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Management and Characterization of Textile Solid Waste in a Local Productive Arrangement

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Abstract
The present research has the objective of identifying the characterization and management of textile solid waste generated in clothing manufacturing within a local productive arrangement (LPA) in Brazil. The importance of this research consists in the data presentation and survey which indicate the scenario of textile solid waste, enabling the promotion of appropriate and sustainable management actions for these materials. Thus it is exploratory research with a qualitative and quantitative approach. After analysing the data, the main characteristics, dimensions and management practices of textile solid waste in these industries are presented. The research results point out a considerable amount of textile solid waste that is generated and appropriate practices for the management of such waste. Nevertheless there is a need for improvement of this process aiming at enhancement opportunities of the materials mentioned as raw material in the development of the same products or other segments, in order to promote sustainable action.

Key words: *waste management, textile solid waste, characterization, local productive arrangement.*

Introduction

Companies operate in a market where there is significant and comprehensive awareness to develop actions that minimise environmental impacts and have activities supporting a sustainable environment. Thus redesigning their processes becomes the responsibility for organizations in order to avoid damage to the environment [1, 2].

Actions to minimise environmental impacts can occur in different sectors and activities. However, during industrial processes wastes are generated which can be reused, recycled or sold as raw materials to other companies that will transform them into new products for the market using proper planning [3]. Therefore this is the focus of this study, i.e., industrial waste generated in production processes of the clothing industry.

Among the assorted industrial sectors and their waste generated, a clothing local productive arrangement selected as the object of this study (LPA), in Paraná State, Brazil, which generates waste defined as textile solid waste, that is, cuts and leftovers of the raw material called fabric, generated in the clothing manufacturing process. This choice is justified as Brazil is ranked among the largest textile producers. It is fifth in the textile segment and fourth in the production segment. In the west, the Brazilian industry is the largest integrated industrial sector - from fibre to final product [4].
In the case of waste generation in production processes, an advantage in analysing a local productive arrangement is the assumption that industrial wastes consist of similarities because they are generated in an arrangement. Villanueva et al., [5] explain that textile solid waste have potential recovery and can become raw material for the same sector or even form a new production chain.

In this sense, the present study aims to identify the characterisation and management of textile solid waste generated in a clothing LPA in Paraná State, Brazil. It is understood that the research results may enable the promotion of new appropriate management and sustainable actions of these materials, supported by knowledge of textile waste characteristics. Besides this, it can be a parameter for further research in order to find solutions for the reuse of those materials potentially rich in recovery possibilities.

Literature review

Textile materials

Textile fibres form textile materials or fabrics, which can be of a single type or a mixture of fibres. The textile fibre or filament is completely natural material from a vegetable, animal or mineral source, as well as any artificial or synthetic materials, which due to their high ratio between their length and diameter, as well as their characteristics of flexibility, softness, elasticity, strength, toughness and finesse are able to be used in textile applications [6].

The fibre composition and its origin are important factors for companies that will use them during the product development, with consequences for consumers who will have comfort and wearability with the fabric in direct contact with their skin. Yet the textile material directly involves designing a model of production processes and even its disposal. For this reason, the fibres used in raw material manufacturing during textiles process will be discussed in this research.

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Fibres from natural sources can be divided into plant sources (cellulose compounds) or animal sources (protein compounds) [7]. Cellulose fibre is made of carbohydrate and forms the main part of plant cell walls. It can be extracted from a variety of plants to make suitable fibres for textile production. Cotton (CO) is an example of this fibre and is used to produce about 40% of the world's fabrics. Other examples of cellulose fibres are flax, hemp, ramie and sisal [7]. According to the same authors, protein fibres are from animals such as sheep, goats, alpacas, camels, llamas and rabbits. Silk is made of a protein fibre obtained from silkworm cocoons.

Artificial fibres are made of cellulosic and non-cellulosic fibres. Cellulose is extracted especially from trees. For these categories rayon, Tencel, acetate, triacetate, and Lyocell may be mentioned. All others are non-cellulosic fibres, i.e., they are made entirely of chemical materials, known as synthetic fibres [8]. The different chemicals used in the process of obtaining the rayon have a specific name, including acetate, cuprammonium and viscose. Modal and Lyocell are improved viscose variations.

