Millersville University

# The Challenges of Plastic Recycling in the Environmental, Social, and Business Spheres

A Senior Thesis Submitted to the Department of Biology and University Honors College in Partial Fulfillment of the Requirements for University Honors

By

Madison Broussard

December 2025

**This is a placeholder page and not part of the original document submitted for approval.**

The original page of this document containing the signatures of the parties involved has been extracted to protect their privacy.

Please contact the

Millersville University Archives & Special Collections

with any questions.

Placeholder version 1.0

Table of Contents

# The Plastic Crisis

## Background Information

Plastic is a relatively new manufactured material that has only been developed in the past century. The first fully synthetic plastic was made in 1907, with the intention of using byproducts from the production of crude oil and natural gas; however, plastic production did not significantly increase until the end of World War 2 (Science Museum, 2019; Napper & Thompson, 2020). Plastic has been important to many manufacturing practices since and today we see plastic everywhere, in the production, development, and packaging of everyday products. For example, plastic packaging of surgical tools prevents contamination and reduces the chance of infection. Plastic offers several benefits including its high durability, lightweight nature, ability to act as an insulator, resistance to corrosion, and cost-effectiveness (Napper & Thompson, 2020; Sigler, 2014). The use of plastic as a metal replacement in cars makes them lighter and more fuel efficient resulting in cost savings.

Plastic is a synthetic polymer that is composed of chains of hydrogen and carbon molecules called hydrocarbons, to which other additives and polymers can be added to get the desired appearance and abilities (Napper & Thompson, 2020). For example, plasticizers like phthalates and PCBs are added to PVC to make it more flexible for piping and cords. Plastic can also be created to mimic the appearance of other more expensive materials that are harder to acquire and work with, such as plastic that is meant to look like ivory, making it a cheaper and more sustainable option. While plastic is versatile and can be used in a variety of ways, around one third of plastics produced are made for single use products which are designed to be used once then discarded, contributing to plastics biggest downfall in that they are created with the intention of being thrown away (Sigler, 2014). It is this widespread use and production of single-

use plastics that makes plastic production an unsustainable and harmful process. Since its creation, plastic has invaded every aspect of our lives, raising growing concerns about how to manage it. In this paper, I will address the following: the impact of plastic pollution on marine ecosystems, the types of recycling and their respective challenges, what constitutes sustainable plastic management, the different forms of accountability, case studies on plastic production and producer attitude, and a survey on the knowledge and attitude of biology students towards recycling.

## Plastic in the Marine Environment

As one of the most widely produced materials in the world, plastic has made its way into almost every ecosystem on the planet and due to its nonbiodegradable nature, when it enters an ecosystem, it stays there for a significant amount of time, therefore the widespread scope of plastic pollution makes it hard to manage and control (Williams & Rangel-Buitrago, 2022; Science Museum, 2019). Although plastic can be degraded with sunlight, microbes, water, and high temperatures, these processes can form microplastics which are pieces of plastic between one nanometer and five millimeters in size (Mrowiec, 2017). There are two types of microplastics: primary and secondary. Primary microplastics are manufactured to that size, while secondary microplastics are created from the fragmentation and degradation of macroplastics (Mrowiec, 2017).

Plastic is the most prominent type of anthropogenic pollution in the ocean and plastic composes between 50-100% of all marine litter and debris (Eriksen, 2014; Williams & Rangel-Buitrago, 2022). Around 70-80% of the plastic in aquatic ecosystems comes from inland manmade sources and can enter seas and oceans through spills, illegal dumping, wastewater treatment plants, shipping lanes, fisheries, urban runoff, and human waste from beaches (Sigler,

2014; Mrowiec, 2017; Iroegbu et al., 2021). Most microplastics come from synthetic clothing which, when washed, shed microplastics into wastewater and subsequently, the ocean (Weis, 2021). A quarter of the waste that enters the ocean comes from ten rivers that are mainly in Asia and Africa, with most plastic coming from the Yangtze River in China (Patel, 2018). Some plastics are easier to gather and identify than others, while microplastics and beads are harder to catch due to their size as it is easier for them to pass through facility treatments and into the ocean (Eriksen, 2014). Nanoplastics, which are smaller than microplastics, can pass through biological membranes and enter bloodstreams, making them a major problem for many organisms and like microplastics, they are too small to be easily caught (Mrowiec, 2017). Most of this plastic litter is found on the ocean's surface or shorelines, however, buoyancy impacts where litter is located and how fast it moves which means that plastics can travel between levels of the ocean, and as a result, are found in all parts of the water column (Morales-Caselles et al., 2021; Mrowiec, 2017).

Many plastics end up stuck inside ocean gyres which are large circular water patterns, and once trapped in the gyre, they accumulate in large piles that can attract pollutants due to their hydrophobic nature (Sigler, 2014; Verma et al., 2016). A potential positive outcome is that large piles of plastic debris and litter can act as a habitat for many organisms, but due to the movement of water, they can also act as rafts for invasive species (Williams & Rangel-Buitrago, 2022; Eriksen, 2014; Sigler, 2014). While the hydrophobic uptake of chemicals can remove them from the environment, it can also lead to a zone full of hazardous chemicals which can impact already vulnerable ecosystems (Iroegbu et al., 2021; Verma et al., 2016). Most pollutants impact the euphotic zone, the top layer of the ocean where most photosynthesis occurs, which can impact primary production and enforce bottom-up control which is when a reduction in organisms and

energy at a lower trophic level, leads to further organismal decreases in higher trophic levels (Dybern, 1974). This has detrimental implications because these ecosystems are already vulnerable due to changing environmental conditions, competition from invasive species, and changes in the chemical processes occurring in the ecosystem. As a result, many species are unable to adapt and change fast enough to counteract these threats.

Marine and coastal environments are highly productive and diverse, therefore, the protection of them is important to humans and other organisms alike (Thushari & Senevirathna, 2020). These ecosystems provide many services that range from recreational to economical. With the close intricacies of aquatic and terrestrial ecosystems, they often impact each other (Thushari & Senevirathna, 2020). Water moves between both systems and is necessary for the survival of many organisms, with many terrestrial species also consuming marine and aquatic organisms for food.

Aquatic wildlife can be injured by plastic in many ways, with the most prominent causes being ingestion and entanglement (Williams & Rangel-Buitrago, 2022; Sigler, 2014; Eriksen, 2014). Because plastics come in all shapes and sizes and have various appearances, it is common for organisms to mistake plastic for something they can eat, which is a phenomenon known as food mimicry. An example of this is when turtles mistake plastic bags for kelp or jellyfish (Eriksen, 2014). Upon consumption, plastic can cause internal injuries, stunt growth, and block the intestines and digestive tracts (Williams & Rangel-Buitrago, 2022; Sigler, 2014). Studies have shown that plastic can fill up an organism's stomach but cannot be moved through their digestive system because they cannot break down plastic in their bodies. As a result, the organisms die of starvation because they cannot consume prey (Williams & Rangel-Buitrago, 2022). Consumed fishing lines can cause the gut of an organism to pinch together resulting in

death (Wabnitz & Wallace, 2010). In general, birds who consume organisms from within the water column, as opposed to the surface, tend to have less plastic in their system because most plastic accumulates on the ocean's surface. Seabirds associate plastic with zooplankton due to the reflective surface of the plastic, leading to more consumption of plastics in birds who eat from the water's surface. An increase in oceanic plastic results in an increase in the amount of plastic consumed by seabirds and juvenile birds especially because they consume large amounts of plastic from the food that is regurgitated from their mothers. Cetaceans do not consume plastic in the same way as other marine organisms because their echolocation allows for them to distinguish plastic from living organisms. However, due to their feeding strategies, they often consume plastic while trying to catch prey, as plastic and prey are mixed. Plastic has been found in many fish species, but data are lacking with regard to specific impacts that it has on them. However, fish are eaten by many organisms, including humans, and microplastics bioaccumulate up the food web (Sigler, 2014). Microplastics are problematic because they can act as endocrine disruptors for mammals and cause death with extreme exposure (Williams & Rangel-Buitrago, 2022).

