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Going green: strategic evaluation of green ICT adoption in the textile industry by using bipolar fuzzy MULTIMOORA method

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ABSTRACT – REZUMAT

Going green: strategic evaluation of green ICT adoption in the textile industry by using bipolar fuzzy MULTIMOORA method

The widespread use of information and communication technologies in all fields has a direct impact on the way the world is viewed. In today's competitive international business environment, companies are increasingly investing in the search for new ideas and approaches in production. The use of information and communication technologies (ICT) is increasingly gaining in importance, especially in the situation of a dynamic market and increasingly demanding consumers. Today's business of contemporary organizations is not conceivable without the support of modern ICT systems. Therefore ICT has a great influence on modern society because the ways in which information and data are exchanged are higher than ever. Green information and communication technologies as one area that is new and in development tend to establish a balance between these technologies and the environment. Adoption of green information and communication technologies is not an easy task and is often related to certain limitations. Therefore, the aim of the paper is a strategic evaluation of green ICT and their implementation in the textile industry by using newly-developed bipolar fuzzy MULTIMOORA method. Effectiveness and efficacy of the proposed approach is demonstrated in the conducted illustrative case study.

Keywords: *Green ICT, ICT, textile industry, MCDM, bipolar fuzzy MULTIMOORA method*

Adoptarea metodei ecologice: evaluarea strategică a adoptării eco-TIC în industria textilă prin utilizarea metodei bipolare fuzzy MULTIMOORA

Utilizarea pe scară largă a tehnologiilor informației și comunicațiilor în toate domeniile are un impact direct asupra modului în care lumea este privită. În mediul de afaceri internațional competitiv de astăzi, companiile investesc din ce în ce mai mult în căutarea de noi idei și abordări în domeniul producției. Utilizarea tehnologiilor informației și comunicațiilor (TIC) capătă din ce în ce mai multă importanță, în special în situația unei piețe dinamice și a consumatorilor din ce în ce mai pretențioși. Afacerile de astăzi ale organizațiilor nu sunt concepute fără sprijinul sistemelor moderne TIC. Prin urmare, TIC au o mare influență asupra societății moderne, deoarece modalitățile prin care sunt schimbate informații și date sunt mai avansate ca niciodată. Eco-TIC, ca domeniu nou și în curs de dezvoltare, tinde să stabilească un echilibru între aceste tehnologii și mediu. Adoptarea eco-TIC nu este o sarcină ușoară și este adesea legată de anumite limitări. Prin urmare, scopul lucrării este o evaluare strategică a eco-TIC și implementarea acestuia în industria textilă, utilizând metoda bipolară fuzzy MULTIMOORA, dezvoltată recent. Eficacitatea abordării propuse este demonstrată în studiul de caz realizat.

Cuvinte-cheie*: eco-TIC, TIC, industria textilă, MCDM, metoda bipolară fuzzy MULTIMOORA*

INTRODUCTION

One of the biggest, oldest and most commercialized industries in the world is the textile industry. The textile industry is an important branch of the manufacturing industry and is of great importance for the economy of a country. Today, the textile industry is one of the most globalized industries. Accordingly, the prerequisite for success is the continuous monitoring of current market trends in terms of standards, raw materials and technical equipment of production [1]. The textile industry, as a very important industrial area is technically and technologically very demanding.

The opportunity for the growth of textile production can be exploited by those managers and organizations that are ready to change their business paradigms and that are open to creating changes and introducing new information and communication technologies (ICT) in production. It is emphasized that new technologies in the textile industry are developed in order to improve textile and clothing manufacturing and trade. Some of the goals which new technologies and above ICT should bring are: "1. providing response to new fashion trends; 2. ensuring the efficiency and effectiveness of mass production through the application of ICT (computer-aided design) and 3. adaptation to increasingly sophisticated customers (selling online through web platforms, offering added value through quality or price, ensuring a long term relationship etc.)” [2].

In today’s competitive business environment, companies are increasingly investing in the search for new ways and approaches in production. The use of information and communication technologies plays a vital role and is increasingly gaining in importance, especially in the situation of a dynamic market and increasingly demanding consumers. Today’s business of contemporary organizations is not conceivable without the support of modern ICT systems. Therefore ICT has a great influence on modern society because the ways in which information and data are exchanged are higher than ever [3].

The role of ICT is becoming increasingly important in all aspects of life (education, work, entertainment, health, etc.). Davison [4] point out that the term is used interchangeably in order to cover the full spectrum of existing and potential ICT that are used, including computers, personal communication devices, digital video and sound systems, email, the Internet, etc. ICT is mainly related to the technologies that are used for accessing, collecting, manipulating and presenting or transmitting the information. ICT technologies may include hardware (e.g. computers and other devices); software applications; and connectivity (e.g. Internet access, local area network infrastructure, video conferencing). Exactly what is most important about ICT is the increasing convergence of computer-based, multimedia and communication technologies, as well as the rapid rate of change that characterizes technologies and their use [5, 6]. ICT is most commonly related to two main components: information technology (IT) and communication technology (CT). IT mostly involves computer hardware and software, while CT is related to Internet communication [7]. ICT is a broader concept that includes communication devices, various services, video conferencing, online learning, etc., in order to provide users with access, storage, transmission and manipulation of information [8].

Veljović et al. [9] point out that the most important components of information and communication technologies are computers. At the same time, the application and development of digital communications enabled an easy, fast, efficient and inexpensive way of exchanging information. Therefore, ICTs include a diverse set of technology tools that are used to identify and organize data and information. Murray [10] states that ICT is expanding the concept of information technology in which particularly is highlighted the role and importance of the integration of communications, telecommunications and computers, as well as the necessary software, storage and audiovisual system that gives users the ability to access, store and further manipulate information.

Today’s business of contemporary organizations is not conceivable without the support of modern ICT systems. Therefore ICT has a great influence on modern society because the ways in which information and data are exchanged are higher than ever. Green information and communication technologies as one area that is new and in development tend to establish a balance between these technologies and the environment. Also, as Din et al. [11] point out, green ICT, as a concept was introduced with the aim to support the implementation of the green environment, i.e. is aimed at conserving energy as one essential domain.

There is no universal definition of green information and communication technologies. Reimsbach-Kounatze [12] emphasizes that the “green ICT is about the study and practice of using computing resources in an efficient, effective and economical way”. Sarkis and Zhu [13] states that “green ICT refers more to the hardware and other infrastructure that can be better managed and designed from an environmental perspective”. Andreopoulou [14] states that green ICT “are ICT tools, certain services and technologies that in combination with green practices and green behavior contribute not only to the protection of the environment but also to the enhancement of the quality of life”. Radu [15] emphasizes that coherence between ICT and the environment is relatively new and that the using of environmental criteria is often referred to as green ICT.

Adoption of green information and communication technologies is not an easy task and is often related to certain limitations. The process of evaluation of green ICT can be a challenging task. However, problem of green ICT evaluation can be easily solved by using multiple-criteria decision-making methods.

Decision making is a process that is constantly happening all around us [16]. In real-world situations, decision-making is most often made on the basis of the existence of a number of criteria, which are often conflicting; therefore, for solving such problems using of multiple-criteria decision-making methods (MCDM) is an option. MCDM enables the selection of a suitable alternative from a finite set of alternatives while respecting the values of the criterion attributes, i.e. it enables decision-making in the presence of multiple, often conflicting criteria [17–22]. Ishizaka and Nemery [23] indicate the growing use of MCDM methods because these methods primarily enable better decision-making and adoption of long-term and sustainable solutions.

The extremely rapid development of the MCDM field has also caused the creation of a wide range of MCDM methods, which have been applied so far in solving different types of problems. Some of the prominent and most applied methods are: SAW, AHP, ELECTRE, PROMETHEE, ANP, VIKOR, COPRAS and so on [24–26]. Also, it is important to note that for the needs of solving more complex problems, a whole generation of new MCDM methods and approaches have been proposed, such as: MOORA, MULTIMOORA, WASPAS, SWARA, ARAS, ARCAS, PIPRECIA, MAIRCA, EDAS, CODAS and so on [27, 28].

Based on the foregoing stated, the aim of the paper is the strategic evaluation of green information and communication technologies adoption in the textile industry by using newly-developed bipolar fuzzy MULTIMOORA method. Therefore, in order to present an MCDM for the purpose of green ICT evaluation, the remainder of the paper is organized into four sections. In Section 1, a literature review is provided. Section 2 contains the presentation of the applied methodology. A case study is introduced in Section 3, which is followed by the section presenting the conclusion.

THE COMPUTATIONAL PROCEDURE OF THE SVBFN-MULTIMOORA METHOD

Extension of the MULTIMOORA method based on Single-Valued Bipolar Fuzzy Numbers is proposed by Stanujkic et al. [29]. Brauers [30] initially proposed the well-known MOORA method, somewhat later Brauers and Zavadskas [31] have proposed MULTIMOORA method. So far, MULTIMOORA method has been applied for solving various problems in different fields, such as: economy [31–34]; personnel selection [35–38]; supplier selection [39, 40]; information and communication technologies [41, 42], robotics [43], comminution circuit design selection [44], assessment of the energy storage technologies [45], and so on.

The computational procedure of the SVBFN-MULTIMOORA method can be expressed as follows [29]:

Step 1. Evaluation of the alternatives in relation to the selected set of criteria for each decision-maker DM. In this step evaluation could be easily performed by using the nine-point Liker scale that is proposed by Stanujkic [29].

Step 2. Determination of the importance of the evaluated criteria for each DM.

Step 3. Determination of the group decision matrix, as it is proposed in [29].

Step 4. Determination of the group weights of the criteria, as follows:

$$w_j = \sum_{k=1}^{K} w_j^k \tag{1}$$

where w_j denotes the weight of the criterion j, and w_j^k denotes the weight of the criterion j obtained from the DM k.

Step 5. Determination of the significance of the evaluated alternatives based on the RS approach**.** This step can be explained through the following substeeps:

Step 5.1. Determination of the impact of the benefit and cost criteria to the importance of each alternative, as follows:

$$Y_i^{+} = \left(1 - \prod_{j\in\Omega_{max}}^{n} (1 - r_{ij})^{w_j}, -\left(1 - \prod_{j\in\Omega_{max}}^{n} (1-(-r_{ij}))^{w_j}\right)\right) \tag{2}$$

$$Y_i^{-} = \left(1 - \prod_{j\in\Omega_{max}}^{n} (1 - r_{ij})^{w_j}, -\left(1 - \prod_{j\in\Omega_{max}}^{n} (1-(-r_{ij}))^{w_j}\right)\right) \tag{3}$$

where Y_i^{+} and Y_i^{-} denote the importance of the alternative i obtained on the basis of the benefit and cost criteria, respectively; Y_i^{+} and Y_i^{-} are SVBFNs.

It is evident that A_w operator is used to calculate the impact of the benefit and cost criteria.

Step. 5.2. Transformation of the Y_i^{+} and Y_i^{-} into crisp values by using the Score Function, as follows:

$$y_i^{+} = s(Y_i^{+}) \tag{4}$$

$$y_i^{-} = s(Y_i^{-}) \tag{5}$$

Step 5.3. Calculation of the overall importance for each alternative, as follows:

$$y_i = y_i^{+} - y_i^{-} \tag{6}$$

Step 6. Determination of the significance of the evaluated alternatives based on the RP approach. This step can be explained through the following substeeps:

Step 6.1. Determination of the reference point (RP). The coordinates on the bipolar fuzzy reference point $r^* = \{r_1^*, r_2^*, \ldots, r_n^*\}$ can be determined as follows:

$$r^* = \left\{(<\max_i r_{ij}, \min_i r_{ij} > | \, j \in \Omega_{max}), \right.$$
$$\left.(<\min_i r_{ij}, \max_i r_{ij} > | \, j \in \Omega_{min})\right\} \tag{7}$$

where r_j^* denotes the coordinate j of the reference point.

Step 6.2. Determination of the maximum distance from each alternative to all the coordinates of the reference point as follows:

$$d_{ij}^{max} = d_{max}(r_{ij}, r_j^*) w_j \tag{8}$$

where d_{ij}^{max} denotes the maximum distance of the alternative i to the criterion j.

Step 6.3. Determination of the maximum distance of each alternative, as follows:

$$d_i^{max} = \max_j d_{ij}^{max} \tag{9}$$

where d_i^{max} denotes the maximum distance of the alternative i.

Step 7. Determination of the significance of the evaluated alternatives based on the FMF:

Step 7.1. Calculation of the utility obtained based on the benefit U_i^{+} and cost U_i^{-} criteria, for each alternative, as follows:

$$U_i^{+} = \left(\prod_{j\in\Omega_{max}}^{n} (r_{ij})^{w_j}, -\prod_{j\in\Omega_{max}}^{n} (-r_{ij})^{w_j}\right) \tag{10}$$

$$U_i^{-} = \left(\prod_{j\in\Omega_{min}}^{n} (r_{ij})^{w_j}, -\prod_{j\in\Omega_{min}}^{n} (-r_{ij})^{w_j}\right) \tag{11}$$

where and are SVBFNs.

Step 7.2. Transformation of the and into crisp values by using the Score Function, as follows:

$$u_i^{+} = s(U_i^{+}) \tag{12}$$

$$u_i^{-} = s(U_i^{-}) \tag{13}$$

Step 7.3. Determination of the overall utility for each alternative, as follows:

$$u_i = \frac{u_i^+}{u_i^-} \tag{14}$$

In the case when evaluation is made only on the basis of benefit criteria Eq. (14) is as follows:

$$u_i = u_i^+ \tag{15}$$

Step 8. Determination of the final ranking order of the alternatives by using theory of dominance.

A NUMERICAL CASE STUDY

In this part of the paper, a numerical case study is considered in order to highlight the proposed methodology. As stated before, there is a tendency towards using green ICT. A textile company has decided to introduce green ICT. For this reason, a team consisted of 3 DMs was formed in order to evaluate four alternatives designated as A_1, A_2, A_3, A_4. Based on carefully literature review [49–50], a total number of 5 evaluation criteria were selected: C_1 – Economic and energy efficiency; C_2 – Eco-friendliness; C_3 –Technology evolution; C_4 – Improved systems performance and use; C_5 – Overall impact of green ICT on the organization.

The ratings of the evaluated alternatives in the form of SVBFNs for the three decision-makers are shown in tables 1–3.

The group decision matrix is shown in table 4.

The group weights obtained from the three DMs by applying the PIPRECIA method [48] and by using equation (1) are accounted for in table 5.

Table 1

THE RATINGS OBTAINED FROM THE FIRST OF THE THREE DMS

Alternatives	C_1	C_2	C_3	C_4	C_5
A_1	<0.80, –0.20>	<0.80, –0.10>	<0.70, –0.30>	<0.80, –0.30>	<0.50, –0.20>
A_2	<0.40, –0.50>	<0.30, –0.30>	<0.40, –0.40>	<0.30, –0.30>	<0.20, –0.30>
A_3	<0.50, –0.30>	<0.40, –0.30>	<0.40, 0.10>	<0.50, –0.30>	<0.60, –0.50>
A_4	<0.90, –0.10>	<0.70, –0.10>	<0.70, 0.10>	<0.80, –0.30>	<0.70, –0.40>

Table 2

THE RATINGS OBTAINED FROM THE SECOND OF THE THREE DMS

Alternatives	C_1	C_2	C_3	C_4	C_5
A_1	<1.00, –0.10>	<0.90, –0.20>	<0.80, –0.20>	<0.60, –0.10>	<0.70, –0.10>
A_2	<0.60, –0.30>	<0.80, –0.40>	<0.70, –0.20>	<0.50, –0.30>	<0.60, –0.30>
A_3	<0.70, –0.30>	<0.50, –0.30>	<0.60, –0.20>	<0.80, –0.20>	<0.50, –0.30>
A_4	<1.00, –0.10>	<1.00, –0.10>	<0.70, –0.20>	<0.80, –0.20>	<0.80, –0.20>

Table 3

THE RATINGS OBTAINED FROM THE THIRD OF THE THREE DMS

Alternatives	C_1	C_2	C_3	C_4	C_5
A_1	<1.00, –0.20>	<0.90, –0.20>	<0.80, –0.20>	<0.70, –0.20>	<0.60, –0.20>
A_2	<0.50, –0.40>	<0.40, –0.20>	<0.50, –0.20>	<0.70, –0.30>	<0.50, –0.30>
A_3	<0.40, –0.20>	<0.50, –0.20>	<0.50, –0.10>	<0.80, –0.30>	<0.60, –0.30>
A_4	<1.00, –0.20>	<1.00, –0.10>	<0.60, –0.10>	<0.70, –0.20>	<0.60, –0.30>

Table 4

THE GROUP DECISION-MAKING MATRIX

Alternatives	C_1	C_2	C_3	C_4	C_5
A_1	<1.00, –0.16>	<0.87, –0.16>	<0.77, –0.23>	<0.71, –0.19>	<0.60, –0.16>
A_2	<0.50, –0.40>	<0.56, –0.29>	<0.55, –0.26>	<0.52, –0.30>	<0.45, –0.30>
A_3	<0.55, –0.27>	<0.46, –0.27>	<0.50, –0.13>	<0.72, –027>	<0.56, –0.36>
A_4	<1.00, –0.13>	<1.00, –0.10>	<0.67, –0.13>	<0.77, –0.23>	<0.71, –0.09>

Table 5

THE GROUP CRITERIA WEIGHTS				
Criteria	w_j^1	w_j^2	w_j^3	w_j
C_1	0.24	0.23	0.27	0.25
C_2	0.19	0.25	0.20	0.21
C_3	0.21	0.23	0.20	0.21
C_4	0.18	0.18	0.17	0.18
C_5	0.18	0.12	0.15	0.15
Total				1.00

Based on the ratings from table 4 and the weights from table 5, the overall significance, the maximum distance to the RS and the overall utility are calculated for each alternative in the next step. The overall significances accounted for in table 6, are calculated by applying equations (2)–(6).

Thereafter, the RP is determined by using equation (7). The maximum distances to the RP accounted for in table 7 are determined by using equation (8) and equation (9).

The overall utility shown in table 8 is calculated by applying equations (10)–(14).

Taking into consideration ranking orders shown in tables 6, 7 and 8, the most appropriate alternative is determined by the theory of dominance, as is shown in figure 1.

As can be seen from figure 1, the alternative denoted as A_4 is the most appropriate in the terms of evaluated criteria.

Additionally, to verify the reliability of the proposed approach and to confirm ranking orders obtained by using the SVBFN-MULTIMOORA method, a sensitivity analysis was conducted with the comparison of the ranking results obtained by using of SVBFN-MULTIMOORA method with 2 well-known and proven MCDM methods (TOPSIS and SAW). The obtained results of the conducted sensitivity analysis are shown in figure 2 and table 9.

It can also be concluded from table 9 that the small inconsistency in the ranking orders of the considered alternatives obtained by applying the TOPSIS

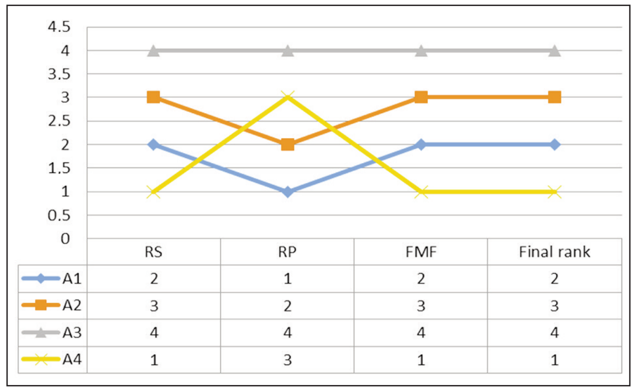

Fig. 1. The final ranking order of the considered alternatives by using theory of dominance

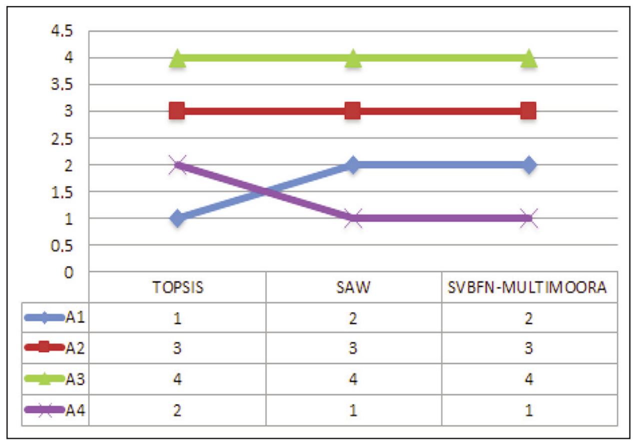

Fig. 2. Results of the sensitivity analysis

Table 6

THE OVERALL SIGNIFICANCES OF THE CONSIDERED ALTERNATIVES						
Alternatives	Y_i^+	Y_i^-	y_i^+	y_i^-	y_i	**Rank**
A_1	<1.00, –0.13>	<0.33, –0.07>	0.94	0.63	0.30	2
A_2	<0.40, –0.23>	<0.22, –0.12>	0.59	0.55	0.04	3
A_3	<0.38, –0.16>	<0.33, –0.13>	0.61	0.60	0.01	4
A_4	<1.00, –0.08>	<0.39, –0.10>	0.96	0.64	0.31	1

Table 7

THE RATINGS OF THE ALTERNATIVES OBTAINED BASED ON THE RP APPROACH							
Alternatives	C_1	C_2	C_3	C_4	C_5	d_i	**Rank**
A_1	0.12	0.13	0.01	0.09	0.08	0.01	1
A_2	0.25	0.22	0.11	0.06	0.07	0.06	2
A_3	0.29	0.28	0.20	0.14	0.16	0.14	4
A_4	0.13	0.10	0.11	0.15	0.19	0.10	3

Table 8

THE OVERALL UTILITY OF THE CONSIDERED ALTERNATIVES								
Alternatives	U_i^+	U_i^-	u_i^+	u_i^-	u_i	**Rank**		
A_1	<0.92, –0.32>		<0.86, –0.53>		0.80	0.67	1.20	2
A_2	<0.66, –0.46>		<0.77, –0.65>		0.60	0.56	1.07	3
A_3	<0.63, –0.35>		<0.86, –0.65>		0.64	0.60	1.06	4
A_4	<0.92, –0.24>		<0.90, –0.61>		0.84	0.64	1.30	1

Table 9

THE FINAL RANKING ORDERS OBTAINED BY USING THE TOPSIS AND THE SAW METHODS				
Alternatives	**TOPSIS**		**SAW**	
	C_i	**Rank**	S_i	**Rank**
A_1	0.527	1	0.646	2
A_2	0.498	3	0.538	3
A_3	0.488	4	0.531	4
A_4	0.526	2	0.672	1

method is caused by a very small difference in C_i values of alternatives A_1 and A_4 that are 0.527 and 0.526. Any slight change in the weight of the criteria or the ratings of the alternative probably would lead to the same ranking order of alternatives.

CONCLUSION

Information and communication technologies play a significant role in the processing of information and their transformation into knowledge, which is a basic condition for creating an information society. As stated before, green ICT as an area that is new and in development is directed towards establishing a balance between these technologies and the environment. Adoption of such technologies is a very complex and challenging task. In this paper, the application of bipolar fuzzy MULTIMOORA method is proposed for the evaluation of green ICT adoption in the textile industry. During the evaluation process, a total of three decision-makers (domain experts) were involved, who evaluated four alternatives. For the purpose of evaluation of alternatives, a total number of five criteria were used. When it comes to the determination of criteria, PIPRECA method was used, because of its simplicity and ease of use, especially when collecting attitudes from the experts who are not close with the MCDM methods. The final ranking of the alternatives was determined by applying the newly-developed bipolar fuzzy MULTIMOORA method. Alternative denoted as A_4 is the best in terms of evaluated criteria. Although the proposed method is relatively new, the same was an excellent choice for the given purpose. The proposed integrated approach that is based on the PIPRECIA and bipolar fuzzy MULTIMOORA method has proved to be easy, effective and applicable for the evaluation of green ICT adoption in the textile company.

Additionally, with the purpose of verification of the proposed approach, sensitivity analysis is conducted. The obtained results have confirmed adequacy and the applicability of the proposed approach. Also, the proposed MCDM approach could be used in other areas as well. As a direction for future research, the proposed model could be easily modified with additional criteria or sub-criteria, if needed. Besides, other methods for weights determination can be used as well, such as the fuzzy PIPRECIA method, the fuzzy AHP method, and the Plithogenic-CRITIC method.

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A comparative analysis of green logistic activities in German and Turkish textile enterprises

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ABSTRACT – REZUMAT

A comparative analysis of green logistic activities in German and Turkish textile enterprises

The main goal of this research is to find out what are the apparel industry activities in the face of green perspective (environment-friendly perspective) in Germany and Turkey. The green perspective is an emerging idea and also has importance for the humanity and the universe. However it is obvious that the green perspective is very broad, it was decided to make this research in the field of supply chain management and the place of logistics in supply chain under the title of green perspective. In this context, a survey, face-to-face interviews were made with professionals in Germany and Turkey. These professionals were the managers who are taking part in the supply chain. In the conclusion part, German and Turkish companies' activities in the face of green perspective under the title of logistics were compared and evaluated.

Keywords: *green logistics, comparative analysis, Germany and Turkey, apparel industry*

O analiză comparativă a activităților logistice ecologice în întreprinderile textile din Germania și Turcia

Scopul principal al acestei cercetări este de a analiza activitățile industriei de îmbrăcăminte în contextul unei perspective ecologice în Germania și Turcia. Perspectiva ecologică este o idee emergentă și are, de asemenea, importanță pentru umanitate și univers. Cu toate acestea, este evident că perspectiva ecologică este foarte vastă și s-a decis efectuarea acestei cercetări în domeniul gestionării lanțului de aprovizionare și a locului logisticii în lanțul de aprovizionare, din perspectiva ecologică. În acest context, au fost realizate un sondaj și interviuri față în față cu profesioniști din Germania și din Turcia. Acești profesioniști au fost managerii care participă la lanțul de aprovizionare. În partea de încheiere, au fost comparate și evaluate activitățile companiilor germane și turcești în fața unei perspective ecologice ale logisticii.

Cuvinte-cheie*: logistică ecologică, analiză comparativă, Germania și Turcia, industria de îmbrăcăminte*

INTRODUCTION

In daily stories of record temperatures, extreme weather, floods and droughts, and of renewable energy, carbon footprints, recycling and energy efficiency, the environment is increasingly becoming headline news. Governments are moving slowly towards new international agreements that will start to address the impact of business on the environment, and these, undoubtedly, will place new requirements on every organization. Consumers expect every business to take responsibility for its actions to look at the way it operates and measure their environmental impact, then determine a strategy to reduce it (figure 1).

According to McKinnon et al. [2], green logistic activities include measuring the environmental impact of different transportation strategies, reducing the energy usage in logistic activities, reducing waste and managing its treatment. In recent years there has been increasing concern about the environmental effects on the planet of human activity and current logistics practices may not be sustainable in the long term. Many organizations and businesses are starting to measure their carbon footprints so that the environmental impact of their activities can be monitored. Governments are considering targets for reduced emissions and other environmental measures. For this reason, there is increasing interest in green logistics from governments, companies, customers and also consumers.

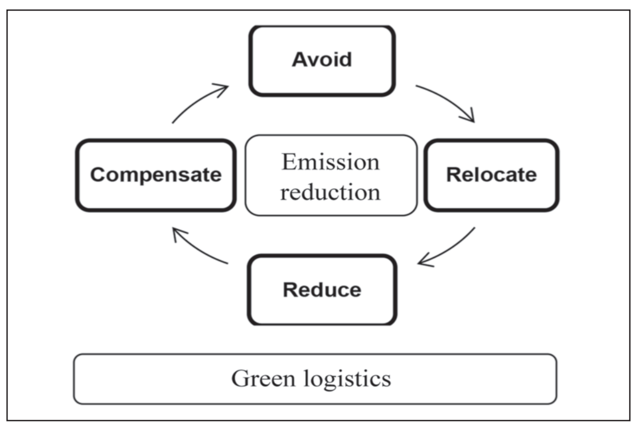

Fig. 1. Green Logistics Cycle [1]

Küçük [3] mentioned that especially in fashion industry, the ability to respond customer requirements on a timely basis has always been a fundamental element of the marketing concept. “Time-based competition” has become the norm in many markets, from banking to automobiles, also fashion.

According to Christopher and Peck [4], nowhere is this pressure more evident than in markets governed by fashion. “Fashion" is a broad term that typically encompasses any product or market where there is an element of style that is likely to be short-lived. Christopher and Peck [4] have defined apparel industry as typically exhibiting the following characteristics:

- ***Short lifecycles*; The product is often ephemeral, designed to capture the mood of the moment; consequently the period in which it is saleable is likely to be very short and seasonal, measured in months or even weeks.
- ***High volatility***; Demand for these products is rarely stable or linear. It may be influenced by the vagaries of weather, hit films, TV shows or even by pop stars and footballers.
- ***Low predictability***; Because of the volatility of demand it is extremely difficult to forecast with any accuracy even total demand during a period, let alone week-by-week or item-by-item demand.
- ***High impulse purchase***; Many buying decisions for these products are made at the point of purchase. In other words, the shopper when confronted with the product is stimulated to buy it, hence the critical role of „availability" and, in particular, availability of sizes, colors, etc.