Natural and synthetic fabrics are obtained through chemical reactions of macromolecules, such as polyester from petroleum. Other fibres are nylon, acrylic, lastex and acetate. In this category, recycled fabrics from transparent plastic bottles are included.

Synthetic fibres improve their qualities when blended with other natural fibres such as polyester blended with cotton, and spandex can be blended with other fibres to provide elasticity. Finally non-synthetic fibres are obtained from the cut of synthetic films such as metal laminates [7, 8]. Fabrics in the textile industry are constituted by fibres, and then distributed to clothing manufacturers of textiles and garments. It can be said that fabric is a generic name that describes the weft interlacing processes. Fabric is the conventionally name for textile articles obtained by weaving plans, also called flat fabric. In addition to this material, there are circular and rectilinear knits, lace, ribbons and nonwoven fabrics [8].

Textile solid waste

The growing consumption of products is an indicator of the increasing amount of waste generated in the world, which has increased environmental awareness and social responsibility, reinforced by strict legislation in developed countries, leading to the creation of more efficient waste management practices [9].

Industrial waste may have benefits in forming a new production chain, through direct sales with the recycling industries or the intermediary general wastes, thus, valuing the above wastes [10]. Textile solid waste (TSW) belongs to the industrial and non-dangerous waste category, and defined as "waste of raw material referred to as fabric trims, scraps or parts rejected by defects" in manufacturing processes of the clothing industry [6, 11].

The generation of textile waste occurs in different variations of volume and textile composition, as well as depending on the number of parts produced and the market segment served by the company. The sizes, shapes and volumes of the fabric scraps vary according to mould shapes, the widths of fabric rolls and their correct rest. Another factor that interferes with the generation of waste is related to the method of modelling, fitting and design that can be developed in an automated or manual mode.

Textile exchange [12] mentions the need for studies on the allocation of textile solid waste and the possibilities for its recovery, as these indicate inefficient production and exaggerated consumption patterns, which suggests a necessary change with focus on waste management. Altun [13] explains that the efficient disposal of this waste requires an accurate prediction of the amount of it generated in production processes.

As regards some solid textile waste recovery possibilities, Jeihanipour et al., [14] reported on waste, mainly cotton and artificial cellulose fibre composition, and maintains, due to the concentration of this fibre, a significant potential for producing different biofuels, such as biogas. In other words, it presents opportunities for optimisation of its life cycle, as it is a potentially rich source of energy. However, the normal routine for this waste disposal is incineration or landfill [14].

Studies from Turkey and Macedonia identified that cotton was the raw material most used within the industries surveyed. In Turkey, cotton represents 29% of the raw materials used, followed by polyester, with 24% [13]. In Macedonia, pure cotton was the most common textile materials, with 50%, while 8.14% of companies work only with synthetic materials. It is noteworthy that clothing sector waste is new and clean and does not require any special treatment before recycling, thereby reducing its cost. In addition to technology, the basic prerequisite for waste recycling is to collect and sort clothes by colour and fibre content [9].

In accordance with concerns on the management of textile waste, a study conducted in the UK and developed by the Department of Environment, Food & Rural Affairs presented designs for the clothing manufacturing sector. They aimed at reducing clothing manufacturing impacts on the environment, reporting complete and specific data on the quality and quantity of textile waste in the UK [15].

Based on this context, it is imperative to understand that the characterisation of textiles waste, being aware of its composition and disposal conditions, may favor the promotion, arrangement and enhancement of such waste through reusing and transformation in different products, as well as recycling, so that it becomes an important source of raw material on the international market [5, 9]. The ability to recapture the value of textile waste may be understood as a matter of clothing manufacturer sustainability adopted by the industry, thereby promoting a reduction of the economic costs of final products due to the upgrading of materials [16].

Solid waste management

The need to reduce waste supply is necessary due to its accumulation. However, this process is considered long-term period, which requires proper management in the short and medium term, avoiding environmental and health problems for humans.