Entanglement occurs when an organism gets stuck in a piece of plastic and this is most prominently seen with nets, fishing lines, and soda wrappers (Williams & Rangel-Buitrago, 2022). Entanglement can also impact the growth and development of organisms and those organisms that get stuck as juveniles do not grow as large as their un-trapped counterparts (Sigler, 2014; Williams & Rangel-Buitrago, 2022). Entanglement also has the potential to cause wounds that could become infected, which could lead to health complications. It has been found that juveniles are more likely to get caught in marine litter because they tend to be more curious than older members of their species and acts of play could lead to them getting caught and

injured (Galgani et al., 2018). Organisms that survive entanglement experience challenges with catching prey and avoiding predators due to the physical affects they experience. Unfortunately, in too many cases death occurs through strangulation and drowning as organisms may not be able to escape (Sigler, 2014).

Management strategies involve preventing plastic production and pollution at its source, and treating pollution that cannot be prevented however, many countries do not have proper policies and enforcement to implement appropriate management strategies (Nikiema & Asiedu, 2022). With the diversity of plastic types and usage, different combinations of policy are often necessary which is why there is not just one practice alone that can solve this problem. There has been a global demand for better practices and bodies that actively enforce laws and hold polluting corporations accountable, however studies have shown that bans on plastic products are only effective when the public is aware of the issue, and said bans can be enforced (Nikiema & Asiedu, 2022). Additionally, countries tend to follow the example of neighboring countries and are more likely to enforce bans and preventative measures when others do it too. Since waste can cross boundaries, international policies are needed to discuss management and prevention strategies. It has been shown that voluntary practices are more effective when they target companies as opposed to individuals because the presence of plastic in so many products makes it much harder for individuals to avoid plastic than it is for companies to stop producing as much, as a result practices that reduce plastic use can be cost effective but tend to rely on increased profit from customer support. Recently, customers have been more likely to investigate the ethical production of products which is seen in the support of a circular and carbon-neutral economy. This means that processes that reuse waste materials, reduce byproducts, and the net amount of carbon released and absorbed are the same (Nikiema & Asiedu, 2022).

Some ways to prevent plastic pollution is to educate the public, invest in green alternatives, and hold companies accountable for their actions (Iroegbu et al., 2021). The redesign of products, beach cleanups, and monitoring plastic removal from ecosystems are all adequate solutions; however, they will not be able to create the big changes needed to save the environment (Sigler, 2014; Wabnitz & Wallace, 2010). Efforts to mitigate plastic pollution need to be more efficient and effective, and companies need to be held accountable by consumers and countries alike for their actions.

## Recycling

### Traditional Plastic Waste Disposal Methods

The traditional way to dispose of plastic waste is by burying the waste in a landfill then covering it from above. However, landfills run into space limitations because there are only so many places to build them. Also, people do not want to live near one as they are not aesthetically pleasing to look at. While well-managed landfills should not cause environmental harm, there is still potential for the waste to leak into the environment and water supply. Another downside is that energy cannot be regained from landfills as the waste is not recovered or remanufactured (Hopewell et al., 2019). Incineration is the process of breaking plastics down to their molecular components with heat. It does not have the same space limitations as landfills; however, the burning of plastic can create pollution and release harmful chemicals. Technology has been created to recover energy from this process, which could aid in the production of new products, but currently it is not an affordable alternative for companies (Hopewell et al., 2019). Downgauging is the process of using less plastic in products. Many companies already do this; however, these new designs tend to be less aesthetically pleasing, and they also have the potential to be less effective due to thinner materials (Hopewell et al., 2019).

The current waste management systems are unstable and will not be able to support themselves with the projected increase in production and consumption rates. It is expected that they will require five times the number of resources that are currently being used. This would only make climate change and health problems worse and continue to deplete our nonrenewable resources. One way to understand this is through the Inter-sectoral Health and Environment Research for Innovation (INHERIT) model, which investigates how processes will impact the environment currently and, in the future, while also looking at inequality and health of citizens. It does this through the utilization of analytical models, conceptual framework, and environmental and social impact assessment tools (Llorente, 2019). The INHERIT model is meant to support people and help with local level change as it gives citizens evidence to support their claims. While it is difficult to apply its findings to a global level, it empowers people at an individual level which aids in the adoption of sustainable practices (Stegeman et al., 2020).

## Background Information

Recycling is the process of collecting materials and remanufacturing them into new products (United States Environmental Protection Agency, 2019). There are three main steps in the recycling process: collection, processing, and remanufacturing. Collection is when materials are collected by recycling companies; processing involves cleaning and sorting the recyclables, which allows for contaminants to be removed, and like recyclables to be paired together; and remanufacturing is when the recyclable materials are turned into new products that can then be redistributed and used again. Recycling benefits both the environment and the economy. Environmental benefits include the reduction of waste, conservation of natural resources, pollution prevention, greenhouse gas reduction, reduction in material consumption, reduction in landfill contamination, and energy efficiency (United States Environmental Protection Agency,

2019; Mwanza, 2021). Economic benefits include the creation of domestically sourced materials, jobs and education opportunities, and profitability for companies. However, recycling also faces many challenges in relation to community and cost (United States Environmental Protection Agency, 2019; Mwanza, 2021). Community problems are related to a lack of understanding of the recycling process, which results in contamination and misplacement of recyclable goods. Another problem is that recycling manufacturers are unable to keep up with the amount of waste produced, a problem that has only increased following the loss of being able to ship waste to other countries (United States Environmental Protection Agency, 2019). Furthermore, recycling sites can be unsafe and unhygienic due to contamination of materials and the environment (Mwanza, 2021). In terms of cost, recycling costs more money than other management strategies and technological advances are not occurring fast enough to reduce this cost which is a problem because recycling is an energy intensive practice (United States Environmental Protection Agency, 2019; Mwanza, 2021).

Only 9% of plastic waste is recycled, and 22% is mismanaged, meaning it is not collected or inadequately handled and because only specific types of plastic can be recycled, most plastic ends up in landfills (OECD, 2022; Science Museum, 2019). As both populations and incomes increase, there has been a steady increase in plastic used and discarded and the current recycling technology cannot keep up with the current and prospective usage rates. Half of the plastic in the world is produced by Organization for Economic Cooperation and Development (OECD) countries, with the United States, European countries, Korea, and Japan being top producers. The United States produces the most plastic waste with 221 kg per person annually (OECD, 2022). Although smaller plastic is easier to recycle as it is less energy intensive, most plastics are not recycled because the process is difficult and it is cheaper and easier to make new plastic than to

reuse old plastic (SL Recycling, 2020; DiFelice, 2023). Recycling is not the only waste management practice, but it is the one with the most room for development.

There are four categories of recycling. Primary recycling is the process of turning plastic into a product with similar properties; a process that uses less materials and energy when compared to the other categories and it is useful when plastic can be separated from contaminants. However, only specific plastic types can be recycled with this method, so it can only be used in limited capacities (Hopewell et al., 2019; Mwanza, 2021). Secondary recycling is the process of turning a plastic into a product with lower properties in this case products of secondary recycling are typically combined with virgin polymers to make a new product (Hopewell et al., 2019). Both primary and secondary recycling use mechanical recycling processes, which result in products that are not as durable because the polymers often get warped in the cleaning and recombination processes which creates products of a lower quality (Mwanza, 2021). Tertiary recycling is the recovery of chemical components, a form of recycling also known as chemical recycling which is common due to its high efficiency, however, this process can be quite expensive (Hopewell et al., 2019). Quaternary recycling is the recovery of energy by burning the recyclable material and generating either heat or electricity (Hopewell et al., 2019; Mwanza, 2021). This process does release hazardous chemicals, and since there is no physical product produced, it is not technically a form of recycling (Mwanza, 2021).

## Types of Recycling

There are two types of recycling. Mechanical recycling washes the plastics and either grinds them down or melts them, which is currently the best plastic management process due to its cheaper cost, energy efficiency, and less ecological harm (SL Recycling, 2020; Mwanza, 2021). The other form of recycling is chemical recycling which breaks plastic down to their

molecular components and turns them into fuel (SL Recycling, 2020). Chemical rec.ycling can keep plastic out of the ocean because it will be broken down in plants instead of disposed of and it allows for plastics that are mixed to be broken down, something that mechanical recycling cannot do (Gribkoff, 2022; Mernit, 2023). Chemical recycling has been heavily criticized because it does not decrease plastic pollution or help to prevent climate change. In fact, this practice introduces new toxins into the environment that are harmful to organisms as it can create air pollution, and introduces microplastics to the environment (DiFelice, 2023; Gribkoff, 2022).

