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An air-based automated material recycling system for postconsumer footwear products

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ABSTRACT

The worldwide consumption of footwear is estimated to be in excess of 20 billion pairs of shoes per year. To date very little work has been done to develop material recycling solutions for mixed footwear products. In fact less than 5% of end-of-life shoes are being recycled, with most being disposed of in landfill sites around the globe. One of the primary reasons is that most modern footwear products contain a complex mixture of leather, rubber, textile, polymers and metallic materials, that makes it difficult to perform complete separation and reclamation of material streams in an economically sustainable manner. This paper discusses the development of an economically feasible automated material recycling process for mixed postconsumer footwear waste. Central to this process are bespoke air-based separation technologies that separate granulated shoe particles based upon the difference in size and weight. Experimental studies with three different types of postconsumer footwear products show that it is possible to reclaim four usable material streams; leathers, textiles, foams and rubbers. For each of the reclaimed materials there are a variety of applications such as surfacing materials, insulation boards and underlay products.
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1. Introduction

The increased availability of cheap mass produced goods, coupled with rapidly changing consumer fashion trends has resulted in a sharp increase in the consumption of products in many industrial sectors. The worldwide per capita consumption of footwear has increased considerably, from 1 pair of shoes per year for every person in the world in 1950 to almost 2.6 pairs of shoes in 2005. In the EU, it is estimated that the amount of waste arising from postconsumer shoes could reach 1.2 million tonnes per year. The vision of 'Zero Waste to Landfill' thus remains as one of the major challenges of 21st century for the footwear sector. This target is very ambitious as currently less than 5% of the 20 billion pairs of shoes produced worldwide every year are recycled or reused (World Footwear, 2005; SATRA, 2003). However, increased raw material costs, producer-responsibility issues and forthcoming environmental legislations are expected to challenge the way the footwear industry deals with its end-of-life (EoL) products.

It is argued that in many situations, material recycling is seen as the most suitable means of dealing with discarded shoes (Staikos and Rahimifard, 2007b). However, for long-term sustainability of such footwear recovery activities an economically viable material recycling system must be established. In the automotive and electrical/electronic industries, where European Producer Responsibility directives, such as the End-of-life Vehicles (ELV) directive (European Commission, 2000) and the Waste Electrical and Electronic Equipment (WEEE) directive (European Commission, 2003) have been introduced, a number of material recycling value chains have now been established. This has been feasible because these products typical contain a large percentage of easily recoverable metallic materials to facilitate an economically sustainable value chain (Coates and Rahimifard, 2007; Barba-Gutierrez et al., 2008; Abu Bakar and Rahimifard, 2008; Kahhat et al., 2008). However, footwear products typically contain a large mixture of materials, such as rubbers, polymers, leather and textiles that have relatively low recycled value.

Therefore understanding and developing methods for footwear recycling is of major concern to the footwear sector and this paper will discuss the development of an automated material recycling system for mixed postconsumer footwear waste. The first part of the paper begins by introducing the various EoL options for footwear and outlines the challenges of EoL footwear recycling. The paper then describes the recycling approach that has been developed, provides a simple economic analysis and outlines some potential applications for recovered materials. The later part of the paper then presents the results of experimental studies with three common types of footwear

