics and Management*, *93*, 254–271.

    https://doi.org/10.1016/j.jeem.2019.01.001

Vázquez-Guardado, A., Money, M., McKinney, N., & Chanda, D. (2015). Multi-spectral

    infrared spectroscopy for robust plastic identification. *Applied Optics*, *54*(24), 7396–

    7405. https://doi.org/10.1364/AO.54.007396

Veasey, T. J. (1997). An overview of metals recycling by physical separation methods.

    Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process

    Mechanical Engineering, *211*(1), 61–64. https://doi.org/10.1243/0954408971529557

Voulvoulis, N., Kirkman, R., Giakoumis, T., Metivier, P., Kyle, C., & Vicky, M. (2020).

    Examining Material Evidence: The Carbon Footprint. Imperial College London.

    https://doi.org/10.13140/RG.2.2.12793.70241

Xanthos, D., & Walker, T. R. (2017). International policies to reduce plastic marine pollution

    from single-use plastics (plastic bags and microbeads): A review. *Marine Pollution*

    Bulletin, *118*(1), 17–26. https://doi.org/10.1016/j.marpolbul.2017.02.048