Pyrolysis is the process of heating plastics so their molecules can break apart. This creates a petroleum-like feedstock, which can then be used to create more plastics or act as fuel; however, this process is not actually recycling because the fuel product can only be used once. The fuel that is burned off by a plane cannot be reused or repurposed which makes this practice single use because there is not a clear cycle, the product is never recovered at the end. Plastic itself is not a renewable resource and should not be treated as such. The process of making this fuel is also dangerous as people who are exposed to emissions in the production process are more likely to get cancer, and it adds emissions to the environment (Mernit, 2023).

Biodegradable plastics are a great alternative because they can easily break down in the environment without as many ecological issues; however, they are only effective when paired with proper technology, money, and consumer education and many companies are not willing to give up their profit for these plastics. Biodegradable plastics also need large amounts of biomass to be produced, which can be difficult and costly to find (Hopewell et al., 2019). At present, our current technologies are not effective enough to tackle the mounting plastic crisis and thus the market for advanced recycling technology will continue to grow (Mernit, 2023). Recycling is ineffective due to increasing mass production of plastics, unrefined technology, and low public

awareness and participation in recycling. Studies have shown that recycling is more common when there is a recycling bin next to trash cans, and when a recycling bin is not near a trash can, people are more likely to throw a recyclable product into the trash. Even when signs are changed to display what items can be recycled, there is not an increase proper recycling or waste disposal. The only way to get the public to change their mindset is to educate them about plastic problems (Andrews et al., 2013).

Technological advancements have the largest potential for creating better sustainable practices. For example, by improving current sorting technologies, more plastics could be properly recycled (Moshood et al., 2022a). Recycling in general will also make these practices better. To increase recycling, there should be better waste collection and separation strategies, a steady supply of waste products, markets that are receptive to these processes, and the production of high-quality items that garner public support (Milios et al., 2018).

## Sustainability

### Background Information

Sustainability is the process of using materials in a way that is not harmful to future generations and typically includes renewable resources, eco-efficiency, and a green supply chain (de Vargas Mores et al., 2018). Through these sustainable practices companies and individuals can make decisions that benefit the environment and themselves. Sustainability focuses on healing the planet, while also maintaining necessary manufacturing processes.

There are three main aspects to sustainable manufacturing: economic, environmental, and societal. Economic aspects look at small and local companies, producer responsibilities, material

cost, competition, technology, and technical requirements that are related directly to the economy, with changes having direct correlations to revenue. In the economic sector, there is often high competition between producers, a lack of responsibility from producers, subpar technology, and unstandardized technical requirements which makes it difficult to maintain sustainable practices in an economic sense (Mwanza & Mbohwa, 2017).

Environmental aspects are related to certifications, testing, waste management, legislation, and product designs. This involves understanding how the products and processes impact the environment, and what can be put in place to prevent negative results. Lack of company certifications, quality testing, proper waste disposal, legislation, and creating environmentally friendly designs are all challenges to environmental aspects of sustainability and are often due to improper funding and not enough public or governmental support (Mwanza & Mbohwa, 2017).

Societal aspects are related to manufacturing, public opinion, domestic demands, and research and development which are driven by the public because they are related to how individuals and groups behave. The limited number of manufacturers, the public's negative views on waste disposal companies, low domestic demand, high quality demands, and lack of research are all challenges to the societal aspects of sustainability (Mwanza & Mbohwa, 2017). All three of these aspects are interconnected and play a role in the regulation and development of sustainable manufacturing. Because manufacturing is a major component of a country's economy and is a necessity for revenue and development, there is a need for more sustainable practices because they have the potential to be more advantageous in the long-term (Mwanza & Mbohwa, 2017).

Sustainable Practices

A common form of sustainability is the creation of sustainable packaging, which is focused on effectiveness, decreasing waste production, and promoting cyclic behavior (Lewis et al., 2010). Sustainable packaging is usually easier to break down and focuses on the large-scale impact as opposed to how well the product will sell. Another sustainable practice is the creation of bioplastics plastics which are biobased and biodegradable plastics (Moshood et al., 2022b). These plastics use renewable resources, can be easily recycled, and have the potential to be more energy efficient than synthetic plastic counterparts (Álvarez-Chávez et al., 2011). Bioplastics can be physically altered to be more durable, allowing for them to better compete with synthetic plastics (Moshood et al., 2022a). Biobased plastics are made from nonpetroleum based feedstocks; however, not all biobased plastics are biodegradable and break down when exposed to microbes. Biodegradable plastics do break down and typically completely break down between 20 to 45 days, while most synthetic plastics take hundreds of years (Moshood et al., 2022b). However, bioplastics also need intense heat to break down efficiently, which is difficult to achieve in the natural environment (Cho, 2017).

One example of a problematic plastic in the environment is plastic bags. Plastic bags have become a staple for recycling advocates, as they are utilized daily and the shift to alternative materials for bags has been a significant sustainable behavior change that allows for individuals to make a positive difference. Plastic bags are used because they are strong, inexpensive to produce, and are waterproof; however, they are a large component of pollution and take hundreds of years to break down. Alternatives to plastic bags are single-use paper bags and plastic reusable bags (Lewis et al., 2010). Paper bags can break down faster than plastic bags and are more environmentally friendly when placed directly outdoors; however, it turns out that plastic bags are more energy and health friendly than paper bags. A Frankline Associate's study

found that plastic bags require 20-40% less recycling energy, contribute to less solid waste, release 90% less waterborne emissions, and have less atmospheric emissions than paper bags. For paper bags to match the energy use of plastic bags during production, paper bags need to be recycled at a rate of at least 60% (Lewis et al., 2010). While single-use paper bags do not have as many environmental impacts on organisms as plastic bags do, they are not a viable replacement. Reuseable bags are better than any type of single use bag, if they are used consistently. They take more energy to produce than plastic or paper bags but are better in the long term if they are used at least four times (Lewis et al., 2010). Therefore, the advocation for reuseable bags has been helpful towards reducing plastic bag usage.

The sustainable practice of reusable bags has taken hold because people want to be environmentally friendly. An Australian survey found that 71% of Australians said that they avoid plastic bags; but beliefs do not always match up to behaviors with an observational study finding that 67% of Australians still use single-use plastic bags (Lewis et al., 2010). However, behavior is easy to change with the proper motivations. A tax on plastic bags in Victoria, Australia resulted in a 79% decrease in plastic bag usage with 86% of customers supporting this initiative. When the same idea was implemented in Ireland, there was a 90% decrease in plastic bag usage (Lewis et al., 2010).

## Problems with Sustainable Practices

While sustainable practices are beneficial to the environment, they are still ineffective in having an impact on the plastic crisis. For example, bioplastics cost more money to produce and become more expensive as a result, which makes them unfavorable to the government and companies (Moshood et al., 2022a). Another problem is that biodegradable plastics have production limitations when compared to synthetic counterparts which makes companies

unlikely to adopt them because they are lacking development (Moshood et al., 2022b). Also, the addition of additives to make them more durable decreases decomposition rates and some types of biodegradable plastics, like resins, are harder for microorganisms to break down (Moshood et al., 2022a). Overall, bioplastics are not currently a better option than synthetic plastics because of technological limitations and fully sustainable bioplastics cannot be made (Moshood et al., 2022b; Álvarez-Chávez et al., 2011). There is also controversy over using land to produce a feedstock for bioplastics instead of using it to produce food for human consumption (Álvarez-Chávez et al., 2011).

Studies have shown that many companies are unable to use sustainable practices due to technological limitations. Technological obstacles include limited machines, a lack of proper sorting and collecting technology, and subpar techniques. These challenges make it difficult to work towards sustainability because their processes are not effective. Furthermore, when areas lack environmental and legislative regulation, there is a decrease in recycling rates (Mwanza & Mbohwa, 2017). Therefore, effective strategies need to focus mainly on technology, but also environmental and social support.

In general, most companies are not motivated toward sustainability because it is currently not profitable. Many companies use sustainable rhetoric, but that does not mean they are implementing sustainable practices since sustainability does not have a governmental definition (Giovannoni & Fabietti, 2013). The government pays more attention to big business than it does to the average consumer, due to their economic power. This means that businesses can put sustainable practices in place but choose not to implement them (Giovannoni & Fabietti, 2013).

Sustainability is common in the beginning steps of the supply chain but tends to be neglected at later levels. By making sure it is implemented at all levels, there will be a decrease

in cost and a better, more honest process. Consumers have more power than they think, and through the power of boycotts and public speaking, they can force producers to engage in more innovative processes (de Vargas Mores et al., 2018).