Vivanco et al., [17] state that political action is imperative in order to advance the implementation of waste management principles and sustainability. It is worth noting in this regard that, worldwide, some countries have organised collection, segregation, recycling, disposal and monitoring systems, while others are yet to find a solution that ensures the minimisation of negative treatment and recycling environmental impacts [18].

With the emergence of the issue, in Brazil, the National Solid Waste Policy (PNRS) was instituted in 2010. This policy aims to regulate as well as provide principles, objectives, instruments and guidelines for integrated management and solid waste management, in order to promote strategic actions that enable processes capable of adding value to waste, thereby increasing the competitiveness of the production sector and reducing the volume of disposable waste. Solid waste management is defined as a set of actions aimed at finding solutions to solid waste considering political, economic, environmental, cultural and social issues, with social control and under the premise of sustainable development [19].

The integrated and sustainable management of solid waste should not only be a priority, but reach beyond technical aspects to include several elements considered essential to sustainability and ensure the success of any management project of solid waste, enabling various elements [20].

The transformation to a more sustainable society requires greater sophistication and details of waste management, which should be seen as part of a new generation collection and disposal system. The traditional reductionist approach is unsustainable because it lacks flexibility and long-term thinking. A sustainable waste management system is focused on processes, covers adaptability and alters waste disposal [20, 21]. On the other hand, inadequate management of industrial waste is related to the fact that not all of it are collected and processed. Thus a huge amount of these materials is disposed illegally, and generators are continually facing the problem of the disposal of their waste [22, 23].
Considering more detailed waste management, the lack of accurate information about the quantity, types and destinations of industrial solid waste is emphasised. Given this necessity, the National Environmental Council published the National Solid Waste Inventory in 2002, defined as a set of information on the generation, features, storage, transport, treatment, reuse, recycling, recovery and final disposal of solid waste generated by the country's industries as a tool for waste management [24].

In the clothing industry, a disposal percentage of fabric raw material in production processes is inevitable. In this sense, it is essential to submit any appropriate and interactive management among the transportation, collection, delivery and disposal of waste, highlighting the recovery or proper disposal of these materials and knowledge of the amount of material types generated in production processes.

Clothing industry

In recent years, the textile and clothing industry has shown dynamic growth in the global production of textiles and clothing products [25]. The clothing textile industry in Brazil has an important role in the economy regarding production capacity. The garment industry has great relevance at the national level in terms of production capacity, employment and marketing. The Brazilian Association of Clothing states there are, in Brazil, 18,000 small and 7,000 medium-sized factories as well as 1,000 plants classified as large in 2010. These factories are distributed throughout the country, located mainly in the southern and southeastern regions [26].

In the same year, these industries consumed about 750,000 tons of flat fabric and 450,000 tons of knitted fabric. Worldwide the Brazilian textile sector and clothing manufacturing has been highlighted because of the dimension of its textile park. It is the fifth largest textile industry in the world and the fourth in manufacturing. In addition, it is the second largest denim producer and third in knitwear production. Brazil produces 9.8 billion pieces/year (of these, around 6.5 billion garments) [16].

Within the clothing manufacturing industry, the construction of garment products involves many processes for the transformation of textile material to a finished product. The basic steps for development up to product delivery to the final customer are as follows: (i) collection planning, (ii) planning the production process, (iii) material stock, (iv) design, (v) folding, (vi) cutting, (vii) preparation for sewing, (viii) sewing, (ix) finishing, (x) ironing, (xi) packing, (xii) products stock, (xiii) shipping, and (xiv) client [27]. During these steps, there is the generation of textile solid waste, and in addition at each step of the productive cycle g waste is generated during the processes. Among them, paper, packaging and other materials, making the industry a large generator of negative impacts on the environment [11, 28].

Clothing local productive arrangements

A Local Productive Arrangement (LPA) is defined as a geographically concentrated group of interrelated companies, formed by economic, political and social agents, and related institutions. Agents are bound by common and complementary elements, adding distributional effects on assets and employment terms to sectoral and regional dimensions [29, 30].