In 2012, Sarkar investigated the potent tools for sustainable green marketing [5]. The article analyzed different dimensions and facets of green supply chain management, including the evolution of the concept, implementation strategy, linkage with transport systems, green innovations and sustainability issues and green logistics strategies for evolving integrated green supply chain management system.

In another study held in 2013, Perera et al. [6], attempt to quantify the environmental performance of supply chain of a manufacturing company. They used multi-criteria decision method for measuring the performance of the criteria that they determined. In the conclusion the proposed model was applied to a case study company to identify the key areas of environmental performance of the company’s supply chain and to assess various product categories manufactured under those key areas.

Batra et al., in 2015 [7], made a research on greening the supply chain. They reviewed the literature on green supply chain & steps to be taken by the enterprises to achieve social, environmental & economic benefits.

Abdullah et al., in 2016 [8], investigated the involvement of Third Party Logistics (3PL) companies in applying Green Logistics initiatives in the event of rendering logistics services to its customers. They implemented this study in Malesia and utilized Malesia’s terms and conditions only.

In a study from 2017 by Desore and Narula [9], they review today’s literature related to sustainability issues of the textile industry for all over the world. The authors categorize the literature to discuss the drivers, barriers, and responses of firms in the textile industry in favor of sustainability.

The goal of a study by Gardas et al., in 2018 [10], is to identify the critical challenges to sustainable development in the textile and clothing sector. In this concept, fourteen critical points about the sustainable development of the textile and clothing sector were identified and a survey and their cause–effect relationship was determined using the DEMATEL method.

Samar Ali et al. in 2019 [11] was made a study about green practices in manufacturing sector and this study aimed to discriminate the sustainable and competitive performance of the Indian manufacturing sector and to comprehend the degree of the impact of green practices of supply chain management.

Table 1 was prepared by taking into account the 6main criteria (1 – Activities of customs administrations, 2 – Infrastructure, 3 – International transportation fee, 4 – Quality of logistic services, 5 – Punctuality of cargo transportation, 6 – Tracking possibility of cargoes) for evaluating the 160 countries’ logistics

Table 1

LOGISTICS PERFORMANCE INDEX (LPI) RANK 2018 [12]

Country	LPI rank	LPI score	Customs	Infrastructure	Logistics competence	Tracking & tracing	Timeliness
Germany	1	4.20	4.09	4.37	4.31	4.24	4.39
Sweden	2	4.05	4.05	4.24	3.98	3.88	4.28
Belgium	3	4.04	3.66	3.98	4.13	4.05	4.41
Austria	4	4.03	3.71	4.18	4.08	4.09	4.25
Japan	5	4.03	3.99	4.25	4.09	4.05	4.25
Netherlands	6	4.02	3.92	4.21	4.09	4.02	4.25
Oman	43	3.20	2.87	3.16	3.05	2.97	3.80
India	44	3.18	2.96	2.91	3.13	3.32	3.50
Cyprus	45	3.15	3.05	2.89	3.00	3.15	3.62
Indonesia	46	3.15	2.67	2.89	3.10	3.30	3.67
Turkey	47	3.15	2.71	3.21	3.05	3.23	3.63

performance. According to this index while Germany is in the 1st place, Turkey is 47th.

The purpose of this study is to find out how are the real explanations of some hypothesis and also the comparison of Turkish and German companies' relevant activities. The first hypothesis is to determine the role of logistics in supply chain management. It affects the customer satisfaction and total cost reduction, as well as company profitability. This is particularly significant as companies are increasingly being driven by the goal of enhancing shareholder value, a key measure of corporate performance. The second is to determine the role of companies' social and environmental responsibility. The last hypothesis is to compare Turkish and German companies' relevant activities in the face of green perspective under the title of logistics.

Moreover, this study is giving a raft of options, suggestions and concrete advice on how to go green on logistics department in the apparel industry. It includes some interviews with the professional managers from Turkish and German companies. Although many of previous articles describe general topics in logistics or supply chain, this study would like to mention the environmental impact of logistics and supply chain under the consideration of sustainable aspects for apparel industry.

Most analyzed previous studies are descriptive on a national basis. In the literature, the studies based on green logistic activity in textile and apparel industry areas are limited. Especially there is no comparison of Turkey and Germany. Therefore, it is intended to fill this gap. For instance, the studies below have done recently in the literature about the green logistics.

MATERIAL AND METHOD

Material

This study is held as a comparative research of Turkish and German apparel companies, the material consists of 6 different Turkish and 6 different German apparel companies and their logistical activities.

Method

In this research which compares the environmental sensibility of logistics activities of the apparel companies in Turkey and Germany, the qualitative research method was used to reveal the similarities and strength and weaknesses of the companies.

The "Qualitative Research Method" was chosen during writing and assessing this research study. The qualitative method involves the gathering of a lot of information from few examination units through interviews and observations. There are three most common qualitative methods which are participant observation, in-depth interviews, and focus groups. Each method is particularly suited for obtaining a specific type of data.

- Participant observation; is appropriate for collecting data on naturally occurring behaviors in their usual contexts.
- In-depth interviews; are optimal for collecting data on individuals' personal histories, perspectives, and experiences, particularly when sensitive topics are being explored.
- Focus groups; are effective in eliciting data on the cultural norms of a group and in generating broad overviews of issues of concern to the cultural groups or subgroups represented [13].

From those methods, the most useful and impressive one was decided to use for this study; in-depth interviews. So the plan was to make some interviews with professional managers and perceive their point of views and opinions.

The interview is an effective method of collecting information for certain types of research questions and for addressing certain types of assumptions. There are two types of interviews: structured and semi-structured interviews. The choice depends on what the research topic is. In structured interviews, formally structured – without any adjustment and additional questions – and the same questions are asked to all of the respondents, whereas in semi-structured interviews, wordings, the level of language and the order of questions are flexible and may be adjusted. There may be also additional questions followed up [13].

Considering the different types of interviews and the research goals of this study, the "structured interview" type was decided to use. The reason of selecting the structured interview is to evaluate all companies equally. There were no adjusted questions or deviations varying from company to company.

Sampling

The samples of this study were selected upon purposive sampling. It was stated by Given [14] that purposive sampling is virtually synonymous with qualitative research. Purposive sampling is explained as: "It is one of the most common sampling strategies according to a criterion relevant to particular research questions. Furthermore, sample size may or may not be fixed prior to data collection, depend on the resources and time available, as well as the study objectives. Purposive sampling is accepted to be the most successful when data review and analysis are done in conjunction with data collection" [15].

The selected companies in the scope of the study are large-scale companies which have activities and investments in the field of textile and apparel logistics in Turkey and Germany. Responses were received via face-to-face and/or telephone interviews. However, 9 companies from Turkey and 10 companies from Germany were selected, the responses were collected hardly from 6 Turkish and 6 German companies.

Data Collection Method: Interviews

A survey was decided to conduct with Turkish and German apparel companies to evaluate the research questions. This survey would be like a short-interview with the companies' managers. In this interview, some questions were determined and would be asked.

During the preparation of these questions, the intent was to get direct, concrete and assessment-easy answers. For that reason; the questions which are shown below were prepared and asked.

Interview questions:

1. What do you think as a company about Green Perspective?
2. The main objective is to make money in the business but it is obvious that the process of Green Application requires some investments which mean additional cost. Could you please explain your standpoint according to this economical aspect?
3. Have you ever applied on Green Process for any departments of your company? If no, are you planning to do and in which department? If yes, when?
4. Do you really think that logistics should be environmentally friendly first? Or, are there some other departments which are more important and have priority on logistics?
5. What do you think about the environmental effect of logistics?
6. Do you think that your company has a productive logistical management system by the ecological point of view?
7. Do you take any precautions against your possible environmental effects of warehousing such as waste, package plastic and etc.? For example do you use recycled material?
8. Do you have as a company your own "Code of Conducts" about logistics?
9. Is it important for your company to determine your supplier to consider the environmental policy of their government/country?
10. How does the government act in the face of green perspective in Germany/Turkey? Is there any governmental inducement/obligation to improve your environment policy on green logistics?

Data Assessment Titles

In order to make the assessment more concrete, the questions were classified among themselves and titles which belong to each classes were identified. The evaluation of the answers collected from the companies, is in the form of the answers being classified under the titles below. Accordingly, the determined titles and the questions are:

- Green perspective and the industry: Question number 1
- Money or environment or both: Question number 2
- Until now…: Question number 3
- Precautions: Question number 7
- Supplier Selection and Environment: Question number 9
- Enough Governmental Inducements/Obligations: Question number 10
- Logistics & Environment: Question number 4, 5, 6 and 8.

FINDINGS

This study is based on qualitative research. The questions and the answers which were obtained through the interviews were discussed separately. The following titles below were analyzed by thinking of the interviewers' answers.

Green perspective and the industry

Turkish case

The general idea in the direction of the answers taken from the companies is, the environmental awareness of the companies is in the front lines among the commercial activities. Companies' sustainability strategy within the framework of the sustainability approach combines in two focus areas: the environment and people. In order to continuously improvement in accordance with the aims and targets which were set by the companies. They:

– Observe the current environmental legislation and discharge the legal obligations,
– Exhibit sensitive and effective behaviors against the environmental pollution,
– Reduce all the emissions and wastes by implementing an effective waste management system,
– Always and regularly observing the environmental management systems.

Additionally Turkish companies stated that, the aim is to have an integrated approach on sustainability where they are able to turn potential sustainability risks into opportunities which ultimately benefit their environment and their company. These opportunities include; waste management, pollution prevention, carbon footprint reduction, water and energy efficiency/production, and more efficient use of raw materials.

German case

During the interviews it was found out that, according to the ideas of the managers, the companies are more or less trying to do something good for the environment. For instance, they try to spread the warning that "do not print if not necessary" about printing. In their office and canteen, they split the rubbish into the categories of paper, plastic, glass and so on. Some of them have never heard the idea of green logistics and some of them have just comprehended the idea. It means, they do not think about the logistics part to do it green obviously.

However they have too much knowledge to do the production environmentally, it is also common that doing logistics green requires up-to-date information. There are no common activities with the logistics to do it green. According to the managers, until now, there have been a lot of studies, books, articles, materials also some workshops about the green production but not for green logistics. It is obvious that day-by-day some researchers in the industry, professors in the universities are doing a lot of research and process development. For that reason, in the production department besides products, the waste and the other things which are harmful for the environment are generated more than logistics department.

Money or environment or both

Turkish case

The general idea about this question is "The publicity of the social responsibility projects as such green applications, brings prestige and subsequently financial gain to the companies". Two companies among the all have the certificate of SA 8000, BSCI (Business Social Compliance Initiative) Oekotex Standard 100, GOTS, OEKO-TEX STeP and OCS.

The other one is a member of Climate Platform established by “Turkish Industrialists’ and Businessmen’s Association (Tüsiad)” and “Regional Environmental Center (REC)”. It is obvious that these companies consider both the environment and their monetary assets. However, it was understood after the interviews with the rest of the companies that they care about the environment in theory, but they do not so successful in practice.

German case

If companies decided to be sustainable on ecology, it directly increases the value and image of the company very positively, so it brings to companies better financial results, prestige and productivity. Also the environment gives back the positive answer: If humans protect the environment, it also protects the humans. They think that the investment in green process is return on investment. Managers are aware of the fact that, if some investments are made to be more environmental friendly, it brings more things than money like good customer relations, profit, a good reputation and so on. They think that it is very necessary to save the planet with some investments but the investment should end up with some profit. If it brings profit then they see this situation as „set a sprat to catch a mackerel". So they set the sprats. From the answers of this question it is obvious that they consider both, money and environment together.

Until now…

Turkish case

All of the interviewed companies confirmed that they have been carrying out various activities and applications in order to protect the environment. One of these companies stated that it produces own electric power through own hydroelectric power plant. Another company calculates the carbon footprint of all activities involved in the production and also administrative areas. The reason behind this act is to reduce their emissions within the scope of their fight against climate change. Apart from this, the most common practice in companies, in this context, is measuring the amount of water used and making efforts to reduce the amount of it. Converting all of the lights to the led system in order to reduce the amount of energy consumed in the lighting also reflects another example in common. The recycling and re-usage of the wastes generated from the daily activities of the employees can be shown as another application.

German case

Until now, according to German companies, safety of the employees always comes first. All production sites are run based on European safety standards. Then they of course take measures under the title of being green. For instance, using of recycled material, collecting all the wastes in a daily base and etc. They added as the common answer that if you do not recycle the wastes in a daily or weekly base, the general cost of these activities would be higher at the end. They also split up their daily wastes as plastics, papers, glass… from production, warehouse, and daily activities to use them for recycling. As mentioned before, one of them gave as an example that they use big windows to exploit natural heating energy to heat the company with less electric energy.

General Precautions for Environment

Turkish case

Each company has some precautions which have been put into practice according to companies' own principles to protect the environment. For instance the cardboard boxes which used for transporting the products. The cardboards are supported for being more stable to use them longer. In this way both the operational costs and the amount of the waste generated are reduced.

The waste of the cardboard boxes and plastic packaging materials are collected and delivered to the licensed companies which collect the wastes and disposal. Also the wastes generated in the company are also classified and send for recycling. In addition, most of the companies force both the customers and the employees to use biodegradable plastic bags.

Another company which is also very active in retail activities started a recall for the apparel products which are not used any more for recycling. In this context, it has been emphasized that the unused apparel products can be utilized by reusing or recycling and at the same time, the future waste can be reduced.

Another company which has ISO 14001 environmental management system certificates was steer to new sustainable production methods and product development which is environment friendly. In these new product development projects, the consumption of the water and energy resources is measured in consideration of environment and human health. In this way, the use of resources such as water, electricity and natural gases can be decreased and the wastes that are generated as a result of the production can be minimized.

German case

Actually companies are very careful about the universe. It could be true that money has the priority like in every business which runs after some profit but companies are also very keen on environment. It is obvious that they have to take some precautions against the environmental effects of their business because of the laws and other regulations. Accordingly, they obey these laws and have some precautions.

As the precautions, for instance; they use recycling bins for all their waste, for example; fluorescent light bulbs, fabric wastes, plastic wastes and waste papers. They collect these materials in every department for recycling. Recycling provides on the one hand getting rid of the wastes from the company and also from environment; on the other hand these materials cost with a cheaper price. The easiest example, also they gave this example, is plastic hangers, because as everybody knows in the apparel industry, a lot of hangers are needed to protect the shape of the products well. So, the hangers which are made of recycled material, as the first reason the companies get these hangers cheaper and secondly they are produced with less emitted CO_2.

Supplier Selection and Environment

Turkish case

According to the interviews, it is very important for the rest of the companies, while this situation is not a very important issue for one of the companies. With regard to the general judgement of all company managers, except one of them, they select their suppliers in accordance with the criteria determined by the companies' previous experiences. The environment oriented selection of the suppliers becomes one of the most indispensable criteria. The criteria that the suppliers are expected to fulfil can be listed as follows: Conformity with laws and regulations, no child labor, non-discrimination, balanced wage system and social rights, the conditions related to the working hours, healthy and safe working conditions and protection of the environment (HSE).

German case

There is a common idea that "environmental policy of suppliers' government/country is of course important to consider". Some of the companies also have some code of conducts to select their supplier/producer. There is a further answer that, European companies with European suppliers/producers do not think about the policy because they all have the same regulation. But the main company may request the fulfilment of requirements in the written and signed form from the supplier/producer.

If the producers/suppliers are not in Europe, they request some certificates but how they get the certificate and what are the terms and conditions to get it are also important.

Enough Governmental Inducements/Obligations

Turkish case

Although in Turkey "green logistics" is not yet made mandatory by laws and regulations, this concept is on the agenda of the sector. In Turkey some fines are applied when the carbon footprint limit of the companies is exceeded. Furthermore, the regulation on following up the greenhouse gases emissions was brought into force in 2019. It has been determined in the regulation that all the emissions will be monitored in the businesses according to the scope of the activity. For that reason, most of the companies make their own carbon footprint measurements in Turkey.

German case

There are certainly both inducements and obligations for companies not to harm environment. The general idea which is understood during the interviews is the obligations and also some inducements for environment and environmental activities have beyond measure importance and these rules or obligations are indispensable for the managers. Managers believe that owing to these obligations and inducements, companies regulate their business activities by the thinking of environment. They also think that sometimes government sets up some rules which are not very logical and companies are not sure whether these rules help to improve environmental effect of companies activities or not. Nevertheless, they are happy that the governments are very keen on protecting the environment and they also think that the European Union has one of the strictest rules in the world.

Logistics & Environment

Turkish case

The common answer from companies about the importance of the logistics activities among other departments in terms of environment; the important point for the companies are human right, labor standards, environment, fight against corruption. That is why, all the activities about environment are carried out considering all the departments.

All the companies think that logistics activities have a negative impact on the environment. For that reason the vast majority of companies follow the carbon footprints including all logistics activities. However this is not just for a measurement of logistics activities. Companies carry out various sustainability projects in order to reduce the carbon emissions year by year. One of the companies also monitors the fuel consumption of each vehicle belonging to the company to determine the carbon emission rate on a yearly base.

One of the companies replied negatively and the rest of them think that they have a productive logistics management system because of the follow-up the carbon footprint about the question of the productive logistical management system by the ecological point of view. One of the companies supported the having an efficient logistic management system with ISO 14001:2004 Environmental Management Systems Certificate, ISO 50001 Energy Management Systems Certificate and Global Recycling Standard certificates that the company has.

It has been understood that the companies have a general code of conducts. There are categorized generally; social performance (such as human rights, employee safety), environmental performance (such as energy and water efficiency), supply chain performance, product and production performance, social responsibility performance. According to the answers, the logistic activities counted in the environmental performance. However, none of these companies have a logistic-wise code of conduct until now.

German case

The general idea about the logistics is that when companies have the environmental glasses on, only focusing on logistics is not enough to be green. Supply chain has much more importance than logistics. According to this manager being green of anything is to save resources as the best way or also it can be said that to get rid of the unnecessary processes. It means the elimination. After the elimination, managers can organize the remaining processes easily and more productively. So they will be green as a result automatically. It means to be green is the end of the processes not the beginning. The meaning of this conversation about the question; supply chain is more important. It is obvious that to be green is an achievement at the end of an efficient supply chain.

The general idea about the environmental effect of logistics, it is huge but if it is compared with the other departments (production, sourcing…) it is low.
Companies answered the question about productive logistics management system in common that there are not many companies in the clothing industry performing an environmental management system. Also it is common for them not to think that their companies have the productive environmental logistics management system. But just one company indicated that they have very productive logistics management system by the ecological point of view, not in the German part of their business but they have it in the USA and in the UK part. To get positive response from the environment, they optimized their transportation routes, calculated the quantity of the liter of petrol consumed and carbon footprints of the activities and so on.
About the code of conduct question, companies stated that they do not have any written „Code of Conduct" on logistics. But they try to organize their activities as sufficient as possible and not to harm the environment.

RESULTS

Within the scope of this study, logistic activities of the companies operating in Turkish and German textile sector were compared under the environmental title. Logistics, in the concept of fast fashion is an important term with variety of applications in order to reduce the cost and improve the value on the products. However, logistic activities also have an impact on the environment like every other activity in the companies.
In this study, the applications about the logistics were compared through the answers received by Turkish and German textile companies. So the opinions about the answers are shown below.

- Green perspective and the industry: While the practices in two countries are similar, the environmental sensitivity of the sector is supported by various environmental legislations.
- Money or environment or both: While Turkish companies consider the environment and the money as a minority, they mostly consider the environment theoretically, but in practice they are very weak. German companies on the other hand, approach this issue more rationally. They consider both the environment and the money together theoretically and practically supporting with the environmental certificates.
- Until now…: Turkish and German companies seem to have done as much study on environment as until now. These studies are mostly focused on production. Such as measuring and following the carbon footprints, separating and sending to recycle the wastes generated in companies day-by-day, using recycled materials as much as possible. As a matter of fact, German companies are very careful to take various precautions considering the health of the employees at the focus of all the work done. It is necessary to point out that a Turkish company established its own hydroelectric power plant in order to provide own electric energy which cannot be ignored as a study done for the environment.
- General Precautions for Environment: Both Turkish and German companies take various precautions to protect the environment. Such as, using recycled materials, modifying the materials to use for a longer time, carrying out various projects supported by environmental laws.
- Supplier Selection and Environment: Both Turkish and German companies consider the environment when choosing suppliers. However, the price offered by the supplier is in front of the environment for Turkish companies. This situation is mostly in the direction of environment for German companies.
- Enough Governmental Inducements/Obligations: "Green logistics" in Turkey is a slightly newer concept than Germany. Within this context, the carbon footprint boundaries of companies are followed in Turkey. However, in Germany there are many applications on "green logistics". Some of those; selection of the transport type, regulation of the transport time, road optimization, following the occupancy rate of the vehicle, considering the age of the vehicle and the type of the fuel, carbon footprint of the vehicle and so on. Accordingly, it can be said that German government has a tighter control mechanism then Turkey.
- Logistics & Environment: Both Turkish and German companies are convinced that logistic activities effect the environment negatively. While few Turkish companies are involved in carrying out various projects to overcome this negative effect, all German companies have undertaken various studies keeping the governmental auditing in this regards. Both companies are convinced that focusing on logistics alone should not be sufficient in terms of environmental conscience. The important thing in this regard is that focusing on the supply chain from the very beginning to the end.

Logistics is a concept that provides added value on products and decreasing the expenditures. Particularly within the context of logistic activities, countries that have a geographical advantage can further increase the benefits that they provide from the logistic activities. In addition to the benefits provided by logistics activities, there are also some environmental threats.
Conducted examinations and the information based on the activities of the two countries' companies show that the activities carried out by the companies in Turkey in order to minimize the damaging effect of logistics are more inadequate than the ones in Germany. When the governments are compared in the same direction, it will be seen that the compulsory conditions of the statutory audits are performed more imperatively by German government than Turkish government. Turkish government should increase the inspections about the environment to industrial enterprises or resettle such as additional taxes and so on. Turkey became a party to the UN Framework Convention on Climate Change (UNFCCC) on 24 May 2004 and the Kyoto Protocol on 26 August 2009. So Turkey needs to apply more

environmentally friendly strategies both in accordance with the UNFCCC and the Kyoto Protocol.

By closing the gap between the countries, not only governments but also companies need to take precautions to at least reduce the carbon emissions [16]. In this context, the auditing on carbon emissions can be increased and some more taxes can be applied. In addition, in order to solve the problems related to logistics, necessary legal arrangements should be made about the sector and a significant control mechanism should be developed together with standards.

In order to benefit more from the geographical superiority as a country which is surrounded on three sides by the sea needs to have better sectoral infrastructure. At the same time, the problems should be solved in areas such as the situation of the ports, combined transportation possibilities, balance between transport modes and their competences, qualified human capital, technology, know-how and legal regulations.

The need of qualified personnel should be resolved to give more importance to the colleges and universities which provide training on logistics in Turkey. In this context, the curricula of colleges and universities offering logistics should be rearranged to follow the developments around the world.

The scope of the concept of green logistics can be expanded with further studies by using this study. For instance, it will be possible to contribute to the literature by analyzing the application of different sectors from different countries.

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A review: life cycle assessment of cotton textiles

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ABSTRACT – REZUMAT

A review: life cycle assessment of cotton textiles

A significant amount of research has been published on the environmental impact assessment of cotton textiles using the life cycle assessment (LCA) method. This review summarized and analysed the findings of these publications, and presented valuable insights for identifying the hotspots that have considerable potential for reducing the environmental burden of cotton textiles. The relevant papers were selected according to two criteria: life cycle assessment of cotton textiles or footprint of cotton textiles. Subsequently, key features were screened and critically analysed: functional unit, system boundary, data sources and geographic location, and impact assessment methods and impact categories. We found that there is an emerging market demand to transform conventional cotton to organic cotton. From the global perspective, a spatially explicit LCA of cotton textiles should be conducted. In addition, a comprehensive and holistic life cycle impact assessment containing more impact categories that are appropriate to cotton textiles is required. LCA is a well-justified approach among practitioners and researchers and has been widely applied to the topic of cotton textiles. This methodology should be studied and developed further to more precisely evaluate the environmental impacts of cotton textiles.

Keywords: *cotton, environmental impacts, footprint, life cycle assessment, review, textiles*

Studiu: evaluarea ciclului de viață al materialelor textile din bumbac

Multiple cercetări au fost publicate cu privire la evaluarea impactului asupra mediului al materialelor textile din bumbac, folosind metoda evaluării ciclului de viață (LCA). Acest studiu a identificat și a analizat rezultatele acestor publicații și a prezentat informații valoroase pentru identificarea punctelor importante, care au un potențial considerabil de reducere a presiunii asupra mediului create din producerea materialelor textile din bumbac. Lucrările relevante au fost selectate în conformitate cu două criterii: evaluarea ciclului de viață al materialelor textile din bumbac sau amprenta materialelor textile din bumbac. Ulterior, caracteristicile cheie au fost examinate și analizate critic: unitatea funcțională, limita sistemului, sursele de date și locația geografică, metodele de evaluare a impactului și categoriile de impact. S-a constatat că există o cerere pe piața emergentă pentru transformarea bumbacului convențional în bumbac organic. Din perspectiva globală, ar trebui implementată o metodă LCA explicită spațial pentru materialele textile din bumbac. În plus, este necesară o evaluare cuprinzătoare și holistică a impactului ciclului de viață, care conține mai multe categorii de impact, adecvate pentru materialele textile din bumbac. LCA este o abordare bine justificată în rândul practicienilor și cercetătorilor și a fost aplicată pe scară largă în ceea ce privește materialele textile din bumbac. Această metodologie ar trebui studiată și dezvoltată în continuare pentru a evalua mai precis impactul asupra mediului al materialelor textile din bumbac.

Cuvinte-cheie*: bumbac, impact asupra mediului, amprentă, evaluarea ciclului de viață, studiu, textile*

INTRODUCTION

Cotton is the most widely utilized natural fiber in the world, and has comprised approximately one third of the textile fibers market in 2000–2016 [1]. Cotton is grown in subtropical, seasonally dry tropical areas, primarily in the Northern Hemisphere. Approximately 32 million hectares of agricultural land is allocated for cotton plants in more than 75 countries, including India, China, the United States, Brazil, and Pakistan, which are the main producers of cotton and account for more than three-quarters of global cotton production. According to the Food and Agriculture Organization (FAO), global cotton consumption is ~31.8 million tonnes, with > 20 million tonnes of cotton being used for textile fibers. Approximately 8 million tonnes of cotton was traded in the global market during 2016/2017 [2].

The entire life cycle of cotton textiles is long and complex, and includes cotton cultivation and harvest, manufacture (ginning, spinning, weaving, dyeing, cutting and sewing, and ironing), consumption (retail and use), and disposal. Generally, cotton is considered to be an environmentally friendly fiber since it is grown and not manufactured. However, it consumes large quantities of water during the agricultural phase, and fertilizer and pesticides are also required, which can lead to eutrophication and toxicity. According to Cotton Inc. [3], global cotton accounts for 3% of land use, 3% of global agricultural water, and 5.2% of global pesticide sales. Previous life cycle assessment (LCA) studies have found that cotton cultivation has significant environmental impacts due to the use of pesticides, fertilizers, and water [4]. Dyeing is the most contaminative process in the life cycle of cotton textiles, the numerous inputs of chemicals such as dyes, wetting agents, and softener account for a huge environmental burden. Water usage for washing during the use phase of cotton textiles has also attracted attention. There have been many initiatives to reduce the environmental burden of cotton products, for example, by growing organic cotton and recycling cotton textiles. Over the past decades, the Better Cotton Initiative (BCI) and Cotton made in Africa (CmiA) as well as other programs have brought momentum to the movement for improving the environmental performance of cotton [5]. The long and complex supply chain of cotton in addition to the numerous associated environmental impacts requires a comprehensive methodology to evaluate the overall environmental burden.

Meanwhile, some practitioners are required to demonstrate how their cotton products or services reduce the environmental burden. LCA is an effective method for providing an interpretation of the entire life cycle of products. Since the introduction of the International Organization Standardization (ISO) 14040:2006 and ISO 14044:2006, LCA has been widely applied in the textile industry as a decision support tool for evaluating the environmental impacts of products and services [4]. The framework of LCA traditionally involves: 1) goal and scope definition; 2) inventory analysis; 3) impact assessment; 4) interpretation. The first step defines the purpose of the study, the product, system boundaries, and the function unit according to ISO 14040:2006 [6]. Inventory analysis is the foundation of impact assessment. The reliability of the results is partially dependent on the quality of the collected data. Many existing life cycle impact assessment (LCIA) databases provide convenience to practitioners. The impact assessment phase aims to evaluate the potential environmental impacts, transforming the life cycle inventory (LCI) into the potential environmental impacts through the use of characterization factors.