## Accountability

### Corporate Accountability

With the increase in climate change, there has been a greater look towards corporations and how they are responsible for driving these changes which has led to a greater demand for corporate responsibility and accountability. Corporate responsibility means that companies have duties to society that exclude economic drive and even without the law and economic regulations, they will prevent environmental and social harm, and work to improve society for everyone. This involves engaging with social and environmental issues. Working to make changes and implementing better practices is corporate accountability and requires that companies establish mechanisms that will hold their behavior to higher standards. For example, tort law is used to determine if a company does something that results in damages to a person or place, the victim can then sue them for reparations (Yan & Zhang, 2020).

For corporate accountability to be effective, strong institutions and regulations need to be put in place. Corporate accountability often relies on voluntary reporting, which results in companies only reporting certain issues such as those that they can recover from because their reputation is on the line (Belal, 2015). Unfortunately, corporations do not abide by the same moral right that people often use to justify decisions (McLaren, 2004). Another way in which corporations are not held accountable is when states do not hold transnational companies accountable because states have moved away from strict regulations and shifted towards self-regulation. This is problematic because states have the power to encourage corporations to have

more environmentally friendly protocols, but they often do not act on the issue. Laws and regulations are the main way to hold developed countries accountable because they define rights and allocations and put everyone on an equal playing field (Garvey & Newell, 2005).

The public fears abuse of power from large corporations particularly in the way that large global companies target developing countries (McLaren, 2004). This is typically because developing countries are easier to exploit and do not have proper protection which leads to a power imbalance where the citizens of these countries do not have the proper support or power to stand up to corporations (Belal, 2015). Corrupt governments also make it difficult for developing countries to defend themselves and transnational companies are often given access to natural resources, which the local communities rely on. This action results in profit being taken from the people and instead going to big corporations. Additionally, many of these practices, like mining for example, can also have drastic environmental consequences, which further impact the livelihood of local communities (Garvey & Newell, 2005).

Stakeholders often lack power as well, so a surrogate can be brought in to temporarily aid an accountability stakeholder during any part of the accountability process. The surrogate is often a nongovernmental organization that gives the local communities a voice and can assist powerless governments in protecting their people. Surrogates can operate by making counter-accounts which are scientific facts that often contradict the information that corporations provide the public. They can also bring light to the stories of people who were exploited by or worked for the corporations (Belal, 2015). Companies often feel pressured to answer for the impacts of their actions, due to the bad press; however, these protocols are underdeveloped and tend to focus more on economic revenue (Garvey & Newell, 2005).

## Social Accountability

Social accountability is the belief that citizens should hold states and companies accountable by demanding better processes and protocols. This process is bottom-up and relies on individuals to drive change (Ruppen & Brugger, 2022). The average person can influence companies and the government, as societal and governmental pressure can drive changes in corporate behavior; however, the effectiveness of social accountability depends on how well citizens can articulate themselves, and if the government is receptive to change (Mason, 2005; Yan & Zhang, 2020). This practice requires that citizens can transform data into articulate talking points and that the government has resources to implement and alter processes (Ruppen & Brugger, 2022). Citizens face challenges with finding and accessing this information, especially if governmental groups are not transparent in their decisions (Mason, 2005).

The most vulnerable groups are the ones most impacted by large corporations because they do not have the decision-making power or resources to collect data for the government, resulting in a large burden of proof for people to prove that change is necessary (Belal et al., 2015; Mason, 2005). Vulnerable populations can make an impact when they are supported by larger groups. They cannot make change on their own, but they have a greater impact on people hearing their lived experiences (Belal et al., 2015). An example of this is the Deka River in Zimbabwe. The Deka river was polluted by multiple companies, and none of them took accountability because the people could not prove where pollution came from. A nongovernmental group, that acted like a surrogate, was able to assist the people and prove who caused what pollution, as well as have the companies agree to add drinking water bore holes; however, the companies still have not made any change to their practices. This is common in many third world countries because companies rely on unenforced laws and regulations and as a result there is little if any pollution prevention (Ruppen & Brugger, 2022). To fix this,

shareholders should be appointed to vulnerable populations to have a say in company policies and actions and can help to dispute existing power dynamics (Belal et al., 2015; Yan & Zhang, 2020). Shareholder activism is more effective in third world countries and can fight against corruption in the government (Newell, 2008).

Social accountability is necessary for holding corporations accountable, but it relies on data that is hard for many groups to collect (Ruppen & Brugger, 2022). Even social awareness towards risks depends on researchers providing information on what are often hidden problems (Mason, 2005). Agendas are often pushed by governmental groups instead of the institutions that will enact them which leads to many people expecting governments to make changes, when, throughout history, it has been groups of citizens who have advocated for large changes (Newell, 2008). For example, consumers can impact companies by directly supporting them through purchases, or boycotting them (Yan & Zhang, 2020). The polluter-pays strategy is appealing to many companies because it makes it more advantageous for them to be environmentally friendly (Ruppen & Brugger, 2022).

Accountability is composed of answerability and enforceability. Answerability requires that institutions justify their actions, while enforceability requires that companies are penalized for actions that are subpar. Accountability follows a checks and balances system which can be difficult to implement across borders, especially since more powerful groups have a larger impact than smaller ones. There are many different social accountability strategies that work better at different times and with different problems.

## Environmental Accountability

Environmental accountability is when a corporation takes responsibility for how their decisions have impacted the environment and establish measures to ensure that these decisions

will not be repeated in the future (Wong et al., 2021). This concept is rooted in the belief that all humans have the right to a safe environment (Belal et al., 2015). Many companies only release information related to their processes when it will create a sympathetic light or can be used as damage control and this has led to the emergence of environmental transparency, where companies make information related to environmental health available to the public. Transparency requires that all information released must be accurate and easily interpreted including information related to a variety of diverse environmental issues, such as how they plan on fixing the problem. In general, companies are more likely to respond to criticism when they can be identified as the cause. External parties could be used to fact check the information provided and determine if it is valid. Environmental impact information also allows for investors to determine profit more efficiently, and make better management decisions (Wong et al., 2021). Companies are more likely to be environmentally friendly when it is cost effective and aids in competitions against other corporations (McLaren, 2004).

Natural systems are often exploited by production because their renewal rates are often much slower than the rate of production. Capitalist production results in a loss in source material, and an increase in sink byproducts which converts nonrenewable resources into material that cannot be recovered and as a result, policies are often put in place after the damage has been done (Belal et al., 2015). This makes it harder to undo the damage, even following policy changes, especially since environmental dangers do not conform to state boundaries and often move between countries.

## Case Studies

### Germany: The Green Dot

Germany is the world's leading country in recycling. Most of this success is awarded to the implementation of the Der Grüne Punkt, called The Green Dot in English. It was founded in 1990 after the establishment of the German Packaging Ordinance and aims to help companies comply with the legal requirements for recycling management. The green dot believes in a closed circular economy by collecting old materials and turning them into new products. It is one of Europe's major traders and providers of raw materials and surpasses its quotas yearly. The system relies on having consumers sort their waste by the material it is made of. This is seen in the different colored recycling bins in Germany. The waste is taken to different plants depending on what type of waste it is. Manufacturers pay to be a part of the system and by doing so, they comply with the German Packaging Ordinance. A green dot can then be printed onto the packaging to show that the manufacturer has fulfilled its obligations (*Der Grüne Punkt*, n.d.).

The Packaging Act aims to reduce the amount of environmental harm caused by product packaging. It says that waste should be avoided when possible and minimized by using recycled materials. To sell products in Germany, the distributor must be registered with a dual system. This allows for the product's packaging to be properly managed and disposed of. The green dot promotes the use of eco-friendly design and product production. The more packaging that is present, the higher the fee is to get the green dot (*Der Grüne Punkt*, n.d.). This incentivizes companies to use fewer materials and be more environmentally friendly.

The Green Dot is an example of how to properly hold producers and consumers accountable regarding pollution and waste. It establishes responsibilities for each party, which is exemplified by how consumers must follow strict laws about proper waste sorting, while producers must make sure that they are abiding by the law. This allows producers and consumers

to work together to reduce excess waste, and it prevents blame from being pushed onto either party.