The industrial clusters are seen as a strategy for micro, small and medium enterprises (MSMEs) to strengthen themselves competitively. These agglomerations, also known as local clusters, represent an opportunity for MSMEs, allowing to complement themselves, as well as increase their production capacity, survival and growth opportunities [31].

The garment industry is fragmented and consists of micro and small enterprises that diffuse the sector's domain, being an important structural environment. One of the factors relevant to the choice of this sector for research is the amount of micro and small enterprises within the country. According to the labour yearbook for micro and small enterprises, for the year 2006 less than 1% of companies registered in the country are large, which means that more than 99% of the companies in Brazil are MSMEs [16].

In this case, the importance of business associations is growing for local production arrangements, to give proper and joint disposal of waste that is common to all of them [32]. Thus the actions of companies in local clusters can be understood as a marketing advantage for micro and small enterprises, which often remain affixed to high costs for waste management.

Methodology

This research focuses on the perspective of industries, namely agents of a local productive arrangement (LPA) of clothing located in Paraná State - Brazil. This LPA was selected for study because it is an industrial complex composed of approximately 1,700 micro, small and medium enterprises. They work with formal clothing, uniforms, caps and finishing services, which constitutes an important

agglomeration of clothing, bringing together the largest number of occupied work forces operating in the sector in Paraná State – Brazil [33].

The study employed qualitative and quantitative methods and can be classified as a survey which aimed to gain insight, understand the problem and undertake a systematic search for data by applying a questionnaire.

The questionnaire had questions aimed at identifying and characterising the consumption of raw materials in textile for a predetermined period, as well as the amount of waste generated, storage and management for the period between November 2013 and May of 2014. The questionnaire was adapted according to the model of the National Solid Waste Inventory [24], composed of single block and open questions. The instrument went through a pre-test where two professionals and two managers of the clothing industry analysed the questionnaire. All companies from this productive cluster were invited to participate in this study by email, along with a covering letter, explaining the importance of participation and assuring confidentiality. Amended in accordance with the suggestions of respondents, it was applied to a sample of thirty-two companies defined by accessibility criteria. The survey was conducted over a period of three months and the respondents were managers of industries.

Knowledge of the characteristics, dimensions and management of this waste form a basis for theoretical discussion and construction of actions for the recovery of textile waste from garment clothing industries. Moreover waste management actions in the garment industries surveyed can be compatible and comparable with the situation of other companies in underdeveloped countries. Therefore it is understood that the results and conclusions may contribute to the general attitudes towards proper management of textile waste.

Results

The management of textile waste in the clothing LPA

Thirty-two companies took part in this study, with 40.62% classified as micro, 56.25% as small and 3.12% as medium-sized. First they were asked whether the practice of textile waste management is considered relevant, and 87.5% answered affirmatively. However, they reported no customer and/or supplier requests for social and environmental practices. This reality is understood as a justification for the lack of projects and implementation of waste management principles in twenty one companies surveyed. Respondents see waste management as a generation of costs without financial returns. This finding indicates that this is a reflection of non-compliance with profit generation and value added to products, as well as due to high waste disposal costs.

The generation of textile waste in production processes of the industries surveyed is considered moderate, and respondents reported that they aim at reducing this amount through the acquisition of new technologies, especially within the cutting and modelling sectors. Regarding knowledge of the steps to the final destination, managers inform they are not aware of the treatment and disposal of materials as waste, because they are arranged to be collected, and then an outsourced specialized company forwards them to the following steps, which were not informed by the respondents, given the fact they do not know the procedures.

Size and characterisation of textile solid waste

The size and characterisation of textile materials and their respective waste generated during the production process are composed of similarities in their composition among companies. The research respondents cited ten compositions that were used in the period from November 2013 to May of 2014, among which, four present cotton fibre in their composition and are among the most used in the manufacture of clothing products in the industries surveyed. They are a cotton blend with spandex (97% CO - 3% PUE) with a consumption of 303,450 kilograms (kg), followed by a composition of 100% cotton (100% CO) with a consumption of 167,850 kg (Kg) of the respective material, as shown in ***Table 1***.