The aims of this review are to: i) explore and document the current state of LCA research with regards to the environmental burden of cotton textiles, ii) identify possibilities for reducing the environmental burden of cotton textiles, and iii) identify possible improvements for the existing LCA evaluation methods used in the cotton textile industry. By reviewing and comparing previous studies we further aim to illustrate the differences between methods and results, and in turn discuss their limitations as a means of providing an initial guide for data collection and method selection among practitioners.

IMPACT ANALYSIS OF COTTON PRODUCTS

Impact analysis of cotton fiber

Impact analyses of cotton fiber have focused on the impacts of the cultivation phase of cotton. The boundary has always been set as from cradle to gate (ginning). The functional unit is 1000 kg (or 1 kg) of cotton lint. Different studies have assessed the environmental performance of cotton in different regions, identified the potential to reduce the environmental burden, and compared the performance of different measures for reducing the environmental impacts.

Water use for cotton production differs considerably between countries due to the variations in climatic conditions and those that are required for cotton production. A report by Chapagain et al. aimed to assess the "water footprint" of worldwide cotton consumption by identifying the location and character of the related impacts [7]. The author analysed the largest 15 cotton producing countries, and found that climatic conditions were highly related to water use and cotton yields. The climatic conditions of Syria, Egypt, Turkmenistan, Uzbekistan, and Turkey – where the evaporative demand is high while effective rainfall is very low – are less appropriate for cotton cultivation because of the irrigation demand, which increases the environmental burden to local water resources. In addition, partial irrigation leads to low cotton yields. Optimal climatic conditions for cotton production are in the USA and Brazil, where evaporative demand is low and cotton can be grown without irrigation. The global cotton trade ensues that most of the cotton produced in a region is actually utilized in another, and countries that import cotton indirectly deprive water resources of the export countries through global trade. Approximately 84% of the water footprint of cotton consumption in the EU 25 region prior to 2005 was located outside Europe, with major impacts having affected India and Uzbekistan in particular. With regards to sustainable water management, it is feasible to hypothesize that improvements may be possible from the cotton consumption perspective if a degree of responsibility for the impacts is taken by consumers.

Cotton made in Africa (CmiA) is cultivated by small-scale famers under rain-fed conditions in crop rotation with other cash or subsistence crops. Agricultural inputs such as fertilizers or pesticides are low and the harvest is performed exclusively by hand. This extensive cultivation practice was found to have significant advantages over other methods in a report by CmiA., which evaluated the cradle to gate environmental impacts of cotton lint made in Africa (functional unit of 1000 kg cotton lint) [8]. Climate change, eutrophication, and acidification were assessed in the report using the Center voor Milieukunde at Leiden (CML) impact assessment methodology framework.

Additionally, water use and water consumption were investigated. Freshwater use includes the withdrawal from surface water, ground water and rainwater and water consumption means that the water removed from but not returned to the same basin. The impact on climate change was quantified as 1037 kg CO_2 eq., which was lower than the global average (1801 kg of CO_2 eq.) [9]. The freshwater used to produce 1000 kg CmiA was determined as ~3400 m^3, but the blue water (surface and ground water) consumed was found to be very small due to the precipitation in this region being sufficient to meet the water demand for growing cotton. The eutrophication impact was evaluated as 20.4 kg PO_4^{3-}, to which soil erosion made a significant contribution. In this report, the emission of N and P was modeled and it found that soil erosion and the nutrient content of the soil were determined to be sensitive parameters with regards to eutrophication, with the potential for eutrophication differing between regions. However, this regional difference of has not yet been considered in existing life cycle impact assessment of cotton.

Xinjiang, China, has become one of the most important cotton producing regions and has the highest yields worldwide. Günther et al. focused on the agricultural greenhouse gas emission and phosphorus consumption during the cultivation of cotton in Xinjiang, which measured as carbon footprint and phosphorus footprint, respectively [10]. Results showed that fertilizer production contributed 63.9% of the carbon footprint (total 4.43 kg CO_2 eq./kg fiber) due to the energy use during the fertilizer production phase. The phosphorus footprint of cotton was 101g P/kg fiber mainly from the high input of phosphorus fertilizer, which also indicated a high potential of eutrophication. Therefore, reduced fertilizer application and reuse of plant residues are the most probable ways to reduce the carbon and phosphorus footprints of cotton production. A limitation of this study was that it was carried out in a dryland area, hence, the findings should be combined with an analysis of the water footprint as a means of moving towards a more holistic picture of the environmental impacts of cotton.

As mentioned, cotton cultivation has considerable environmental impacts. Organic cotton that avoids the use of artificial fertilizers and pesticides has been encouraged by specialists [11]. A report published by Textile Exchange, a non-profit organization, addressed the LCA of organic cotton for the top five countries involved in organic cotton cultivation: India, China, Turkey, Tanzania, and the USA, which were found to collectively account for 97% of global cotton production [12]. The LCA of organic cotton were based on the CML impact assessment methodology framework. Comparison of organic and conventional cotton was made using the Cotton Inc. (2012) study of conventional cotton. The results indicated that organically grown cotton had the following potential impact savings over conventional cotton: 46% reduced global warming potential (GWP), 70% reduced acidification potential (AP), 26% reduced eutrophication potential (EP), 91% reduced blue water consumption, and 62% reduced primary energy demand (non-renewable). The lower agriculture inputs (e.g., mineral fertilizer, pesticides) as well as the practices required by the principles of organic agriculture accounted for the lower environmental impact of organic cotton. However, it should be noted that the low blue water consumption of the organic cotton cannot be attributed exclusively to the organic cultivation operations, since the irrigation requirements of a crop are mainly determined by climatic conditions, and the actual water usage is also influenced by irrigation techniques.

The recovery of cotton from discarded cotton presents a potentially wise strategy for reducing the environmental burden of cotton. A study undertaken by Esteve-Turrillas and Guardia [13] compared the environmental impacts of recovered cotton with virgin cotton. Findings showed that the use of recovered cotton avoided impacts related to cultivation and the dyeing process, although electricity consumption was relatively higher for recovering cotton (functional unit of 1 kg of colored cotton yarn). The results also illustrated a great advantage of recovered cotton because it was found to save 13.98 kg CO_2 eq. with respect to GWP, 0.32 kg SO_2 eq. for AP, 0.033 kg PO_4^{3-} eq. for EP, and 5594 kg water for the water use. However, the data of this study was taken from literature that was based on different regions and methods, hence, the advantages of recovering cotton may have been overestimated.

Many efforts have been made by the cotton industry in different countries to meet international obligations regarding emission reductions. The Australian cotton industry has made particular advances in this regard. Hedayati et al. assessed the effects of an array of on-farm mitigation options as a means of providing farm-level strategies for reducing emissions [14]. The climate change impact evaluation using the Intergovernmental Panel on Climate Change (IPCC) method of cotton lint on a cradle to port basis was determined as 1601 kg CO_2 eq. per tonne of cotton lint. The hotspots assessment found that the production and use of synthetic nitrogen fertilizers made the largest contribution to the emissions profile (46% of total). Farm level management options to minimize the life cycle of greenhouse gas (GHG) emissions were also compared. The results indicated that GHG emissions could be reduced by i) 5.9% through the controlled-release of stabilized N fertilizers, ii) 8.1% by changing from diesel to solar-powered irrigation pumps, iii) 3.4% by changing from diesel to biofuel-powered farm machinery, iv) 3.9% by changing from continuous cotton to a cotton-legume crop rotation, and v) 2.1% through the use of N fertigation. This study therefore demonstrated opportunities to reduce GHG emissions at the farm level.

Other strategies to reduce the environmental burden of cotton include the reuse of clothing (e.g., second-hand clothing) and cotton recycling to produce other products. A new technology has been reported recently for producing cellulose carbamate fibers using discarded cotton textiles as the raw material [15]. The authors compared the environmental impacts of two cellulose carbamate (CCA) fibers under different production scenarios with cotton fiber. The data for the reference cotton was taken from van der Velden, N. M., et al. and Shen and Patel, et al. [16–17]. Two CCA fiber production scenarios were modelled with Sustainability tool for Ecodesign, Footprints & LCA (SULCA). Assumed that CCA Intergrated fiber was produced in a factory integrated with a pulp mill, which included water circulation, recycling of chemicals and using renewable energy. CCA Standalone fiber was produced in a stand-alone factory, which represented a non-optimized process. 1 tonne of CCA Integrate fiber had a GWP value of 1979 kg CO_2 eq., which was ~30% lower than of that for the reference cotton fibers. However, CCA Standalone fiber generated twice of GWP of cotton fibers (6020.1 kg CO_2 eq.). The water use of CCA Integrated fiber and CCA Stand-alone fiber were 31 m^3 and 86 m^3 respectively, which is much lower than cotton (4342 m^3 per tonne of cotton fiber). Paunonen et al. concluded that the reuse of discarded cotton for CCA fiber can considerably reduce water use [18]. However, due to the huge contribution to GWP, it should be suggested to integrated spinning factory with pulp mill to optimized the production of CCA fiber.

In addition to an intensive water use, cotton production is also characterized by intensive land use during the cultivation phase. However, these two impacts are seldom addressed as impacts further down the cause-effect chain. Sandin et al. contributed to the developed of methods for characterizing the impacts of water and land use in the LCA, and assessed the impacts of water use and land use with respect to textile fibers [19]. The study used four indicators proposed by Pfister et al. to characterize the impact of water use: a midpoint indicator (water deprivation) and three endpoint indicators (human health, ecosystem quality impact, and resources) [20]. Sandin et al. also used the method proposed by Schmidt for characterizing the impact of land use on biodiversity [19, 21]. The results showed that the location of operations significantly influenced the impact of water use. The transformation of natural land had a greater impact on biodiversity than the occupation of land. Moreover, the study highlighted that the methodological aspects of both water and land use impact assessment require further research down the cause-effect chain.

To balance the economic and environmental performances of cotton cropping systems, Ullah et al. performed an eco-efficiency analysis [21]. The authors assumed that farm size was a possible factor in the performance variation, and their results demonstrated that the use of pesticides and fertilizers, field emissions, field operations, and irrigation were the main sources of environmental impacts. Findings revealed that the production of 1 kg of seed cotton delivered at the farm gate could generate a GWP of 3–3.4 kg CO_2 eq. and could require 5–6 L of water, with no significant differences being observed with farm size. Small farms were found to have a potentially higher eutrophication impact in comparison to larger farms, but this could be counterbalanced by higher profits. Unfortunately, the study illustrated that the combination of high economic returns with low environmental impacts was seemingly impossible under the assumed conditions. However, the greatest potential for balancing economic and environmental performances was found to be through the reduction of pesticides and fertilizers with no effect on yield.

Impact analysis of cotton clothing

Cradle to grave LCA can be used to assess the advantages of recycling clothing, address environmental performance of garments, and identify the hotspot during the life cycle of a T-shirt or a pair of jeans, for example. The impact categories selected to address environmental burden of products are different from each study depending on the purpose and the chosen LCA methodology. The most utilized life cycle impact assessment (LCIA) methods in cotton textile are environmental design of industrial products (EDIP), ReCiPe and CML.

Woolridge et al. conducted a LCA for the reuse/recycling of donated waste textiles from an energy saving perspective [23]. To address the net energy saving from reused textiles, the authors used a case study of a charity bank, which recycled clothing and textiles by providing a collection and distribution infrastructure for donated second-hand clothing, textiles, shoes, and accessories. The energy use required for reuse and recycling was mostly attributed to the use of polyester packaging/bags and transportation. In comparison to virgin materials, 1 tonne of second-hand clothing was found to save 65 kwh energy (i.e., 97.4% of the energy used for virgin cotton clothing).

Many charity organizations collect used clothing and either resell or donate them. Not all clothes are suitable for reuse, and only ~60% may be recycled. The potential to reduce the environmental burden of recycled textiles was quantified by Farrant et al. [24]. The authors assessed the environmental benefits of reusing clothes by the EDIP method and a functional unit of 100 pieces of 100% cotton T-shirt. The concept of a “replacement rate” was introduced to evaluate the replacement of new clothes by second-hand clothing. Compared with directly discarded cotton T-shirts, reuse via second-hand shops in Estonia was found to decrease i) the GWP by 14%, ii) acidification impacts by 28%, and iii) nutrient enrichment impacts by 25%.

Baydar et al. used LCA to compare the environmental impacts of eco-T-shirts (produced from organically grown cotton and processed with green dyeing recipe) to those of conventional T-shirts [25]. Comparison was made of their contributions to global warming, acidification, aquatic and terrestrial eutrophication, and photochemical ozone formation using a functional unit of 1000 items of knitted and dyed cotton T-shirt (200 kg total weight). The environmental impacts over the period from cotton cultivation to disposal were assessed using EDIP 2003. The results revealed that the eco T-shirts had a lower impact potential across all of the observed categories. The most dramatic decrease in impact potential was observed for aquatic eutrophication potential (AEP) (up to 97% reduction), which related to the elimination of nitrogen and phosphorus containing chemical fertilizers during the cotton cultivation stage. GWP was by far the largest environmental impact for both conventional and eco T-shirts, with the main impact coming from the use phase (evaluated as 4140.4 kg CO_2 eq.), and this was followed by the cultivation and harvesting phase and then the fabric processing phase. In terms of AP, the use stage was found to make a considerable contribution to acidification that resulted mainly from wastewater treatment (51%), soap production (25.3%) and electricity consumption (22.4%). The elimination of certain chemicals during wet processing resulted in a significant reduction across all impact categories. Although the authors concluded that the use of organic cotton can significantly reduce environmental impacts, any immediate transition to organic cotton cultivation was considered to be challenging. Gradual reductions in the application of fertilizer and pesticides were determined as being more feasible for reducing the environmental impacts.

The LCA of a product includes the challenges of globalized production and consumption, and requires a spatial LCI to be developed. Steinberger et al. established a cradle to grave spatially explicit LCI for a cotton T-shirt and a jacket at the country level [26]. The cotton T-shirt was produced in India and the polyester jacket was manufactured in China, and both were consumed in Germany. The LCI included CO_2, SO_2, NO_x and particulate emissions, as well as energy use, which were disaggregated by country. The LCI of the T-shirt and jacket showed striking differences, > 70% of the CO_2 emissions and energy use associated with the T-shirt occurred in the consumption country, whereas > 70% CO_2 of emissions associated with the jacket occurred in the producing country. This striking difference of the CO_2 emission was related to the different washing frequency of two apparels (50 times and 6 times for the jacket). For SO_2, > 60% of emissions occurred in the production country for both the T-shirt and the jacket due to the combustion of fossil fuel in production phase. The difference in the emission of CO_2 and SO_2 of two garments was mainly depended on the location energy infrastructure. Analysis of the use-phase indicated the importance of consumer behaviour (e.g., washing machine temperature settings and air versus laundry drying) over equipment efficiency. In addition, the lifetime of a garment was also found to play a significant role in the contribution to environmental impacts, a longer lifetime increased the environmental impacts of the use phase, whereas the daily environmental burden of a garment being worn decreased. These findings indicate the necessity of a functional unit that provides the lifetime of a garment when conducting a LCA of clothing.

Large environmental impacts for cotton textiles are caused during the use phase, especially with respect to energy consumption for washing and ironing clothes. Cartwright et al. assessed the cradle to grave environmental impacts of a shirt using a functional unit of a button-up, short-sleeved, uniform work shirt made of 65% polyester and 35% cotton [27]. The shirt was washed 52 times over a 2-year lifespan. The environmental impacts (energy, water use, and GWP) were analysed for four distinct phases: material acquisition, shirt manufacturing, use and disposal. The total life-cycle energy use of the shirt was 102 MJ, the cumulative water use was 2728 l, and the GWP was 5.7 kg CO_2 eq. The results showed that the amount of resources used and the GWP were highest during the shirt's use phase, which accounted for 64% of total energy use, 72% of total water use, and 76% of the overall GWP. This was due to four main processes in: water heating, washing, drying, and transportation. The study concluded that more effort should be made to improve the environmental performance of the use phase, for example, by increasing equipment efficacy.

Hackett et al. addressed the cradle to gate phases of the life cycle assessment of a pair of denim jeans and a T-shirt [28]. The system boundaries that were assessed included: raw material production, fabric production, garment manufacturing, and transportation and distribution. The study showed that cotton fiber cultivation and harvesting made the most significant contributions to the overall environmental impacts, and that these originated from the use of fertilizers, pesticides, and irrigation water. The authors suggested that initiatives could therefore encourage the cultivation and harvesting of organic cotton that remove the use of artificial fertilizers and pesticides. However, due to concerns over low yields and finances, the transformation from conventional cotton to organic cotton was considered as having a long way to go. Limitations of the study included that the data came from existing LCAs, and that the comparison between the selected apparel was less meaningful because the environmental impacts of the cotton apparel varied from countries and the results are highly dependent on chosen methodology, hence, we suggested that the comparison of environmental impacts between two type different apparel (e.g. T-shirt versus jeans) should be based on LCIA results that evaluated under similar systems.

Zhang et al. aimed to identify hotspots in the life cycle of cotton textiles for the purpose of improving their sustainability [29]. The functional unit was one 100% cotton long-sleeved T-shirt and the scope was from cradle to grave. The data were obtained from a representative mill and from questionnaires for the use phase in China. Abiotic depletion, AP, GWP, photochemical ozone creation potential, EP, water use, and toxicity were assessed using CML 2001 and USEtox model. From a life cycle perspective, the study showed that cotton cultivation, dyeing, making-up, and the use phase were the main contributors to the environmental impacts. The author concluded that improving a product's environmental sustainability is not only a matter for the government and suppliers, but also for consumers.

In 2015, Levi Strauss and Co. conducted an LCA to assess the environmental impact of a pair of Levi jeans. The functional unit was one pair of women's Levi's 501 medium stonewash-jeans (340 g) that were made of cotton [30]. The LCA analysed the environmental impact of the denim during the entire life span, which encompassed the production of the raw materials, the manufacturing process, logistics, garment use, reuse of the denim, recycling, and disposal. The LCA focused on the product's use phase and end-of-life disposal phase because these are critical stages in a product's life cycle, which depend on consumer behaviours. ReCiPe 2008 was used to assess climate change potential, water consumption, EP, land occupation, and abiotic depletion. One pair of Levi's 501 denim jeans were found to emit 33.4 kg CO_2, to consume 3781 kg water and 48.9 g PO_4^{3-}, and to occupy 12 m^2/year of land. The study demonstrated that fiber production and consumer care activities consumed most of the water during the entire life cycle (91%), whereas fiber production consumed 68% and consumer care activities (e.g., cleaning and washing) consumed 23%. The results showed that consumer care contributed the largest impact (37%) to climate change over the life cycle. Moreover, processing factors such a washing frequency, washing water temperature, and the use of a washing machine were found to influence GHG emissions. The fabric product had the second largest impact on climate change (27%). Fiber cultivation had the highest impact on eutrophication due to the use of fertilizer and pesticides (Levi Strauss & CO, 2015). This study provided a comprehensive assessment of the environmental burden of a pair of cotton jeans, which could be used for improving the performance of jean.

The textile industry uses chemicals intensively in production phase. Toxicity assessments are therefore performed, and it is important that the results are both relevant and representative because it is crucial that there is confidence in the results. Three methods for strategic product toxicity assessment were compared by Roos and Peters as a means of disclosing the inherent characteristics of chemicals used in cotton manufacturing [31]. The differences resulting from the choice of toxicity assessment method were illustrated and compared using the wet treatment of a cotton T-shirt. The results showed that three different toxicity assessment methods did not give a consistent evaluation of the different chemicals used in the wet treatment. For example, optical brightener received a high score in the score system method but a very low score from USEtox. This was considered to mainly relate to the environmental persistence of organic chemicals, a property that is handled differently in these toxicity assessment methods.

Roos et al. calculated the GWP using ReCiPe and toxicity using USEtox, and used the score system as a supporting method [32]. The study addressed the importance of the life-cycle perspective as a means of avoiding improving part of a system in a manner that negatively affects other parts of the system. The environmental impacts of two white nightgowns were compared, whereby one was bleached and one was not. The results showed that, contrary to expectations, the environmental burden associated with the bleached nightgown over its life cycle was lower than that of the unbleached gown, owning to a shorter lifespan for the unbleached gown. A shortcoming was identified during the impact assessment step, many textile chemicals lacked character factors CFs and could not therefore be included in the LCA calculations. This represents an aspect for further study in the methodology of chemical assessments. From this study, we proposed that the operational lifespan of products should be determined when conducted LCA, which significantly influence by consumer behaviours. Assuming that consumers dispose of clothes when they are worn out, a long-life span ensures a lower replacement rate for consumers, which may be more environmentally friendly from a comprehensive perspective.

The carbon footprint of a pure cotton shirt (average weight of 0.28 kg) from cultivation to use stage in China was evaluated by Wang et al. using the IPCC method. This study constructed an operable carbon footprint assessment method and framework at the product level to establish the provision of a carbon labelling system [33]. The calculated carbon footprint was 8.771 kg CO_2 eq., and the indirect carbon footprint accounted for most of the total carbon footprint over the shirt's life cycle (96%) owing to the use of energy and materials. The industrial production process contributed 57% of the total carbon footprint, 36% for raw materials, 11% for use phase. A limitation of the study was that it only assessed climate change. According to previous research, the consumption of water and land use are other hotspots for cotton textiles. The authors emphasized that a product should be assessed in a comprehensive manner to inform consumers sufficiently, when develop environmental impact polices making or management decision. We proposed that a comprehensive eco-label will be an effective way to reduce the environmental burden of garments.

DISCUSSION

Goal and scope

LCA of cotton textile aims to assess the environmental impact of cotton textile during the life cycle. The entire life cycle of cotton textiles includes many processes, and is related to many regions and has a long time-span. It can be separated to four main processes: cotton cultivation, production, use phase, and disposal (figure 1).

From the reviewed LCA studies on cotton, the system boundaries were always either from cradle to gate (fiber) or from cradle to grave (textiles). However, the gate can refer to a farming gate, ginning gate, factory gate, or family gate. Many studies for cotton fibers have focused on the environmental contribution of cotton cultivation beginning with cotton cultivation and ending at ginning, and used a functional unit of 1 kg/tonne of cotton lint. Others investigations have

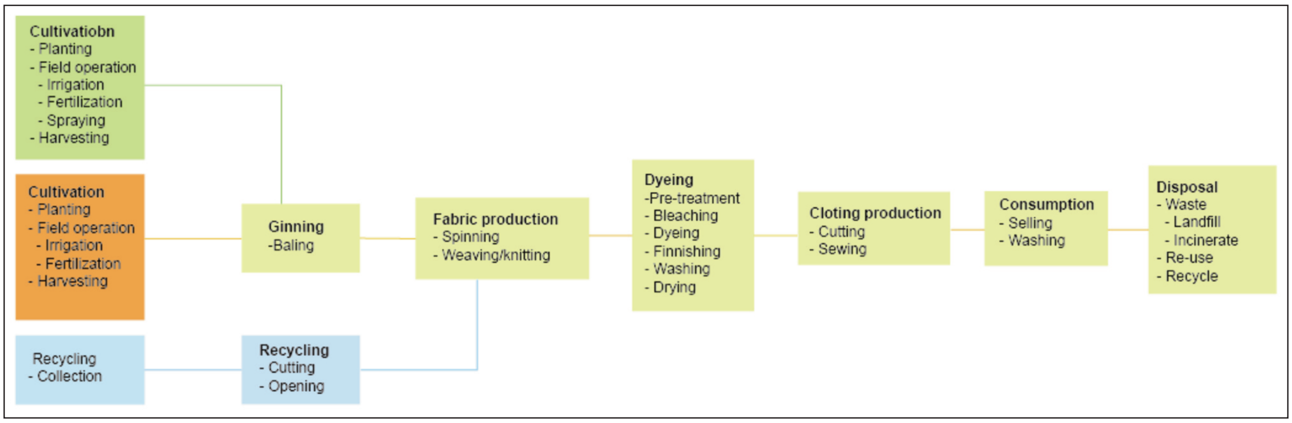

Fig. 1. Process of life cycle of cotton textiles

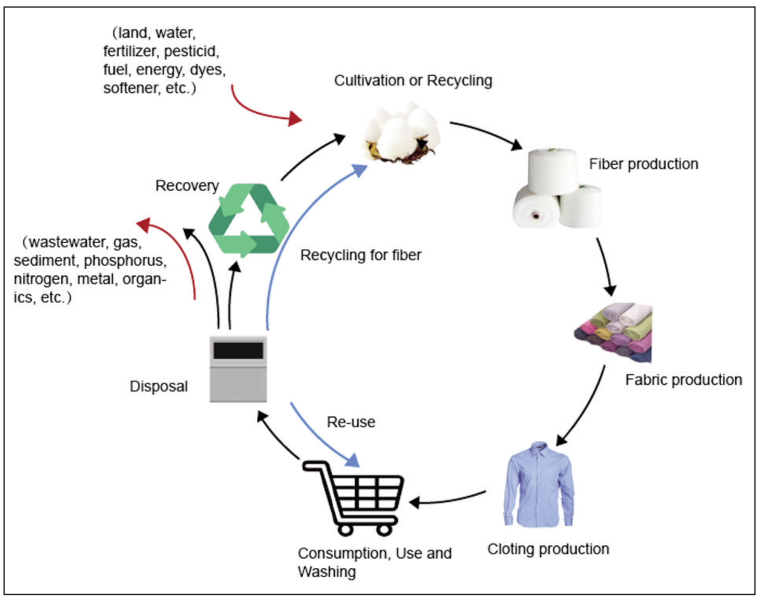

Fig. 2. The whole life cycle of cotton textile

aimed to evaluate the environmental burden from a holistic perspective that contains more processes. For cotton textiles, many researchers chose the functional unit as one piece of cotton garment, and ended at either the use phase or disposal stage. The inputs such as land use, water consumption, chemical inputs and output (e.g. wastewater, gas emission, metal and organics) will be documented and assessed (figure 2).

Impact assessment results

The most widely used LCA methods for cotton textiles have been EDIP, CML and ReCiPe, which are comprehensive methods that contain many environmental impact categories (table 1). The impact categories and their characterization as well as applicable locations vary between methods and studies. GWP, AP, EP, and water consumption are the most common impact categories in the LCA of cotton textiles (table 1). USEtox model focuses on the toxicity assessment that has been applied in the textile industry in recent years. The carbon footprint and water footprint are specialized parameters for evaluating the effects of GHG emissions and water consumption, which are concentrated on a smaller scope containing only one impact category. In the LCA assessment of cotton textiles, the selected impact category indicators for GWP, AP and EP are mid-point indicators, which evaluate the impact of the pollutants by using the equivalency of a reference substance. In terms of the impact assessment of acidification and eutrophication with respect to cotton textiles, the impact categories may include freshwater acidification/eutrophication or terrestrial acidification/eutrophication, depending on the characterization method used and issues being addressed. Water scarcity categories have been developed to address the different water stresses in various regions, and can report the water consumption effects in a location-specific way. There is a possibility that cotton industry areas may be affected by water stress. However, water consumption assessment of cotton textiles in an LCA is often reported in a loading assessment level by simply including the volume of water used. Few studies have applied water scarcity or assessed the water consumption effect down the cause-and-effect chain.

From the published LCA results for cotton textiles, it is difficult to form a consistent conclusion with regards to which factor contributes most to the overall environmental burden. This is due to the different assessment methods, locations, and production technologies amongst other reasons. However, it is possible to summarize the possibilities for reducing environmental impacts. A cradle to grave LCA of a piece of a cotton garment that contains comprehensive impact categories can support decision makers, although data quality is a high requirement. LCAs of a pair of jeans and a piece of T-shirt were reported in [25, 29, 30]. The most common impact categories in these studies were GWP, AP, EP, and water use.