Coca Cola: Greenwashing

Coca-Cola is one of the major polluters in the world. With the increased awareness around environmental pollution, Coca-Cola has experienced increased scrutiny from the public and environmental groups which led to Coca-Cola creating the World Without Waste program in 2018 ("2018 World without Waste Report," 2018). There are three parts to this program: design, collect, and partner. The design component aims on making 100% recyclable bottles, while the collection effort focuses on promoting proper recycling. The partnership aspect is about working with other environmental and social groups to make a difference ("2021 World without Waste Report," 2021).

The effectiveness of this program is questionable due to the small increases in beneficial data throughout the years. From the establishment of the program, Coca-Cola has pledged to make 100% of its packaging recyclable by 2025 globally; however, there has been minimal improvement in their numbers from 2018 to 2021. In 2018 and 2019, 88% of their packaging was recyclable, while in 2020 and 2021 there was a small increase to 90% of their packaging being recyclable ("2018 World without Waste Report", 2018; "2019 World without Waste Report," 2019; "2020 World without Waste Report," 2020; "2021 World without Waste Report," 2021). The website claims that its bottles in North America are 100% recyclable excluding the lids and labels and that 40 countries have at least one Coca-Cola brand in 100% recycled plastic bottles (*Coca-Cola Launches 100%* Recycled PET Bottles for the First Time in Singapore*, 2023). However, it feels ingenuine to say bottles are 100% recyclable when the lid and label are not, especially because the average consumer is not going to be looking at these reports, and

putting nonrecyclable materials in recycling bins can lead to contamination and reduce the recycling effort. Furthermore, in 2020, 22% of recycled materials were used in packaging globally with an increase to 23% ("2020 World without Waste Report," 2020; "2021 World without Waste Report," 2021). Coca-Cola has a goal of 50% of recycled materials being used in packaging in 2025. With the trend that is present in the reports, these goals are not attainable. Coca-Cola has not done anything to alter or better achieve them and this has resulted in allegations of greenwashing which is when companies make claims that sound ecofriendly but often are deceptive. Earth Island Institute tried to sue Coca-Cola by claiming that their sustainability claims were deceptive, however, the case was dismissed because Coca-Cola's claims were general goals, and there is no legal ground to sue them over a goal (*Coca-Cola Company Accused of Greenwashing Sustainability Claim*, 2024). The World Without Waste program has also been criticized for not advocating for reduction, as most of their reports want consumers to recycle properly instead of reducing plastic usage in the first place. As a top polluter, it is hard to trust Coca-Cola regarding environmental health and sustainability when the company causes a significant amount of environmental damage. The World Without Waste program was also criticized as many feel like it was used to better Coca-Cola's image instead of helping the environment (Pynadath et al., 2024).

Coca-Cola wants to use the World Without Waste program to reduce its carbon footprint. Currently, packaging accounts for 30% of their carbon emissions ("2021 World without Waste Report," 2021). This brings into question if packaging is the largest part of their carbon footprint, and how changing it will impact the total. The World Without Waste program is helpful and has had many social benefits, however, it fails in its goals. It is hard to compare the groups Coca-Cola partners with the statistics they provide and there is no explanation of how they collected

their data. There is an expectation that the reader needs to trust Coca-Cola and believe that they have good intentions when they do not have a positive image regarding environmental sustainability.

Encina: The Lack of Environmental Transparency

Environmental transparency has become more prevalent with the rise in consumer awareness and Encina is a company that has shown progress towards becoming more environmentally friendly and open with their customers. Encina is a manufacturing company that recycles plastics using chemical recycling. Their mission is to start the transition into a sustainable, circular economy that does not allow any product to go to waste (*Encina*, 2022). They convert end-of-life plastics into feedstock that their customers can use to produce new products and makes circular gases by breaking down plastics into their chemical components (*Encina*, 2022). The process by which they do this is not revealed to the public because it is a proprietary process, meaning they own an exclusive right to it. Often these processes are unknown to the public because they make the company unique or are important to their brand. Encina claims that their products are ISCC-certified and are used on a "drop-in basis", meaning that customers take materials when they need them. On their company website, they show how benzene and circular gases are used to make products, such as benzene being used in pharmaceuticals, adhesives, and sports equipment (*Encina*, 2022).

Nowhere on their site do they explain their process or how it is better for the environment. They claim that it uses less carbon and contributes to a circular economy, but no specifics are given. By using buzzwords like "green" and "sustainable", but not revealing how their process works, they have not provided full transparency to consumers and are only showcasing the positive sides of their corporation, and none of the potentially negative

outcomes. While this works for a business, it does not work in terms of environmental transparency and if they cared about sustainability, they would reveal this information or certain parts of it to the public and would also be clearer about why their process is better, even if it has potential downsides. They faced a large public backlash when trying to establish a plant in Pennsylvania, that has since been cancelled. This cancellation is due to public backlash, not meeting height and design requirements, and logistic factors related to water usage.

## Recycling Survey

### Survey Parameters

A survey was conducted on Millersville University biology students to determine their attitude towards and knowledge of recycling processes and information. The survey was split into two sections. The first section looked at student attitudes and asked questions on a Likert scale. With the categories being Strongly Disagree, Somewhat Disagree, Neutral, Somewhat Agree, and Strongly Agree. Students were given 12 statements, and they had to select the category that best reflected their feelings about the statements. The questions asked are listed in Appendix A. The second half of the survey was a true or false section. There were 11 statements listed and the students had to indicate if they believed the statement was true, false, or if they were unsure. The unsure category was included to prevent people from guessing when they did not know the answer. The questions and their correct answer are listed in Appendix A. The survey was entirely anonymous and voluntary. Students were recruited through an email sent to all biology students. The email is in Appendix B. The survey was released on September 5th, 2024, and was closed on October 1st, 2024. A total of 85 responses were received, but only 75 people completed the first section, and 67 people completed the second section. Pie charts were

made to show the percentage of people that selected each answer in the first section. While the percent correctness was calculated for the second section.

Results

For the attitude section, most students have a positive outlook on recycling and believe that it is an important and beneficial process. Questions 1, 3, and 4 especially show that students believe that recycling is an efficient strategy and one that they take part in (Table 1; Figure 1a, Figure 1c, Figure 1d). However, questions 5 and 8 show that fewer students are familiar with different recycling processes and whether specific plastics can be recycled (Table 1; Figure 1e, Figure 1h). These two factors are key in recycling being done properly. This contradicts Q11, where 84% of students agreed that human contamination prevents proper recycling (Figure 1k). More students agree with that idea, but they are unaware of the ways to properly recycle. From this survey, most students agree that both individuals and companies have a responsibility towards proper recycling. With questions 10 and 9 having 86% and 76% agreement respectively (Figure 1j, Figure 1i). Question 12 has the lowest percent agreement with only 16% of students agreeing that plastics are recycled (Figure 1l). This is interesting when compared to question 2, where 69% of students agreed that most plastics can be recycled (Figure 1b). This shows that students believe that plastics can be recycled but are not actually being recycled. This also ties into Question 7, where 61% of students agreed that plastics should be recycled if they have a low energy requirement (Figure 1g). In question 6, most students agreed that converting old plastics into new plastic is a sustainable practice (Table 1; Figure 1f).

For the true and false section, the question with the most correct answers was TF2, a question about if plastic harms organisms through food mimicry, and the one with the least correct answers was TF9, which asked if chemical recycling is the most effective recycling

management strategy (Table 2; Table 3). TF9 was a question about chemical recycling, and the low percent correctness is supported by the results of question 5 from the attitude section of the survey. In general, as the percentage correctness of a question decreased, there was an increase in the number of unsure answers selected (Table 2). Of the 11 true or false questions, only six of them had above 50% correctness (Table 3). These questions follow a wide range of topics that are not similar enough to determine if students are more knowledgeable regarding a certain area.

Overall, the students' attitudes were consistent with the public in that most of them understand the importance of recycling and consider it something that they partake in. However, the students' knowledge on recycling was low, showing that while people understand why recycling is necessary, they do not understand the processes behind it and what is required to ensure that proper recycling is taking place. This disconnect means that people believe they are helping the planet by recycling and contributing to sustainable plastic production, but they are perpetuating the problems that recycling faces.

