

A Proposal for Collecting and Reusing PET to Reduce Environmental Damage and Supply Additive Manufacturing Material.

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**Casper Mads Clausen
BSc Product Design**

Introduction

Recycling Polyethylene bottles is a popularized practice for consumers because the repayment of money from recycling at a bottle deposit booth is both seen as a social and environmental benefit; however, the benefits and necessities for recycling post-consumer plastics extend beyond doing a social good. Our wellbeing on the planet depends on our maintaining the natural environment around us. One critical and remote environmental concern is the Great Pacific Garbage Patch, a vortex of post-consumer plastic in the Pacific Ocean. A solution to skim plastics from this surface has potential to alleviate the environmental damage caused to sea life and human beings in the future by use of a 100km-wide floating boom. The collected plastics can be bought and reconstituted as recycled plastics for reuse in what is called a circular plastic economy. A circular plastic economy reassigns value to retrieved and recyclable plastics and adds a value proposition to cleaning the environment. A common reused recycled plastic is that of recycled polyethylene (rPET) can be obtained by recycling food trays and plastic bottles. The recycling processes for obtaining rPET require decontamination of the retrieved PET to meet safety standards. rPET can also be used to create new technologies that improve existing technologies with what is conventionally considered waste. This paper aims to explore the processes, incentives, and necessities behind plastic recycling.

Methods

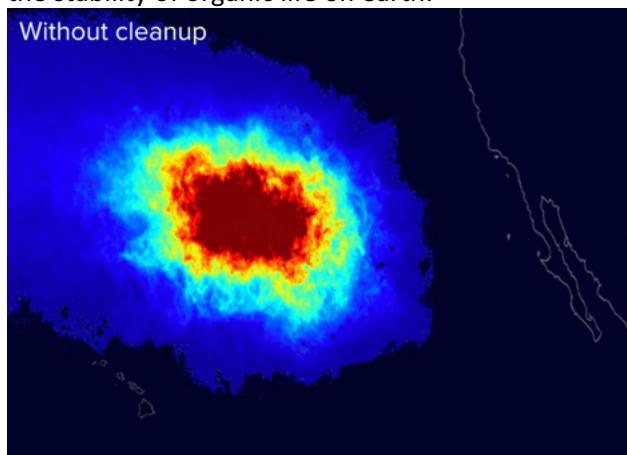
The study for this paper was conducted by reading articles from peer reviewed academic journals as well as journalistic articles published for

periodicals online. Peer reviewed academic journals were searched for using EBSCO Discovery Service to find articles regarding the recycling of Polyethylene (PET). Search terms used were: "PET," "rPET" (recycled PET), "Recycling," "Bottles," and "Plastic." Topics of the articles consisted of recycling programs, evaluations of PET recycling processes based on decontamination efficiencies, studies of PET recycling emissions, and uses of rPET. Articles found through a simple web search regarding recycling plastic bottles using Google's search engine revealed articles on the consequences of post-consumer waste. The subject researched was "plastic bottle statistics," which revealed information regarding the environmental consequences from mismanaging post-consumer plastic waste. Articles spanned the subjects of what the great pacific garbage patch and how to clean it up, how many bottles are consumed worldwide per year, what happens when sea life eat the plastic and how that plastic waste ends up in our food, how Johnson & Johnson are replacing plastic in their cotton buds with paper, how plastic bottle taxation could encourage soft drink producers to use rPET bottles, how the arctic is being affected by plastic waste, and how supermarkets may implement a plastic-free isle. The researched articles present a reality that threatens the wellbeing of people, animals, and our environment while providing promising information as to how to minimize environmental damage by recycling and reusing collected PET bottles.

Plastic Mismanagement

The great pacific garbage parch resembles a garden patch in the ocean growing pieces of plastic waste. Pieces of discarded plastic waste drift along ocean currents and collect in a vortex in the middle of the Pacific Ocean (Milman, 2016). The vortex in the pacific is only one of five total oceanic current vortices on earth that could all contain garbage patches if waste continues to be mismanaged. Milman also writes that a study performed by The Ocean Cleanup, an organization aiming to clean the ocean from plastics, found that the total area of the great pacific garbage patch had a heart of 1 million square kilometers, and an additional periphery of 3.5 million square kilometers (Milman, 2016). This area is so large that it covers an area larger than India, the 7th largest country in the world by area.