The life span of cotton garments is separated into four phase cotton cultivation, production, use, and disposal. Cotton cultivation, wet processing during

Table 1

SUMMARY OF LIFE CYCLE ASSESSMENT OF COTTON TEXTILE			
Textile products	**Source**	**Method**	**Impact categories***
Cotton fiber	Chapagain et al., 2005 [7] Paunonen et al., 2019 [18] Günther et al., 2017 [10] Sandin et al., 2013 [19]	footprint	CF, EF, PF, WF
Organic cotton fiber	CmiA., 2014 [8] Textile Exchange, 2016 [5]	CML	AP, ADP, EP, FWAE, GWP, HTP, OLD, PED, TEP, WU, WC
Organic cotton fiber	Textile Exchange., 2016 [5]	USEtox	TP
Cotton lint	Hedayati et al., 2019 [14]	Australian impact method, Australian Indicator Set V3	GWP
Cotton fiber	Paunonen et al., 2019 [18]	ReCiPe	GWP
Seed cotton	Ullah et al., 2016 [22]	CML 2001	ADP, AP, EP, HTP, FWAE, GWP, OLD, TEP, WU
Recycled clothing	Woolridge et al., 2006	footprint	EF
Cotton T-shirt	Farrant et al., 2010 Baydar et al., 2015	EDIP	AP, AEP, GWP, OD, POFP, TEP
A work shirt	Cartwright et al., 2011	EDIP	GWP
Denim jean	Hackett et al., 2015 [28]	ReCiPe 2008	AD, EP, GWP, LO,WU,
Cotton T-shirt	Zhang et al., 2015 [29]	CML 2001	AD, AP, EP, GWP, POCP, WU
Cotton T-shirt	Zhang et al., 2015 [29] Roos and Peters, 2015 [31]	USEtox	EP, HTC, HTNC
A cotton nightgown and a cardigan	Roos et al., 2015 [31]	ReCiPe	GWP
A cotton nightgown and a cardigan	Roos et al., 2015 [31]	USEtox	TA
A pure cotton shirt	Wang et al., 2015 [33]	Footprint	CF

Note: * CF – carbon footprint; EF – energy footprint; PF – phosphorus footprint; WF – water footprint; AP – acidification potential; ADP – abiotic depletion potential; EP – eutrophication potential; FWAE – fresh water aquatic ecotoxicity; GWP – global warming potential; HTP – human toxicity potential; OLD – ozone layer depletion; PED – primary energy demand; TEP – terrestrial eutrophication potential; WU – water use; WC – water consumption; TP – toxicity potential; AEP – aquatic eutrophication potential; OD – ozone depletion; POFP – photochemical ozone formation potential; AD – Abiotic depletion; LO – Land occupation; POCP – photochemical ozone creation potential; HTC – human toxicity-cancer; HTNC – human toxicity-non cancer; TA – toxicity assessment.

production and the use phase have been found to be the main contributors to the overall environmental burden across all impact categories. In the cultivation phase, the intensively use of water, fertilizers, and pesticides have been reported as contributing most of the environmental impacts and can be considered as hotspots. Water consumption is highly related to the climatic conditions of a cotton growing region, and areas with a low evaporative demand but high effective rainfall are more attractive for cotton cultivation. Synthetic fertilizers have the potential to contribute considerably to eutrophication due to their nitrogen and phosphorus contents, whereas pesticides can negatively affect freshwater and terrestrial toxicity [17]. Wet processing during the production phase is another hotspot across the indicators of water consumption, GWP, AP, EP and toxicity. Most of the environmental burden has been found to originate from diverse chemical inputs (e.g., acids, alkalis, dyes, metals, and organic compounds) in the dyeing phase. An additional hotspot is the use phase, the high contribution of energy use to global warming during this phase is due to water heating, washing, drying, and ironing. Washing detergent has also been reported to account for high AEP. Furthermore, studies have illustrated that different consumer behaviours (e.g., life time span, frequency of use, and washing habits) can result in quite different environmental consequences related to energy and water use.

Strategies for reducing environmental impacts

Strategies for farm operations, organic cotton cultivation, to recycling of cotton textiles can all contribute to a reduction in environmental impacts. Opting for organic cotton versus conventional cotton is one strategy for reducing the environmental impacts of cotton cultivation, it avoids the use of artificial chemicals such that impacts related to the GWP and eutrophication are reduced. However, the cost and yields of organic cotton mean that there is still a long way to go to switch from conventional cotton to organic cotton. As mentioned previously, the various chemical inputs during wet processing can result in wastewater that contains high concentrations of pollutants. Feasible strategies include using substitute chemicals that have a lower environmental burden or recycling without dyeing. From a holistic life cycle perspective, cleaner consumption is more important than cleaner production due to its long-life span during the use phase. Lower water temperatures and hand washing have also been suggested by previous studies. However, the impacts related to detergent have seldomly been considered in the impact assessment of cotton textiles.

Limitations and potential improvements

As mentioned, LCA methods for cotton textiles contain many impact categories. However, many studies have only included a limited number of environmental indicators. Comprehensive impact categories that include eutrophication, acidification, and ecotoxicity could make cradle to grave studies more scientific and credible. This could also avoid missing potential hotspots, especially when new techniques are applied in the cotton textile industry. In addition, a more comprehensive water footprint that includes water scarcity would be more appropriate and relevant to current research.

The environmental impact assessment of cotton textiles in use phase was found to have high contributions to water consumption and energy use and results more uncertainties owing to various consumption behaviours. The results of LCIA are sensitive to parameters such as washing frequently, lifespan. Hence, the lifespan, washing frequency, washing temperature and other related operations in consumer care phase must be determined when assess the environmental impact of cotton garment in use phase. Moreover, the functional unit for use phase should be 1 mass of cotton garments per month or year.

Cotton textiles are characterized by a global circulation, moving between different regions through a long and complex chain. LCIA practitioners should recognize that the impacts of this movement depend on the array of locations involved [34]. Impact categories such as acidification, eutrophication, and water use are more site-specific. Site-dependent characterization models have rapidly developed in the past decade. Regionalized methods have included impact categories such as acidification [35, 36], eutrophication [37, 38], water scarcity, and their related impacts on human health and ecosystems [20, 39, 40]. Therefore, LCIA practitioners should chose appropriate methods to produce more accurate results as a scientific reference for decision makers.

Many sectors that use LCA require evaluation results to be of an increasingly high quality. Hence, there is a need for characterization models to include toxicity persistence and bioaccumulation assessments as well as generic exposure/effects assessment.

Furthermore, future LCAs of products such as cotton, which have long chains and are related to many regions during their entire life time, should involve a site-specific exposure/effects assessment.

CONCLUSIONS

We reviewed LCA research findings on the environmental burden of cotton fibers and textile products, which considered the degree to which eco-products or strategies can reduce the environmental impacts in comparison to convention cotton.

It can be concluded that cotton cultivation significantly contributes to the environmental burden of cotton due to the use of water, fertilizers, and pesticides. Cotton cultivation that is located in regions where precipitation can meet the water demand and evaporation is low is recommended if they do not increase the burden on local blue water resources.

Furthermore, the cultivation of organic cotton can significantly reduce the environmental burden of cotton fiber. During the manufacturing phase, the use of water, energy, and chemicals is traditionally high. Alternative chemicals that reduce the environmental burden should be encouraged. In addition, cleaner consumption is more important than cleaner production due to the significant contribution of the use phase to global warming and water scarcity. Consumption habits such lower water temperatures during clothes washing and the use of second-hand clothing should also be encouraged for consumers.

LCIA based on regional differences may be the next step for assessing the environmental burden of cotton due to the global consumption and production of cotton textiles. Regionalized LCIA is a credible method for i) determining the optimal locations for factories or suppliers, and ii) resource management and sustainable development. Moreover, comprehensive impact categories with a cradle to grave approach can disclose the environmental burden. The risk of simply shifting pollution and other environmental issues from one phase to another could be avoided by using more developed LCA methods that have the potential to cover the significant impacts in various categories. A credible LCA of cotton can support sustainable decision-making by providing a comprehensive and structured account of the potential environmental impacts.

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ADDITIONAL INFORMATION

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Organic cotton fabric dyed with dyer's oak and barberry dye by microwave irradiation and conventional methods

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ABSTRACT – REZUMAT

Organic cotton fabric dyed with dyer's oak and barberry dye by microwave irradiation and conventional methods

In this work, organic cotton fabrics were dyed using barberry (Berberis vulgaris L.), dyer's oak (Quercus infectoria Olivier) and dyer's oak + barberry (Quercus infectoria Olivier + Berberis vulgaris L.) by microwave irradiation and conventional dyeing methods. They were used in equal percentages. The dyed fabrics were analyzed by different analytical and technical methods. Colouring compounds were analyzed in the dyed fabrics, dye extractions (before dyeing bath and after dyeing bath) by High Performance Liquid Chromatography with Diode Array Detector (HPLC-DAD). Identified coloring compounds based on the dyestuff analysis were berberine, berberine derivative, phenolic acid, ellagic acid, ellegic acid derivatives, gallic acid and gallic acid derivative.

*Colour characteristics of all the dyed fabrics were measured by CIEL*a*b* spectrophotometer and pH values were determined by surface-pH meter. Scanning Electron Microscopy equipped with Energy Dispersive X-ray Spectrometer (SEM-EDX) was used for imaging and elemental analysis of the surfaces of the dyed organic cotton fabrics.*

The colouristic and colour fastness properties of the dyed fabrics were investigated and compared with each other. No damage was observed in the fabrics dyed by the microwave and conventional dyeing methods. Almost the same colour yields were obtained in both dyeings using different processing times.

According to the analyses and test results, microwave irradiation method is very eligible compared to conventional dyeing methods, considering coloristic properties of dyed fabrics, time saving and the cost effectiveness wise.

Keywords: *microwave dyeing, organic cotton, natural dye, HPLC-DAD, SEM-EDX, fastness*

Vopsirea țesăturii din bumbac organic cu colorant din stejar și din afine prin iradiere cu microunde și metode convenționale

În această lucrare au fost vopsite prin iradiere cu microunde şi metode convenţionale de vopsire țesături din bumbac organic, folosind coloranţi obţinuti din afine (Berberis vulgaris L.), stejar (Quercus infectoria Olivier) și stejar + afine (Quercus infectoria Olivier + Berberis vulgaris L.). Aceştia au fost utilizaţi în procente egale în băile de vopsire. Țesăturile vopsite au fost analizate prin diferite metode analitice și tehnice. Compușii coloranți au fost analizați în țesăturile vopsite, iar extractele de colorant (din baia iniţială de vopsire şi după vopsire) au fost analizate prin cromatografie lichidă de înaltă performanţă cu detector de matrice diodică (HPLC-DAD). Compușii coloranți identificați pe baza analizei coloranților au fost berberina, derivatul de berberină, acidul fenolic, acidul elagic, derivatul acidului elagic acidul galic și derivatul acidului galic.

*Caracteristicile culorilor tuturor țesăturilor vopsite au fost măsurate cu spectrofotometrul CIEL*a*b*, iar valorile pH-ului au fost determinate cu un pH-metru de suprafață. Microscopia electronică de baleiaj echipată cu spectrometru de raze X cu dispersie de energie (SEM-EDX) a fost utilizată pentru imagistica și analiza elementală a suprafeței țesăturilor din bumbac organic vopsite.*

Caracteristicile culorii și proprietățile de rezistență ale culorii țesăturilor vopsite au fost investigate și comparate. Nu s-a observat nicio deteriorare a țesăturilor vopsite în prezența microundelor sau a metodei convenţionale de vopsire. Au fost obținute randamente tinctoriale similare în cazul ambelor metode de vopsire, folosind timpi de prelucrare diferiţi.

Conform analizelor și rezultatelor testelor, metoda de iradiere cu microunde este eligibilă în comparație cu metodele convenționale de vopsire, având în vedere proprietățile coloristice ale țesăturilor vopsite, economisirea timpului și eficiența costurilor.

Cuvinte-cheie: *vopsire cu microunde, bumbac organic, colorant natural, HPLC-DAD, SEM-EDX, rezistența culorii*

INTRODUCTION

Natural organic dyes are obtained from dye plants, dye insects, dye molluscs, lichens, etc. They were used in the textile dyeing from ancient times to the mid to late nineteenth century. Natural dyes are known for their use in dyed of natural protein fibres like wool, silk, mohair, etc. as major areas of application since prehistoric times [1]. Increasing environmental awareness has made people realize the importance of living in a world with a clean atmosphere.

Organic cotton fabrics dyed with different percentages of the roots of barberry (*Berberis vulgaris* L.) via gall oak (*Quercus infectoria* Olivier) and alum mordant [2]. Tannins and gallotannins are water-soluble polyphenolic secondary metabolites in many plants.

Tannins are distinguished two main groups according to their structures: condensed tannins (proanthocyanidins) and hydrolyzable tannins. Hydrolyzable tannins are composed of esters of gallic acid (gallotannins) or ellagic acid (ellagitannins), with a sugar core which is usually glucose. Major commercial gallotannin (tannic acid) sources are Turkish gallnut, Chinese gallnut and sumac leaves. Both Turkish and Chinese gallnuts contain a large amount of tannin and gallotannin, (50–70%), and a small amount of free gallic acid and ellagic acid. Dyer's gall oak (*Quercus infectoria*) is one of the tannin sources which has historically been used mainly for tanning leather and in the manufacture of inks and dyes [3].

Quercus infectoria has been used for cotton and wool dyeing. As natural dyes show no direct affinity for cotton fabric, such as textiles are treated with *Terminalia bellirica* before any natural dye. This product serves as a mordant that helps to fix the dye on cotton fibers by providing hydroxyl groups, which act as dye sites [4]. Dyer's oak (*Quercus infectoria*) presents a variety of pharmacological properties such as anesthetic, astringent, antifungal, antiviral, anti-diabetic, [5, 6], antibacterial [7, 8], larvicidal [9], anti-inflammation [10] and wound-healing [11] properties. Many literature sources shows that tannins, especially those of plant origin, have been determined to possess antimicrobial activity. The high tannin (colouring compound) present in oak galls is responsible for its antimicrobial activity. In this work, organic knitting cotton fabrics were dyed using dyer's oak dye (*Quercus infectoria* Olivier), barberry dye (*Berberis vulgaris* L.) and dyer's oak-barberry dye (*Quercus infectoria* Olivier – *Berberis vulgaris* L.) by a conventional dyeing method and a microwave (MW) dyeing method. The advantages of natural dyes are cost effective, renewable and non-carcinogenic in nature, no disposal problems and have no allergic reaction on skin [12].

Usually, the aqueous extraction method (conventional method) is used to produce natural dyes from dye plant species and needs several hours for extraction. Microwave energy is an alternative method to conventional heating methods because it provides uniform and fast heating – with its easy penetration property into the matter. In recent studies, it has been proven that microwave (MW) methods need shorter process time and save energy [13]. Microwave irradiation has been used for surface modification surface grafting, pre-treatment, dyeing and finishing of textile materials, but its use in natural dyeing processes is limited. Therefore, in the present research, microwave irradiation was used for both extraction of plants and dyeing of natural cotton fabrics.

MW has between 1 cm and 1 m wavelength and between 30 GHz and 300 MHz frequencies. In electromagnetic spectrum, MW covers the radio frequencies and infrared radiation [14]. The energy is carried by photon; MW photons is 0.125 kJ/mol, which is very low considering the necessary energy for chemical bonds breaking. Therefore, the molecular structure of the materials cannot be affected directly by MW irradiation and the electronic structures of atoms can't change. Microwave absorption can also increase kinetic energy in the molecules [15–18].

Energy is transferred in solids by conduction, convection or radiation of heat, in conventional thermal processing, whereas, the microwave energy is transferred directly in the materials through molecular interaction in the presence of electromagnetic field. It can penetrate the materials and deposit energy throughout the volume of the material. Therefore, microwave is a volumetric heating and it is fast, whereas conventional heating is a surface heating and it is slow (figure 1) [19, 20].

Fig. 1. Volumetric microwave heating and conventional surface heating

At the present time microwave energy is used in various sectors like chemistry, metallurgy, ceramic, food and textile. MW irradiation methods are safe, eco-friendly and cheap. It also enables dye molecules to diffuse into fabrics (penetrate) instantly and bond more strongly to the materials [14, 16, 21, 22].

Microwave Dyeing of Cotton

It was recently reported, that microwave irradiation improved the dyeability of cotton and cotton-wool blend fabrics. It was also observed that there was a large increase in dye uptake and rate when compared with conventional heating.

The results of the scanning electron microscope and X-ray diffraction pattern indicate that the crystallinity of the fiber decreases with increasing exposure time of MW irradiation.

This decrease in crystallinity is associated with an increase in fibre diameter. Crystallinity has a major impact on properties including fiber strength, flexibility, dye uptake, and colour stability and "lower crystallinity" means "higher amorphous regions" in the cellulose molecules. A fiber which has a lower % crystallinity is able to absorb water, dyes and other chemicals much more compared to a fiber with high % crystallinity.

Additionally, fastness tests for washing, rubbing, perspiration as well as fastness to light are relatively lower than their corresponding samples dyed using microwave heating [23, 24].

In recent studies it was observed that the microwave energy doesn't damage the cotton fibers. The colour fastness of microwave dyed cotton fabric is similar or higher compare to the conventional process. MW irradiation provides saving energy greatly by shortening dye time [25].

In this work, 100% natural cotton fabric was dyed with the natural dyes extracted from dyer's oak (*Quercus infectoria*) and barberry (*Berberis vulgaris*) via microwave irradiation and conventional methods. Dyer's oak was also used as a mordant for the dyeing quality. Then the dyed fabrics were analysed using different analytical and technical methods.

EXPERIMENTAL WORK

Material and methods

Plant, fabric and chemicals

The dyer's oak (*Quercus infectoria* Olivier), organic cotton knitting fabric and all chemicals used in this study were supplied by the Turkish Cultural Foundation. 100 % organic knitting interlock cotton fabric was used and the weight of the fabric was 230 g/m^2. Dyestuffs used as reference standard were provided by TCF-DATU (Turkish Cultural Foundation, Cultural Heritage Preservation and Natural Dyes Laboratory in Istanbul-Turkey). The following dyestuff standards were used as references: gallic acid, berberin from Merck and ellagic acid from Alfa Aesar. Hydrochloric acid (HCl), acetonitrile (CH_3CN, HPLC grade), trifluoroacetic acid (TFA) and methanol (CH_3OH) used as sample preparing and mobile phase for HPLC analysis were also obtained from Merck.

Extraction

The procedure of the extraction processes is shown in table 1.

Table 1

EXTRACTION OF BARBERRY, BARBERRY + DYER'S OAK AND DYER'S OAK DYE

Extraction		
Method	Conventional	Microwave irradiation
Dye plant	Barberry Barberry+dyer's oak Dyer's oak	Barberry Barberry+dyer's oak Dyer's oak
Time	60 min	10 min (100 Watt)
Temperature	100˚C	90˚C

The microwave irradiation and conventional method were used for the extraction processes. Then the peak areas and heights of the colouring compounds of the extracts were examined by HPLC-DAD for the determination the efficient method.

According to the results of HPLC-DAD, it was decided that it was more appropriate to use extracts obtained according to the MW irradiation for dyeing processes.

Dyeing process

In this work, 100% natural cotton fabrics 230 g/m^2 were dyed with natural dyes dyer's oak and barberry according to conventional and microwave irradiation methods. The 100% natural cotton fabrics were first scoured with 0.5 % non-ionic detergent in the bath with fabric to liquor ratio (F:L) 1:20. Dyer's oak, barberry, barberry and dyer's oak dyes together were used for the dyeing processes, respectively. Dyer's oak was also used as mordant. The scoured cotton fabrics were dyed according the meta-mordanting (simultaneous mordanting) method. In this method dyeing and mordanting processes were carried out in the same bath. Then the dyeings were rinsed thoroughly in tap water and allowed to dry in the open air. All dyeings were carried out in 250 ml glass beakers with and without microwave heating. The dyebath/fabric ratio was 20:1. Dyes were applied at 1% owf (over weight fiber) depth of shade. According to the conventional method, the dyeings were initiated at 20°C. The temperature was raised to 60°C in 10 minutes and then kept 30 solution.

Microwave-assisted dyeings were carried out in a microwave oven Samsung model – MS23K3515AW (max. output power: 800 watt, 2450 megahertz). Each dye bath which was in the 250 ml beaker was placed into the microwave oven. The temperature of the bath was at first 20°C. Then it was increased to 60°C in 1 minute by using the 800 watt-energy level of the microwave oven. The dye bath was kept at this temperature for 5 minutes by using the 100 watt-energy level. Finally, the beaker was taken out of the oven and the dye solution was cooled. The dyed samples were rinsed with cold tap water.

Three different process-times (6, 8, 10 min) were used for dyeing cotton fabrics in MW conditions. There are no significant differences between the colour characteristics of all the dyed cotton fabric samples which were dyed using microwave irradiation time 6, 8 and 10 minutes. Therefore, in this study, the samples which were dyed according to the shortest microwave irradiation time (6 minutes) were used.

HPLC Analysis (High-Performance Liquid Chromatography)

The HPLC instrumentations and the HPLC elution program were as described in earlier reports [26–31]. The reference sample and dimethylformamide used in HPLC analysis were supplied by "Sigma Aldrich", and the mobile phases and chemicals used in sample preparation were supplied by "Merck".

Colour measurement and colour Fastness

Colour measurements of the dyed organic knitting cotton fabrics were carried out a using Konica Minolta CM-2300d Software Spectra Magic NX (D65 illuminant,10° standard observer) and the results are shown in tables 2 and 3. In CIEL*a*b*(1976) coordinates, L* corresponds to brightness, a* to the red-green coordinate (+ = red, – = green), b* to the yellow-blue coordinate (+ = yellow, – = blue), and C* to vividness-dullness (100 = vivid, 0 = dull) [31]. From the reflectance values (R) in the visible spectrum (380–700 nm) at the maximum absorption wavelength (λ_{max}) for each dyeing, the corresponding colour strength (K/S) values of the samples were calculated by using Kubelka-Munk equation [32]:

$$K/S = (1 - R)^2 / 2R \qquad (1)$$

where *S* is the scattering coefficient of the substrate, *K* is the absorption coefficient of the substrate and *R* is the reflectance of the dyed samples at λ_{max}. Table 4 shows the colorimetric parameters and the colour strength (K/S) values of cotton fabrics dyed with *Berberis vulgaris*, *Berberis vulgaris* + *Quercus infectoria* and *Quercus infectoria* extracts using conventional and microwave irradiation methods.

Colour fastness tests on the dyed fabrics were examined according to washing (TS EN ISO 105-C06-A1S) and to rubbing (ISO 105-X12) Standards, respectively.

SEM-EDX analysis

The untreated and dyed cotton fabrics were analyzed by Scanning Electron Microscope equipped with Energy Dispersive X-ray Spectrometer (SEM-EDX) for surface imaging analysis with Secondary electron (SE) detector. In this study, TESCAN VEGA3 SEM (Brno, Czech Republic) and Bruker EDX detector (Massachusetts, ABD) were used. The fabrics were coated using Au/Pd (60/40) target in a sputter coater for surface imaging.

RESULTS AND DISCUSSION

According to the microwave and conventional methods, the colouring compounds and their peak areas and heights were determined by HPLC-DAD for the dyed samples and dyeing extracts (before dyeing and after dyeing).

Identified colouring compounds based on the dyestuff analysis for dye extracts and the dyed fabrics are shown in table 2 and table 3, respectively. It was observed that using microwave irradiation is more efficient for the extraction than using the conventional method (table 2). According to these results, it was decided that it was more appropriate to use extracts obtained according to the MW irradiation for dyeing processes.

The colouring compounds (phenolic acid, berberine and berberine derivative) were detected in barberry solution and were extracted by using microwave irradiation and conventional methods (table 2).

According to the microwave dyeing method, berberine and berberine derivatives were detected in the barberry dyed fabric. Berberine colouring compound was detected alone in the cotton fabric dyed with the conventional method. Although the extracts of barberry contain phenolic acid and berberine derivatives, the phenolic acid compounds were not bound to the fabrics. Berberine derivatives were detected in the microwave dyed fabric, whereas they were not found in the conventional dyed fabric. The area and height of peaks of berberine and berberine derivatives in the microwave method were higher than the conventional method (table 2). This indicates that the microwave irradiation is more efficient for the extraction of colouring compounds from the barberry for dyeing than the conventional method. This also applied to barberry + dyer's oak dyeing. Berberine derivatives were not found in the fabrics which were dyed with the conventional method. When microwave irradiation was used, the peak height and the peak area of berberine, ellagic acid and its derivatives were higher (table 2). Ellagic acid and its derivatives were also detected in the dyer's oak dyed fabric and extraction.

Identified colouring compounds based on the dyestuff analysis are shown in figures 2–4. Peak

Table 2

IDENTIFIED DYESTUFFS AND THEIR PEAK (AREAS AND HEIGHTS) IN THE EXTRACTS (BEFORE AND AFTER DYEING)

Dye plant	Identified Dyestuff	Microwave method				Conventional method			
		Total area of peak		Total area of height		Total area of peak		Total area of height	
		Dye bath (before dyeing)	Dye bath (after dyeing)	Dye bath (before dyeing)	Dye bath (after dyeing)	Dye bath (before dyeing)	Dye bath (after dyeing)	Dye bath (before dyeing)	Dye bath (after dyeing)
Barberry	phenolic acid	2199.2	2871.6	65.2	81.3	2062.6	2137.9	55.4	57.2
	berberine derivative	1713.0	1121.8	59.6	41.9	882.5	334.0	31.5	15.5
	berberine	6966.3	7703.9	238.0	199.9	6735.4	5466.6	167.7	115.6
Barberry + Dyer's oak	ellagic acid derivatives	13146.7	15727.8	289.5	538.2	4384.2	10381.5	383.0	663.5
	ellagic acid	42832.5	46974.8	913.9	988.5	4860.7	15417.2	86.7	355.6
	berberine derivative	1312.1	653.9	55.5	22.1	-	-	-	-
	berberine	6726.6	4437.0	169.8	11.2	685.1	3204.0	18.0	66.5
Dyer's oak	ellagic acid derivatives	142010.6	16356.0	759.8	608.0	24289.7	25063.1	674.6	838.6
	ellagic acid	120093.7	16766.0	2756.0	364.7	13360.2	14765.9	302.3	376.7

Table 3

IDENTIFIED DYESTUFFS AND THEIR PEAK (AREAS AND HEIGHTS) IN THE DYED SAMPLES					
Dye plant	**Identified Dyestuff**	**Microwave method**		**Conventional method**	
		Total area of peak	**Total area of height**	**Total area of peak**	**Total area of height**
Barberry	phenolic acid	-	-	-	-
	berberine derivative	92.7	3.2	-	-
	berberine	1236.8	28.6	345.2	12.2
Barberry + Dyer's oak	ellagic acid derivatives	11569.5	2616.3	5943.6	1315.5
	ellagic acid	10310.9	173.3	4684.1	69.2
	berberine derivative	339.1	7.7	-	-
	berberine	2460.0	57.3	687.9	23.3
Dyer's oak	ellagic acid derivatives	9649.8	2245.3	5177.9	1174.7
	ellagic acid	9715.3	162.8	4895.2	76.0

heights of the identified dyestuffs in the HPLC analysis are shown in table 2 (for extracts) and table 3 (for dyed fabrics).

As a result, it was observed that the microwave irradiation is more efficient for extraction and dyeing of colouring compounds than the conventional method (tables 2 and 3).