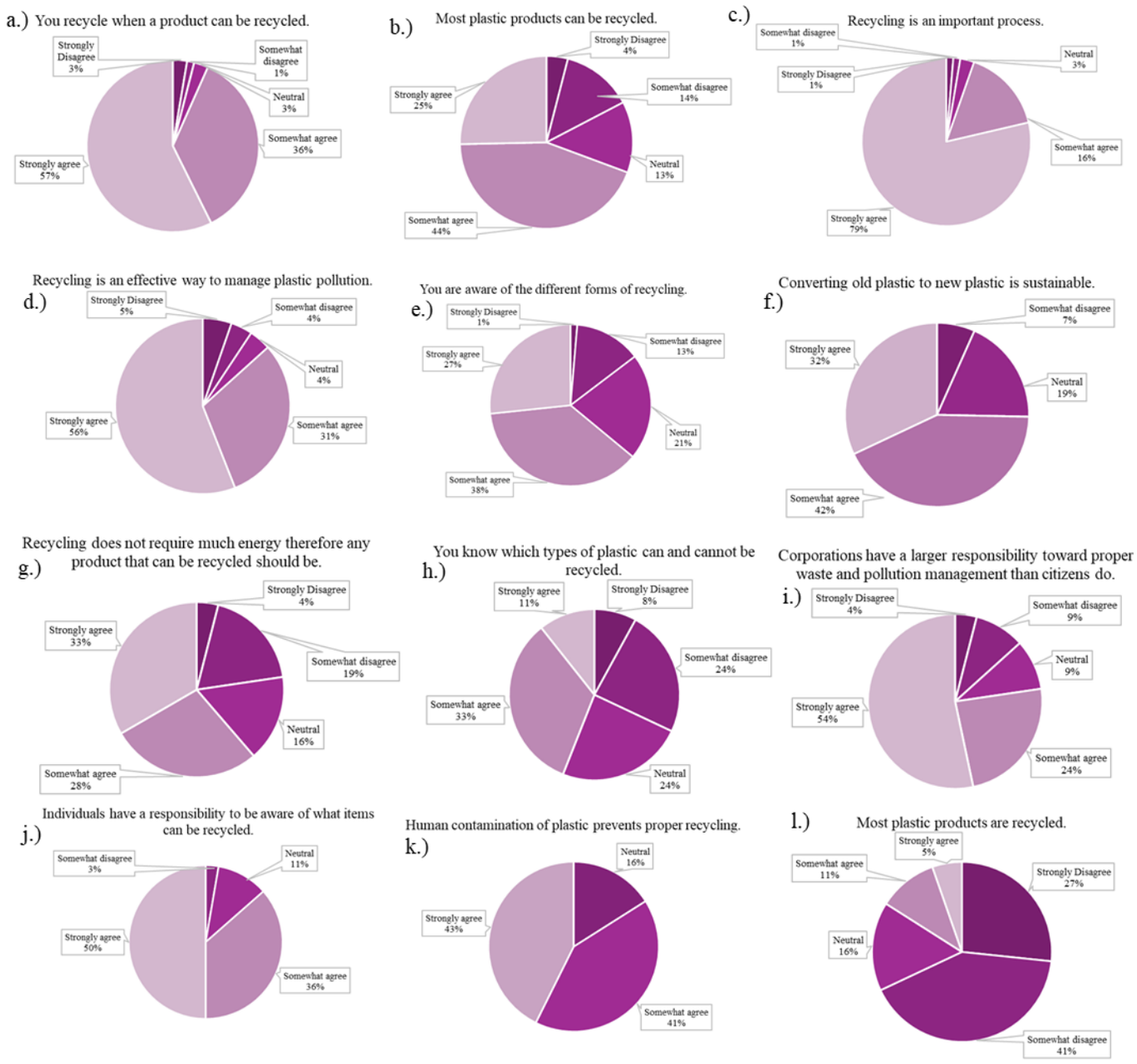


Figure 1. Percentage distribution of Millersville University biology student responses for each question in the attitude section of the plastic recycling survey. These questions were on a Likert scale and answers represent the total percentage of respondents for each question.

Table 1. The total reported responses from Millersville University biology students for each question in the attitude section of the survey.

| | Reported Responses | | | | |
|---|---|---|---|---|---|
| Question | Strongly Disagree | Somewhat Disagree | Neutral | Somewhat Agree | Strongly Agree |
| Q1 | 2 | 1 | 2 | 27 | 43 |
| Q2 | 0 | 2 | 8 | 27 | 37 |
| Q3 | 0 | 0 | 12 | 31 | 32 |
| Q4 | 20 | 31 | 12 | 8 | 4 |
| Q5 | 3 | 10 | 10 | 33 | 19 |
| Q6 | 1 | 1 | 2 | 12 | 59 |
| Q7 | 4 | 3 | 3 | 23 | 42 |
| Q8 | 1 | 10 | 16 | 28 | 20 |
| Q9 | 0 | 5 | 14 | 32 | 24 |
| Q10 | 3 | 14 | 12 | 21 | 25 |
| Q11 | 6 | 18 | 18 | 25 | 8 |
| Q12 | 3 | 7 | 7 | 18 | 40 |

Table 2. The total reported responses from Millersville University biology students for each question in the true or false section of the plastic recycling survey.

| | Reported Responses | | |
|---|---|---|---|
| Question | True | Unsure | False |
| TF1 | 28 | 35 | 4 |
| TF2 | 63 | 4 | 0 |
| TF3 | 6 | 9 | 52 |
| TF4 | 6 | 29 | 32 |
| TF5 | 50 | 15 | 2 |
| TF6 | 4 | 22 | 41 |
| TF7 | 6 | 18 | 43 |
| TF8 | 25 | 33 | 9 |
| TF9 | 18 | 42 | 7 |
| TF10 | 22 | 30 | 15 |
| TF11 | 2 | 29 | 36 |

Table 3. The percent of correct responses from Millersville University biology students in the true or false section of the plastic recycling survey.

| Question | Percent Correctness |
|---|---|
| TF1 | 42% |
| TF2 | 94% |
| TF3 | 78% |
| TF4 | 48% |
| TF5 | 75% |
| TF6 | 61% |
| TF7 | 64% |
| TF8 | 37% |
| TF9 | 10% |
| TF10 | 33% |
| TF11 | 54% |

## Conclusion

The plastic crisis is a problem that is difficult to solve, and current technology and education are not adequate to fix this issue. In addition, big corporations are still large polluters and efforts to enforce accountability for their actions have not resulted in significant change. We need to act now to change the current policies and increase public awareness to make a difference for the future.

In order to address the problems of plastic recycling, newer recycling technologies need to be developed, specifically chemical recycling practices which have a promising future unfortunately current processes are not providing enough benefits to make is a viable practice at present. Introducing new people into this field and, most importantly, funding new technology is the way forward for chemical recycling to become the future of recycling. If more people become educated on chemical recycling and its potential future scientists would become more inspired to pursue new technological ideas.

Efforts also need to be made to increase education and social awareness about the problems and solutions to plastic pollution. To improve recycling education, there should be a larger focus on it during school particularly by teaching both children as well as older teens about the different types of recycling and plastic so they can become more aware of plastic pollution and management. Based on my survey results, many college students said that they were aware of the topics related to plastic and plastic recycling but struggled with the true or false questions related to these topics. My study results seem to indicate that people think they know more about recycling than they do, and as a result recycling practices are not as effective as they could be. Improved technology and education alone are not going to solve this problem.

Big corporations can be held accountable by the public and people need to know that their voices have power. By uplifting and publicizing issues related to pollution, particularly when they are causing harm to people or the environment, ordinary citizens can put pressure on companies to be more environmentally friendly. Another way to make corporations accountable and to force them to adopt environmentally friendly actions is through taxation. By implementing a program like the green dot, companies save money by creating more ecofriendly products and packaging. Because corporations are fueled by money, the easiest way to change their behavior is to use money. If it is economically viable to be environmentally friendly, companies will do so.

Overall, the plastic crisis is a multinational problem. It involves everyone around the world and requires cooperation to be fixed. By becoming aware of the problems and working to implement new better technology and personal practices, everyone can help to reduce the plastic used and wasted.

## Reflections

This paper enlightened me on the issue of plastic pollution and how current technology is one of the largest problems in the field. While I was aware of the problems that aquatic organisms and the environment face from plastic pollution, the scale of the problem was not something I realized. I had thought that the technology surrounding recycling was advanced as it is the main way we mitigate the plastic crisis. However, there are many alternatives to plastics and mechanical recycling, but due to limited knowledge and study, they are not viable and cause more environmental problems than benefits.