The relative size was spoken to by The Ocean Cleanup's flight over the area, mentioning that the sight was "bizarre" and much larger than expected (Milman, 2016). The garbage patch exists for a reason, and that is because post-consumer waste plastic does not always get disposed of properly. About 5 to 13 million tons of post-consumer plastic "leaks" into the water systems, which suggests that there is a failure to manage all waste intended to be disposed of through the waste collection system (Laville & Taylor, 2017). The waste seeping into the oceans and contributing to the great pacific garbage patch is of concern because its presence threatens the stability of organic life on earth.



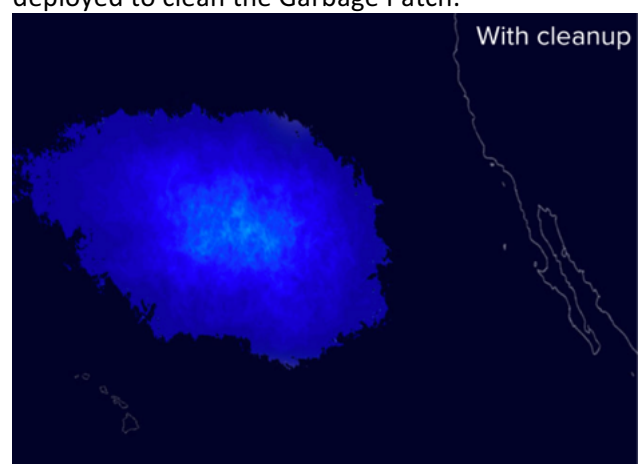
A model by The Ocean Cleanup (www.theoceancleanup.com, n.d.) predicting the size of the Great Pacific Garbage Patch in 5 years time if nothing is done.

The massive amounts of mismanaged plastic waste end up harming sea life, the humans who eat the sea life, and present consequences for the oxygen content in the earth's atmosphere. The plastic in the great pacific garbage patch overlaps regions of algal blooms that attract the plankton that feed off the algae. The attracted plankton attract small fish, shellfish, and bird species that eat the plankton. The algae produce dimethyl sulfide, which triggers sea birds' feeding instinct, causing them to confuse the plastic post-consumer waste for krill (Kaiser, 1999). This likely results in death from malnourishment in sea birds, as they are feeding on what they sense is like food, but is not. Young perch are also reported to prefer feeding on the micriplastics instead of the zooplankton that they would normally eat (Rochman, 2016). McGrath reports that Dr. Oona Lonnstedt from Uppsala University mentions that successful egg spawn rate, predatorily avoidance, and longevity all suffer in the

perch that feed on polystyrene (McGrath, 2016). Like the sea sea birds mentioned in the study by Kaiser (1999), the perch are triggered into thinking that polystyrene is a high-energy food source, yet it is causing their species to decline. Smillie (2017) reports on a study by Professor Richard Thompson and his team that found that plastic concentrations in seafood are likely to cause problems for people's health if we continue to let the problem occur. The human, animal, and environmental health is at stake if nothing is done about the accumulation of plastics in the ocean.

