Portable Near-Infrared Spectrometer for Classification of Recyclable Plastics

The Environmental Effect of Single-Use Plastics as Driven by Legislations and Corporate Activity

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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.

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Introduction

Plastic waste and its destructive environmental effects has been a prominent issue in society, leading to the development of the recycling system. However, the current system lacks the efficiency and effectiveness required to mitigate the effects of plastic. There is an ever-growing need for improvements in recycling technology, as well as calls for the issue to be fought at its source, the production of single-use plastics.

The amount of recyclable waste that is generated by our society requires automated solutions for classifying and sorting materials in recycling facilities. Various sorting methods exists such as the use of magnets to separate metals from plastics (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). A solution is near-infrared spectroscopy, which can be used to sort plastics by detecting differences in the relative reflectance at multiple near-infrared wavelengths. This technology is discussed in the technical portion of the thesis, in the context of developing a portable spectrometer for plastic classification.

Sorting plastic waste is only a component of a solution to the systematic problem of single-use plastics. Despite advancements in recycling technology, the large majority of plastic waste does not get recycled, contributing to damaging environmental effects. In recent years this has led to a push for legislation limiting single-use plastics, such as California's ban on single-use plastic carryout bags (California, n.d.). The STS portion of the thesis will focus on the role of single-use plastics in society and explore how their impact has been shaped by the interactions

between corporations and legislation. This paper will conclude with a discussion on various key texts that will contribute towards completing this project.

Technical Project

Near-infrared reflectance spectroscopy provides a promising solution to the challenge of sorting recyclable plastic waste. This technology uses near-infrared electromagnetic radiation to measure the reflectance of a sample at multiple wavelengths. The relative ratios between reflectance at different wavelengths are used as an identifying feature that is unique for various types of resins. Recyclable plastic sorting systems have been created using this method and show effective results, for example one system achieved "accurate identification and separation of five major resins [by] calculating the relative reflectance at two wavelengths in the NIR region" (Masoumi et al., 2012). Automated systems allow for much higher efficiency than manual sorting, but most of the available industry technologies are very costly and are not as viable of an option for lower volume recycling centers (Bruno, 2000). In addition to inefficiency, manual sorting is labor intensive—it can be difficult to distinguish some polymers, especially if the samples are in poor condition or lack a label. A less expensive application of spectroscopy could help alleviate these problems by increasing availability of automated solutions.

The technical portion of the thesis will follow the development of a low-cost, portable spectrometer with the goal of increased availability of plastic classification technology. This device achieves a lower cost by measuring with shorter wavelengths of near-infrared radiation that can be implemented with less expensive parts, with the tradeoff of limiting the classification scope to three common polymers: polyethylene terephthalate (PET), high density polyethylene (HDPE), and polypropylene (PP). This project strives to explore the feasibility of smaller scale plastic classification technology that could be applied to automated recyclable waste sorting solutions. The end goal is to improve the efficiency of the recycling system and mitigate the

environmental impact of single-use plastics. The greater societal context of single-use plastics and possible legislative solutions are discussed in the STS portion of this paper.

STS Project

The recycling system has been shown to be shockingly ineffective at preventing plastic waste from reaching landfills. In 2019, only approximately 5% of plastic waste was recycled, while 86% was landfilled (Milbrandt et al., 2022). Although improvements in recycling efficiency could help increase the amount of plastic that gets recycled, a full solution to plastic waste will require examining the root technology of single-use plastics and its place in society. Legislation to limit single-use plastics has been enacted in various countries and states in attempts to reform the system itself to reduce our reliance on the inadequate plastic recycling process (Goldstein, 2019). However, some states currently have legislation on the other side of the issue, referred to as "preemption" laws, that prevent local governments from regulating plastics (Root, 2019). The STS project will explore how single-use plastics and their environmental impact has been driven by the corporations producing them and recent legislative actions to limit them. Understanding these interactions is critical to find large scale solutions for reducing the plastic waste that ends up releasing greenhouse gases while slowly decomposing in landfills and oceans.

