A High-Performance Waste Solution for Polystyrene

Currently, waste management systems are being implemented in efforts to increase the amount of polystyrene recycling and “to reduce emission of greenhouse gases” such as carbon dioxide in the environment (Gutierrez, 2016). Because polystyrene is a non-renewable polymer, its disposal causes environmental pollution, which is why the need for properly recycling this material is crucial (Gutierrez, 2016). The recycling of polystyrene and various other materials aids in the conservation of natural resources, benefiting the environment and the organisms that live in it (Hamad, 2013). Polystyrene is used frequently worldwide as food trays and packaging products because of its “excellent shock absorbing property” and durability (Hattori, 2009).

Additionally, due to its low cost and high availability, polystyrene, along with numerous other polymers and plastics, is deemed ideal in various industries. Its uses are vast and far-reaching, and it has impacted modern technology and processes significantly, especially in the construction and food packaging industries (Brydson, 1999). However, polystyrene is typically disposed of improperly and data has shown that each year, more than three million tons of expanded polystyrene are produced globally; the majority of this goes unrecycled, leaving mass amounts of polystyrene to remain in the environment (Hearon, 2014).

In fact, recent research experiments display alarming numbers regarding the rate at which polystyrene is produced and the land capacity of the earth to provide landfills to store this waste: while the landfill area is projected to increase at a rate of 7.5% per year, the rate of plastic waste (including polystyrene consumption) is expected to rapidly rise at a rate of 25% per generation per year (Ávila, 2003). The large difference between these two figures identifies the urgent need to implement and maintain a solution to prevent polymer waste from accumulating and harming the environment, which is the driving purpose behind this project, as the goal is to identify an efficient way to break down polystyrene so it can be used for other purposes and not negatively impact the environment.

In order to reduce the amount of pollution polystyrene has on the environment, Since polystyrene is not biodegradable, it negatively impacts the environment by adding onto the amount of waste in landfills (Ávila, 2003). As a result of the overwhelming amount of pollution this causes, waste management systems use polystyrene, limonene-d (+), and extreme pressures of carbon dioxide to “produce microcellular foams”, which is a more environmentally friendly product than polystyrene blocks or pellets (Gutierrez, 2016).

When left in the environment, polystyrene is broken down into polystyrene nanoparticles. Polystyrene nanoparticles are strong pollutants and pose a potential threat to aquatic environments. These nanoparticles are a serious danger to the organisms in the aquatic ecosystems because they accumulate in organisms within an aquatic food chain (Libralato, et al., 2017). Polystyrene nanoparticle exposure can also cause an increase in cardiovascular risk and negatively affect iron absorption. Although polystyrene exhibits no short-term cytotoxicity, it still poses a great risk to long lasting environmental pollution when not recycled (Loos, et al.,2014). Polystyrene toxicity’s main source in the environment is its monomer styrene; it can be released during the heating and manufacturing of polystyrene and is a suspected carcinogen.

This is why it is important that polystyrene is recycled in an efficient manner and not left sitting in the environment. This project will provide a method of polystyrene recycling that requires less energy and heat which will lower the amount of toxicity produced when compared to other recycling plants.Polystyrene is the fourth most produced thermoplastic by production volume. Polystyrene is made by “stringing together” or polymerizing styrene, and it can be produced by many different batch processes (Schlager, et al.,2006).

When individual molecules of styrene are polymerized, they form into chain-like molecules creating polystyrene (Wünsch,2000). A polystyrene production plant may contain multiple process trains that produce a variety of different grades of polystyrene. The most common type of polystyrene is expanded polystyrene or EPS which is made by mixing air with molten polystyrene resulting in a lightweight foam (Troiano,2018).

This foam is sold under the name Styrofoam. Only five percent of a styrofoam cup is made of polystyrene; the rest is made of air. Polystyrene does not readily decompose so accumulates in landfills and contributes significantly to the solid waste problem in the United States.Limonene is a clear colourless liquid at room temperature, a naturally occurring chemical, and makes up over 90% of orange oil. Limonene has the chemical formula of C10H16. Limonene is an olefin hydrocarbon, and is typically found in nature as essential oils.

Since it is a naturally occurring hydrocarbon, it is not harmful to the environment, and is of low toxicity (Kim, et al). Due to its two available double bonds and its possibility for hydroxylation, limonene can be used for chemical modifications, one of which being a biomaterial. Plants that produce limonene typically store them in the peels of their fruit, which is why citruses have high limonene concentrations; citrus oil usually contain 70-98% limonene (+), and this product is easily accessible as it is produced at more than 60,000 t/year. (Jongedijk, et al., 2016). Because of their similar structure, limonene is able to dissolve polystyrene. The product of this reaction is a sticky gel-like substance that inhabits a significantly smaller amount of volume.