Before doing this study, I did not know how to hold companies accountable as I would just boycott them, which as a single consumer, is not effective. However, reading about the different forms of accountability has helped me look at myself as a consumer and better articulate to others the problems with plastic usage. This topic is not extensively talked about and by sharing information related to proper recycling and reducing plastic waste, I can help others become more educated and aware.

I have always recycled, however, the information I learned has helped me make better decisions about how to contribute to a more sustainable recycling process. I think that the future of recycling is promising, particularly bioplastics and chemical recycling. With the advancement of better techniques and practices, the cost of these will decrease, and hopefully new technologies will limit the negative impacts of these products and processes. Recycling is not an ineffective practice; it is one that has been neglected and misunderstood by many.

If I were to do this study again, I would send the survey to a larger population. One would expect biology students to be more aware of environmental issues, and I think comparing different groups based on age, sex, education, and economic background would be a good way to see if there are other social and political factors impacting someone's attitude and knowledge towards recycling. Based on those factors, better policies and practices could be put in place to improve plastic disposal and production. Overall, there is still time to fix this problem, and the future is promising due to younger generations being more aware of environmental issues and wanting to fix them.

# Appendix

Appendix A. The acronyms and answers to the questions asked in the survey.

| Acronym | Question | Correct Answer |
|---|---|---|
| Q1 | You recycle when a product can be recycled. | - |
| Q2 | Most plastic products can be recycled. | - |
| Q3 | Recycling is an important process. | - |
| Q4 | Recycling is an effective way to manage plastic pollution. | - |
| Q5 | You are aware of the different forms of recycling. | - |
| Q6 | Converting old plastic to new plastic is sustainable. | - |
| Q7 | Recycling does not require much energy therefore any product that can be recycled should be. | - |
| Q8 | You know which types of plastic can and cannot be recycled. | - |
| Q9 | Corporations have a larger responsibility toward proper waste and pollution management than citizens do. | - |
| Q10 | Individuals have a responsibility to be aware of what items can be recycled and how to properly do so. | - |
| Q11 | Human contamination of plastic limits proper recycling. | - |
| Q12 | Most plastic products are recycled. | - |
| TF1 | Plastic is the most common form of anthropogenic pollution. | True |
| TF2 | Plastic causes harm to organisms due to food mimicry. | True |
| TF3 | Most plastic put in recycling bins is appropriately recycled. | False |
| TF4 | Plastic waste cannot be exported to other countries. | False |
| TF5 | Invasive species can use plastic as a way to move between areas. | True |
| TF6 | Plastic usage and production will decrease over time. | False |
| TF7 | 50% of all plastic produced has been recycled. | False |
| TF8 | Companies experience more challenges dealing with inadequate recycling technology than from financial problems. | True |
| TF9 | Chemical recycling (recycling that involves breaking the waste down to its molecular components) is the most effective recycling management strategy. | False |
| TF10 | Due to the energy requirements for production, paper bags are not as energy efficient as plastic bags. | True |
| TF11 | By exporting plastic waste to China, the US has efficiently recycled most of their plastic waste. | False |

Appendix B. The email that was sent to biology students at Millersville University to ask if they would participate in the recycling survey.

Hello,

For my thesis, I have been investigating plastic recycling and current management strategies. Part of this thesis looks at public awareness. To measure this, I created a survey that is meant to assess biology student's awareness and knowledge of plastic recycling. It is anonymous and voluntary, and the data will only be used in my thesis. Your help is very much appreciated. Here is the link if you are interested: https://millersville.qualtrics.com/jfe/form/SV_8raVtgZY3LZ6LBQ. The survey will be available until September 30th, 2024. Feel free to contact me with any questions or concerns.

Thank you,

Madison Broussard

mjbrouss@millersville.edu

## References

2018 World Without Waste Report. (2018). In *The Coca-Cola Company*. https://www.coca-colacompany.com/content/dam/company/us/en/policies/pdf/sustainability/world-without-waste-report-2018.pdf

2019 World Without Waste Report. (2019). In *The Coca-Cola Company*. https://www.coca-colacompany.com/content/dam/company/us/en/reports/coca-cola-world-without-waste-report-2019.pdf

2020 World Without Waste Report. (2020). In *The Coca-Cola Company*. https://www.coca-colacompany.com/content/dam/company/us/en/reports/pdf/coca-cola-world-without-waste-report-2020.pdf

2021 World Without Waste Report. (2021). In *The Coca-Cola Company*. https://www.coca-colacompany.com/content/dam/company/us/en/reports/pdf/coca-cola-world-without-waste-report-2021.pdf

*A UN treaty to end plastic pollution*. (n.d.). Ellen Macarthur Foundation. https://www.ellenmacarthurfoundation.org/un-plastics-treaty/overview

Álvarez-Chávez, C. R., Edwards, S., Moure-Eraso, R., & Geiser, K. (2011). Sustainability of bio-based plastics: general comparative analysis and recommendations for improvement. *Journal of Cleaner Production*, *23*(1), 47–56. https://doi.org/10.1016/j.jclepro.2011.10.003

Andrews, A., Gregoire, M., Rasmussen, H., & Witowich, G. (2013). Comparison of recycling outcomes in three types of recycling collection units. *Waste Management*, *33*(3), 530–535. https://doi.org/10.1016/j.wasman.2012.08.018

Belal, A. R. (2015). *Development Oriented CSR* (pp. 153–166). Green Leaf, Sheffield.

https://www.researchgate.net/publication/281088455_Social_and_Environmental_Accountability_in_Developing_Countries

Belal, A. R., Cooper, S. M., & Khan, N. A. (2015). Corporate environmental responsibility and accountability: What chance in vulnerable Bangladesh? *Critical Perspectives on Accounting*, *33*, 44–58. https://doi.org/10.1016/j.cpa.2015.01.005

Cho, R. (2017, December 13). *The Truth about Bioplastics*. State of the Planet; Columbia Climate School. https://news.climate.columbia.edu/2017/12/13/the-truth-about-bioplastics/

*Coca Cola Company Accused Of Greenwashing Sustainability Claim*. (2024, January 2). Lloyd Gray Whitehead Monroe Law Firm. https://lgwmlaw.com/coca-cola-company-accused-of-greenwashing-sustainability-claim/

*Coca-Cola Launches 100%* Recycled PET Bottles for the first time in Singapore*. (2023, December 18). The Coca-Cola Company. https://www.coca-cola.com/sg/en/media-center/coca-cola-launches-100-recycled-pet-bottles-for-the-first-time-in-singapore#:~:text=Coca%E2%80%91Cola%20currently%20offers%20at

de Vargas Mores, G., Finocchio, C. P. S., Barichello, R., & Pedrozo, E. A. (2018). Sustainability and innovation in the Brazilian supply chain of green plastic. *Journal of Cleaner Production*, *177*, 12–18. https://doi.org/10.1016/j.jclepro.2017.12.138

*Der Grüne Punkt*. (n.d.). Der Grüne Punkt. https://www.gruener-punkt.de/en/

DiFelice, M. (2023, June 16). *What You Need to Know About Chemical "Recycling."* Food & Water Watch. https://www.foodandwaterwatch.org/2023/06/16/chemical-recycling/

Dybern, B. (1974). Water Pollution: A Problem with Global Dimensions. *Ambio*, *3*(3/4), 139–145. https://www.jstor.org/stable/4312068

*Encina*. (2022). Encina. https://www.encina.com/about/

Eriksen, M. (2014). The Plastisphere—The Making of a Plasticized World. *Tulane Environmental Law Journal*, *27*(2), 153–163. https://www.jstor.org/stable/43294161

Galgani, F., Pham, C. K., Claro, F., & Consoli, P. (2018). Marine animal forests as useful indicators of entanglement by marine litter. *Marine Pollution Bulletin*, *135*, 735–738. https://doi.org/10.1016/j.marpolbul.2018.08.004

Garvey, N., & Newell, P. (2005). Corporate accountability to the poor? Assessing the effectiveness of community-based strategies. *Development in Practice*, *15*(3-4), 389–404. https://doi.org/10.1080/09614520500075763

Giovannoni, E., & Fabietti, G. (2013). What Is Sustainability? A Review of the Concept and Its Applications. *Integrated Reporting*, 21–40. https://doi.org/10.1007/978-3-319-02168-3_2