Table 1. *Characterization of textile materials used in clothing industries in the period from November, 2013 to May, 2014.* ***Legend****: CO = cotton; PUE = spandex; PES = polyester; CV = viscose; PA = polyamide.*

Composition	Consumption, Kg	Stock, Kg	Waste, Kg
97% CO - 3% PUE	303,450	48,080	9,340
100% CO	167,850	27,180	19,086
100% PES	154,850	24,550	11,441
97% PES - 3% PUE	131,075	16,150	7,906
100% CV	66,000	7,320	2,735
96% CV - 4% PUE	61,590	5,450	1,655
100% PA	42,769	3,760	1,750
90% CO - 10% PA	36,000	6,000	1,500
53% PES - 44% CO 3% PUE	20,000	0	900
87% PA - 13% PUE	11,000	2,100	1,394
TOTAL	**994,584**	**140,590**	**57,707**

The amount of textile material in stock was verified, as it is understood that this may be an indicator for a possible continuation of material generation, having the same composition for a period. Among the ten materials listed, one of them does not present stock (53% PES/44% CO/3% PUE), and the composition of 97% cotton and 3% spandex (97% CO - 3% PUE) has a stock of 48,080 kilograms (kg) among the companies surveyed. This result refers to the fact that managers acquire only the amount for production over an estimated period, avoiding stocks (lean production). This behaviour is justified due to high turnover and the variety of fabrics used for collections developed in accordance with the fashion trends adopted by companies.

As for textile waste, the object of this study, within the estimated period, an amount of 57,707 kg was generated, or an average of 8,243 kg per month. Within this amount, it was found that most industries generate a waste proportion of 100% cotton composition, with a total of 19,086 kilograms (Kg), followed by a composition of 100% polyester (PES 100%), with a total of 11,441 kilograms (Kg). These data demonstrate that the similarity and amount of waste generated by companies with respect to the origins when sending their waste to a single point, evidencing the importance of micro and small enterprises meeting in production clusters. Thus knowing the characterization of waste textiles may favour the promotion, arrangement and enhancement of such waste to become

Table 2. Waste generated in the clothing production processes.

Stages	Generated waste
Collection planning	Paper, fabric scraps, magazine; paperboard; defective parts; packing; printer cartridges.
Material stock	Paper; metals (rivets, buttons); defective parts; zippers; thread; labels; plastic; paperboard; fabric scraps.
Design	Paper; paperboard; plotter pens; fabric scraps; metal clips; plastic.
Folding	Paper; plastic; fabric scraps; paperboard; adhesive tape.
Cutting	Paper; fabric scraps; sewing machine sandpaper; paperboard; plastic.
Preparation for sewing	Thread; fabric scraps; paper; elastic; plastic; cardboard box.
Sewing	Thread; paper; fabric scraps; plastic cones; needle; trims; stitching yarn.
Finishing	Thread; fabric scraps; trims; labels; adhesive paper; stitching yarn; plastic; paperboard.
Packing	Plastic; toner; labels.
Shipping	Paper; adhesive tape; paperboard.

Table 3. Waste, ways of storage and destination.

Generated waste	Storage	Destination
Fabric scraps	Plastic bags, trash cans; burdens; plastic barrel; cardboard box and plastic box; or simply discard.	Specialized company; donation; sold.
Plastic cones	Plastic bags; cardboard boxes.	Returned to the yarn and thread producing company.
Plastics	Trash; plastic bags.	Selective collect; donation.
Cartridges/toner/printer pens	-	Remanufactured
Trims; metals	Plastic bags.	General waste.
Thread	Plastic bags; trash.	General waste; specialized companies.
Paper; paperboard	Plastic bags, tied with cloth; bales; cardboard box.	Sold; donation; selective collect; specialized company.

an important source of raw materials on the international market [5, 32].

To complement the information on the management of general waste in industries, a survey was carried out to identify the waste generated at each stage of the production process. It is believed that these data contribute in revealing the attitude and behaviour of the manager in relation to waste management.