Initiatives

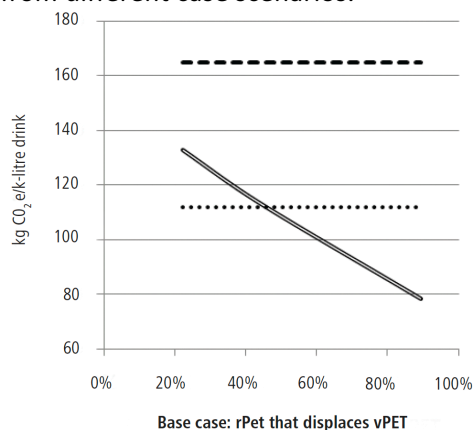
The plastic leakage causing this assemblage of post-consumer waste in the ocean provides reason for recycling systems to engage in cleaning up the oceans. The Ellen McArthur foundation writes a proposition for a "New Plastics Economy" in which the supporters aim to reduce the externalities of environmental damage and create an economy in which discarded plastic has value because it is still part of a closed loop recycling system that reuses it instead of discards it (New Plastics Economy). The method proposed to clean up the ocean is by using a 100km-wide v-shaped boom that traps the plastic as it floats along the current passing through the boom. The plastic that gets trapped in the boom would be collected by ships (Wageningen, 2015). The image below presents a scenario in which the boom has been deployed to clean the Garbage Patch.



A model by The Ocean Cleanup (www.theoceancleanup.com, n.d.) predicting the size of the Great Pacific Garbage Patch in 5 years time if the 100km-wide boom is deployed.

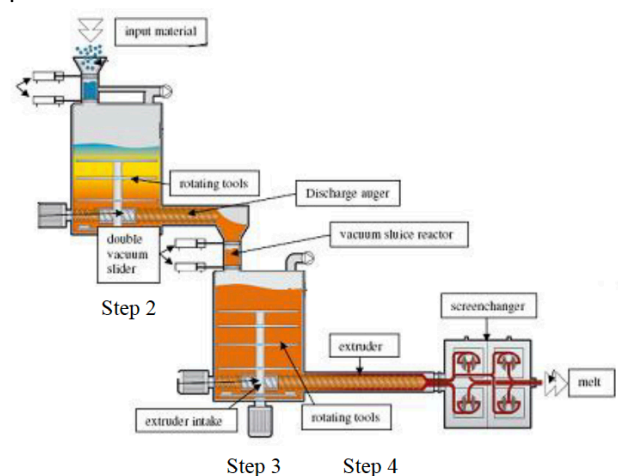
NOAA spokeswoman Asthma Mahdi mentions that skimming plastic off the ocean's surface could also cause environmental damage by removing surface sea life such as plankton, which produce half of the oxygen on earth (Wageningen, 2015). The Ocean Cleanup mentions that the 100km-long ocean barrier could remove 50% of the great pacific garbage patch in 5 years, and would prevent the breakdown of large pieces of plastic into microplastics that do the most harm (www.theoceancleanup.com, n.d.). The Ocean Cleanup's founder, Boyan Slat, mentions that the collected plastic is of interest to companies that would buy the plastic (Wageningen, 2015). Cleaning up the oceans prevents environmental damage that eventually causes problems for other life on earth as well as uses human, animal, and environmental prosperity as justification for a circular economy.

Recycling discarded post-consumer plastics and transforming Polyethylene, the most common form of plastic used in the manufacture of plastic beverage containers, requires both collecting the PET and transforming it into reconstitutable raw material to satisfy the conditions for creating a circular plastic economy in which the plastic we use is reused. The economic situation for recycling PET bottles provides an incentive for people to recycle because of the monetary payback that people receive for depositing them at recycling centers or booths. This seems like a promising step for recycling. However, 80% of plastic bottles still go to landfill. A threshold for the recycling percentage of PET bottles must be met for offsetting the carbon footprint of producing bottles from virgin PET (vPET). Johnson and Arne (2010) write in their study that 45% of PET bottles from post-consumer waste must be recycled to offset the carbon footprint of using recycled PET (rPET) instead of virgin PET. The image below indicates the varying kgCO₂ output from different case scenarios.



A model by Johnson and Arne (2010) indicating the kg CO₂ footprint of incinerating (dashed line), landfilling (dotted line), and recycling (hollow line). The graph indicates that recycling is carbon footprint reducing when greater than 45% of rPET replaces vPET.

