LIFE CYCLE ASSESSMENT OF TWO ALTERNATIVE END-OF-LIFE SCENARIOS FOR LEATHER SAFETY SHOES

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This paper provides a brief overview of the environmental impact of footwear industry and the end of life solutions. Nowadays almost 23 billion pairs of shoes are produced worldwide every year and most of them are landfilled after their use. Currently the lifetime of a pair of shoes is falling because of the customer preferences and the fast fashion trend at market and fashion industry. As a result, huge amounts of wastes are being landfilled. The aim of this paper is to analyses the environmental implications of shoes landfilling and incineration end-of-life scenarios. To achieve it, these two scenarios were applied in a life cycle assessment of a pair of shoes performed for this study.

Keywords: end-of-life, sustainable footwear, landfilling, incineration, life cycle assessment

INTRODUCTION

In the last years the footwear industry is trying to become more sustainable, improving the energy and material consumption and eliminating the hazardous substances from the production phase (Staikos, 2006). The fast fashion trend creates new challenges to footwear companies; they have to adapt to the market changes in order to satisfy the consumers.

Less than 5% of 20 billion pairs of shoes produced per year are recycled or reused, and the rest goes to landfill or are stocked in the wardrobes for years (Lee and Rahimifard, 2012). But, in the last years, the number of footwear produced worldwide has increased, reaching 23 billion pairs in 2017 (World Footwear, 2017).

Because of the diversity of materials, not all shoes collected can be recycled, most of them are made from a mix of materials such as leather, polyurethanes, textiles, adhesives, polymers, rubber, which are difficult to separate.

Environmental Impact of Footwear Industry

The highest environmental impact of footwear industry, according to Haworth *et al.*, 2006 is the end-of-life phase because of the huge quantity of waste generated. This fact can be explained because the majority of the shoes worldwide are discarded in landfills which lead to groundwater, surface, and soil contamination.

If in the design phase is taking into consideration the end-of-life scenarios it can offer the possibilities to integrate the distinct elements of circular economy (White *et al.*, 2013). Basically the design of a product decides the waste management approach.

The nature and the quantity of waste generated by the footwear industry can be classified in two groups:

a. The type of the materials (leather, polyurethane, foam, rubber, plastic);
b. The type of assembling technology (bonding, direct moulding, stitching).

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Waste management options for shoes at the end of their life use are (Staikos, 2006): Reusing, extending the lifespan of the shoes; Recycling – down-cycling; Energy recovery – incineration, gasification, pyrolysis; Landfill.

The EU Landfill Directive has an important role, developing the waste management policies, landfill restrictions. The Landfill Directive also defines the waste categories (municipal waste, hazardous waste, non-hazardous waste and inert waste) and presents the legislation and procedure for the acceptance of waste in a landfill.

The EU Waste Incineration Directive is establishing the emission limit values for incineration and co-incineration plants and is monitoring the requirements for pollutants to air such as sulphur dioxide (SO_2), hydrogen chloride (HCl), dust, nitrogen oxides (NOx) or heavy metals.

RESEARCH METHODOLOGY

To analyses the environmental implications of shoes landfilling and incineration end-of-life scenarios, these two scenarios were applied in a life cycle assessment of a pair of shoes performed for this study. Life cycle assessment is a method for evaluating the environmental impact of a product or an activity over its life cycle. The LCA asses only the environmental impact of a product without taking into consideration economic or politic aspects (LCA Compendium, 2017).

For this study it was applied “cradle to grave” approach, this refers to the activities involved in the life cycle of a product, presented in figure 1, starting from the raw materials extraction, manufacturing, use, maintenance and, in the end, disposal.

Figure 1. Footwear life cycle phases

Inventory Data

Several sets of data were required to assess the environmental implications of shoes landfilling and incineration end-of-life scenarios. Life cycle assessment was applied to a pair of safety boots, for men, size EU 42 with its primary packaging. Shoe materials are classified in three main components: upper, sole and packaging. In the upper it was used bovine leather, polyurethane, and textile. The sole is separated in outsole and midsole, both made of polyurethane.

The background inventory data was obtained from Ecoinvent database, version 3.4. The manufacturing and assembling of safety footwear includes several processes: cutting, stitching the parts for upper and injection for outsole and midsole.