Gribkoff, E. (2022, September 28). *Chemical recycling and its environmental impacts - EHNChemical recycling grows — along with concerns about its environmental impacts*. Environmental Health News. https://www.ehn.org/chemical-recycling-2658348681.html

Hopewell, J., Dvorak, R., & Kosior, E. (2019). Plastics recycling: Challenges and Opportunities. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2115–2126. https://doi.org/10.1098/rstb.2008.0311

Iroegbu, A. O. C., Ray, S. S., Mbarane, V., Bordado, J. C., & Sardinha, J. P. (2021). Plastic pollution: A perspective on matters arising: Challenges and opportunities. *ACS Omega*, *6*(30), 19343–19355. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8340096/

Lewis, H., Verghese, K., & Fitzpatrick, L. (2010). Evaluating the sustainability impacts of packaging: the plastic carry bag dilemma. *Packaging Technology and Science*, *23*(3). https://doi.org/10.1002/pts.886

Llorente, I. (2019, October 24). *INHERIT Model - INHERIT*. INHERIT. https://www.inherit.eu/project/inherit-model/

Mason, M. (2005). The new accountability: environmental responsibility across borders. *Choice Reviews Online*, *43*(01), 43-060143-0601. https://doi.org/10.4324/9781849773140

McLaren, D. (2004). Global Stakeholders: corporate accountability and investor engagement. *Corporate Governance*, *12*(2), 191–201. https://doi.org/10.1111/j.1467-8683.2004.00360.x

Mernit, J. L. (2023, June 1). *As Plastics Keep Piling Up, Can "Advanced" Recycling Cut the Waste?* Yale Environment 360. https://e360.yale.edu/features/advanced-plastics-recycling-pyrolysis

Milios, L., Esmailzadeh Davani, A., & Yu, Y. (2018). Sustainability Impact Assessment of Increased Plastic Recycling and Future Pathways of Plastic Waste Management in Sweden. *Recycling*, *3*(3), 33. https://doi.org/10.3390/recycling3030033

Morales-Caselles, C., Viejo, J., Martí, E., González-Fernández, D., Pragnell-Raasch, H., González-Gordillo, J. I., Montero, E., Arroyo, G. M., Hanke, G., Salvo, V. S., Basurko, O. C., Mallos, N., Lebreton, L., Echevarría, F., van Emmerik, T., Duarte, C. M., Gálvez, J. A., van Sebille, E., Galgani, F., & García, C. M. (2021). An inshore–offshore sorting system revealed from global classification of ocean litter. *Nature Sustainability*, *4*(6), 484–493. https://doi.org/10.1038/s41893-021-00720-8

Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., & AbdulGhani, A. (2022a). Biodegradable plastic applications towards sustainability: A recent innovations in the green product. *Cleaner Engineering and Technology*, *6*. https://doi.org/10.1016/j.clet.2022.100404

Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., & AbdulGhani, A. (2022b). Sustainability of biodegradable plastics: New problem or solution to solve the global plastic pollution? *Current Research in Green and Sustainable Chemistry*, *5*. https://doi.org/10.1016/j.crgsc.2022.100273

Mrowiec, B. (2017). Plastic pollutants in water environment. *Ochrona Srodowiska I Zasobów Naturalnych*, *28*(4), 51–55. https://doi.org/10.1515/oszn-2017-0030

Mwanza, B. (2021). Introduction to Recycling. *Recent Developments in Plastic Recycling*, 1–13. https://doi.org/10.1007/978-981-16-3627-1_1

Mwanza, B. G., & Mbohwa, C. (2017). Major Obstacles to Sustainability in the Plastic Industry. *Procedia Manufacturing*, *8*, 121–128. https://doi.org/10.1016/j.promfg.2017.02.021

Napper, I. E., & Thompson, R. C. (2020). Plastic Debris in the Marine Environment: History and Future Challenges. *Global Challenges*, *4*(6). https://doi.org/10.1002/gch2.201900081

Newell, P. (2008). Civil Society, Corporate Accountability and the Politics of Climate Change. *Global Environmental Politics*, *8*(3), 122–153. https://doi.org/10.1162/glep.2008.8.3.122

Nikiema, J., & Asiedu, Z. (2022). A review of the cost and effectiveness of solutions to address plastic pollution. *Environmental Science and Pollution Research*, *29*, 24547–24573. https://doi.org/10.1007/s11356-021-18038-5

OECD. (2022). *Plastic pollution is growing relentlessly as waste management and recycling fall short, says OECD*. OECD. https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm

Patel, P. (2018). Stemming the Plastic Tide: 10 Rivers Contribute Most of the Plastic in the Oceans. *Scientific American*, *318*(2), 15–17. https://doi.org/10.1038/scientificamerican0218-15a

Pynadath, M., Sangeetha, K. L., & Bhaumik, A. (2024). FACADE OR FACT? DELVING INTO GLOBAL CORPORATE COMPLIANCE IN GREENWASHING. *Business, Management, and Economics Engineering*, *22*(1). https://businessmanagementeconomic.org/pdf/2024/1154.pdf

Ruppen, D., & Brugger, F. (2022). "I will sample until things get better – or until I die." Potential and limits of citizen science to promote social accountability for environmental pollution. *World Development*, *157*. https://doi.org/10.1016/j.worlddev.2022.105952

Science Museum. (2019, October 11). *The Age of Plastic: From Parkesine to pollution*. Science Museum. https://www.sciencemuseum.org.uk/objects-and-stories/chemistry/age-plastic-parkesine-pollution

Sigler, M. (2014). The Effects of Plastic Pollution on Aquatic Wildlife: Current Situations and Future Solutions. *Water, Air, & Soil Pollution*, *225*(11). https://doi.org/10.1007/s11270-014-2184-6

SL Recycling. (2020, September 30). *What Plastics Can and Cannot be Recycled?* SL Recycling. https://www.slrecyclingltd.co.uk/what-plastics-can-and-cannot-be-recycled/#:~:text=Following%20sorting%2C%20there%20are%20two

Stegeman, I., Godfrey, A., Romeo-Velilla, M., Bell, R., Staatsen, B., van der Vliet, N., Kruize, H., Morris, G., Taylor, T., Strube, R., Anthun, K., Lillefjell, M., Zvěřinová, I., Ščasný, M., Máca, V., & Costongs, C. (2020). Encouraging and Enabling Lifestyles and Behaviours to Simultaneously Promote Environmental Sustainability, Health and Equity: Key Policy Messages from INHERIT. *International Journal of Environmental Research and Public Health*, *17*(19). https://doi.org/10.3390/ijerph17197166

Thushari, G. G. N., & Senevirathna, J. D. M. (2020). Plastic pollution in the marine environment.

*Heliyon*, *6*(8). https://doi.org/10.1016/j.heliyon.2020.e04709

United States Environmental Protection Agency. (2019, April 17). *The U.S. Recycling System*. Www.epa.gov. https://www.epa.gov/circulareconomy/us-recycling-system

Verma, R., Vinoda, K. S., Papireddy, M., & Gowda, A. N. S. (2016). Toxic Pollutants from Plastic Waste- A Review. *Procedia Environmental Sciences*, *35*(35), 701–708. https://doi.org/10.1016/j.proenv.2016.07.069

Wabnitz, C., & Wallace, N. (2010). Editorial: Plastic Pollution: An Ocean Emergency. *Marine Turtle News Letter*, *20*. https://www.researchgate.net/publication/268187066_Editorial_Plastic_Pollution_An_Ocean_Emergency

Weis, J. S. (2021). Most Microplastics Come from Clothes. *BioScience*, *71*(4), 321. https://doi.org/10.1093/biosci/biab015

Williams, A. T., & Rangel-Buitrago, N. (2022). The past, present, and future of plastic pollution. *Marine Pollution Bulletin*, *176*(113429), 113429. https://doi.org/10.1016/j.marpolbul.2022.113429

Wong, C. W. Y., Wong, C. Y., Boon-itt, S., & Tang, A. K. Y. (2021). Strategies for Building Environmental Transparency and Accountability. *Sustainability*, *13*(16), 9116. https://doi.org/10.3390/su13169116

Yan, M., & Zhang, D. (2020). From Corporate Responsibility to Corporate Accountability. *Hastings Business Law Journal Hastings Business Law Journal*, *16*. https://repository.uclawsf.edu/cgi/viewcontent.cgi?article=1200&context=hastings_business_law_journal