The results of colour values and colour strength (K/S) of the dyed samples were given in table 4. Using microwave irradiation yielded a significantly deeper colour compared to conventional dyeing method. Table 4 shows that the microwave-dyed cotton fabric with **barberry** extract is slightly darker, less red, more yellow and slightly saturated (C*=28.70) compared to

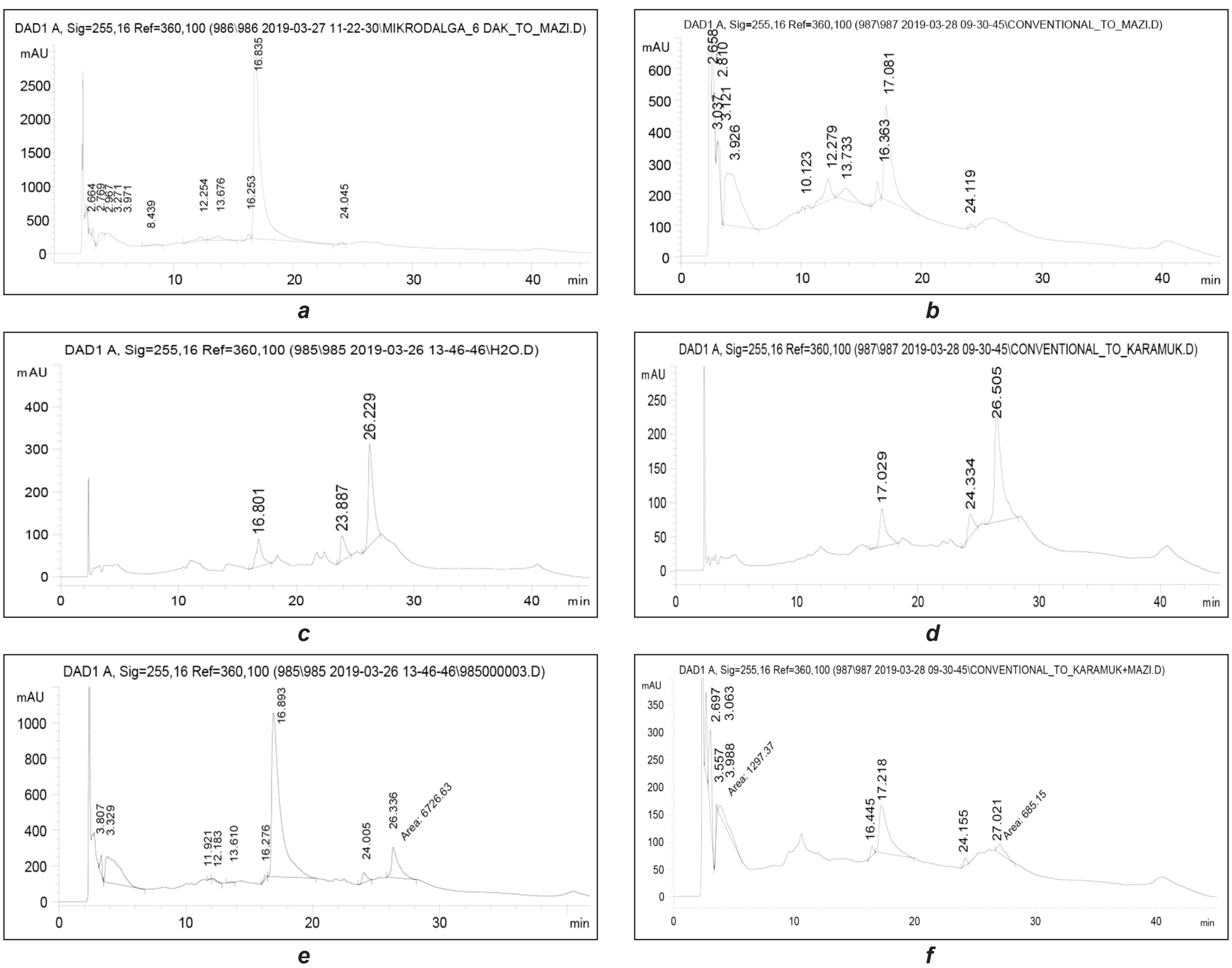


Fig. 2. Chromatograms of extractions: *a* – dyer's oak MW; *b* – dyer's oak conventional; *c* – barberry MW; *d* – barberry conventional; *e* – dyer's oak and barberry MW; *f* – dyer's oak and barberry conventional

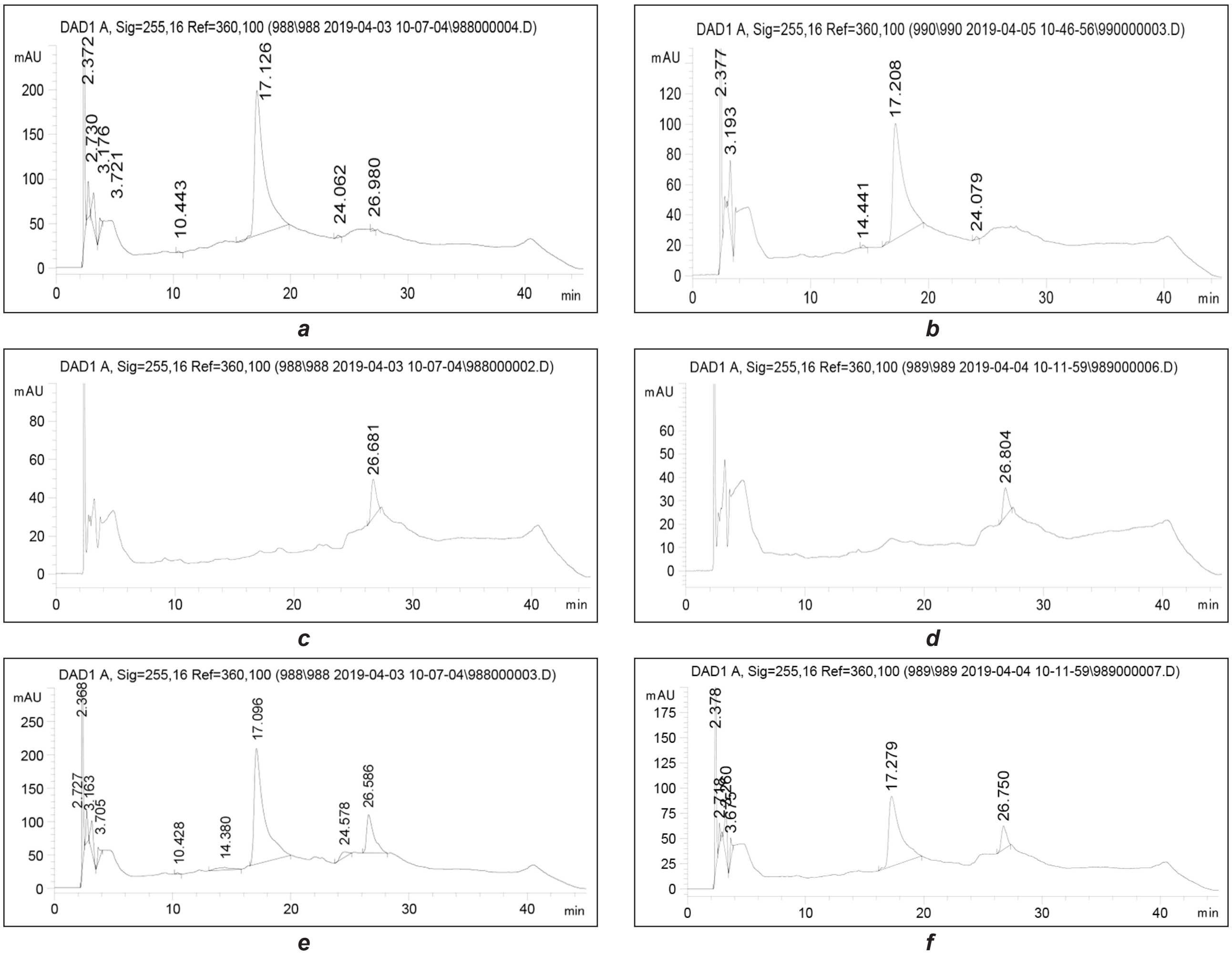


Fig. 3. Chromatograms of the dyed fabrics: *a* – dyer's oak MW; *b* – dyer's oak conventional; *c* – barberry MW; *d* – barberry conventional; *e* – dyer's oak and barberry MW; *f* – dyer's oak and barberry conventional

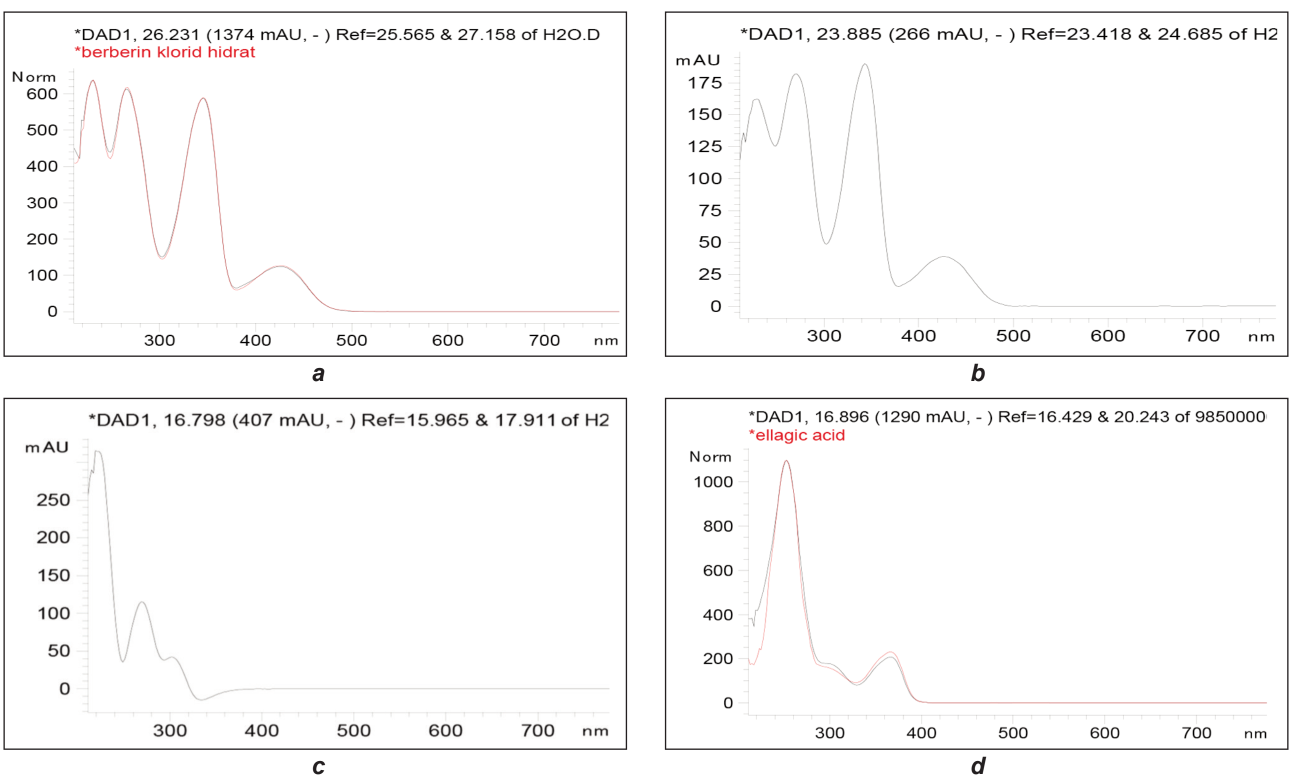


Fig. 4. Spectra of identified colouring compounds: *a* – berberine; *b* – berberine darivitives; *c* – ellagic acid derivative (fenolic acid); *d* – ellagic acid

the conventional-dyed samples. The K/S values of dyed fabrics dyed with barberry extract are 0.36 and 0.56 for the microwave irradiation and the conventional method, respectively. There is not significant difference in colour strength values between two methods.

Cotton fabrics dyed only with **dyer's oak** extract yielded similar values for both conventional dyeing and microwave irradiation methods (K/S values: 1.75 – 1.76).

In this study, dyer's oak extract was used as mordant. In the meta-mordanting process, **barberry and dyer's oak** were used simultaneously in the same bath. The microwave-dyed samples with barberry-dyer's oak dye were slightly darker, redder, more yellow and more saturated than the conventional-dyed samples. The K/S values are 3.20 and 1.51 for the microwave-dyed fabric and the conventional-dyed fabric, respectively.

All of these results indicate that the samples dyed by microwave irradiation method are slightly better than dyed by the conventional methods, although using a very short dyeing time.

Colour fastness of all the treated samples were examined according to ISO 105-C06 (A1S) and ISO 105-X12:2016 Standards; the results were given in table 5.

Comparing the two methods, it was observed there were small differences in the color fastness values of the dyed samples. The color change values were found to be 3–4 and 5 for dyer's oak dye using microwave and conventional dyeing methods, respectively. The staining test results of adjacent multifibers were generally found to be 4–5 grey scale ratings. All of the dyed fabrics have excellent fastness levels to rubbing (5).

The SEM images of undyed and dyed fabrics are shown in figure 5 (*a* – untreated fabric, *b* – fabric dyed

Table 4

COLOR VALUES AND COLOR STRENGTH OF THE UNDYED AND DYED FABRICS

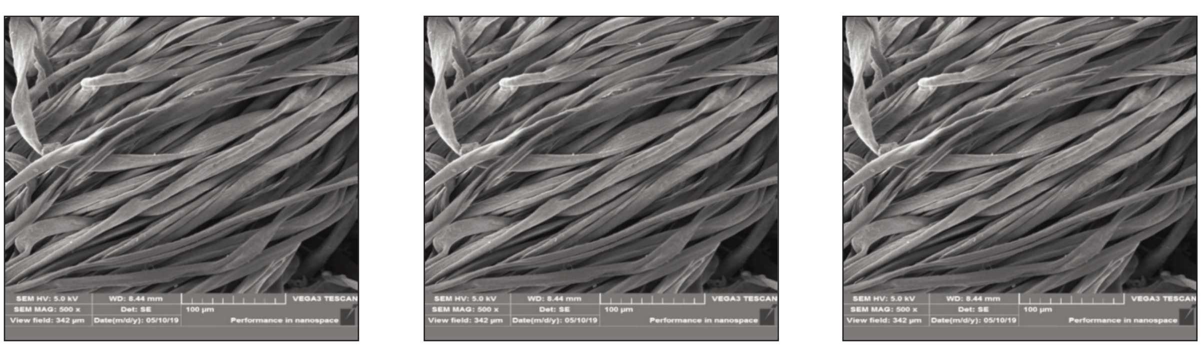
Dye	Method	L*	a*	b*	C*	h°	K/S
Undyed fabric	-	91.81	0.66	10,06	10.09	86.25	0.10
Barberry	conventional	89.41	–2.37	22.94	23.07	95.89	0.36
Barberry-Dyer's oak	conventional	82.98	0.34	29.13	29.13	89.34	1.51
Dyer's oak	conventional	82.97	1.06	22.90	22.92	87.36	1.75
Barberry	microwave	88.38	–2.6	28.58	28.70	95.19	0.57
Barberry-Dyer's oak	microwave	80.19	0.76	39.54	39.55	88.89	3.20
Dyer's oak	microwave	82.99	1.37	19.54	29.59	86.00	1.76

Table 5

FASTNESS PROPERTIES OF NATURAL DYES USING MICROWAVE AND CONVENTIONAL DYEING METHODS

Dyed Sample	Method	Colour change	Staining*						Rubbing	
			Wo	PAN	PES	PA	Co	CA	Dry	Wet
Barberry	conventional	2	4-5	4-5	4-5	4	4-5	4-5	5	5
Barberry-Dyer's oak	conventional	3-4	4-5	4-5	4-5	4	4-5	4	5	5
Dyer's oak	conventional	3-4	4-5	4-5	4-5	4	4-5	4	5	5
Barberry	microwave	2	4-5	5	5	4	5	4-5	5	5
Barberry-Dyer's oak	microwave	4	4-5	5	5	3-4	5	4	5	5
Dyer's oak	microwave	5	5	5	5	5	5	5	5	5

Note: * CA – Cellulose Acetate, Co – Cotton, PA – Polyamide, PES – Polyester, PAN – Acrylic, Wo – Wool.



a *b* *c*

Fig. 5. The SEM images: *a* – undyed; *b* – conventional dyed; *c* – microwave irradiation

conventionally, *c* – fabric dyed using MW irradiation). It was observed that the fibers dyed with barberry + dyer's oak dye had retained their structures without any damages after the both dyeing processes.

CONCLUSIONS

It can be concluded that microwave heating enhances the dye uptake of cotton fiber and dyeings especially with *Berberis vulgaris*-*Quercus infectoria* can be obtained with good coloristic properties and adequate colour fastnesses.

According to the results of RP-HPLC- PAD analyses for the dye-extract and dyed samples, the quantity of the total colouring compounds at the microwave method are much more than conventional method. The concentration of coloring compounds in the extract is higher in the microwave method. Therefore, the colour properties of the dyed samples have also good results under microwave irradiation.

The dyeing times for the conventional and the microwave methods were about 40 and 6 minutes, respectively. These results show that, the dyeing time were reduced by using of the microwave irradiation, so a great amount of time saving energy conservation and the cost-effectiveness are possible. In addition, this dyeing process is very eco-friendly because of used the natural organic cotton fabric and natural dyes.

Microwave irradiation heating has a promising future in dye extraction from biological sources and sustainable natural dyeings.

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Investigating the impact of CO_2 emission and economic factors on infants health: a case study for Pakistan

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ABSTRACT – REZUMAT

Investigating the impact of CO_2 emission and economic factors on infants health: a case study for Pakistan

This study has attempted to investigate the consequences of CO_2 emissions on infants' health in Pakistan over the period of 1975 to 2013. Several economic factors have been employed in our analysis and the estimates show insignificant impact of CO_2 emissions in affecting children mortality. Increasing health facilities lowers children mortality over a short period were also observed but the relationship inversed in the long-run. In short-run, urbanization appeared as a decreasing factor to children mortality. While income inequality remains inversely related with children mortality. Both poverty and fertility are found enhancing factors to children deaths. The poor sector of the economy seemed to observe higher children mortality due to inadequate health facilities and low standards of living. Overall, we have observed greater impact of economic factors in explaining children mortality than CO_2 emissions in case of Pakistan. These issues have a significant impact on the representative industries in Pakistan, such as the cotton textile and traditional clothing industry (apparel manufacturing).

Keywords: *CO_2 emissions, economic factors, environment, infants health, Pakistan, children mortality, textile industry*

Investigarea impactului emisiilor CO_2 și a factorilor economici asupra sănătății infantile: un studiu de caz din Pakistan

Acest studiu empiric a analizat consecințele emisiilor de CO_2 asupra sănătății infantile din Pakistan în perioada 1975–2013. Anumiți factori economici au fost utilizați în analiza realizată și estimările arată un impact nesemnificativ al emisiilor de CO_2 asupra mortalității copiilor. Creșterea numărului de facilități de sănătate scade rata mortalității infantile pe o perioadă scurtă de timp, dar această relație s-a inversat pe termen lung. Pe termen scurt, urbanizarea a apărut ca un factor cu influență descrescătoare privind evoluția mortalității infantile. Pe de altă parte, inegalitatea veniturilor rămâne invers corelată de mortalitatea infantilă. Atât sărăcia, cât și fertilitatea au rezultat ca fiind factori care ameliorează rata mortalității infantile. Sectorul economic subdezvoltat evidențiază o mortalitate infantilă mai ridicată din cauza instituțiilor sanitare inadecvate și a nivelului de trai scăzut. În general, am observat un impact mai mare al factorilor economici în explicarea mortalității infantile comparativ cu impactul emisiillor de CO_2 în cazul Pakistanului. Aceste probleme au un impact semnificativ asupra industriilor reprezentative din Pakistan, cum ar fi industria produselor textile din bumbac și industria de îmbrăcăminte tradițională.

Cuvinte cheie: *emisii de CO_2, factori economici, mediul înconjurător, mortalitatea infantilă, sistemul de sănătate, Pakistan, industria textilă*

INTRODUCTION

A historical review of the developing nations provides widening disparities in children mortality. The gap in best and worst performance regarding mortality was about 7 in 1960's that extend to 15 by 1980's. However, the progress of Middle East was better than African regions [1]. In terms of overall health, the situation is even bitter in developing regions. In African and South-East Asian countries, number of children who died in 1999 before attaining the age of five years was 15 and 6.7 in terms of percentages respectively [2]. Poor economic performance of 1980's was considered the cause of such increase in child mortality during 1990's among developing countries. For the same period child mortality decreased in rich economies while poor countries suffered high mortality rate [3]. Child mortality (less than five years) was increased in 106 countries from 1990 to 2000 [4]. The progress in attaining Millennium development goals regarding health was also different among economies. The estimated decline in child mortality was 4.2% annually from 1990 to 2015 but developing countries could attain nearly 2.5% level by 2007 [5]. This issue was discussed by researchers in cross countries and some particular regional studies.

Pakistan's economy is based on the textile industry sector which is the largest and most productive. Moreover, the textile sector makes a major contribution to reducing unemployment and sustaining a decent standard of living. Implicitly, the empirical results obtained in this research study have an impact on the level of understanding of this representative sector dynamics. The economic factors which were analysed are significant in Pakistan.

Many economic and environmental factors were also discussed to explain such disastrous situation. Global climate change was found one of the factors influencing health. Black carbon and other particulate matters were considered disrupting our environment and became a cause of premature deaths although, the increasing mortality and air pollution in Asia and Africa could be controlled by decreasing black carbon and methane emissions [6]. CO_2 emissions do contribute in climate change and global warming as well [7]. The anthropocentric goals have made environment unhealthy. Human activities emit pollutants that cause air pollution. It has deep effects on human health through diseases from respiration problems to lungs cancer [8]. Further, goods produced have deep carbon dioxide emissions that last for many years. All these factors have polluted our environment to a considerable extent and created alarming hazards. Health hazards are among the major consequence of pollution. At one place technology has revealed cure for many diseases whereas on the other it has polluted our air through emissions that creates distinct and different diseases.

Tukker and Jansen [9] revealed that impact of manufactured products on environment is huge. A little amount of products from households involving food, appliances, construction contain over 70 percent of damage (among all products life cycle) to environment. In a way it could be stated that economic factors controlled by household incomes and expenditures play pivotal role in determining carbon emissions. The study highlights the importance of economic factors including poverty and income inequality for including in analysis. However, indoor efforts involving controlled consumption and utilization could be helpful in reducing CO_2 emissions. Through such reductions, better air could improve respiration which reduce diseases spread [10]. Schmalensee et al. [7] found CO_2 emissions and income per person are interrelated. The study provides this relationship as inverse U-shape can also be called CO_2 Kuznets curve. The increase in income of person at lower income level made more emissions than at others levels. Backlundet al. [11] pointed out the same type of relationship between income level and mortality. So, income levels are quite important determinant of emissions and health. The major part of population in developing countries earns low levels of incomes. This attracts us to find out that in a developing country like Pakistan how these income and emissions impact infant health? The literature contains fewer studies involving emissions and economic factors for explaining health in Pakistan. The present study therefore fills this gap by allowing CO_2 emissions and many economic factors along with the health facilities for elaborating their impact on health for Pakistan economy. We have found fewer roles of CO_2 emissions though whereas health facilities explain more.

THE EFFECTS OF CO_2 EMISSIONS ON HEALTH: A LITERATURE REVIEW

Discussing the impact of emissions on health there are several studies on developed and developing (emerging) countries. Nweke and Sanders III [12] found out that African people suffered severe disease burden due to emissions. Existing problems like malnutrition made situation worse for them. However, there is need of improving environmental conditions for the sake of lowering diseases and improving health. Janssen et al. [13] analysed the importance of including black carbon particles in the study of air. They found it useful indicator of air quality (comparing to other combustion particles) for evaluating health hazards. Patz et al. [14] investigated impact of climate change on health across the globe. The study used cumulative depleted CO_2 emissions per capita for quantifying global warming. Their study concluded that climate changes are increasing health dangers and poor nations are less responsible for it.

Contrarily, they are more exposed to the health hazards and could suffer more than industrialized nations. The rise in the number of elderly population, ongoing technological advancements and increase in health consciousness are fuelling the growth of global medical textiles market [15] Younger et al. [16] analysed human activities including construction, transportation and other utilizations are major source of emissions of greenhouse-gases. The use of land also found affecting environment through altering atmospheric level of CO_2. Their study recommended devising such health policies which enable to reduce climate changes and in turn improve health. Wilkinson et al. [10] examined the impact of hypothetical methods involving efficiency and environment that leads to improve infant health. The study encompassed India and UK economies. For decreasing CO_2 emissions, the main focus was driven on indoor activities ventilation, fuel utilization, stoves, etc. The empirics provide reduction of 0.6 mega tones in CO_2 emission and 850 less disability-adjusted life years (DALYs) at yearly basis (per million population). The results provided drop in infections and several diseases in India. Empirical results have provided 12500 less DALYs and reduction in CO_2 emissions in UK economy. Later Frielet al. [17] highlighted agriculture sector's impact on health in UK and Brazil economy. The study prescribed decrease in livestock consumption for reduction in heart diseases and it can decline 2850 and 2180 DALYs in UK and Brazil yearly. However, these changes have contradiction from culture or political view point of society. Woodcock et al. [18] pointed out the use of vehicles emits low carbon is beneficial for health while analysing UK (London) and India (Delhi). Adopting such measure with active travel study forecasts 7439 and 12995 less DALYs in London and Delhi respectively. This also could lower the disease in both economies. Haines et al. [19] further added climate change for analysing health. Their study recommended promotion of considering climate changes with emissions (greenhouse-gases) for devising policies about health.

Foster et al. [20] analysed relationship between air quality and mortality in Mexican economy. The study revealed increase in health costs due to air pollution and compulsory need of enforcing regulations about it. It was also highlighted that air pollution could cause bitter situation in developing economies. The cause may be bad air quality and fewer regulations along with lower monitoring capacities. Franz and FitzRoy [21] examined 61 countries and included environmental and several economic factors involving fertility and consumption of poor people. They estimate models in two stages, i.e., firstly estimate fertility using economic variables then use this estimation for estimating children mortality under 5 years. Results showed about 41% increased mortality for Central Asian Republics that possibly arise due to environmental degradation in those economies. Pakistan is a developing economy where there are no strict environmental policies implemented for the sake of enhancing economic growth. Due to its rising CO_2 emissions persistently from 1980 onwards (figure 1), the figures have reached to dangerous levels for infant health. Complementary to this, the health sector too does not get much importance from policy makers. The population increased more than 2 percent from 1970 onwards whereas the health expenditures could not attain even 1 percent of GDP during the same period (figure 2). The increase in population provides more doctors so that population per doctor is decreasing continuously (figure 3). However, the amount of existing health facilities could be explained by viewing population per bed that remained more than 1300 from 1970 to 2014 (figure 4). This is an alarming situation for the economy and needs to be addressed on urgent basis. The current study, therefore, has tried to highlight this side of the problem by incorporating both emissions and economic factors impact on health in case of Pakistan. On the other hand, Woolf and Bravemen [22] observed health conditions of US economy and advocated increase of rich share in income whereas less share of poor by 2009. That leads to lower US ranking in world about life expectancy and children mortality. Daly et al. [23] highlighted the importance of income inequality and health relation while analysing US economy through longitudinal data. The study distinguishes different levels of income distribution. Depth of poverty attached with the lower income group explains mortality more than the rich part of the society's incomes. Mortality does not appear significantly determined by inequality except for middle income people of age 25 and 64.

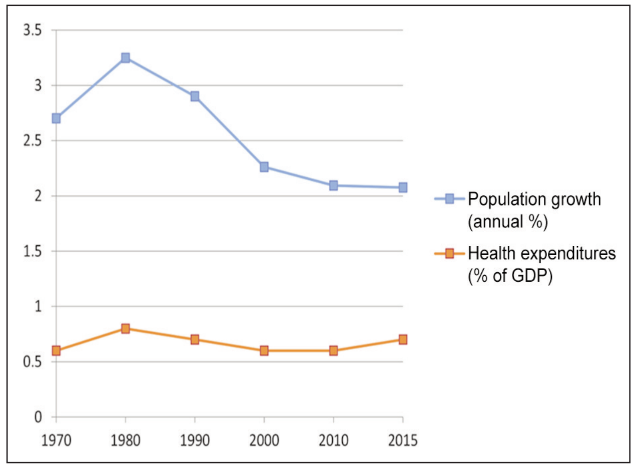

Fig. 1. Population growth and health expenditures of Pakistan [24]

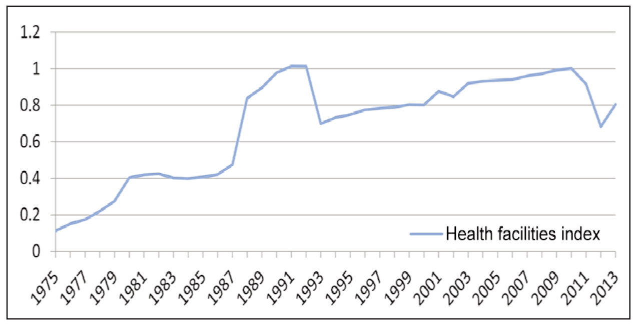

Fig. 2. The trend of Hospital facilities index

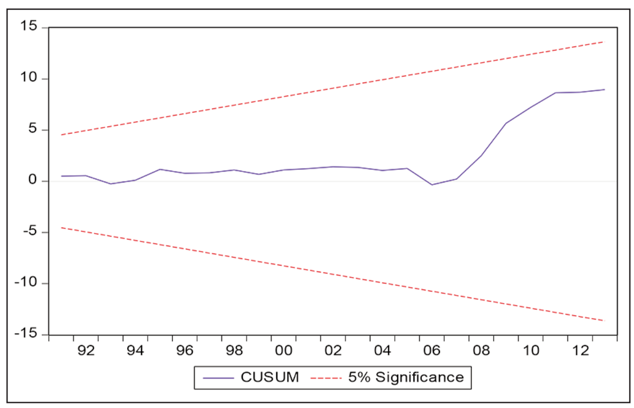

Fig. 3. Plot of Cumulative Sum (CUSUM)

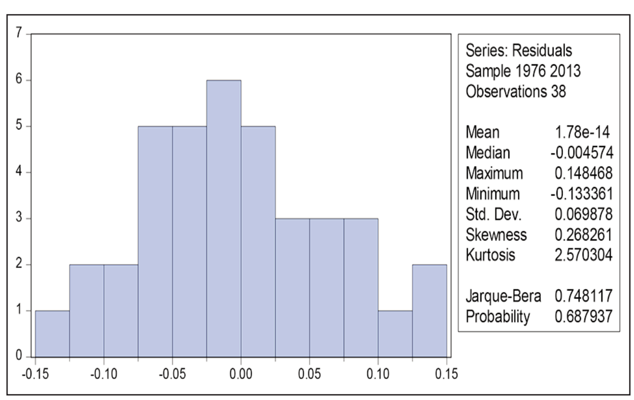

Fig. 4. Normality test for residuals

Backlundet al. [11] analysed the same economy over 1979 to 1989 to investigate relationship between mortality and income. The study concluded rising incomes are decreasing factor to mortality at lower income levels. This effect is less observed in case of higher income levels. Discussing the same economy, Cutler et al. [25] found health degrading due to rising urbanization. Urbanization enhances sanitary problems and allowed spreading more diseases among people. Farag et al. [26] investigated the important role of health expenditures on children mortality within 133 countries. Their study highlighted direct effect of good governance in controlling the usefulness of government health expenditures. This usefulness is attached with the institutions and policies of government about health. However, composition of health expenses is recommended for acquiring benefits even beyond their calculations. Rodgers [27] investigated mortality in cross-section analysis. The study involved income level and income inequality as deriving factors of health. Environmental factors and education were considered important but did not include in the study. The results showed that income inequality directly affects mortality. Larger the inequality exists more would be the mortality. Waldmann [28] established the same results. His study kept the real income of poor in countries alike. Then incomes of rich showed a strong direct relationship with infant mortality. This relationship just effected a little even after inclusion of other variables in the model. Jain et al. [29] investigated various regions of Indian economy for determining socioeconomic inequality in child mortality. Their study discovered highest rate of inequality in the most advanced regions. Crucial causes of findings were access towards maternal and children health facilities, government concentration and healthcare programs. Analysing European economies, Strittmatter and Sunde [30] also advocated healthcare improvements as decreasing factor to infant mortality. Gruber et al. [31] investigated the impact of healthcare reform 2001 in Thailand. The study found this program helpful for poor and reduced the infant mortality considerably in relatively poor provinces. It also suggested such supply-side reforms and availability of medical services to improve health situation and reducing infant's death. In an analysis on underdeveloped countries, Flegg [32] pointed out many other factors influencing child mortality other than income and income inequality. It took medical care, education (maternal) and fertility for explaining that phenomenon. When the study incorporated medical care and education along with income, its effect became insignificant. However, conclusions revealed that income distribution is more important than income. Deaton [33] also found income inequality as a determinant of mortality. Income inequality represents inappropriate environment, nutrition, sanitation, etc. for the poor countries. He observed poverty as a major cause behind child and infant mortality within developing countries. But, existing literature does not pay much attention towards various economic factors for affecting health in Pakistan. The present study is an empirical analysis of Pakistan economy that compares the impact of CO_2 emissions and various economic factors on health in case of Pakistan.