Impact Assessment

The impact was determined using Global Warming Potential (GWP) where the contribution of emissions to the global warming for 100 year period are calculated according to the values of Intergovernmental Panel on Climate Change (IPCC, 2007).

The impact of greenhouse gas emissions were measured as relative carbon dioxide and are expressed in terms of an equivalent mass of carbon dioxide (kg CO_2eq).

The Life cycle analyses were conducted using SimaPro software.

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RESULTS AND DISCUSSION

The majority of the used shoes are landfilled or incinerated (depending on the legislation of the country, for example in Romania there is no municipal incineration plant). The recycling process is not involved in this study therefore there is no material recovery.

Landfilling Scenarios

According to the report Diverting waste from landfill – effectiveness of waste management policies in the European Union (EEA report, 2009) there are three scenarios for the end of life of professional footwear, presented in table 1.

Table 1. Scenarios for the end of life of professional footwear

	Percentage
Average landfilling in weight for professional footwear	79,2%
Average incineration in weight for professional footwear	19,8%
Average recycling in weight for professional footwear	1,0%

To estimate the GWP of the analysed shoes in landfill is was used SimaPro software. The total emissions associated with the end of life treatment of professional footwear are small. At the end of their life use, in the first scenarios (figure 2), it was assumed that they are landfilled and this emits 0.0996 kg CO_2 –eq per pair resulting from emissions of methane during anaerobic decomposition of organic matter in landfills. The total emissions are only 0.554% of the total life cycle impact of the analysed product.

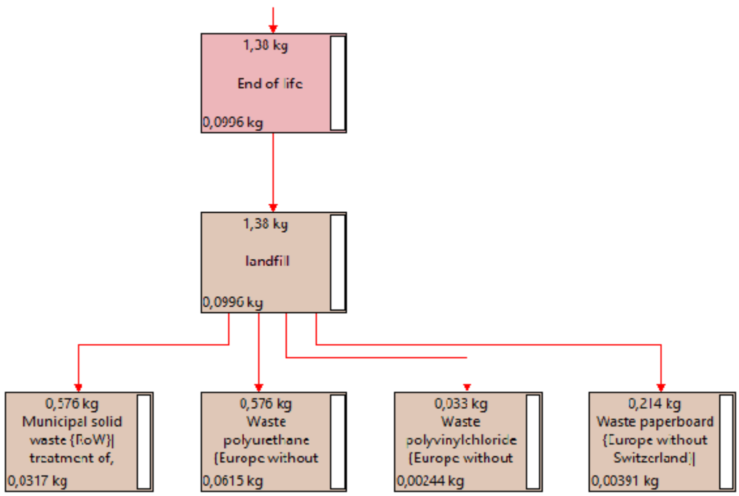

Figure 2. Waste generated from landfill

The value can be explained by the fact that, the method used, Global Warming Potential, is taking into consideration the impact of emissions for a period of 100 years.

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In this time the materials used are not degraded, some of them have a faster degradability than others, that is the reason why the CO_2 emissions have a small value (i.e. a midsole made of EVA can last up to 1000 years on landfill (Lippa *et al*., 2016)).

The consequence of the anaerobic conditions that exist in landfills is the release of biogas, especially methane (CH_4). Methane have a radiative forcing 21 times greater than CO_2 (Simple Shoes Report, 2008).

Incineration Scenarios

Energy Recovery at Municipal Incineration Plants

In the case of leather the advantages are: substitution of fossil fuels and reduction of CO_2 emissions. The biggest concern, in a classic process of incineration, is the conversion of chromium III to chromium VI (Lety, 2018).

Polyurethane, as well as other plastics, is a good material to recover energy from, because, according to Thompson and Thompson (2014), has a high energy content.

The main disadvantages of municipal incineration plants are: harmful air emissions and is not accepted in all European countries.

At the end of their life use, in the second scenarios, it was assumed that the shoes are incinerated. The end of life emissions are 1.86 kg CO_2 –eq or 9.48 % of the total life cycle impact. The emissions are higher to incineration compared to landfill because all the components of the shoes are destroyed at the same time and the CO_2 is release immediately.