There are many different social groups that interact with single-use plastics, including political decision makers at various levels of government, people with positions of power in the corporations that manufacture and use single-use plastics for packaging, and everyday consumers. Consumers are a very broad group that ultimately serves as the link between single-use plastics and their fate as recycled or landfilled plastic waste, though consumers only have as much agency in the matter as the system allows. Any discussion on single-use plastics and possible alternatives will need to consider the consumer point-of-view, though the most important social groups for my STS project will be the political decision makers and the plastic

manufacturers, as they have significantly more power over how single-use plastics are used in our society.

In order to complete this research project, I will employ the actor-network theory framework (Latour, 2002) and public policy framework to characterize the interactions between single-use plastics, their manufacturers, legislation, and consumers. Plastic recycling centers are also a key actor, and tie back to the plastic sorting technology focused on in technical portion of this project. However, the STS project is more concerned with the production and use of single-use plastics than the details of the plastic recycling technology, which is only a single aspect of a large network. I will also use methods of history as well as public policy to explore the concrete effects of single-use plastics on the environment in the past and how legislation has changed those effects. This will involve finding and synthesizing previous literature to draw connections with current systems and their legislative actors. Additionally, I will investigate the processes by which plastic legislation has been created, specifically looking at what groups lobby for and against single-use plastics and what the impact of that lobbying has been.

This thesis project will be completed mostly during the spring semester of 2023, although I plan to begin foundational work in the months before. This includes completing the design of the technical project by then end of the fall semester, as well as beginning the research process and gathering primary sources that can be synthesized together for the final thesis paper. The work done in the spring semester will begin with researching the overall trends of single-use plastic production and the environmental impacts. As the semester continues, I will shift towards researching single-use plastic legislation in depth and identifying possible ways in which corporate lobbying has affected such legislation. The following section of this paper will identify and discuss a few key primary sources that will be important for completing the STS project.

Key Texts

An important source for understanding the current state of the recycling system and its effect on plastic waste is a study done by the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) (Milbrandt et al., 2022). This study explores the effectiveness of plastic recycling by quantifying the amount of plastic waste, where that waste ends up, and the pertinent economic effects. This contributes to the STS project by establishing a baseline for current methods of mitigating plastic waste.

Another primary source that will be useful for this project is a 2019 report done by the California Department of Resources Recycling and Recovery that evaluates the effects of the 2014 California legislation against single-use plastic bags (Smithline, 2019). The report will serve as an important look into the effectiveness of single-use plastic legislation and help to determine whether legislation is a viable solution to reducing plastic waste. The report also recommends areas to clarify in the law, which could provide insight to any interactions with society that may not have been fully thought out in the process of writing the law. This creates an opportunity for iterative sociotechnical analysis to determine how the legislation could be altered to be most effective.

A 2020 report by the Center for Environmental Policy at the Imperial College London and Veolia UK provides a different perspective on the environmental effects of single-use plastics and their alternatives (Voulvoulis et al., 2020). This report argues that plastic waste is a relatively unimpactful source of greenhouse gas emissions, and that the production of alternatives to single-use plastic bottles such as aluminum or glass emit more greenhouse gases. This will be an important perspective to consider for the STS project, as it investigates the

practical effects of alternative materials such as fiberboard or glass that would be required under single-use plastics bans.

A 2020 research brief by Greenpeace summarizes actions that plastic industry corporations have taken against single-use plastic regulations (Schlegel et al., 2022). This includes a look at how Covid-19 affected public perception about reusable plastic alternatives and their safety. The paper also provides a timeline of notable recent events relating to plastic legislation and an overview of some of the main actors working against plastic legislation. This source will be important for gaining a full view of who is involved in the processes surrounding single-use plastic legislation and will help identify specific cases to research further.

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