Table 2 shows the stages of the production cycle, and their waste generated and identified is presented as follows: (i) collection planning, (ii) material stock, (iii) design, (iv) folding, (v) cutting, (vi) preparation for sewing, (vii) sewing, (viii) finishing, (ix) packing, and (x) shipping. Paper is waste generated at all stages of production processes [10].

After identifying the waste generated at each stage of the clothing production process, the storage and destination form or reuse/recycling form of this waste by the companies researched was established, presented in ***Table 3***.

In the design, folding and cutting stages, paper, plastic and fabric scraps are produced. It was found that papers are ready for donation or recycling; the fabric and its scraps, besides being sent to specialised companies, are also donated, in minimum amounts as there are regulations prohibiting such practice, and the larger pieces are sold to handcraft producers on a small-scale. Ink cartridges, toner and plotter pens are remanufactured, i.e., their life cycle is optimised.

In the preparation stages for sewing and finishing, the waste produced is in the form of plastics, plastic cones (threads, trims), fabric scraps, printer cartridges and pens, trims, metals and staples, thread, paper and paperboard. Among the waste, it was found that paper, plastic and paperboard are stored properly in a cool dry place, and then forwarded for selective collection and/or donated to collectors who regularly retract the materials.

As for plastic cones from threads and trims, there is an agreement with the suppliers to return these materials, providing a reduction in the acquisition value of new products.

Textile waste is stored in plastic or cloth bags, barrels, containers and in a cool dry place. In 100% of the responding companies, the materials are stored internally, protected from the sun, rain and other climate hazards. This waste is separated from the others.

Threads and yarns in 75% of the companies are finally taken as general waste. In only 25% of the organizations, this is performed through a specialised company which is responsible for the collection of textiles. The packing and shipping stages are sectors that generate a smaller range of waste during the process. Cardboard boxes are used to the maximum before they are prepared for donation or sent for selective collection.

The storage form is crucial to the quality of waste and indicates if the material can be reused. For instance, wet waste or that exposed and dirty has restrictions on its reuse. However, when it is clean and stored in a cool dry place, this increase the chances of gaining benefits. In this sense, the importance of adequate storage is noted, to allow for the return of industrial waste.

Conclusion

In this study, the characteristics and management of textile waste in a clothing LPA were identified in the Paraná State, Brazil. Based on the number of companies interviewed, compared to the number of participants in this clustering, a considerable amount of textile waste generated in the production processes was found, totalling within the estimated period 57,707 kilograms (Kg), equivalent to 8,243 kg/month. Especially cotton (100% CO), whose waste is produced in larger quantities (19,086 kg) compared to other materials cited, has significant potential and greater possibilities for optimization of its life cycle [14]. As for the materials made of mixed fibres, such as polyester (PES) and elastane (PUE), there are major problems because of their non-biodegradability, and therefore priority should be given to the task of recycling such fibres [9].

The waste management and characterization presented highlight possibilities for the promotion, arrangement and enhancement of textile waste that can become a source of raw materials in the market. Thus this study can be used as a parameter for the execution planning of textile waste management projects, enabling a vision that promotes strategic actions which make processes viable and add value to the waste, thereby increas-

ing the competitiveness of the production sector and reducing the disposal volume by considering the principles and objectives of solid waste management [19].

Similarly information regarding characteristics and quantity support the proper disposal of waste, which may result in appropriate management actions to reduce clothing manufacturing impacts on the environment through knowledge of complete and concrete information on the quality and amount of textile waste. This knowledge supports the actions of project planning management, new storage possibilities, transport, treatment, reuse, recycling, recovery and final disposal of solid waste generated by clothing manufacturers industries of the LPA. In addition, it can be understood as a matter of sustainability adopted by clothing manufacturing industries, promoting an economic reduction in the final product costs due to revaluation of materials [16].

It should also be emphasised that this study provides more knowledge for activity often developed by companies and poorly investigated by researchers. There are few studies in the literature that address this issue specifically, which is comprehensive field for research that can provide advances for business, society and the environment, since it brings about proper management of this waste. Additional studies on costs, conflicts in the production chain and product development are needed.

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