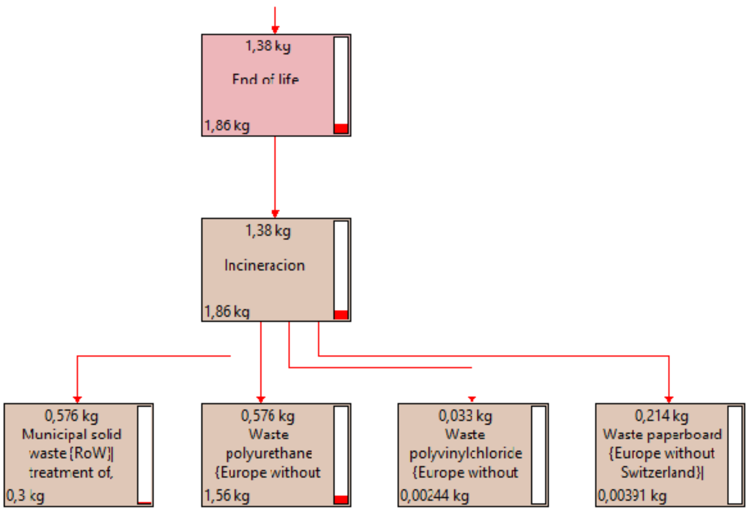

Figure 3. Waste generated from incineration

Figure 3 illustrates the waste that is sent to a municipal incinerator. Polyurethane have the most significant impact on the environment, 1.56 $kgCO_2$ –eq per pair.

As a result of this analysis, the use of polyurethane in a shoe represents a hotspot of carbon impact, this means that shoe designers should focus on other materials in order to reduce the material impact (recycled materials, biodegradable).

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Alternatives Scenario for the End of Life of Shoes

Recycling

A recycled material can be uncycled or downcycled. The recycled materials recovered from a shoe and their applications are considered as downcycling, but it is better compared to the disposal to landfill (James and Rahimifard, 2012).

If the components of a shoe are separated, there are several recycling options used nowadays in order to add value to the materials instead of landfilling or incineration. From a quantitative point of view this method cannot be used on a scale mass. The SOEX company and its partners developed an industrial-scale footwear recycling plant. This plant is able to recycle all types of shoes and to separate the different components such as leather, rubber, foam, metal.

The recycling process is presented in figure 4, first step is shredder the shoes (all types it is not necessary to sort them) after that the materials are separated (metals, non-metals, textiles, rubber, foam, leather) and in the end they are granulated. The new raw materials derived are leather fibres, foam granules, rubber granules. An example of reusing these materials is creating soles and floor mats from rubber granules, or production of inner soles, floor covering from foam granules. The amount of shoes passing through the system is 2000 pairs per shift, the waste reduction per shoe is up to 70%, the daily waste reduction of shoes is up to 45% (SOEX Footwear Recycling).

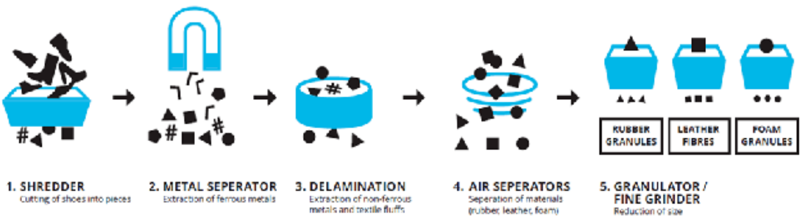

Figure 4. Recycling process for footwear (source SOEX Footwear Recycling)

CONCLUSION

The purpose of the study was to determine environmental implications of shoes landfilling and incineration end-of-life scenarios. For this, these two scenarios were applied in a life cycle assessment of a pair of safety shoes.

Based on literature, the end-of-life phase is considered to have the significant environmental impact because of the huge quantity of waste generated. The majority of the used shoes are landfilled or incinerated.

The results indicate that for the disposal of mixed materials in a sanitary landfill, ecoinvent 3.4. estimates the environmental impact at 0.0996 kgCO_2-eq per pair waste disposed. For waste that is sent to a municipal incinerator plant, the impact is higher at 1.86 kg CO_2-eq per pair.

In the first scenario, landfilling, the total emissions represents 0.554% of the total life cycle impact (GWP 100 years). In the second scenario, the used shoes are incinerated and the emissions associated are 9.48 % of the total life cycle impact of the product.

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