RESEARCH METHODOLOGY

The Basic aim of economic theory is to understand behaviours of economic agents by considering individuals or overall state. The basic purpose behind establishing the economic model is to elaborate the behaviour of specific phenomenon in the presence of some selected characteristics. The phenomenon is the dependant variable that is children mortality in our study whereas the characteristics are regressors under consideration. Since in real world economic factors are interrelated and there may be many that affect a single variable. However, all such factors cannot be included in a single model due to various econometric problems and for which reason the assumptions are made. Thus, in viewing the principal of parsimony, some most important factors are included in the model while the remaining factors affecting our dependent variables are assumed to be constant and their impact is united in a single value of intercept in the model. The present study includes urbanization, hospital facilities, income inequality, CO_2 emissions growth rate, poverty and fertility rate for explaining the children mortality in Pakistan. All the mentioned explanatory variables are considered important in previous researches and provide the initiative to conduct the present study. These details are discussed in the following section.

Health indicators

In simple words, health is assumed to have absence of disease. But McKeown [34] quoted: "*The World Health Organization says that health is not merely the absence of disease but an overall state of physical, mental and social well-being*" (page, 70). The effect of medicines and other cures combined must be calculated for the sake of determining health situation. McKeown prescribed the decreasing mortality as a measure of improvements in health. Mortality also appears to be able to compare the effectiveness of implementing several health facilities. Cutler et al. [25] also pointed out decreasing mortality as the measure of good health. Study further highlighted infants and children are sensitive and acquire the impact of diseases early. Ahmad et al. [2] pointed out infant mortality rate under the age of five years as better approach than infant mortality rate. It is less affected from assumptions lying in computing than mortality rate and enables to study principal diseases impact on children well. It also recommended that it can be used to analyse impact of health programmes on children as well. Patz et al. [14] analysed climate changes and health in global perspective. The study used CO_2 emissions (in form of index) for viewing warming. Further the study quoted, "*According to the WHO, 88 % of the disease burden attributable to climate change afflicts children under age 5*" (page, 397). Since we are discussing CO_2 emissions impact on health and children are sensitive to environment. Considering these facts, we use children mortality under five years as our target variable. Woolf and Bravemen [22] surprisingly pointed out U.S. health care system as one of the cause of declining health situation. Rodgers [27] considered importance of health technology and availability for determining mortality in developing countries. Gruber et al. [31] found healthcare facilities significant in infant mortality analysis. Fuchs et al. [32] revealed health services availability mostly significant in analysing child mortality. Maternal centres in Pakistan are a source of such knowledge. Therefore, present study includes number of hospitals and maternity centres by constructing a combined index and named it as hospital facilities. Number of hospitals (HOS) can describe the general health care system. While the amount of maternity centres (MAT) provide mothers (maternal education) and children special care and it is included in the study due to selection of mortality under five years as the dependent variable. The method is described by equation 1 and results are represented in figure 2. The index ranges from 0 to 2. The value of 2 highlights best and 0 indicate worst health facilities. As a rule of thumb, its value near or greater than population growth rate may describe the better health facilities while its value close to zero describe worse health situation. Pakistan yearly population growth rate is approximately two percent or above (figure 1) while hospital facilities index remained lower than 2 (for the period of our study).

$$\left(\frac{HOSt - minHOS}{maxHOS - minHOS}\right)\beta 1 + \left(\frac{MATt - minMAT}{maxMAT - minMAT}\right)\beta 2 = HSPFACt \quad (1)$$

Many researchers including Rodgers [27], Franz and FitzRoy [21] and Flegg [32] used and suggested several economic and environmental factors to be included for mortality analysis. From their findings and suggestions, present study establishes the functional form of model as follows:

$$ChM_t = f(URB_t, CO_2gr_t, INI_t, HSPFAC_t, POV_t, FERRT_t) \quad (2)$$

where *ChM* is children mortality (infant mortality under five years per thousand live births), *URB* – urbanization (population density, people per square km of land area), CO_2gr – CO_2 emissions growth rate (annual percent), *INI* – income inequality (Gini coefficient), *HSPFAC* – hospital facilities (index of hospitals and maternity centres), *POV* – poverty (head count ratio) and *FERRT* – fertility rate, total (births per woman).

The present study includes intercept term while analysing the long run relationship among explanatory variables and explained variable. The model can be stated in the form of equation as follows:

$$ChM_t = \alpha_0 + \alpha_1 URB_t + \alpha_2 CO_2gr_t + \alpha_3 INI_t + \alpha_4 HSPFAC_t + \alpha_5 POV_t + \alpha_6 FERRT_t + e_t \quad (3)$$

The data of variables is taken from various issues of Economic Survey of Pakistan and World Bank online database. While the hospital facilities is the computed index as stated in the section of health indicators above. An initial plotting the children mortality and CO_2 emissions growth rate is shown in figure 5. This figure remains ambiguous in finding the linear pattern between them. However, the plot of hospital facilities and children mortality (figure 6) clearly identifies the inverse relationship. So, it is expected that the relationship would be decreasing between children mortality and hospital facilities, whereas no clear statement arises about the relationship of children mortality and CO_2 emissions growth rate.

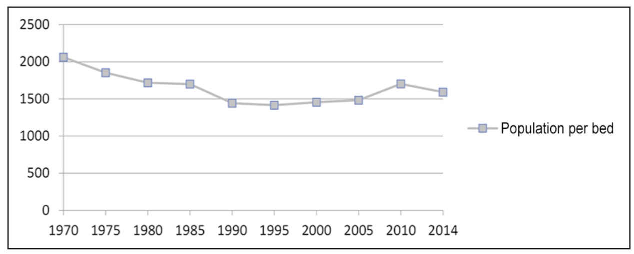

Fig. 5. Population per bed in Pakistan [36]

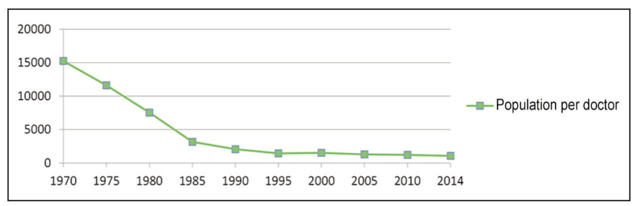

Fig. 6. Population per bed in Pakistan [36]

The econometric tools help in quantifying the economic phenomena. Most of macroeconomic factors include time trend that makes it non stationary and leads to unreliable regression results. Nelson and Plosser [37] revealed that macroeconomic variables possess unit root problem when data assessed have time series. In case, if the time series data has only negative or positive shocks, the time series data is nonstationary [38]. In literature, several unit root tests are available for testing data stationarity. The present study uses Augmented Dickey-Fuller (ADF) unit root test [39]. The general forms of the ADF can be written as:

$$X_t = X_{t-1} + \sum_{j=1}^{q} X_j X_{t-j} + e_{1t} \quad (4)$$

$$X_t = \alpha + \delta X_{t-1} + \sum_{j=1}^{q} X_j X_{t-j} + e_{2t} \quad (5)$$

$$X_t = \alpha + \beta t + \delta X_{t-1} + \sum_{j=1}^{q} X_j X_{t-j} + e_{3t} \quad (6)$$

where X_t is time series for testing unit root problem, t – the time trend and e_t – error term having white noise properties. If $j = 0$, it represents the simple DF test. The null hypothesis acceptance provides the series has unit root, while the rejection of null hypothesis indicates the series is stationary.

Auto Regressive Distributed Lag Model (ARDL) approach to cointegration

In literature, a number of cointegration tests are available for econometric analysis. Most famous and traditional cointegration tests are the residual based Engle-Granger [40] test, Maximum Likelihood based on Johansen [41, 42] and Johansen-Juselius [43] tests. One thing is common in these tests is that they require same order of integration for their analysis. These cointegration tests become invalid and inefficient when the variables of the model have different level of integration. ARDL bound testing approach presented by Pesaran and Pesaran [44], Pesaran and Shin [45], and Pesaran, Shin and Smith [46] has numerous advantages over traditional methods of cointegration. Firstly, ARDL can be applied regardless of the order of integration. Secondly, ARDL bounds testing approach to cointegration can be used for small sample size [47]. Thirdly, this approach allows taking sufficient number of lags for capturing the data generating process in a general to specific modelling framework [48]. This technique is based on Unrestricted Vector Error Correction Model (UVECM) which has better properties for short and long-run equilibrium as compared to traditional techniques [49]. After lag order selection for ARDL procedure, simple OLS can be used for identification and estimation. Valid estimates and inferences can be drawn through the presence of unique long-run alliance that is crucial for cointegration.

$$\Delta \ln Y_t = \beta_1 + \beta_2 t + \beta_3 \ln Y_{t-1} + \beta_4 \ln X_{t-1} + \beta_5 \ln Z_{t-1} + \\ + \ldots + \sum_{h=1}^{p} \beta_h \Delta \ln Y_{t-h} + \sum_{j=0}^{p} \gamma_j \Delta \ln X_{t-j} + \\ + \sum_{k=0}^{p} \phi_k \Delta \ln Z_{t-k} + \ldots + u_{it} \quad (7)$$

At first this study finds the direction of relationship among the variables in case of Pakistan by applying the bounds test using F-Test test.

H_0: $\beta3 = \beta4 = \beta5 = 0$ (no cointegration among the variables).

H_A: $\beta3 \neq \beta4 \neq \beta5 \neq 0$ (cointegration among variables).

If there exists long-run cointegration relationship among the variables, then for finding short-run relationship the Vector Error Correction Model (VECM) can be utilised. The VECM is explained as under:

$$\ln Y_{it} = \beta_1 + \beta_2 t + \sum_{h=1}^{p} \beta_h \ln Y_{it-h} + \sum_{j=0}^{p} \gamma_j \ln X_{t-j} + \\ + \sum_{k=0}^{p} \phi_k \Delta \ln Z_{it-k} + ECT_{t-1} + u_t \quad (8)$$

EMPIRICAL RESULTS AND DISCUSSIONS

Temporal properties of dataset are important for analysis. Descriptive statistics is useful for such analysis. Its results are shown in table 1. The empirical estimates declare presence of positive skewness in infant mortality under five years, urbanization and poverty, whereas CO_2 emissions growth, income inequality, fertility rate and health facilities are negatively skewed. The estimates provide positive kurtosis for all variables. The individual series normality test is performed using Jarque-Bera statistic. The results of normality test affirm that data is normally distributed for all the variables involved in analysis.

Correlation matrix is presented in table 2. The correlation of infant mortality rate under five years with CO_2 emissions growth rate and fertility rate are shown positive and significant. Correlation is significant and negative in case of urbanization and hospital facilities, whereas it is insignificant for poverty and income inequality. Urbanization possesses positive and significant correlation with hospital facilities. It is negative and significant with CO_2 emissions growth rate and fertility rate. Correlation of urbanization is insignificant with income inequality and poverty.

Table 1

DESCRIPTIVE STATISTICS							
Variables	**ChM**	**URB**	**CO_2gr**	**INI**	**HSPFAC**	**POV**	**FERRT**
Mean	128.3410	156.3253	5.2660	35.1813	0.6906	29.4492	5.3206
Median	128.3000	155.1019	6.3324	35.3569	0.7899	28.6800	5.4820
Maximum	172.0000	235.0465	13.5125	41.6788	1.0137	46.5000	6.6120
Minimum	85.6000	86.6432	–5.9437	22.2225	0.1121	20.7100	3.6820
Std. Dev.	26.9353	44.8753	4.3575	4.3585	0.2806	7.3530	1.0879
Skewness	0.0194	0.0891	–0.3496	–0.5109	–0.6528	0.5755	–0.1852
Kurtosis	1.6721	1.7935	2.6428	3.1372	2.0546	2.2957	1.3998
Jarque-Bera	2.8681	2.4168	1.0016	1.7276	4.2221	2.9589	4.3837
Probability	0.2383	0.2987	0.6060	0.4215	0.1211	0.2277	0.1117
Sum	5005.300	6096.687	205.3760	1372.070	26.9346	1148.520	207.5030
Sum Sq. Dev.	27569.33	76524.28	721.5422	721.8866	2.9925	2054.554	44.9738
Observations	39	39	39	39	39	39	39

Table 2

PAIR WISE CORRELATION							
Variables	**ChM**	**URB**	**CO_2gr**	**INI**	**HSPFAC**	**POV**	**FERRT**
ChM	1.0000						
URB	–0.9982 (–102.1057)***	1.0000					
CO_2gr	0.4704 (3.2429)***	–0.4878 (–3.3991)***	1.0000				
INI	–0.0248 –0.1512	–0.0274 –0.1670	0.2814 (1.7841)*	1.0000			
HSPFAC	–0.8177 (–8.6421)***	0.8032 (8.2022)***	–0.2641 –1.6655	0.2991 (1.9069)*	1.0000		
POV	–0.2037 –1.2657	0.2362 1.4789	–0.3830 (–2.5220)**	–0.6735 (–5.5426)***	–0.2393 –1.4995	1.0000	
FERRT	0.9846 (34.2668)***	–0.9814 (–31.1043)***	0.4751 (3.2845)***	0.00096 0.0058	–0.7488 (–6.8719)***	–0.3199 (–2.0541)**	1.0000

Note: ** and * represents significance at 5% and 10% levels respectively.

CO_2 emissions growth rate provides positive and significant correlation with income inequality and fertility rate. Correlation is negative and significant for poverty whereas insignificant for hospital facilities.

Correlation of income inequality revealed negative and significant with poverty. The correlation is positive and significant with hospital facilities and is insignificant with fertility rate. Correlation of hospital facilities with fertility rate is negative and significant, while same is insignificant with poverty. The correlation of poverty and fertility rate is revealed negative and significant. The correlation of infant mortality rate under five years that is dependant variable is revealed significant with most of the variables. The correlation matrix advocates no evidence of multicollinearity among regressors of the model.

Table 3 shows the estimates of unit root tests, ADF test is used for this purpose. The null hypothesis under consideration is that variable has a unit root. The results show infant mortality under five years, CO_2 emissions growth rate and fertility rate do not possess unit root at level. So, they are stationary at level or **I (0)** process variables. Urbanization, hospital facilities, income inequality and poverty are non-stationary at level. However, they became stationary at first difference which are **I (1)** process variables. The estimates provide mix order of integration and this is highly recommended for ARDL to be a best suitable technique for analysing cointegration.

Table 3

RESULTS OF UNIT ROOT				
Variables	**At level**		**At first difference**	
	t-statistic	**Prob.***	**t-statistic**	**Prob.***
ChM	–5.5188	0.0003	–3.8208	0.0275
URB	–0.6342	0.9705	–4.6804	0.0032
CO_2gr	–6.6548	0.0000	–5.2956	0.0007
HSPFAC	–1.6431	0.7565	–5.4666	0.0004
INI	0.1590	0.9968	–6.6435	0.0000
POV	–1.1742	0.9016	–7.8923	0.0000
FERRT	–5.8313	0.0002	–4.0400	0.0180

Note: * MacKinnon [50] one-sided p-values.

Empirics from ARDL Bounds Testing Approach

To analyse the cointegration in infant mortality rate under five years, urbanization, CO_2 emissions growth rate, hospital facilities, income inequality, poverty and fertility rate; ARDL bounds testing approach is utilized. Its results are shown in table 4. The estimated F-statistic (16.8698) is larger from upper bound at 1 percent significance level. This leads to rejection of null hypothesis of no cointegration. Results verify existence of cointegration among infant mortality rate under five years, urbanization, CO_2 emissions growth rate, hospital facilities, poverty and fertility rate. Hence, the model variables are cointegrated and we can estimate long run relationship among them.

Table 4

ARDL BOUND TESTING APPROACH		
ARDL (1, 1, 1, 1, 1, 1, 1) Dependent variable: children mortality (under five years)		
Critical values	**F-Statistic** (16.8698)***	
	Lower Bound	Upper bond
99%	3.15	4.43
95%	2.45	3.61
90%	2.12	3.23

Note: ** and * represents significance at 5% and 10% levels respectively.

The results of long run relationship among children mortality, urbanization, CO_2 emissions growth rate, hospital facilities, poverty, income inequality and fertility rate are shown in table 5. Urbanization estimate reveals negative and significant (at 1 percent level) that indicates their inverse relationship. The estimate shows that increase in urbanization decreases the child mortality. This is supported by economic theory that urbanization leads to more facilities and thus decreases children deaths. The CO_2 emission growth rate has revealed positive and insignificant role towards children mortality. Income inequality has shown the negative and significant (at 1 percent level) relationship with children mortality. An increase in income inequality became a cause of decreasing children mortality. It resembles with Jain et al. [29] study and imply more chances of child death belongs to low-income people while fewer for rich in comparison. The health facilities are found an increasing factor to child mortality at 10 percent significance level. It seems contradictory from theory. Faraget al. [26] concluded that it is policies and institutions attached with good governance that enhances usefulness of health expenses. Our coefficient of health facilities reveals positive sign seems to occur due to volatile behaviour of government regarding health policies that is declining the effectiveness of already low resources contributed to health sector. The estimate of poverty has provided positive and significant relationship with children mortality. The increase in poor people leads to increase the children mortality. This finding is in line with Deaton [33]. Fertility coefficient has shown positive and significant (at 1 percent level) relationship with children mortality. We found increase in fertility rate provide increase in children mortality as similar to the results of Franz and Felix Fitz Roy [21]. The intercept term is rather large in our analysis. This indicates that other important factors are also playing huge role in explaining the children mortality in Pakistan. The results indicated that enhancing urbanization and income inequality became a cause of decreasing children mortality. While, hospital facilities, poverty and fertility rate are contributing factors to children mortality. The Carbon dioxide emissions are playing insignificant role in explaining children mortality in Pakistan economy.

Estimated short-run dynamics

The present study uses Vector Error-Correction Model (VECM) for analyzing short-run dynamics among children mortality, urbanization, CO_2 emissions growth rate, income inequality, hospital facilities, poverty and fertility rate for Pakistan economy. Estimated results are shown in table 6. Both urbanization and CO_2 emissions growth rate are estimated to have pos- itive and insignificant impact on children mortality. Income inequality has shown negative and significant effect on children mortality. The hospital facilities became the decreasing factor to children mortality in short-run analysis. It is contrary to long-run results. However, this immediate improvement in mortality is same as observed by Strimatter and Sunde [30]. The coefficient of poverty indicates positive and significant relationship with children mortality. This finding is similar to long-run analysis and in line to economic theory. Fertility rate has shown the positive and significant relationship with children mortality same as in long-run analysis. The short-run dynamics provide that children mortality can be decreased by controlling poverty and fertility rate whereas income inequality and hospital facilities appeared as decreasing factors to children

Table 5

ESTIMATED LONG RUN COEFFICIENTS				
ARDL (1, 1, 1, 1, 1, 1, 1) **Dependent variable: children mortality (under five years) time period 1975–2013**				
Regressor	**Coefficient**	**Standard-Error**	**T-Ratio**	**Prob.**
URB	–0.5251	0.0340	–15.4551	0.0000
CO_2gr	0.0621	0.0366	1.6969	0.1027
INI	–0.1691	0.0352	–4.8030	0.0001
HSPFAC	1.6938	0.8398	2.0170	0.0550
POV	0.1551	0.0223	6.9638	0.0000
FERRT	3.5868	1.0877	3.2975	0.0030
C	183.7622	8.2598	22.2478	0.0000

Table 6

VECTOR ERROR-CORRECTION MODEL (VCEM)				
ARDL (1, 1, 1, 1, 1, 1, 1) **Dependent variable: children mortality (under five years) time period 1975–2013**				
Regressor	**Coefficient**	**Standard-Error**	**T-Ratio**	**Prob.**
URB	0.1085	0.1828	0.5937	0.5582
CO_2gr	0.0091	0.0054	1.6885	0.1043
INI	–0.0364	0.0098	–3.7234	0.0011
HSPFAC	–0.3693	0.1886	–1.9586	0.0619
POV	0.0190	0.0093	2.0380	0.0527
FERRT	4.7541	0.8184	5.8088	0.0000
ECM(–1)	–0.3121	0.0721	–4.3291	0.0002
R-squared 0.9471		Adjusted R-squared 0.9184		
S.E. of regression 0.0868		F-statistic 33.0365		
Mean of dependent variable –2.2737		Prob(F-statistic) 0.0000		
Residual sum of squares 0.1807		S.D. of dependent variable 0.3037		
Akaike Info. Criterion –1.7740		Equation Log-likelihood 47.7053		
Durbin-Watson statistic 1.8050		Schwarz criterion –1.1706		

mortality in Pakistan. The coefficient of ECM (–0.3121) is negative and significant which is according to theoretical framework. Its value indicates the speed of adjustment from short-run towards long run equilibrium. The coefficient of ECM indicates correction of 31.21 percent per period. It also shows that short-run converges to long-run equilibrium by approximately three years and two months.

Diagnostic tests

After estimating the model, econometric problems including heteroscedasticity and autocorrelation must be discussed. Heteroscedasticity is checked using Breusch-Pagan-Godfrey. Its results are presented in table 7. The null hypothesis under consideration is absence of heteroscedasticity in the model. Since the estimated F-statistic is less than its critical value, so we do not have evidence of rejecting our null hypothesis and concludes that there is no heteroscedasticity in our computed model. Breusch-Godfrey Serial Correlation LMtest is used for checking the model for autocorrelation. Its results are shown in table 7. The null hypothesis is absence of autocorrelation in estimated model. As calculated F-statistic lies in acceptance region, so we accept our null hypothesis of no autocorrelation in our model. So, the estimated model of present study is free from both heteroscedasticity and autocorrelation.

Table 7

HETEROSCEDASTICITY TEST: BREUSCH-PAGAN-GODFREY			
F-statistic	0.6482	**Prob. F(13,24)**	0.7905
Obs*R-squared	9.8746	**Prob. Chi-Square(13)**	0.7042
Scaled Explained SS	3.0926	**Prob. Chi-Square (13)**	0.9976

Table 8

BREUSCH-GODFREY SERIAL CORRELATION LM TEST			
F-statistic	1.3542	**Prob. F(1,23)**	0.2565
Obs*R-squared	2.1129	**Prob. Chi-Square(1)**	0.1461

The economies are dynamic and economic factors keep changing over time. So, it is necessary to check that if our estimated model is shifted over time. Cumulative Sum (CUSUM) test can be used for such diagnostic. The results are presented in figure 3. The estimated model Cumulative Sum occurs in midway of critical bands. This shows that model of present study is stable. Figure 4 reports the histogram of residuals. The value of Jarque-Bera points out residuals are normally distributed. Since, there is no econometric issue regarding the results which makes the results reliable.

CONCLUSIONS

Air pollution is considered one of the biggest causes of effecting health in developing countries. We have attempted to investigate significance of relationship in CO_2 emissions and health in the presence of some other economic factors in Pakistan economy over the period from 1975 to 2013. We have used Jarque-Bera probability for estimating normality, Augmented Dickey Fuller test for checking stationarity and Auto Regressive Distributed Lag model for estimating long run relationships among variables of the model. Spulbar et al. [51] suggested that sustainable development has a significant impact on emerging countries, especially considering their characteristic features, such as: environmental degradation, social inequality, demographic dynamics, high degree of poverty, poor quality education, migration, high levels of urbanization, health system deficiencies, rapid technological change and unsustainable economic growth. Children mortality under five years is considered for analysing health. Results did not find any evidence of CO_2 emissions growth significance in affecting health in Pakistan. Urbanization appeared to be playing role in improving health over the long period of time. Estimates provide increasing income inequality as an improving factor for health whereas increase in poverty and fertility are found worsening health situation in our economy. The health facilities are found decreasing children mortality in short run whereas it became increasing factor in long run analysis. The inappropriate health facilities and economic situations have made survival difficult for children belonging to poor families. We have found children mortality explained better by economic factors than CO_2 emissions. The coefficient of ECM indicates that in three years and two months short-run converges to long-run equilibrium. More than establishing environment laws about CO_2 emissions our analysis suggests an immediate need of addressing economic factors for lowering children mortality. Poor people are suffering more and there is need to reduce poverty and improve provision of health facilities to them. So, there is need for devising poverty alleviation policies and improving access to health for poor for reducing children mortality and improving overall health dynamics in Pakistan.

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Research for the conservation of cultural heritage in the context of the circular economy

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ABSTRACT – REZUMAT

Research for the conservation of cultural heritage in the context of the circular economy

The heritage woven objects could be analyzed for defects hidden to the naked eye using non-invasive and non-destructive ultrasonography techniques. Ultrasonography is able to offer information about altered areas, such as gasps, interruptions, discontinuances, narrowed areas, fiber breaks, different densities of the material, defects caused by natural or anthropic factors: improper storage and exposure conditions, the presence of microorganisms and traces of their activity, mechanical causes etc. By recycling of the cotton fibers from other decrepit materials, which are not directly usable, the recondition and rendition of the national and world cultural heritage of these refurbished objects would be accomplished. The impact on the environment is diminished compared to the case when new cotton fibers are created.

Keywords: *cultural heritage, ultrasonography, recycling, circular economy*

Investigații privind conservarea patrimoniului cultural în contextul economiei circulare

Textilele de patrimoniu ar putea fi analizate în ceea ce privește unele defecte care nu pot fi văzute cu ochiul liber, prin folosirea tehnicilor de ultrasonografie non-invazive și non-destructive. Ultrasonografia este capabilă să ofere informații despre zonele modificate, precum adâncituri, întreruperi, discontinuități, zone înguste, rupturi de fibre, diferite densități ale materialului, defecte cauzate de factori naturali sau antropici: condiții de depozitare și expunere necorespunzătoare, prezența microorganismelor și urme ale activității lor, cauze mecanice etc. Prin reciclarea fibrelor de bumbac din alte materiale uzate, care nu sunt direct utilizabile, s-ar putea realiza recondiționarea articolelor deteriorate, obiectele recondiționate putând fi redate patrimoniului cultural național și mondial. Impactul asupra mediului este diminuat în comparație cu cazul în care sunt create noi fibre de bumbac.