The gel is safe enough to be stored or implemented into glues, adhesives, and seals.The processes by which polystyrene is recycled are applicable to this project as they provide a basis for the procedures and machinery that are to be implemented; previous polystyrene recycling plants utilized the use of limonene to dissolve amounts of polystyrene, which provides insight to the goals of this project. As the production of polymers like polystyrene increases, the amount of waste from these polymers increases in landfills. The common problems observed in polymers like styrofoam is that they are not biodegradable and require massive amounts of space to store. Three millions tons of non-degradable plastic are thrown away every year and 70% of that waste is used for food and beverage packaging (Hearen et. al, 2014).

However many recycling companies do not recycle the polystyrene because of the cost and the lack of profit from the recycling. Statistics put out about the effect polystyrene has on the environment and its percent composition in landfills are misleading because they measure by weight rather than volume ignoring the amount of space it takes up (Somerville, 2017). It is important that something is done to reduce the volume of polystyrene in landfills because it is a widely used method to dispose of municipal solid waste (MSW). In developing countries, 91% of waste produced are in landfills because they provide a cheap form of waste management (Rong, Zengguang, & Junrui, 2018). Unfortunately, landfills pose a threat to homes and communities as the grow out of control’ they can cause landslides or collapse on people’s homes. This project poses a low cost solution to the volume of polystyrene in landfills while also giving a new recycling technique for the substance.

Scientists have discovered that the natural chemical found in citrus oils, d-Limonene, can dissolve polystyrene reducing waste. Limonene is a good solvent for the dissolution of polystyrene because the substances are highly compatible. Terpenic oils dissolve polystyrene easily and the polymer is highly soluble in the oils because the structures of limonene and the monomer are very similar (Gutiérrez, Rodriguez, Gracia, De Lucas, & García, 2013). Both limonene and polystyrene are hydrocarbons meaning that they are made of carbon atoms and hydrogen atoms only. Though one hydrocarbon chain is artificially made (polystyrene) and the other occurs in naturally (limonene) their chemical makeups make the reaction between them possible.

The byproduct of this reaction is easily recyclable and takes up less space in landfills. Because d-Limonene occurs naturally in nature, it is non-toxic meaning it does not produce harmful waste. Limonene is also of relatively low cost so it can be implemented in recycling plants with low budgets. Solvent based material recycling compacts the material by using a solvent to break it down and a densifier to decrease its volume. Not only does limonene work as this type of solvent but it also creates a new monomer with properties different than the one observed in polystyrene (Hearen et. al, 2014). Results from experiments conducted on d-Limonene and polystyrene suggest that engineers can design a biodegradable polymer or a machine that can breakdown polystyrene in a better way.

In this project, limonene will be used as a solvent to dissolve expanded polystyrene inside a machine.Wastes management machines are used to dispose or recycle waste that builds up from growing populations; these machines vary depending on the material machines are built for (Li, Wu, & Chen, 2013). Polystyrene waste is typically burned or heated; however, this requires a huge amount of energy. One of the benefits of the design for the polystyrene machine is that it uses a natural solvent rather than heat. reducing the energy used. Other forms of wastes management include sea dumping, landfills and incineration, all of which harm the environment it some way. Waste management machines help aid those procededures. Waste management machines for styrofoam and other plastics include the plastic shredder, plastic grinder, and a plastic granulator. After polymers go through these machines they become more susceptible to processes like molding, thermoforming, compacting, and other process that allow the substances to be reused or to take up less space in landfills (Plastic Shredders: Solutions for Plastic Scraps, 2018). Densifiers are used to compact styrofoam into dense blocks that are easy for storage and take up less space in landfills.

There are four main types of densifiers: hydraulic, thermal, screw drive, and a hybrid. Hydraulic densifiers use water power rather than heat to compact foam materials because it does not give off smoke or odors. Thermal densifiers use heat and melt foam; the foam is the compact and molded in its molten state. A screw drive densifier uses speed and pressure to compact foam rather than heat. Augers push the foam through a chamber where the foam goes through said conditions. The hybrid densifier combines the screw drive densifier and the hydraulic densifier to compact foam and release the least smoke and waste (Recycling Equipment, 2018). A polystyrene foam densifying machine is installed and operated within a mobile container that includes multiple walls, a top surface, and an interior space.

The polystyrene material is ground up, shredded and either heated or cold compressed by the densifier machine. (Troiano, 2018). A conveyor belt is commonly used to feed plastics like polystyrene into machines like mincers and densifier; a conveyor belt then feeds the affected materials out of the machines. The conveyor belt and the recycling machine are usually connected to the same power source but are connected to different motors (Avrorov, Lovtseva, Pol'dyaeva, & Tutov, 2017). The design for the limonene recycling machine uses a conveyor belt and the concept of a densifier; however, the design uses a chemical densifier as opposed to the densifiers listed above.