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Recycling of plastic wastes with poly (ethylene-co-methacrylic acid) copolymer as compatibilizer and their conversion into high-end product

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A B S T R A C T

This paper deals with the utilization of plastic wastes to a useful product. The major plastic pollutants that are considered to be in maximum use i.e. PET bottle and PE bags have been taken for consideration for recycling. As these two plastic wastes are not compatible, poly (ethylene-co-methacrylic acid) copolymer has been used as compatibilizer to process these two plastic wastes. Effect of dose of poly (ethylene-co-methacrylic acid) copolymer as compatibilizer has been studied here. It has been shown that only 3 wt % of poly (ethylene-co-methacrylic acid) copolymer is sufficient to make 3:1 mass ratio of PET bottle and polyethylene bags compatible. Compatibility has been examined through mechanical testing, thermal and morphological analysis. After analysing the property of recyclates, better mechanical and thermal property has been observed. Almost 500% of tensile property has been improved by addition of 3 wt% of poly (ethylene-co-methacrylic acid) copolymer in 3:1 mass ratio blend of PET bottle and PE bags than that of pristine blend. Morphological analysis by FESEM and AFM has also confirmed the compatibility of the blend. Experimental data showed better performance than available recycling process.

1. Introduction

Over last few decades our day to day activities have been revolutionized by plastics. Plastic consumptions are increasing without any limitations because of their low cost and easy disposal from households. With increase in population, the plastic consumptions are getting higher and on the other hand accumulation of waste materials are exceeding which affects both human and wild animals. Major contribution to plastic wastes are commercially available soft drinks, water bottles and polyethylene bags (commonly known as carry bags) which are being discarded in an inappropriate way. Several countries have banned (Clapp and Swanston, 2009) the usage of these above-mentioned items, but it's still not globally possible because of which a proper plastic waste disposal is in demand.

One of the effective way of reducing plastic waste is recycling and reuse of consumed items. Recycling is in practise for several decades (Gourmelon et al., 2015), but only less percentage of plastic waste is recycled. The task of recycling falls into four major steps: collection, separation, processing/manufacturing and marketing. Since wastes are accumulation of many different materials separations are done by sorting, gravity, and electrostatic method depending on the type (Shent et al., 1999).

In older days glass and some metal cans were used for packaging applications. Conversion of post consumed glasses and jars into new applications was easily possible. Nowadays the above-mentioned glasses and jars have been replaced with PET because of its excellent un-breakability, low weight, high clarity, good barrier property. Recycling of post consumed PET bottles into new food packaging material is undesirable because of lack of information on contaminations. Hence, they are either recycled to develop bottle to bottle transformation or for fibre applications. As the accumulation of waste bottles are increasing, the development of bottle to bottle recycling are increasing more and more. For removal of contamination at various, levels, super clean recycling process was developed based on depolymerisation and partial depolymerisation (Welle, 2011).

Apart from bottles the other major contributor for plastic wastes are plastic bags. Since they are used by all set of people, the term "plastic pollution" has reached every corner globally. Approximately 150 bags are being used by a human being per year (Plastics ain't so fantastic, 2010). Unlike bottles, bags are difficult to recycle and the available methods of recycling them are costly. Thermal decomposition i.e. pyrolysis is the most commonly used way of recycling bags. The process of recycling through pyrolysis is resulted in liquid fraction similar to gasoline (Achilias et al.,

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2007). For a high-end product, right composition of input is needed, which is not possible economically and technically every time (Pinto et al., 1999). These limitations make recycling harder and accumulation of these scraps are increasing at alarming rate. Lack of proper recycling and reuse facility to handle the increasing consumptions resulted in plastic pollution from land to ocean. In 2010, 275 million metric ton of plastic waste was observed among which around 12.7 million metric ton enters into the ocean (Jambeck et al., 2015).