Cuvinte-cheie: *patrimoniu, ultrasonografie, reciclare, economie circulară*

INTRODUCTION

When thinking about the textile industry for the past century, it should be mentioned that most of the garments have been reused and recycled, as the technological process to obtain them was difficult and time consuming, but the materials were of natural provenance. In this manner, the impact over the environment was minimum, natural materials decomposed easily and there were no questions if the natural resources would be exhausted although the society was intensively using them. Amid the aggressive promotion of the consumer society, the world is currently witnessing, the increase of the moral perishability process of textile products, despite the fact that physically and functional they meet all the requirements. Scientists figured out that a linear economy is no longer sustainable for the society and the circular economy flourished, proving real benefits both for now and for the future. Nevertheless, in the last few years, due to a growing awareness of the environmental issues, there has been a considerable interest in repair, maintenance, recycling and regeneration of the products. Some designers and producers have adopted techniques such as refurbishment, restyling and clothing redesigning, additional decorations and overlapping, patchworks, in order to restore used fabrics, increasing its value and delaying the removal from the landfill of waste. The study case is represented by an element of textile heritage, respectively an embroidered peasant blouse ("ie") around 100 years old from Bihor County, Romania (figure 1). The embroidered peasant blouse ("IA"), part of the cultural heritage, represents an essential clothing component of the Romanian folk costume, incorporating a multitude of defying aspects for the specific identity of the local, especially rural, respectively of the geographical and historical space where it

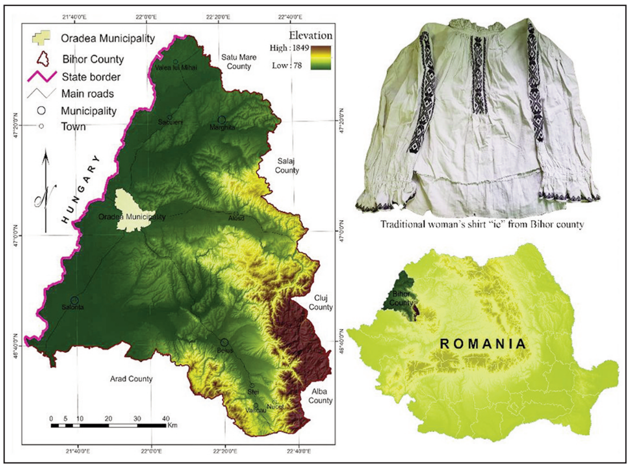

Fig. 1. The geographical location of the area of origin of the traditional women's shirt "ie"

appeared and evolved [1, 2]. There has been a while when, either from ignorance or carelessness, the embroidered peasant blouses were thrown away to the garbage can, as they were not "fashionable anymore". The disappearance of the custom of wearing embroidered peasant blouses represents a dramatic period for the Romanian traditional art. The major fashion houses started to be inspired by the patterns and motifs sewn once on the traditional costumes, including the Romanian ones. In the last few years, the embroidered peasant blouses have experienced a delightful come back. Famous designers have brought on the fashion catwalk the Romanian embroidered peasant blouse. Once returned" in trends", the famous blouse of the traditional folk costume gained the attention of the Romanian women as well. The embroidered peasant blouses started to be reused, to be reconditioned, even workshops were created where women are learning how to create an embroidered peasant blouse. The old embroidered peasant blouses are different from the ones that are now being worked in series to be marketed, because they are made of cotton cloth different in texture from the present ones. For the assessment of the fibrillary structure of the fabric's identification of visible and less visible defects on naked eye of the textile materials, the use of high ultrasonography has been tried. Common in medicine, it can also contribute to the analysis of other structures that can be penetrated by ultrasounds. Modern ultrasounds are equipped with high resolution (high frequency) suitable to qualitative analysis of superficial structures, such as fabrics. The extremely high resolution of the obtained images gives the possibility of a fine analysis of the structure of the yarns of a woven material.

CASE STUDY

Literature review

The circular economy proposes a different approach based on the reuse and recycling of the goods instead of disposing them as soon as there are no longer useful [3, 4]. There is a major link between circular economy and sustainable development as circular economy embraces the principles of sustainable development, having its starting point in the Agenda [4, 5]. Mostly CE it is referred as cyclical closed – loop system which could solve the linear economy environmental issues [6, 7]. The interest for the circular economy is high among scholars from different domains due to the benefits it brings to the modern society and the perspective for the future [8]. Large sports equipment companies have started using recycling since 2010 to create highly performing sports equipment with the least impact on the environment [9, 10].

The purpose of the present study is to highlight new methods and techniques for investigating some elements of textile heritage for the assessments of their condition, conservation and reconditioning, in the context of imposing a new conceptual approach to the circular economy, focused on volume reduction of waste, recycling and reuse [11–21]. The present study is a continuation of others scientific approaches that had as subject different elements of textile heritage [22–29].

Method

X-radiography tools used for textile contributes to a good documentation for a better condition assessment and for the preserving of the objects, being a non-invasive and non-destructive technique; the analysis and interpretation of the obtained images highlight certain details and the hidden characters of the textile material, the techniques of sewing and weaving, repair, use, patterns of decay and dating, through digital image manipulation and interpretation [30]. Such techniques have been successfully used in the analysis of textile on the mummies in Peru, within the Peruvian Institute of Bioanthropology [31], Utrcht Museum being a pioneer in introducing the public in the use of X-rays in research [31]. As an objective method of analyzing the integrity of the fabric we used ultrasonography, a Samsung RS 80 (Samsung Healthcare Ultrasound) device, equipped with high resolution linear probes: L3-12A probe, with variable frequency up to 12MHz, respectively LA4-18B probe, with variable frequency up to 18MHz.

Results and discussions

At a frequency of 15–18 MHz, high-frequency ultrasonography achieves an axial resolution (the possibility to distinguish two points perpendicular to the plane of the ultrasound waves) of 100 µm/pixel and a lateral resolution (the possibility to distinguish two points in the plane parallel to the ultrasound waves) of 90 µm/pixel, which can be used to differentiate certain lesions and interruptions in mass of material larger than 0.1 mm [32].

The study object is an embroidered peasant blouse around 100 years old from Bihor County, Romania (figure 1). The aim was to identify on the ultrasound images the interrupted, thin threads or the presence of larger defects inside the fabric, the lack of homogeneity of the material and respectively the presence

Fig. 2. Clinical echography images of the fabric of the traditional shirt (“ie”)

Fig. 3. Photo of deteriorated fabric of traditional shirt (“ie”)

of several gaps in its mass (figures 2 and 3). It is possible to identify and interpret, monitor and map the degraded and vulnerable areas, where the density of the material is different from the average, where there are gaps in the mass of the material, broken, broken or thinned fibers, etc. In the future, an objective method of analysis will be refined regarding the examination protocol: choosing the place where the examination will be carried out; the surface of the fabric examined; meticulous identification and quantification of defects identified in the field and use of statistical methods.

The cotton material of the embroidered peasant blouse could be reconditioned on the areas thus identified and which requires it, with the use of a similar or even identical raw material by recycling/regenerating the cotton yarns from other materials, not recoverable for direct use [33, 34].

CONCLUSIONS

The circular economy proposes a different approach based on the reuse and recycling of the goods instead of disposing them as soon as there are no longer useful so that the impact on the environment is greatly diminished. This is successfully implemented by the major fashion houses in the world, but also in the field of high-performance sports. The non-invasive and non-destructive technique of monitoring and interpreting the images obtained by ultrasonography (including textile materials) has proved very useful in evaluating the state of the objects, identifying, quantifying, interpreting material defects (gaps, broken fibers, thinned etc.) for good preservation by recycling/regenerating textile fibers from other end-of-life materials, but which can be used successfully for reconditioning and reinvents the materials for future generations.

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Assessing the environmental profit and loss of the textile industry: A case study in China

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ABSTRACT – REZUMAT

Assessing the environmental profit and loss of the textile industry: A case study in China

The textile industry contributes a lot to China's economy in history and present. However, it also causes serious impacts on the environment. Environmental prices methodology was proposed to convert various environmental impacts into corresponding social marginal value and it can be applied for the evaluation of the environmental loads. This study applied environmental prices methodology to calculate the social marginal value of the caused environmental impacts in China's textile industry during the period from 2001 to 2015. The results showed that the minimum value of caused environmental impacts was €9.556 billion and the maximum value was €16.599 billion. Among the three sub-industries of China's textile industry, Manufacture of Textile had the highest value, followed by Manufacture of Chemical Fibers, and Manufacture of Textile, Wearing Apparel and Accessories. The value of greenhouse effect caused by CO_2 emission was the largest. The value of ammonia nitrogen in wastewater was the largest and followed by the values of COD, As, cyanide, Hg, Pb and Cd. An in-depth analysis of the results indicated that the social marginal value of the textile industry closely related to the scale of the industry, the international market and government policies.

Keywords: *environmental price, social marginal value, environmental load, textile industry, impact pathway model*

Evaluarea profitului și pierderii de mediu din industria textilă: un studiu de caz din China

Industria textilă a contribuit foarte mult la economia Chinei în istorie și în prezent. Cu toate acestea, provoacă și daune grave asupra mediului. S-a propus metodologia calculării prețurilor de mediu pentru a converti diferitele tipuri de impact asupra mediului în valoare socială marginală corespunzătoare și aceasta poate fi aplicată pentru evaluarea impactului asupra mediului. Acest studiu a aplicat metodologia prețurilor de mediu pentru a calcula valoarea socială marginală a impactului asupra mediului cauzat de industria textilă din China în perioada 2001–2015. Rezultatele au arătat că valoarea minimă a impactului asupra mediului a fost de 9.556 miliarde euro, iar valoarea maximă a fost de 16.599 miliarde euro. Dintre cele trei ramuri ale industriei textile din China, fabricarea produselor textile a avut cea mai mare valoare, urmată de fabricarea fibrelor chimice și fabricarea produselor de îmbrăcăminte și accesoriilor. Valoarea efectului de seră cauzat de emisiile de CO_2 a fost cea mai mare. Valoarea azotului amoniacal în apele uzate a fost cea mai mare și a fost urmată de valorile COD, As, cianură, Hg, Pb și Cd. O analiză aprofundată a rezultatelor a indicat faptul că valoarea socială marginală a industriei textile este strâns legată de amploarea industriei, de piața internațională și de politicile guvernamentale.

Cuvinte-cheie*: prețul de mediu, valoarea socială marginală, impactul asupra mediului, industria textilă, modelul evaluării impactului*

INTRODUCTION

China is the largest producer, exporter and consumer of textile and clothing products. The textile industry is a pillar of China's national economy. However, textile industry consumes large quantities of freshwater, energy and chemicals in the production of textile products. More severely is that the textile industry discharges wastewater and emits waste gases that not only cause high economic losses, but also cause serious damage to human health and ecological system [1, 2]. The quantification and assessment of environmental impacts caused in the textile industry has gained more and more attention. Single index methodologies, such as water footprint (WF), carbon footprint (CF) and chemical footprint (ChF) have been proposed and widely applied in environmental impacts quantification and assessment of textile products. For example, Chapagain et al. [3] calculated the green water footprint, blue water footprint and grey water footprint of cotton from 1997 to 2001. Wang et al. [4] analyzed the industrial water footprint of seven kinds of dyed cotton knits. Yan et al. [5] calculated the industrial water footprint of heather grey, bleached cloth, dyed fabric and yarn-dyed fabric. Yao [6] calculated the carbon footprint of cotton fiber and divided its system boundary into four stages. Li et al. [7] discussed the calculation method of C 18.2 tex cotton carded yarn carbon footprint in each stage. There are also sufficient literatures on various fabrics and garments of carbon footprint, such as polyester filament fabric [8], gambiered Carbon silk [9] and jean [10]. Qian et al. [11] calculated the chemical footprint of denim fabric during dyeing and finishing, including human toxicity and ecological toxicity. Tian et al. [12] studied the chemical footprint of textiles and proposed the need for uncertainty analysis of characteristic factors and optimization of the USEtox model to improve the accuracy of the results. However, both water footprint, carbon footprint and chemical footprint are single indicators, which only quantify a part of the environmental impact in a specific area.

With the in-depth study and widely application of environmental assessment methodology, the European Commission proposed product environmental footprint (PEF) methodology in 2012 [13]. PEF is a multi-criteria measure of the environmental performance, which quantifies the integrated environmental load of products or services by incorporating different types of environmental impact category. He et al. [14] constructed 14 environmental models based on PEF theory and applied them to environmental assessment of agricultural picking robot. Pyay et al. [15] evaluated the environmental footprint of rubber products in Thailand from plantation phase to intermediate rubber products stage. In addition, PEF has also been applied in the environmental evaluation of dairy products [16], photovoltaic modules [17], strawberries [18], olive oil [19] and other products.

All the proposed indicators (e.g., WF, CF, ChF, PEF) evaluate the environmental impacts at the midpoint level and the substantial environmental impact (for human health, ecosystems, resources, etc) cannot be indicated. In order to solve this problem, Goedkoop et al. [20] developed a new characterization model that can transform environmental impact at the midpoint level to the endpoint level. The impact pathway approach used in the externe project [21] also established the relationship between emissions and endpoint environmental impacts. Sander et al. [22] established the environmental prices, which can convert various impacts of endpoint level into corresponding external costs, and finally obtain the economic loss caused by resources consumption and pollutants emissions. This method has been used in the study of average environmental prices in EU28 countries [23]. Other similar methods such as True Price, Trucost, PwC-environmental profit and loss account (EP&L) were also established and applied. For example, the real price of a T-shirt made of certified cotton produced in India was €22.3, of which the external cost was €7.3 [24]. The true price of a pair of jeans was €30 higher than the traditional market price. The price gap was mainly contributed by environmental external costs and social external costs [25]. In addition to the applications on textile products, True Price also calculated the external costs of cocoa [26], tea [27], banana [28] and other products. Trucost worked with PwC to carry out an EP&L study, which stated that the total monetary impact of PUMA's direct and supply chain operations was €145 million in 2010 [29]. Similar studies of EP&L included Novo Nordisk [30], American Chemistry Council [31] and The Green Electronics Council [32], etc. These methods converted environmental impacts into external cost, but there were differences in the specific evaluation methods. Environmental prices [22] evaluated 11 kinds of midpoint impacts (i.e., ozone depletion, climate change, particulate matter formation, photochemical oxidant formation, acidification, eutrophication, human toxicity, ecotoxicity, ionizing radiation, noise and land use), while PwC-EP&L mainly included air pollution, greenhouse gases, land use, solid waste, water consumption and water pollution [33]. Although the impacts of the midpoint level were different, the evaluation of the endpoint level was similar, that mainly included the impact on human health, ecosystem services, buildings and materials, etc. In terms of social impact, True Price considered more detailed categories [34], including gender inequality, public safety risks and breaches of privacy, etc. The method of environmental prices was also considered the impact of wellbeing [22]. The applications of True Price and Trucost were mostly focused on specific products (T-shirt, bananas, cocoa, etc.), while EP&L research was mainly applied at the enterprise and organizational level. However, there are few reports on environmental impacts assessment of the textile industry based on EP&L methodology though the textile industry does cause serious environmental impacts.

Therefore, this paper calculated the external cost of environmental damage caused by China's textile industry with the environmental profit and loss methodology. The parts of this paper are organized as follows. Section 2 provides methodology and data. The results are discussed in section 3. Section 4 is the conclusion of this paper.

METHODOLOGY AND DATA

Method

Environmental prices methodology is regarded as a more scientific method to evaluate the social marginal value of preventing emissions [22]. It establishes the impact of emissions on 11 environmental midpoints, including ozone depletion, climate change, human toxicity, etc. It evaluates the endpoint damage caused by each midpoint to human health, ecosystem services, buildings/materials, resource availability and wellbeing, and finally calculates the external cost of these damages. The method consists of three important parts: characterization models, impact pathway models and valuation methods. The overall framework is shown in figure 1.

Characterization model

The characterization model quantifies the physicochemical relationship among emissions, midpoint impacts and endpoint damages. The midpoint characteristic factor (CFm) is obtained by introducing relevant environmental impact pollutants to quantify the relationship between emission and midpoint. The endpoint characteristic factor (CFe) is obtained by analysing the damages caused by the midpoints to

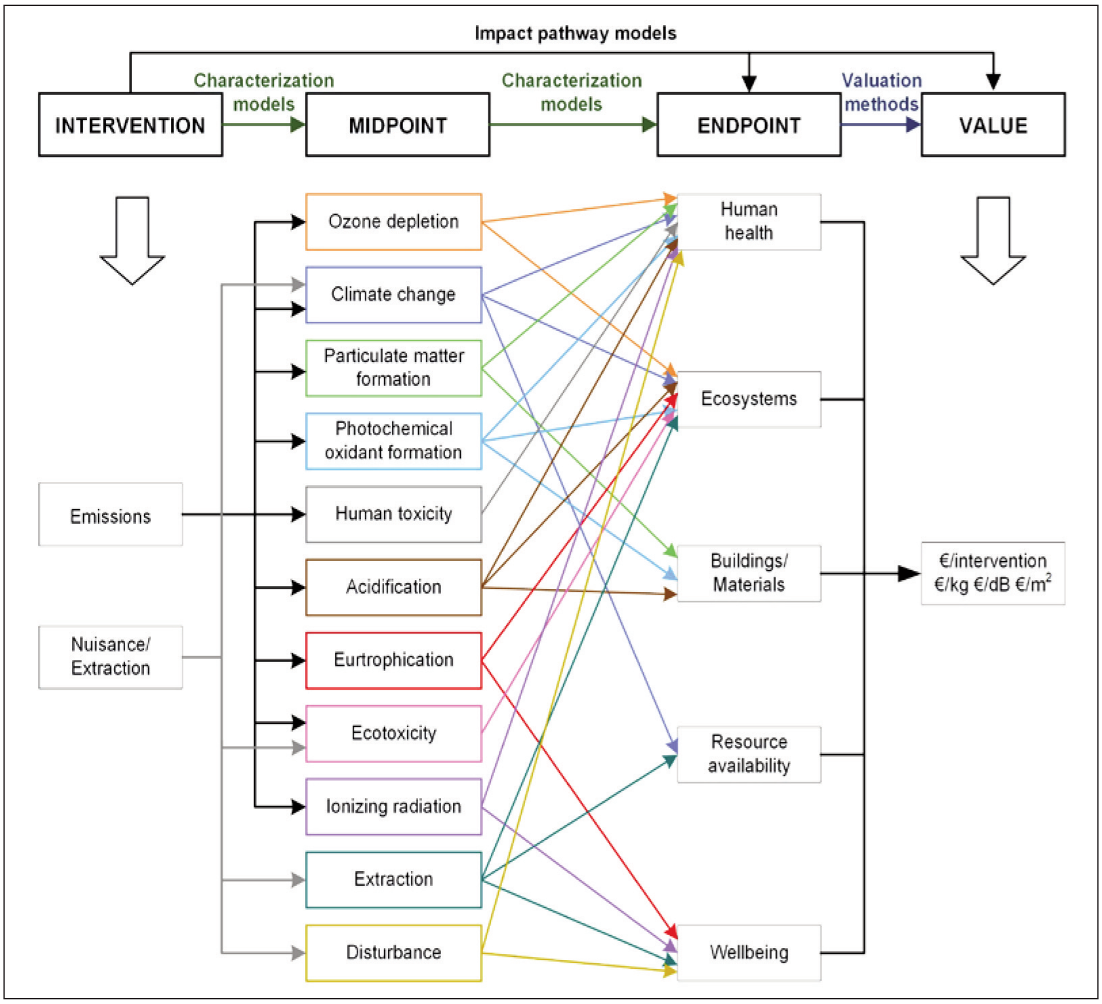

Fig. 1. The framework of environmental prices methodology

different protection areas (human health, ecosystem quality and resource scarcity) [20].

In order to maintain the consistency of midpoint and endpoint impacts, different cultural perspectives (i.e., Individualist, Hierarchist and Egalitarian) are adopted. The CFm and CFe can be calculated as follows:

$$CFm_{x,c} = \frac{S_{x,c}}{S_{r,c}} \quad (1)$$

$$CFe_{x,c,a} = CFm_{x,c} \times F_{m \rightarrow e_{c,a}} \quad (2)$$

where $CFm_{x,c}$ is the midpoint characterization factor of substance x for cultural perspective c. $S_{x,c}$ is the amount of substance x for cultural perspective c. $S_{r,c}$ is the amount of reference substance r for cultural perspective c. $CFe_{x,c,a}$ is the endpoint characterization factor of substance x for cultural perspective c and area of protection a. $F_{m \rightarrow e_{c,a}}$ is the conversion factor from midpoint to endpoint for cultural perspective c and area of protection a.

Impact pathway model

The impact pathway model is a bottom-up method, which can simulate the dispersion and chemical transformation of emission in different environmental media, and convert it into corresponding concentration. The effect on the endpoint is quantified by dose-response function and the impact is assigned to the corresponding monetary value. The specific steps are shown in figure 2.

The model of Meteorological Synthesizing Centre-West of European Monitoring and Evaluation Programme (EMEP/MSC-West) is adopted in the process of emission concentration conversion, which distributes the changes of concentration and deposition per unit of emission into the EMEP grid cells to establish the relationship between emission and concentration in specific areas. The concentration-response function is used to evaluate the endpoint effect in each EMEP grid cell. It can be expressed by mortality, morbidity and potentially disappearing species.

Valuation method

Valuation method establishes the economic relationship between the impacts of the endpoint and the external costs. The model calculates the external costs of five environmental endpoints: human health, ecosystem, building materials, resources and welfare. The valuations are different in different endpoints. For example, the impact of human health is generally expressed in terms of mortality and morbidity, which are measured in life years. Value of a Life Year (VOLY) assigns the monetary values for

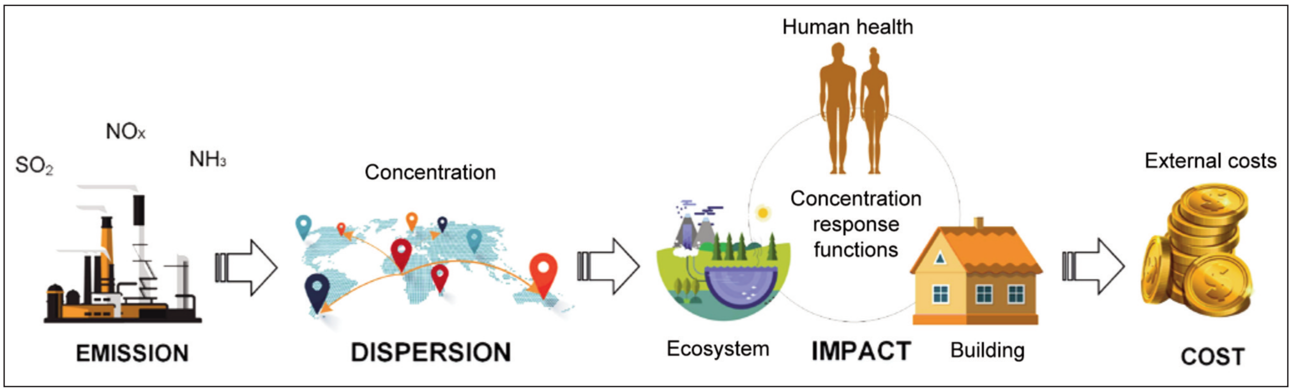

Fig. 2. Impact pathway approach

Table 1

THE VALUATION METHOD OF ENVIRONMENTAL PRICES			
Human health	Health impact	Indicator	Valuation
	Mortality	YOLL (Years of Lost Life)	VOLY [35] (Value of a Life Year)
	Morbidity	QALY (Quality-Adjusted Life Years)	
Ecosystem services	Indicator		Valuation
	PDF (Potentially Disappeared Fraction of Species)		VEDP [36] (Value of Ecological Damage Potential)
Buildings/ materials	Impact		Valuation
	Corrosion due to acidification		NEEDS Project [37]
	Particulate pollution		Rabl [38]
	Corrosion impacts on cultural heritage		Rabl [38] VMM [39]
	Impacts on paint and plastics		Watkiss et al. [40]
Resource availability	Uncertain (Further research is needed)		
Wellbeing	Impact		Valuation
	Noise nuisance		Bristow et al. [41]

Years of Lost Life (YOLL) and Quality-Adjusted Life Years (QALY). Specific evaluation methods are shown in table 1.

Data

China's textile industry can be divided into three sub-industries: Manufacture of Textile (MT), Manufacture of Chemical Fibers (MCF), and Manufacture of Textile, Wearing Apparel and Accessories (MTWAA). In this paper, energy consumption data and wastewater pollutants data of China's textile industry from 2001 to 2015 were collected at the national level. The wastewater pollutants in China's textile industry included Hg, Cd, Pb, As, cyanide, COD and ammonia nitrogen. Environmental prices for pollutants referred to the recommended median values in the environmental prices models. In addition, the missing environmental price of COD was obtained by converting COD into phosphorus through the characteristic factor of water degradation footprint pollutants. The specific data types and sources are shown in table 2.

Table 2

SPECIFIC DATA TYPES AND SOURCES		
Data type	**Unit**	**Source**
Energy consumption	10^4 tce	China Energy Statistical Yearbook (2001–2015) [42]
Wastewater pollutants	ton	China Environment Yearbook (2001–2007) [43] Annual Statistic Report on Environment in China (2007–2015) [44]
Environmental prices	€/kg	CE Delft [22]

RESULTS AND DISCUSSION

Based on the environmental prices methodology, the social marginal values of waste emissions from China's textile industry and the three sub-industries from 2001 to 2015 were calculated and shown in figure 3.

According to figure 3, the social marginal value of the textile industry increased in volatility, from €9.556

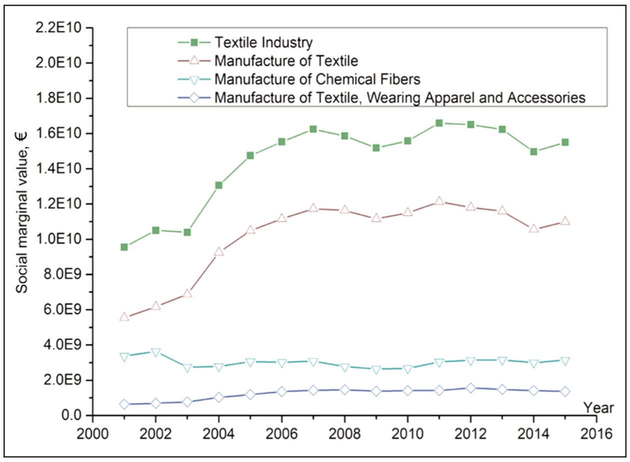

Fig. 3. The social marginal value of the textile industry and its sub-industries from 2001 to 2015

billion in 2001 to €15.508 billion in 2015, with an increase rate of 62.30%. From 2001 to 2003, the social marginal value of environment increased firstly before a little declining. While from 2004 to 2007, the value increased rapidly and reached a peak of €16.252 billion in 2007. The reason for the sharp increase during this period was that the Chinese government issued a series of policies to accelerate the development of the textile industry. According to the data of China textile industry development report [45], the gross value of industrial output of textile enterprises above designated size increased from RMB 1610.7 billion in 2004 to RMB 3058.2 billion in 2007, with an increase rate of 89.87%.

Influenced by the global financial crisis in 2008, China's textile industry economy showed a downward trend for the first time after years of steady and rapid growth. According to the national bureau of statistics' data [45], the growth rate of the gross value of industrial output of textile enterprises above designated size dropped by 8.84% in 2008 compared with the same period in 2007. The exports of textile and apparel also dropped by 11.13%. With the overall slowdown in production and sales, the social marginal value of the textile industry experienced a synchronous decline to €15.191 billion in 2009. To cope with the sluggish economy, the government adopted a series of macro-control policies to provide a relatively loose domestic environment for China's textile industry since 2009. According to the statistics [45], the growth rate of industrial output value of the textile industry increased by 17.16% in 2010 and 26.84% in 2011 respectively. As showed in figure 3, the value increased again from 2009 to 2011, and reached the maximum value of €16.599 billion in 2011. Contrary to expectation, the social marginal value had revealed a trend of gradual decrease since 2012. Aimed at improving environmental benefit, the government issued strict restrictions on the textile industry, including energy consumption restriction, carbon dioxide emission intensity restriction, water consumption restriction and emission restriction of major pollutants. These restrictions led to the decline in social marginal value. Obviously, it can be concluded that the social marginal value of wastes in China's textile industry was not only closely related to the scale of the industry, but also influenced by the international market and government policies. Figure 3 also shows the potential contribution of social marginal value in the three sub-industries. MT was found to have the largest social marginal value followed by MCF, and MTWAA. The value of MT was much higher than that of other two industries. Another notable finding is that the fluctuation trend of MT was consistent with the general trend of the textile industry and the value of MCF and MTWAA changed slightly from 2001to 2015. It can be argued that the MT dominated the social marginal value of the textile industry, which means that the MT had a greater environmental impact.

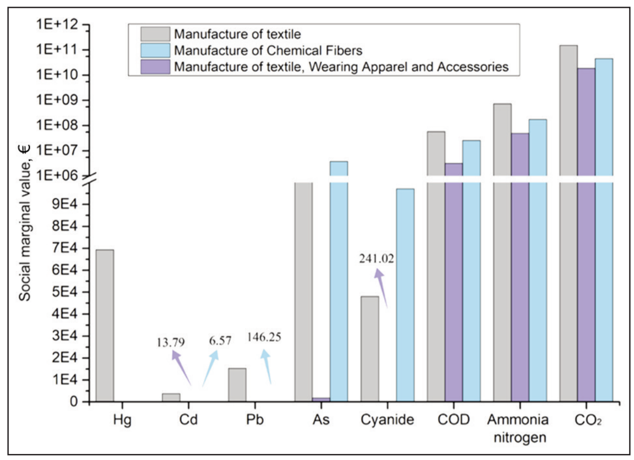

Fig. 4. The social marginal value of pollutants in three sub-industries

Figure 4 shows the social marginal value of pollutants in three sub-industries from 2001 to 2015. The pollutant with the highest value in the three sub-industries was CO_2, which contributed more than 95% of the total social marginal value. According to the results in Figure 4, the value of ammonia nitrogen was the largest and followed by the values of COD, As, cyanide, Hg, Pb and Cd. Therefore, it can be concluded that ammonia nitrogen caused the greatest impact on water environment. Since there was no corresponding consumption in the production phase, the values of Hg and Pb in MCF and MTWAA were zero. The major contribution of As and cyanide came from MT and MCF. The generation of Hg in the textile industry was little, but the environmental price was higher than that of other pollutants due to its high toxicity and more serious damage to the environment. Therefore, its social marginal value was even higher than the sum of Cd and Pb in the three sub-industries. In general, it can be considered that ammonia nitrogen, COD were the pollutants that had the greatest impact on water environment.