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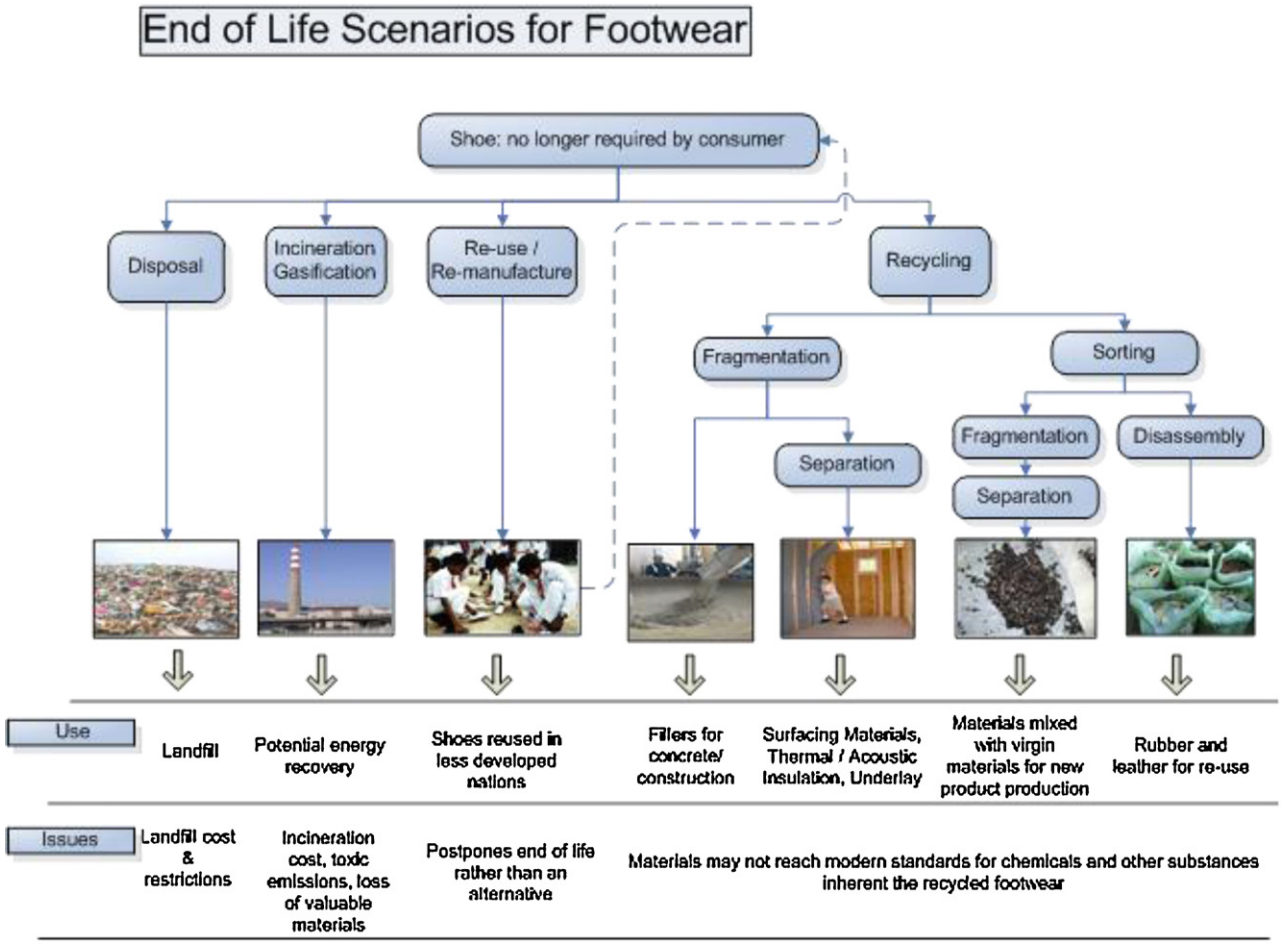

Fig. 1. End of life scenarios for postconsumer footwear products.

products. Finally further work is discussed and conclusions are drawn.

2. Background

As discussed by Staikos and Rahimifard (2007a) there are four main EoL options that can be considered for postconsumer footwear products, as illustrated in Fig. 1, these are: landfill, incineration/gasification, reuse and recycling. For each of the EoL options there are various environmental impacts, economic benefits and technical requirements that must be considered.

Land-filling is considered the most undesirable option, due to the obvious negative environmental impact, depletion of resources, increasing landfill taxes and in some countries the limited availability of landfill space. Incineration is still considered a controversial technology with environmental concerns over the release of polluting emissions. Reuse involves the collection of worn or unwanted shoes for distribution mainly within developing countries. Charitable organisations such as the Salvation Army Trading Company Ltd. (SATCOL) and Oxfam, together with local authorities and municipalities are the main supporters of reuse schemes in the UK. However, it is argued that as the economic power of developing nations grows the demand for second hand shoes may begin to fall. Furthermore, not all shoes that are collected can be reused, due to their poor conditions, and in such situations material recycling is seen as the most suitable option.

Nike is currently the only footwear manufacturer which is engaged in postconsumer footwear recycling on a commercial scale. Their scheme has been labelled the Nike 'reuse-a-shoe' programme and has been developed to recycle worn and defective athletic shoes (NIKE, 2012). Consumers can return any brand of unwanted athletic shoes via Nike's worldwide network of collection points placed within retail stores. The collected shoes end up in one of two central recycling plants – in the USA or in Belgium. In these plants the shoes are shredded and put through a series of mechanical recycling processes to separate them into three material streams: Nike Grind (rubber), Nike Foam and Nike Fluff (textiles). These materials are then used for various sports related applications such as running track underlay, playground surfacing and basketball court underlay. The Nike 'reuse-a-shoe' scheme has been operating for over a decade and Nike claims to have recycled around 25 million pairs of shoes to date (NIKE, 2012). However, the scheme is not designed to deal with the recycling of other non-athletic types of postconsumer footwear waste. Therefore, a more generic recycling approach as outlined in this paper is required to deal with various types and styles of footwear products.

2.1. Challenges related to material recycling of mixed footwear products

Postconsumer footwear products are a largely untapped commodity with a significant potential for recycling. This highlights the economic and environmental benefit that can be obtained from establishing a sustainable shoe recycling chain (Staikos and Rahimifard, 2007c). However, current material recycling facilities and operators are either incapable of dealing with the specific material mix in footwear products or do not provide the best method of recovering maximum value from postconsumer shoes waste. One

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