In this fast-growing technology, post use plastic recycling makes sense only when an efficient system is implemented. Recycling the different type of plastics separately into individual output is a slower process comparing to the rate at which plastics are consumed. So, the manufacturing step in recycling is improved by blending of materials. The General Electric Company demonstrated that, polymer resin blended with automobile parts can be reused for manufacturing commercial goods like toys and other house hold goods. This blending technology can improve the usage of high performance polymers and also can increase the performance of recyclates. Plastic wastes are blended with other virgin materials and their performance are evaluated. In some cases, plastic wastes are used in composites and as a part of concrete (Utracki, 2002; Sojobi et al., 2016) considering potential environmental benefits. PET bottles waste and PC waste from glasses/bottles blended for building applications, showed suitable mechanical properties (Ghernouti et al., 2014). Blending of HDPE waste with maximum percentage of virgin HDPE along with talc for composites showed better energy absorption (Fraïsse et al., 2005).

Various plastic wastes separately or by combining with virgin materials are used for different applications as a step towards environmental benefit. Recycled plastic waste bottles inside concrete block showed better compressive strength, while some technical and non-technical aspects like mix design and feasibility in production are still a question mark (Safinia and Alkalbani, 2016). Recycled high density polyethylene waste and Portland cement are used in production of plastic cements which showed possibility of lightweight materials (Jassim, 2017). Among total stored wastes in landfill 69.13% was plastic bags. Increnation as residue derived fuels for energy recovery is also used as a recycling process (Zhou et al., 2014). The major treat for growing pollutions are waste bottles and plastic bags which need rapid conversion into secondary product. Till date on recycling, works are done on post consumed plastics wastes separately or in combination with other materials and no efficient recycling on dual plastic pollutants is reported. Recycling of dual plastic wastes is not adopted also till date due to their non-compatibility.

This paper introduces dual plastic pollutant recycling process. It focusses on reducing the plastic pollution by blending/compounding post consumed plastic bottles and plastic bags into a single recyclate by using poly (ethylene-co-methacrylic acid) copolymer as compatibilizer. The compositional parameters investigated here by varying the level of compatibilizer for a constant ratio of post consumed materials. Plastic bag and bottle wastes are not blended together into single product till date because of their very different physical and chemical nature. The method presented here primarily focus on reducing the existing plastic waste into considerable extent by recycling the used materials with copolymer. Indeed, our strategy is to study the effect of mixing copolymer with waste plastics, their response to stress-strain and analysis on property enhancement of recyclates. Approach has been taken to check the compatibility of the blend of waste plastics by field emission scanning electron microscopy and atomic force microscopy.

2. Materials and methods

2.1. Materials

Poly (ethylene-co-methacrylic acid) copolymer (EMAA) is used as compatibilizer from sigma Aldrich. Plastic wastes like used bottles and bags are collected and used without further chemical treatments to cut down the traditional recycling steps because of which pigments are retained. The collected post consumed bottle and plastic bags are cut into small flakes (Fig. 1) suitable for machining. The materials are directly used after water washing and drying.

2.2. Experimental method

Plastic bottles and bags are cut into small flakes and stored. The compatibilizer is dried at 40 °C for 24 h. Scraps of bottle and bag are taken in 3:1 (PET:PE) mass ratio (Kalfoglou et al., 1994) is kept standard and percentage of compatibilizer (Table 1) is varied.

The mentioned ratios in Table 1 are recycled/processed into secondary product using Thermo scientific HAAKE MiniCTW Micro compounder and HAAKE MiniJet piston injection moulding system. The processing parameters need to be monitored continuously. The micro compounder has a micro conical twin screw compounder where melting and homogenization takes place. It is immediately transferred into injection system where recyclate is obtained. The compounder is maintained at 285 °C, rpm of 30–50 and mixing time 5–7 min while the injection moulding had various parameters to monitor. Temperature of cylinder is maintained at 285 °C, temperature of mould at 80 °C, Injection pressure around 400 bar and time is set to 5sec. Some of the laboratory scale moulded specimens are shown (Fig. 2). The colour variations are because of direct feeding (without removal of pigments).

3. Characterization techniques

3.1. Mechanical property

The mechanical property of the samples are measured using Instron Universal Testing machine (model No 3365, Instron Co., Macclesfield, UK) with a load cell of 5 KN at a crosshead speed of 5 mm/min following ASTM D638 standard. It is performed by applying longitudinal or axial load at a specific rate for a dog bone shaped specimen of known dimension. The main parameter measured using tensile tests are stress and strain. Sensors that provide electrical signals are used for measuring load and displacements.

Fig. 1. Photograph of plastic scraps converted into respective flakes.

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