Green Chemical Methods of Recycling of Polyethylene Terephthalate (PET)

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Abstract

Green chemistry and sustainability are critical topics in modern science. The sustainability of the plastics industry in this manner ought to be of considerable concern. Polyethylene terephthalate (PET) is a familiar high volume thermoplastic polyester resin. PET is used predominantly in plastic packaging, textiles and beverage bottles. Improvement in the green techniques for reusing PET has in this way been examined with regards to green chemistry and sustainability. It has been observed that the progress made in the commercial recycling strategies of PET has brought about a not very green and unsustainable system for the production and effective removal of PET from the environment.

Keywords

Green chemistry, Polyethylene terephthalate (PET), Recycling strategies, Polycondentsation , Alcoholysis

1. Introduction

Plastics are an extremely common material used around the world, in this way their environmental effect and sustainability are getting to be essential subjects of concern [1]. Because of the broad nature of the subject, focus is made on polyethylene teraphtalate (PET), which is a typical, high volume thermoplastic polyester resin and is extensively used in plastic packaging, textiles and most notably, beverage bottles [2]. As a result, over the past three decades, recycling and reusing of used plastics across the world has risen enormously. The recycling and reusing of plastics has had its challenges nonetheless, where it was required to be inefficient, illogical, impractical and not economically viable [3]. This is because of the low value of recycled PET and its monomers notwithstanding the costly procedures of recycling. All things considered, the relative amount of PET waste occupying landfills has decreased since its use commercially [3]. Thusly, development in the processes of PET recycling and new applications for recycled PET are suspected to have been expanded.

2. Methods of Recycling PET

PET is a material that is vigorous to atmosphere and biological way of degradation [4]. Zhang, J., et al. (2004) investigate the biodegradation of PET with revelation to microbes and lipase [5]. The conclusion was that there were just cracks on PET fibers after move along degradation. In this manner, recycling is the only technique to achieve noteworthy PET degradation and reuse. By and large, there are four discernable strategies of plastics recycling: direct reuse, chemical reprocessing, mechanical reprocessing, and lastly, energetic recovery [3]. Energetic recuperation is where the plastic is combusted to yield thermal energy. Because of the sensible presumptions that reuse and energetic recovery yielded no significant improvement, where the former offers no potential application of chemistry and that the latter is on a very basic level unsustainable, focus is made on advancements in chemical and mechanical reprocessing.

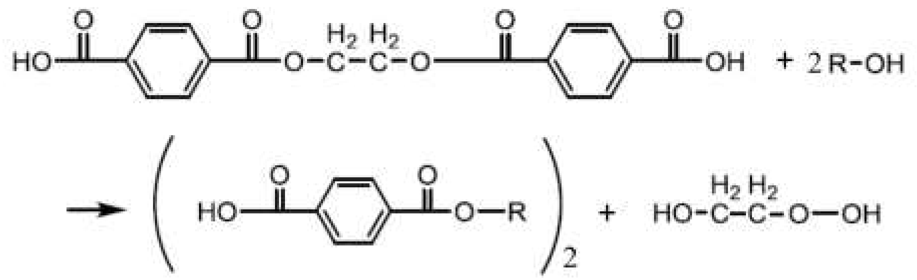
3. Chemical Reprocessing

Chemical reprocessing is the most lengthy and costly type of plastics recycling as it often includes depolymerization and repolymerization often following purification, which can incorporate distillation, recrystallization and additional chemical reactions [3]. PET belongs to the group of plastics known as polyesters and is usually synthesized through the polycondensation reaction of terephthalic acid (TPA) or dimethylterephthalate (DMT) and ethylene glycol (EG) [6]. Either pair of reagents first form the monomer bis (hydroxyethyl) terephthalate (BHET). After the addition of specific stabilizers and additives, the pre-polymer (BHET) undergoes polycondensation to form PET and release (n-1) moles of EG as shown in following scheme 1:

$$\text{nBHET} \leftrightarrow \text{PET} + (\text{n-1})\ \text{EG}$$

Scheme 1: Polycondentsation of BHET

Depolymerization consequently involves the breaking of the bonds formed in the polycondensation reaction. This is in general accomplished by solvolysis [7]. The depolymerization processes that have reached the level of commercial viability are glycolysis and methanolysis [8]. Presumably, glycolysis involves depolymerization in the presence of EG and methanolysis involves depolymerization in the presence of methanol. These two depolymerization processes are categorized under the tag alcoholysis and progress as follows in scheme 2:



Scheme 2: Alcoholysis of PET Dimer

Methanolysis is performed in overabundance methanol at high pressure and temperature along with a transesterification catalyst, such as zinc acetate [7]. The products of the methanolysis reaction are DMT and EG. Glycolysis is like methanolysis with the end goal that high temperatures and pressures are required, yet the reaction is performed in excess ethylene glycol and methanol is not fragment of the cycle [7]. Furthermore, an esterification catalyst is likewise used and is most commonly zinc acetate [6]. An intriguing aspect of glycolysis is that partial glycolysis can be performed, resulting in oligomers of lower chain lengths known as glycolyzates. The products of what is known as profound glycolysis of PET are BEHT and EG [7].

A significant research done in chemical processing using glycolysis is not in development of improved methods of chemical processing, rather research in uses of the glycolyzates obtained from glycolysis and numerous are portrayed in [7]. An adverse outcome is this has caused stagnation in the improvement of commercial chemical recycling processes of PET. This is made obvious since glycolysis and methanolysis were proposed as recycling processes since the first commercial uses of PET in the 1950s [7]. Other methods of solvolysis such as hydrolysis [2] have never made it to the commercial scale.

4. Mechanical Reprocessing

This method of reprocessing includes activities, such as the grinding, melting, reforming and extrusion of PET waste [9]. This process is subject to particular concerns however involving the purity of the recycled PET and its structural integrity [9]. Mechanically recycled PET may incorporate contaminants, making it unsuitable for food containers. Also, post-consumer PET encounters a loss in inherent viscosity when recycled mechanically due to hydrolysis reactions in the melting process and resulting is shorter chain length [9]. Chain length and inherent viscosity are imperative parameters in plastic polymers because they are direct estimations of the strength of the polymer. Significant loss in polymer strength may bring about the inapplicability of the recycled polymer for its previous uses. This is one of the main downsides of mechanical processing. Recycled PET can be mixed with virgin polymer of longer chain length in attempt to prevent this [3], but this reduces the effectives of this recycling process as far as sustainability.

5. Conclusion

Deplorably, a day will come when the recycled PET cannot be reprocessed any further and will once again reoccupy landfills, potentially spliced with numerous different substances, for example, chain extenders, plasticizers and other plastics. All of these compounds will conceivably continue and harm the environment. Be that as it may, mechanical processes from a green chemistry point of view are greener than chemical processes since there are no or possibly extremely insignificant stoichiometric reagents (negligible in the case of chain extenders) and they can be performed with or without solvent. Even though mechanical processes require significant energy input as it is a physical transformation, when contrasted with chemical reprocessing, mechanical reprocessing can be thought about roughly on par. This is a direct result of the substantial energy requirements of solvolysis, represented by the high temperature and pressure requirements of the reactions. Also, the energetic and chemical prerequisites of the refinement steps associated with chemical reprocessing. Consequently concerning green chemistry, mechanical reprocessing can be viewed as greener than chemical reprocessing, however its products will end up having a negative environmental impact because of their unsustainability.

As expressed, the basis of the commercial techniques (solvolysis) of chemical reprocessing for PET have remained mostly unaltered since PET began becoming of commercial use. The majority of research and development has gone into potential methods for uses of recycled PET, where the subsequent products of these techniques are just more polymer resins and other non-biodegradable synthetic products. This exploration bearing is vigorously affected by monetary impetus, since the cost and effort of recycling PET will always be more noteworthy than the production of virgin PET. What's more, the recycled PET and its monomeric units have a low market value, which is the reason new high market value recycled PET based products is the coveted focal point of research. This is impeding to the sustainability of the PET industry since there is no cyclic nature of the production and recycling of PET. The amount of PET in landfills has been reducing; however it is simply being transformed into other non-biodegradable materials. The only way for PET to be manageable is if it somehow managed to be chemically recycled and reformed specifically back into PET to be reused. Despite the fact that this is impossible because of the monetary aspects previously specified. In addition, there is the societal responsibility of people to properly dispose of their PET waste and give it recyclers, which is a different issue totally in itself.

It can be inferred that the present commercial techniques of PET recycling are in some important aspects not green and do not provide a sustainable system of PET production and expulsion from the environment.

6. References

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