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Developing a compression moulded thermal insulation panel using postindustrial textile waste

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ABSTRACT

Postindustrial textile has incrementally become a major issue of global concern over the last decade, especially, synthetic textiles, given their non-biodegradability, toxicity and expected growth with ever-increasing production quantities. Absence of proper waste management facilities and technologies poses both environmental and social challenges in textile waste management. Multi-material systems further increase the complexities in textile recycling. Mixing of Spandex with Nylon to improve stretchability of fabrics is extremely common nowadays although it renders Nylon almost impossible to be recycled. Here in, a complete process to develop a novel thermal insulation material is presented, using synthetic material cutting waste (Nylon/Spandex and Polyurethane). Thermal insulation panels were developed using compression moulding. A sample matrix of panels with different proportions of Nylon/Spandex and Polyurethane was subjected to testing for thermal conductivity. The combination giving the best thermal insulation was experimentally found to be 60% Nylon/Spandex fabric shreds mixed with 40% Polyurethane shreds. The thermal insulative behaviour of the novel material was modeled using a power series, using the material thickness as the parameter.

1. Introduction

1.1. Textiles waste context

Textile and apparel production involves one of the most complicated global industrial chains in product manufacturing (Fletcher, 2008; Köksal et al., 2017). Consumption of textile products has been growing over time due to rising population and changing consumption patterns (Tojo et al, 2012; Marshall and Farahbakhsh, 2013). This situation has accelerated the environmental consequences associated with the global textile industry. While environmental impacts arise at all stages of a textile product life cycle, key environmental issues are highlighted as the consumption of massive amounts of energy, water, hazardous chemicals, and the generation of hazardous waste (WRAP, 2017; Chapman, 2010).

Textile waste can be either postindustrial or postconsumer. Postindustrial textile waste refers to the waste generated during manufacturing process and usually includes apparel cutting waste, excess fabrics and rejections due to quality issues (Tomovska et al., 2016). Postindustrial textile waste is often referred to as 'clean waste' since fabrics are unused at the time of disposal. Postconsumer waste refers to the unwanted garments that are discarded by the consumer after being used. Sustainability efforts to date have incorporated managing postconsumer textile waste, yet, little attention has been paid towards managing postindustrial textile waste. However, increasing fashion consumption means rising production quantities, and subsequent generation of postindustrial waste, particularly in developing countries, where most of the manufacturing facilities are located in. This issue has been further complicated by the absence of proper waste management systems in place to deal with postindustrial textile wastes generated in hundreds of tonnes on a daily basis. The amount of textile wastes generated daily is so enormous and an accurate figure cannot be placed due to proper systems to track these statistics being unavailable.

Solid waste management poses challenges in developing countries, mainly due to technological and financial barriers (Guerrero et al., 2013). General understanding is that municipal councils are responsible for waste management, but they often fail to implement appropriate waste management systems due to lack of technical skills, lack of investments and limited resources (Jordeva et al., 2015). Priority is given only to remove wastes from

Abbreviations: NS, nylon/spandex; PU, polyurethane.

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urban areas and their disposal is mostly unregulated (Wilson, 2007). Open dumping and landfilling of wastes have become increasingly problematic due to public health as well as environmental implications (Marshall and Farahbakhsh, 2013). Waste management in developing countries is typically limited to a collection and removal service, and the environmental protection or resource recovery has been given little or no attention (Guerrero et al., 2013).

Environmental concerns associated with textile wastes are increasing with the rising volumes of textile consumption (Briga-Sá et al., 2013). While cotton remains important in the market as a natural fiber, world synthetic fiber consumption keeps growing. Synthetic fiber consumption in 2016 was reported to be 64% of the total fiber consumption (Textile Exchange, 2017). Textile wastes become a serious threat to the environment when landfilled since they carry the potential of groundwater contamination and formation of greenhouse gases upon decomposition. Decomposition of biodegradable textile waste generates methane, a powerful greenhouse gas contributing to global warming (Wang, 2010). Decomposition of organic yarns such as wool generates ammonia, which is highly toxic in both terrestrial and aquatic fields (Jayasinghe et al., 2010). Nevertheless, the highest contributor to the carbon footprint in the apparel production chain is the fiber extraction or agriculture (WRAP, 2017), in which case disposing fabrics that have never been used is a serious concern: resources are being depleted and the environment is being polluted to produce something that is being thrown away without even being used.

