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Combined application of energy and material flow analysis and ecological footprint for the environmental evaluation of a tailoring factory

Marta Herva[a], Antonio Álvarez[b], Enrique Roca[a,*]

[a] Sustainable Processes and Products Engineering Group. Dept. of Chemical Engineering, University of Santiago de Compostela, Campus Vida, 15782 Santiago de Compostela, Spain
[b] Industrias de Diseño Textil, S.A., Edificio Inditex, Av. de la Diputación s/n, Polígono de Sabón, 15142 Arteixo – A Coruña, Spain

HIGHLIGHTS

- The ecological footprint (EF) is a suitable environmental screening indicator.
- Combining energy and material flow analysis (EMFA) and EF enhances the analysis.
- Incorporating air emissions into the EF significantly altered the figure obtained.
- EMFA provides useful information at detecting stages requiring priority actions.

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ABSTRACT

Two environmental evaluation methodologies, namely energy and materials flow analysis (EMFA) and ecological footprint (EF), were combined to assess a tailoring factory that produced jackets in the period 2002–2005. During the EMFA, aided by the software Umberto® 5.5, cutting was identified as the most energy consuming stage and gas-oil as an important source of pollution in spite of its low contribution to energy supply. The EF appraisal was built on the basis of a previous work, incorporating methodological contributions developed by the authors that made the indicator more suitable for its application at corporate level. Initially, an increasing tendency in the indicator was observed (from 37.8 in 2002 to 45.2 gm^2/jacket in 2005). When including other emissions apart from CO_2, the results conveyed a significant increase in EF that ranged from 80% in 2002 to 14% in 2004, demonstrating that this contribution should not be disregarded when evaluating production processes. Finally, sensitivity analyses were carried out to assess the influence in the EF of the variability in input variables. When emissions were not included, the most influencing input flow was the cotton fabric; otherwise gas-oil became the most relevant factor. Therefore, its substitution for cleaner sources of energy was advised.

1. Introduction

Companies are incorporating environmental aspects as additional criteria in the design and operation of their industrial processes, not only due to the increasing legislation pressure, but also to the economic benefits linked to reduction of materials and energy consumption [1]. Hence, interest has been focused on the evaluation of the environmental impact of productive processes [2–4].

Different tools and methodologies are currently available to deal with this task [5,6]. In this paper, energy and material flow analysis (EMFA) and ecological footprint (EF) were selected. Flows of energy and material are valuable environmental indicators both at micro and macro scale. Actually, a key task of industrial ecology is to identify, trace and allocate energy and material flows throughout the system [7]. When applied to production processes, this is suitable to pursue reductions in the consumption of energy, raw material, water and in the discharge of effluents, emissions or wastes. However, it also means handling a lot of information expressed in different units, complicating the decision-making. In contrast, the EF is a composite indicator that expresses the pressure on natural resources using a single figure. An appropriate definition of the EF for the corporate level is that it determines the space required to support an activity by means of the area needed to provide the resources consumed and to absorb the wastes generated [8,9]. The aggregation into a single indicator is conducted using weighting coefficients based on the relative productivity of the different area types [10] rather than on the relative importance derived from the subjective opinion of experts or decision makers, making the indicator more robust. However, the methodology also presents a series of weaknesses (reviewed in further detail

* Corresponding author. Tel.: +34 881 816 774; fax: +34 881 816 702.
E-mail address: enrique.roca@usc.es (E. Roca).
URL: http://prodes.usc.es (E. Roca).