Johnson & Arne's study makes a case for industry because it proposes that recycling PET for a closed-loop plastic economy requires recycling PET on a large scale. Several technologies exist to recycle PET using industrial methods. These studies all use a form of thermal transformation to change shredded PET into pellets Silano, V., Bolognesi, C., Castle, L., Cravedi, J., Engel, K., ... Milana, M. R. (2017) and the EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids (CEF) & European Food Safety Authority (EFSA), Parma, Italy. (2013) conducted studies that involved several different technologies for producing rPET and found that many of the technologies were suitable for producing food-grade rPET, yet only the "CLRrHDPE," "Biffa Polymers," "Kruschitz," "Vogtland PET", "Veolia", "ITW Polyrecycling", "Texplast", "Alimpet" and "Esox Prodimplex," and "EREMA Recycling (MPR, Basic and Advanced technologies)." A diagram of the EREMA Advanced technology below describes the process that PET bottles go through to be transformed into rPET pellets.



The EREMA Advanced technology uses a series of two continuous reactors to liquefy, extrude, and produce pellets. Contaminants in the input PET evaporate due to the high temperatures in the reactor, while the rPET crystallizes. EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids (CEF)

These technologies all use a continuous melting process that decontaminates the plastic, making it measurably safe for use in food trays and water packaging. The methods proposed contribute to a closed loop (circular) plastic economy by offering recycled materials that are suitable for reuse in the food packaging industry. The closed loop economy of plastic bottles is not the only prospect for reusing PET.

Alternative Applications of retrieved PET

PET bottles are being used in both bottle and reconstituted states in technologies that do not intend to create more food or beverage packaging. Mansour and Ali (2015) studied the viability of using PET bottles as volume in mortar and found that air-filled PET bottles encased in cement outperformed the traditional housing materials in Oman by both insulating more efficiently, being lighter, and bearing heavier loads before failing. Their innovation to use PET bottles in housing presents a case where the industrial recycling processes are unnecessary to create value from discarded PET bottles. The image below displays the orientation and placement of the bottles within a combined mortar and PET bottle block.



Mortar blocks built by the research team to be cured. These blocks represent individual units to be used in housing construction with the cap-end of the bottle facing outwards (Mansour & Ali, 2015).

This process contributes to a circular plastic economy indirectly by recognizing the value in reusing PET and reducing environmental consequences from their mismanagement. Recycled PET bottles can also be used to create stock filament for Fused Deposition Modeling printing because of its close similarity to polycarbonate-ABS

(Zander, Gillan, Lambeth, 2018). Zander, Gillan, and Lambeth's research finds that rPET's characteristics when cooled in water make for a filament that is acceptably close to virgin PET manufactured for 3D printing. The use of rPET in 3D printing makes an argument for recycling PET because of its close characteristics to vPET. rPET is also being used in nanotechnology through the creation of nanometer-sized water filters. Zander, Gillan, and Sweetser (2016) created nanometer-sized rPET filaments into the shape of a mat used as a device for filtering beads varying in size from 30 to 500nm in diameter. The rest showed that the mats were effective and that rPET was superior to off-the-shelf vPET because rPET has a higher relative tensile strength. The potential for using rPET for applications that extend outside of the food and beverage industry has potential for incentivizing recycling due to the potential increases in performance that recyclables and rPET has for technology.

Conclusion

Recycled polyethylene is a valuable material that can be acquired by harvesting it from municipal waste and the greater environment. A system for capturing post-consumer waste is already in planning stages and will likely be a necessity for acquiring recyclable materials into the future. The discovery of rPET outperforming vPET in one case sets a promising argument for the investigation into further developing recycled materials for their unique material qualities. Cleaning the ocean and initiating a threshold-breaking plan to recycle more than 45% of plastic bottles are two ways in which we protect the longevity of our ecosystems and species by preventing plastic from entering the food chain. The Ocean Cleanup should continue its efforts to skim the ocean surface and monitor its efficacy due to its possibility of affecting zooplankton's oxygen production capacity. If nothing is done to reduce the environmental impacts of mismanaged post-consumer plastic waste, then the health of the environment, animals, and human beings will be at stake. The magnitude of this problem for the wellbeing of life on earth will grow as demand for plastic increases; however, doing nothing about the problem will only exacerbate it.

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