Moving from landfill-based to resource recovery-based solutions requires accurate knowledge of waste composition as well as implementation of waste collection and characterization processes (Adeniran et al., 2017; Burnley, 2007). According to Briga-Sá et al. (2013), textile wastes carry a group of reusable materials with different possibilities and applications. Recovery routes of textile waste generally include reuse or recycling. It is estimated that 95% of textile waste can be recycled. According to Wang (2006), recycling technologies are divided into four categories: primary (recycling industrial scrap), secondary (mechanical processing of postconsumer products), tertiary (converting plastic waste into chemicals, monomers or fuels) and quaternary (burning for heat generation). Depending on the point of waste generation, said technologies could vary from single polymer to multi materials, and a waste stream of a single type of polymer is easier to recycle than a mix of polymer materials (Wang, 2010). Yet, the practical scenario is that, postindustrial textile wastes represent different sizes, shapes, compositions and properties, which increase the difficulty in finding appropriate recycling solutions (Briga-Sá et al., 2013).

1.2. Textile waste management in manufacturing hubs

While global apparel consumption is highly concentrated in the European Union, United States and Japan, manufacturing facilities are mainly located in third world countries, given the availability of cheap labour (Cattaneo et al., 2010). Even though there are strict legislations and regulations in place in the developed part of the world in terms of textile waste management, the apparel manufacturer of the supply chain has neither commitment nor facilities to manage their textile wastes. In third world countries such as Bangladesh, Sri Lanka and Vietnam where the apparel industry is dominant, significant amount of postindustrial textile wastes are being generated, yet recycling rates are considerably low. Even though landfill disposal is the least preferred option in any waste management strategy, that remains the most preferred option in the manufacturers' point of view (Jordeva et al., 2015).

Apparel industry in Sri Lanka is the strongest manufacturing sector of the country in terms of employment generation and foreign exchange earnings. This export oriented industry has achieved a high growth rate over the last decade, with a total export income of USD 4.6 Bn, representing 46% of the total merchandise exports of the country (EDB, 2017). These values are expected to grow in the near future due to the regaining of GSP + tariff concession by the European Union. Sri Lankan apparel industry produces a wide range of fashion clothing for various international fashion brands such as Victoria's Secret, Marks & Spencer, Nike, GAP, La Senza, H&M etc., mainly for the USA and EU markets. Approximately 300 manufacturing units are scattered around the country, and the majority belongs to 10 major apparel exporters (EDB, 2012). High quality, sustainable and ethical manufacturing practices have placed the Sri Lankan apparel industry in a competitive position in the global market.

In 2014 alone, a total of 294,000 tonnes of textiles were imported and a minimum of 44,100 tonnes of textile waste was generated (Park, 2017). Textile waste generation is predicted to be increased with the rising quantities of production. Currently, there are no recycling facilities available in Sri Lanka and effective waste management programs are yet to be developed. Current practice is to remove waste from urban areas to be eventually sent for open dumping. Recent incident of toppling of one of the 'waste mountains' in Meethotamulla area that caused deaths of 30 people living nearby indicates the inappropriate selection of landfill spaces by the authorities. Moreover, analysis of this situation by a set of experts from Japan reported a high concentration of methane in the area, indicating a highly polluted environment that is unsuitable for human habitat in that area. However, open dumping of waste in selected lands is still continued as the general practice, irrespective of the environmental and health concerns poised.

Usually municipal councils do not have any systematic process to separate and collect textile waste from other waste categories, thus textiles are contaminated with other industrial wastes, if directed to the general waste stream. In addition, no substantial textile recycling activities take place in Sri Lanka, and postindustrial textile wastes are being sent for open dumping or incineration. Those textile wastes mostly consist of synthetic materials, Particularly NS that are being used to manufacture both active wear and intimate wear, and are problematic to recycle. Currently, recycling technologies for NS blended fabrics are limited, even though Nylon, as a single polymer, could be recycled (Yin et al., 2014). Similarly, significant amount of PU foam wastes are generated during the bra cup manufacturing process, which eventually end up in landfills, causing environmental issues.

Primary objective of this research was to convert postindustrial textile waste into a useful material that would otherwise end up in landfills. Recycling of NS blended fabrics remains a challenge to date, and hence this research aimed at providing a novel solution to manage such NS blended textile waste. The other material used in this research is postindustrial PU waste, considering its availability and thermal performance. The possibility of converting the aforementioned textile wastes; specifically into a thermal insulation material was further explored on the grounds that PU is an excellent thermal insulator by itself, while NS would provide binding upon melting to form a rigid, composite material.

2. Materials and methods

2.1. Materials

PU and NS fabric offcuts as input were obtained from a local apparel manufacturer. The type of PU used in the experiment was thermoset PU. The percentage of Nylon by weight in the NS