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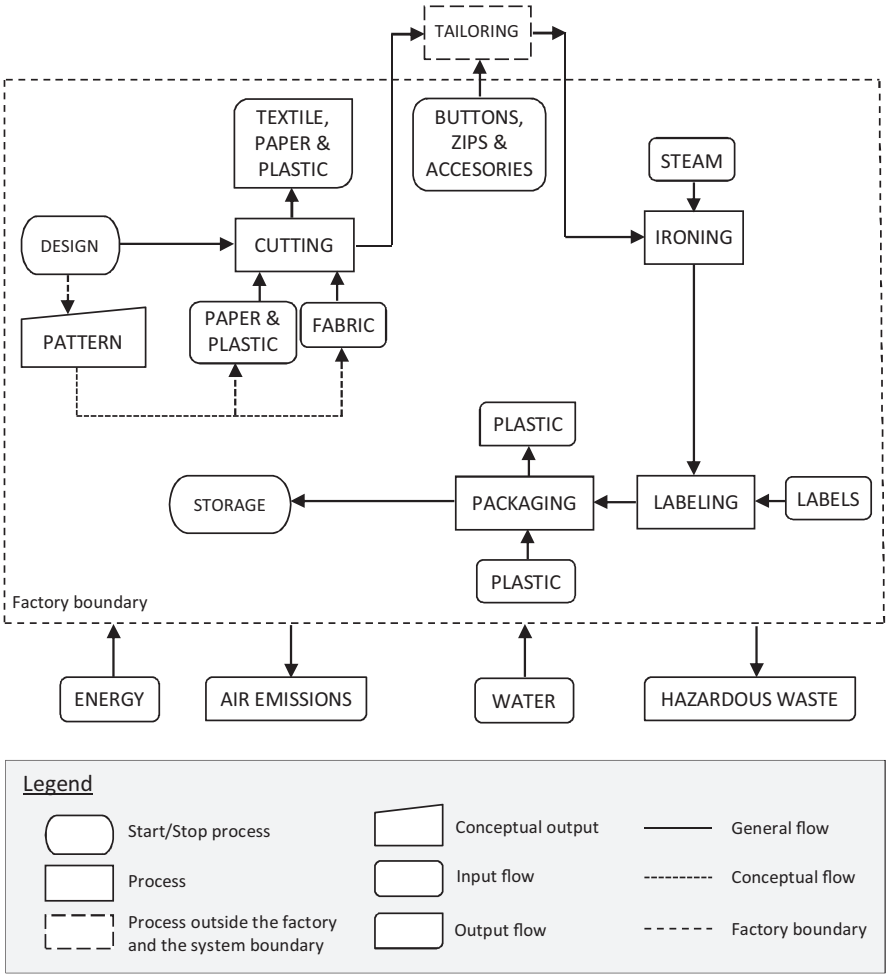

Fig. 1. Dressmaking factory process flowsheet.

in Ref. [6]), making advisable the combined application with other environmental evaluation methodologies to achieve more comprehensive and accurate assessments.

In the framework of the textile industry, all stakeholders from the whole production chain should take actions together during the whole life-cycle of products to promote the market for greener products [11–13]. A number of life-cycle assessments were carried out on textile products in the EDIPTEX project [14] or in the framework of the COST Action 628. The latter was established to produce industrial environmental data of textiles in Europe and to suggest tools for comparisons of present technologies and practices with cleaner applications [15]. In contrast, the EF is a more recent indicator and, consequently, its application in the textile sector is scarcer, although there are some examples like the estimation of the area required for the production of natural fibers [16]. Regarding EMFA, and although not directly related to the environmental perspective, De Toni and Meneghetti [17] modeled a knitwear network for production planning in the textile-apparel industry.

Considering the increasing demand for environmental performance evaluation of industry and the subsequent need for sector-specific environmental performance indicators [18], this work aimed to develop an environmental evaluation tool to assess the performance of a tailoring factory. This was built on a previous work in which the application of the EF to the tailoring factory was proposed by the first time [19]. The selection of this indicator was steered by the company's communication strategy, for which an aggregated indicator easy to be interpreted by all the stakeholders was found very appealing. The EF appraisal is now enhanced by the incorporation of methodological developments proposed by the authors [20,21]. Also, as a previous step to complete the most exhaustive as possible inventory of the process and to complement and deepen the assessment, EMFA was applied.

2. Materials and methods

The following sections refer to the production process studied, the environmental evaluation methodologies applied and the strategy followed for their combined application.

2.1. Description of the production process

A general scheme of the production process is shown in Fig. 1. To manufacture the jackets, the fabric enters the factory to be cut and sewed according to a given pattern. The pieces of the jacket are first drawn on paper and then placed on the fabric, putting plastic over them to avoid undesired movements during the cutting process. Buttons, zips and other ornamental elements are added to the item of clothing. This part of the process is carried out externally, although the accessories are provided by the factory, and there are not records of energy consumption during this stage. Back at the plant, the jackets are ironed, labeled and packed into bags to be stored and later distributed. The sources of energy are: electricity, wind-power, propane and gas-oil. The latter two are employed in cogeneration units (common for a series of dressmaking factories belonging to the same company), where air emissions are generated and released. The hazardous wastes are mainly generated