CONCLUSIONS

Textile industry has a serious impact on the environment. This study applied environmental prices methodology to calculate the social marginal value of the environmental impacts caused by the textile industry. The results showed that the minimum social marginal value of China's textile industry was €9.556 billion and the maximum value was €16.599 billion between 2001 and 2015. Among the three sub-industries of the textile industry, MT had the highest social marginal value, while the MTWAA had the lowest. MT dominated the social marginal value of China's textile industry. The pollutant with the highest social marginal value was CO_2. The value of ammonia nitrogen was the largest in wastewater and followed by the values of COD, As, cyanide, Hg, Pb and Cd.

Environmental impact is playing an increasingly important and even decisive role in enterprises' decision-making. Environmental prices can transform various environmental impacts into a unified unit of value. It is useful in identifying pollutants that have a greater impact on the environment in an intuitive way. Therefore, environmental prices methodology can be applied in enterprises' cost-benefit analysis and then find out the hot-spots for costs reduction.

Environmental prices methodology is also a useful tool for environmental governance. The environmental impacts of different companies can be quantified with this tool. The companies with high quantified value will be restricted and even be punished. Moreover, environmental prices methodology can also be applied in environmental tax calculation.

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New composite materials using polyester woven fabric scraps as reinforcement and thermoplastic matrix

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ABSTRACT – REZUMAT

New composite materials using polyester woven fabric scraps as reinforcement and thermoplastic matrix

In this study, polypropylene-based thermoformed composites have been obtained using polyester woven fabric scraps as reinforcement. Four types of matrix have been used for the experiments: biaxially oriented polypropylene bag waste (BOPP), polypropylene nonwoven waste (TNT), 50/50 BOPP/TNT waste and virgin polypropylene fibres (PP). The percentage of matrix has been varied at four levels: 20%, 30%, 40%, and 50%. The effect of matrix/reinforcement mass ratio and matrix type on the mechanical properties of composite materials has been studied. Since the composite materials are intended to replace the oriented strand boards (OSB) in construction and furniture applications, comparison with the characteristics of 8 mm OSB has been made.

Keywords: *composite materials, polypropylene waste matrix, polyester fabric scraps reinforcement, recycling*

Noi materiale compozite care utilizează resturi de țesături din poliester ca armare și matrice termoplastică

În acest studiu, compozitele termoformate pe bază de polipropilenă au fost obținute folosind resturi de țesături din poliester. Patru tipuri de matrici au fost folosite pentru experimente: deșeuri din pungi de polipropilenă orientate biaxial (BOPP), deșeuri din nețesute din polipropilenă (TNT), deșeuri 50/50 BOPP/TNT și fibre virgine de polipropilenă (PP). Procentul de matrice a fost variat la patru niveluri: 20%, 30%, 40% și 50%. A fost studiat efectul raportului de masă matrice/armare și al tipului de matrice asupra proprietăților mecanice ale materialelor compozite. Întrucât materialele compozite sunt destinate să înlocuiască plăcile OSB în aplicații de construcții și mobilier, s-a efectuat o comparație cu caracteristicile OSB de 8 mm.

Cuvinte-cheie*: materiale compozite, matrice de deșeuri din polipropilenă, armare cu resturi de țesături din poliester, reciclare*

INTRODUCTION

The growth trend of world population, the improvement in the living standard, and the shortening of product life cycle all lead to an increase in the amount and diversity of waste. Even if waste management has improved significantly in the last decades, there are still great amounts of waste that are landfilled. Waste disposal into landfills has negative impacts on:

- environment – chemicals contained in waste can contaminate air, soil and ground water with harmful consequences for animals, plants and ecosystems;
- climate – emissions of methane and carbon dioxide from landfills cause the greenhouse effect on planet;
- human health – people's health is affected by air, soil and water pollution;
- economy – valuable materials are thrown away and this causes pressure on virgin resources.

In 2015, the European Commission has launched the first Circular Economy Action Plan that aimed to stimulate the transition to a circular economy in order to accelerate the sustainable economic growth and to create new jobs. The traditional linear economy is characterized by a "make-use-dispose" pattern. Instead, in a circular economy the waste is reduced at minimum by keeping the materials and resources within the economy as long as possible. Although 95% of all textiles worldwide can be reused or recycled, only less than 1% are recycled into new products [1]. The necessity of textile recycling has become a top priority due to fast fashion culture that shortens the product life cycle and generates larger amounts of both post-consumer and pre-consumer waste.

Textile recycling has an old history, textiles being recycled since the eighteenth century. Traditionally, in the mechanical recycling the fabric scraps are shredded into fibres and then spun into yarns or converted into nonwoven fabrics [2–8]. In recent years, research has been done concerning the use of shredded fibres as reinforcement in composite materials [9–14].

In the first research works regarding the obtaining of a composite material based on textile waste, the authors used virgin polypropylene fibres ax matrix and shredded fibres from knitted fabric scraps as reinforcement. The resulted composite material has found applications as chair seat, successfully replacing the textile straps. As the advanced shredding of the knitting fabric scraps is costly and the virgin polypropylene fibres are quite expensive, research has been focused towards the use of textile waste both as matrix and reinforcement. Therefore, pre-consumer and post-consumer waste in the form of polyester woven fabric scraps have been used as reinforcement and 100% polypropylene waste has been used as matrix (BOPP packaging bags and/or nonwoven material) in order to obtain composite materials at the Research Center for Advanced Processes, Products and Materials from the Faculty of Industrial Design and Business Management of Iasi.

This research work aims to study the influence of matrix/reinforcement mass ratio and matrix type on the mechanical properties of thermoformed composites. Matrix/reinforcement ratios of 20/80, 30/70, 40/60, 50/50 have been selected. Four variants of matrix have been used: BOPP bag waste, nonwoven (TNT) waste, 50/50 BOPP bag waste/TNT waste, and, for comparison purposes, virgin polyprolylene fibres. Polyester woven fabric scraps have been used as reinforcement. The composite materials have been engineered as sustainable replacement for fibreboards or oriented strand boards (OSB).

MATERIALS AND METHODS

The raw materials used to obtain composite materials with matrix/reinforcement ratios of 20/80, 30/70, 40/60, 50/50 are presented in table 1.

The composite materials have been manufactured by thermoforming. The technological flow used to obtain composite materials that have waste of BOPP and/or TNT as matrix is the presented in figure 1.

The matrix and reinforcement components were manually blended using “sandwich” (horizontal) layers. The blend was fed to the cutting machines placed perpendicular to each other. The technological parameters of the cutting machines were as follows: blade speed 900 rpm, feeding speed 1.2 m/min, and the gauge between feed roller and the rotating blade 40 mm.

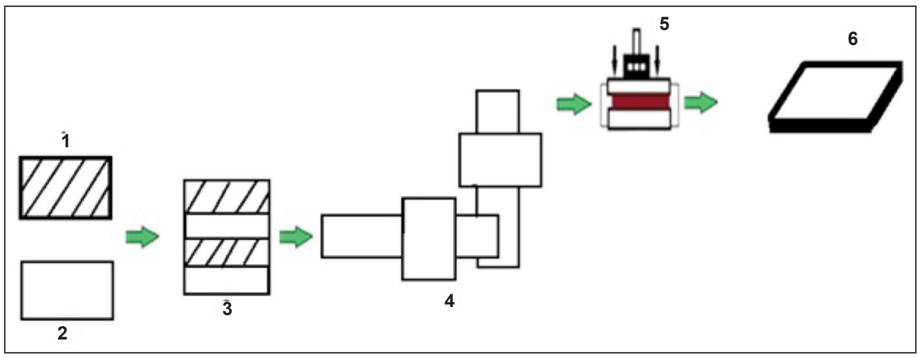


Fig. 1. Technological flow of thermoformed composite manufacturing process: *1* – matrix; *2* – reinforcement; *3* – matrix/reinforcement blend; *4* – cutting machines; *5* – thermoforming machine; *6* – composite material

Table 1

RAW MATERIALS USED TO OBTAIN COMPOSITE MATERIALS

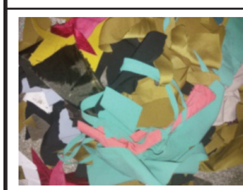
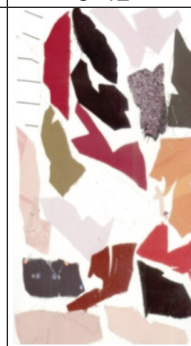
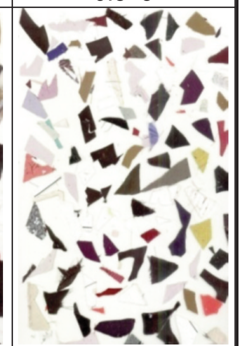
Raw material		Description	Function
	Polyester (PES) woven fabric scraps	Clippings generated in garment manufacturing	Reinforcement
	BOPP bag waste	Nonconformities of BOPP bags used in food packaging	Matrix
	Polypropylene nonwoven waste (TNT)	Clippings generated in upholstery industry	Matrix
	Virgin polypropylene fibres	Linear density 6.69 dtex, fibre length 76 mm, tenacity 3.33 cN/dtex, elongation at break 222.62%, melting point 165^{o}C	Matrix

Table 2

THE SIZE OF THE PIECES OF PES WOVEN FABRIC SCRAPS AFTER CUTTING					
Size class (cm^2)	12–15	8–12	5–8	3–5	0.5–3
					
Mass (g)	180	120	96	72	132
Percentage (%)	30	20	16	12	22

The blend between virgin polypropylene fibres and PES woven fabric scraps has been done after scraps' cutting. Samples of 600 g of cut pieces have been used to analyse their size. The pieces have been scanned and the area of each piece has been measured using AutoCad software. Cut pieces have been distributed in five classes according to their size. The percentage of each class has been determined. As can be seen in table 2, the weight of the classes corresponding to an area higher than 5 cm^2 is significant (66%).
The thermoforming has been done on a machine specially designed and manufactured for the experiments. The thermoforming machine has two plates that can be electrically heated up to 250 °C in order to melt the polypropylene matrix. The plates are connected to a water-cooling system (figure 2).
A quantity of 1200 g of each intimate blend of matrix and reinforcement was placed in a mould (40 cm length × 30 cm width × 15 cm height) jointed with the inferior plate. In order to obtain the composite material, the blend of matrix and reinforcement was heated and pressed.
Based on previous experiments, the following technological parameters have been kept constant:

- Temperature – 190 °C;
- Pressure force – 9 tf;
- Thermoforming time – 15 min.

Sixteen variants of composite materials using virgin PP, BOPP waste, TNT waste and 50/50 BOPP/TNT waste as matrix and PES woven fabric scraps as reinforcement have been obtained in the following mass ratio: 20/80, 30/70, 40/60, 50/50.
Composite materials have been subjected to flexural and tensile testing on LBG testing equipment using TCSoft2004 Plus software (figure 3). Six samples of each composite material variant have been prepared for flexural tests according to BS EN 310 standard. This standard for wood-based materials has been used because the investigated composite materials are aimed to replace the fibreboards/oriented strand boards in construction applications. The sample

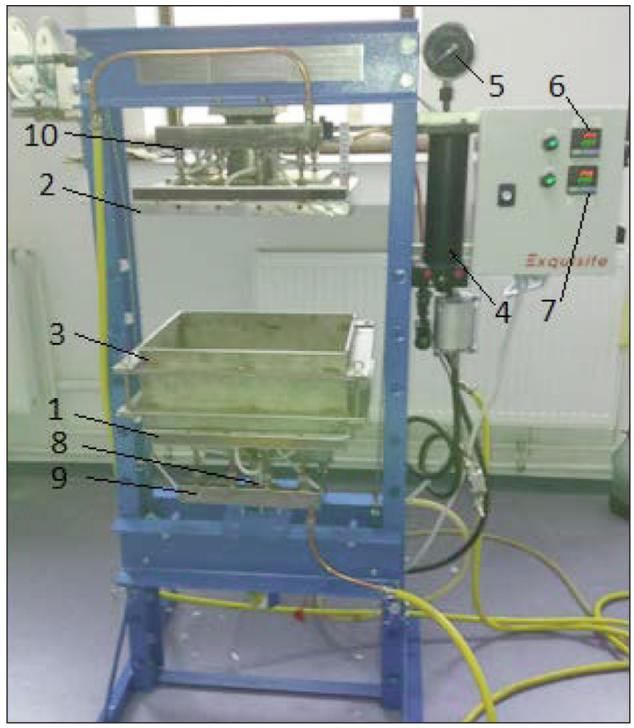
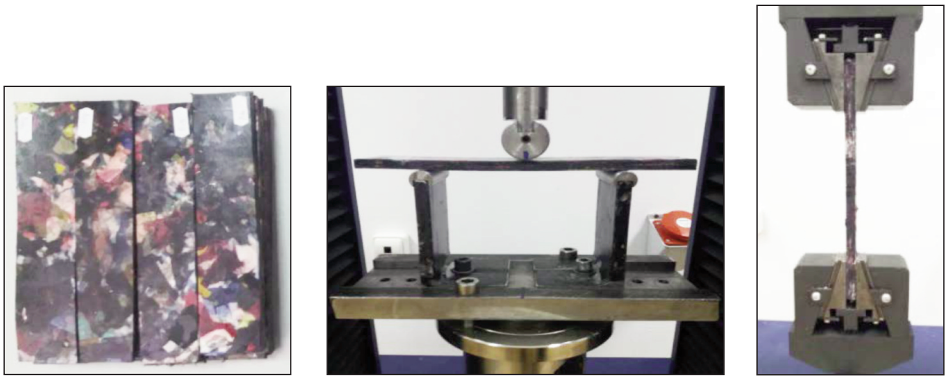


Fig. 2. Thermoforming machine: *1* – inferior plate; *2* – superior plate; *3* – stainless steel mould; *4* – hydraulic pump; *5* – manometer; *6* – superior plate temperature display; *7* – inferior plate temperature display; *8* – hydraulic cylinder; *9, 10* – water-cooling system

width was 50 mm. The sample length was established in accordance with the thickness of the samples at 20%·(20·t + 50 mm), where t is the sample thickness (mm) and 20·t is the distance between supports. The reduction by 20% of the distance between supports has been decided because the samples subjected to flexure did not break. In order to record the maximum bending force in 60±30 s, the speed test was set at 20 mm/min.
The bending strength of composite samples is calculated as a ratio between the bending moment (at the maximum load F_{max}) to the moment of inertia of its full cross section:



a *b* *c*

Fig. 3. Testing of composite materials on LBG testing equipment: *a* – front view of composite samples for flexural tests; *b* – flexural testing; *c* – tensile testing

Taking into account that the matrix and the reinforcement components were randomly blended, the samples for tensile and flexural testing were cut only in longitudinal direction.

RESULTS AND DISCUSSIONS

The mechanical properties of the manufactured composite materials are presented in table 3. Since the composite materials have been engineered as sustainable replacement for oriented strand boards, the mechanical characteristics of 8 mm OSB were also determined, for comparison purposes. Table 3 also presents the requirements set out in standard for bending strength and bending modulus of elasticity of oriented strand boards of 6 to 10 mm thickness.

In figure 4, the tensile stress of composite materials is presented. Regardless of the matrix type, as matrix percent increases up to 30–40% the tensile strength of composite materials increases. After this matrix content the increase is attenuated. The bonds between PES scraps and PP matrix are physical

$$f_m = \frac{3F_{max} l_1}{2bt^2} \quad (1)$$

where f_m is the bending strength [N/mm^2], F_{max} – the maximum load [N], l_1 – the distance between the supports [mm], b – the width of the test sample [mm], t – the thickness of the test sample [mm].

The samples for tensile testing have been cut according to EN 326-1 standard at the dimensions of type 2 sample: 250 mm length and 25 mm width. The tensile tests were run in accordance with SR EN ISO 527-42006 standard using a crosshead speed of 20 mm/min and a distance between grips of 150 mm.

Table 3

MECHANICAL PROPERTIES OF COMPOSITE MATERIALS AND ORIENTED STRAND BOARD

Variant	Composition	Tensile stress (Mpa)	Breaking elongation (%)	Bending strength (Mpa)	Bending modulus of elasticity (N/mm²)
V1	20/80 PP/PES woven scraps	7.56±1.3	10.55±1.16	15.1±2.1	948.08±135.56
V2	30/70 PP/PES woven scraps	11.65±1.25	9.73±0.82	22.0±1.89	1073.04±119.02
V3	40/60 PP/PES woven scraps	12.72±0.6	11.64±1.38	24.2±1.48	1177.70±181.03
V4	50/50 PP/PES woven scraps	13.31±0.53	11.97±1.09	26.5±1.47	1196.60±170.95
V5	20/80 TNT/PES woven scraps	8.54±0.5	14.20±1.71	18.1±2.4	1033.80±198.07
V6	30/70 TNT/PES woven scraps	14.22±1.4	18.19±2.6	30.4±1.4	1173.40±69.28
V7	40/60 TNT/PES woven scraps	19.24±1.14	24.08±1.55	32.3±0.74	1265.90±87.43
V8	50/50 TNT/PES woven scraps	20.47±0.19	24.44±1.23	32.4±1.57	1246.20±81.54
V9	20/80 BOPP/PES woven scraps	8.64±0.77	16.40±1.72	14.3±1.5	966.10±213.61
V10	30/70 BOPP/PES woven scraps	13.03±0.4	19.06±2.67	25.9±2.12	1056.13±152.13
V11	40/60 BOPP/PES woven scraps	20.07±0.81	23.63±2.69	30.8±1.83	1138.70±66.96
V12	50/50 BOPP/PES woven scraps	20.19±1.66	23.82±2.12	31.8±2.46	1235.11±88.66
V13	20/80 (BOPP+TNT)/PES woven scraps	9.07±1.01	16.00±1.09	17.1±1.51	1084.90±191.49
V14	30/70 (BOPP+TNT)/PES woven scraps	13.84 ±1.2	18.70±1.92	28.7±2.41	1275.32±107.21
V15	40/60 (BOPP+TNT)/PES woven scraps	20.73±2.4	24.24±2.12	33.8±1.22	1305.70±101.01
V16	50/50 (BOPP+TNT)/PES woven scraps	21.19±1.64	25.20±4.29	34.5±1.65	1379.55±98.56
-	OSB – transversal 8 mm	2.26	1.40	9.9	1499.00
-	OSB – longitudinal 8 mm	5.68	1.20	23.2	3427.70
-	OSB SN-EN300:2006 transversal 6–10 mm	-	-	11	1400
-	OSB SN-EN300:2006 longitudinal 6–10 mm	-	-	22	3500

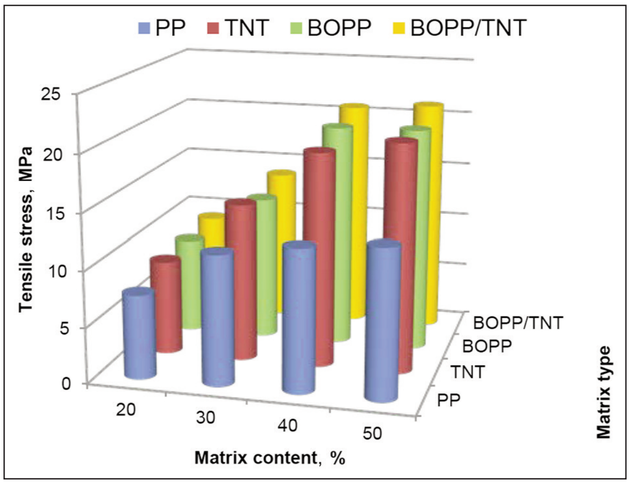


Fig. 4. Tensile stress of composite materials

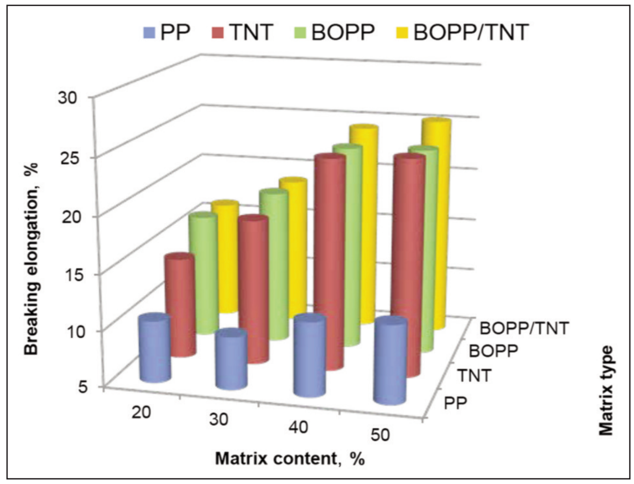


Fig. 5. Breaking elongation of composite materials

bonds. The augmentation of matrix content improves the blend homogeneity and the impregnation with melted PP of PES woven scraps. Therefore, the number of bonds between reinforcement and matrix increases. The lowest value of tensile stress was shown by the virgin polypropylene based-composite materials, probably due to the differences in the form of presentation of matrix component and reinforcement component that led to a non-uniform blend. The matrix component was in the form of densely packed fibers, while the reinforcement component was in the form of scrap pieces with an area ranging from 0.5 to 15 cm^2. The 50/50 TNT/BOPP waste-based composite materials showed the highest tensile strength, no matter the matrix percent. Given the number of determinations (6) and the experimental error, the differences between V8, V12 and V16 are small. A possible explanation for the better tensile strength of V16 variant could be the use of both types of polypropylene waste in the matrix. BOPP and TNT waste have different thicknesses and textures which improves the homogeneity of the mixture with the polyester reinforcement. Irrespective of the matrix type and content, when compared with OSB tensile strength (5.68 MPa in longitudinal direction), the composite materials show an increased tensile strength by 33 % to 373 %.

Figure 5 shows the breaking elongation of investigated composite materials. Generally, an increase in the matrix content leads to an increase in the elongation at break of composite materials. For a given matrix content, the virgin polypropylene based-composite materials presented the lowest values of breaking elongation. The blend of PP fibres and PES scraps is more uneven than the other matrix/reinforcement blends because of the differences between the dimensions and volume of the two components. A comparison between composite materials and OSB highlights values of breaking elongation of composite materials higher by at least 595 % than the values of OSB breaking elongation. Wood has low elongation at break in comparison with both PP matrix and PES reinforcement.

The bending strength of composite materials using virgin PP, BOPP waste, TNT waste and 50/50 BOPP/TNT waste as matrix and PES woven fabric scraps as reinforcement is presented in figure 6. The aim of this research is to validate the possibility to

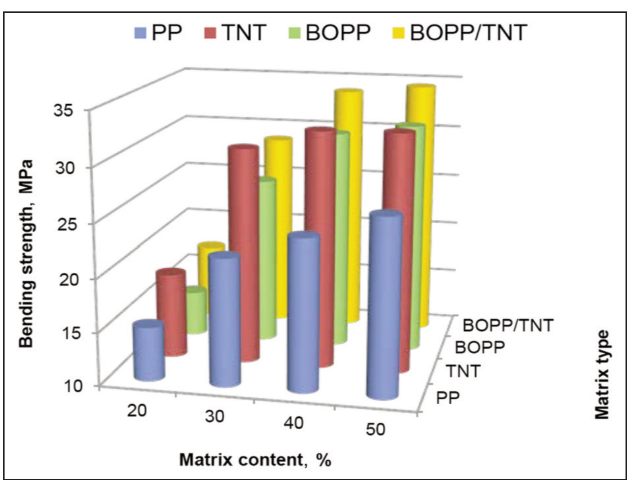


Fig. 6. Bending strength of composite materials

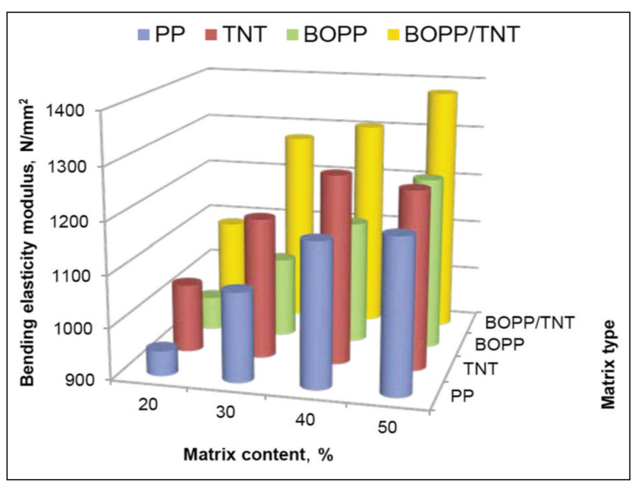


Fig. 7. Bending modulus of elasticity of composite materials

use PES woven scrap waste and PP waste in order to obtain composite materials that have similar characteristics with OSB. Except for the composite materials obtained with a matrix content of 20% that show bending strength lower than the requirements set out in standard for OSB (22 MPa in longitudinal direction), all the other variants of composite materials have a bending strength up to 56.8 % higher than the OSB standard requirements (table 3).

As seen in figure 7, an increase in the matrix content leads to an increase in the bending modulus of elasticity. The bending modulus of elasticity is the only characteristic of composite materials that has lower values than those of OSB, but this could be an advantage in such applications as furniture elements.

CONCLUSIONS

The results of the study show that the recycling of woven fabric scraps into reinforcements of polypropylene waste-based composites is a viable solution for recycling of both post-consumer and pre-consumer textile waste. The use of virgin polypropylene fibres as matrix brings no advantage to the mechanical characteristics of composite materials, all the more so as their price is higher than the price of polypropylene based waste. Composite materials with 50/50 matrix/reinforcement ratio show the best mechanical properties. Taking into account that PES woven fabric scraps are difficult to shred, the aim is to embed in the composite material an amount as large as possible of this category of waste. The TNT and BOPP waste can be reused in the same application as their original one. Therefore, the recommended percent of matrix is 30–40 % due to the fact that the composite materials with this matrix content fulfil the requirements set out in standard for OSB mechanical characteristics.

Taking into consideration the short technological flow, the low costs of raw materials and the solutions provided to environmental issues, the polypropylene waste-based thermoformed composite materials constitute a new solution for the sustainable replacement of fibreboards or oriented strand boards (OSB) used both in construction applications and furniture industry.

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Quantification and evaluation of chemical footprint of woollen textiles

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ABSTRACT – REZUMAT

Quantification and evaluation of chemical footprint of woollen textiles

The chemical pollutants discharged in the production processes of textile products cause severe impact on the environment. The chemical footprint (ChF) methodology provides a new way to quantify the toxicity impacts caused by chemical pollutants. ChF does well in identifying priority chemical pollutants and helping enterprises to select greener chemicals to reduce the environment impacts. In this study, the ChF of woollen yarn were assessed with the data that collected from the production processes. The results showed that the ChF of dyeing process (4.10E+06 l) accounted for the largest proportion, because a large number of auxiliaries were used in the dyeing process to prevent uneven dyeing and colour difference, followed by scouring (7.79E+05 l) and finishing (8.11E+03 l). Among all the discharged chemical pollutants, polyoxyethylene nonyl phenyl ether (1.37E+06 l) caused the most ecotoxicity severe impact on the environment due to its high bioaccumulation and high toxicity to ecosystem, followed by sulfuric acid (1.03E+06 l). Sodium chloride and hydrogen peroxide were the two substances that caused the least environmental load. The overall uncertainty caused by toxicity prediction data accounting for 20.2% of the total ChF, and the uncertainty of the scouring process was the most. The results are referable for wool textiles producers to enhance the textile chemicals management.

Keywords: *chemical footprint, assessment of mean impact, dyeing and finishing, environment load, woollen yarn*

Cuantificarea și evaluarea amprentei chimice a materialelor textilelor din lână

Poluanții chimici rezultați din procesele de producție a produselor textile provoacă un impact sever asupra mediului. Metodologia amprentei chimice (ChF) oferă o nouă modalitate de a cuantifica impactul toxicității cauzate de poluanții chimici. ChF se ocupă de identificarea cu prioritate a poluanților chimici și ajută întreprinderile să selecteze substanțe chimice ecologice, pentru a reduce impactul asupra mediului. În acest studiu, ChF-ul firelor de lână a fost evaluat cu datele colectate din procesele de producție. Rezultatele au arătat că ChF-ul procesului de vopsire (4.10E + 06 l) a reprezentat cea mai mare proporție, deoarece un număr mare de auxiliari au fost utilizați în procesul de vopsire pentru a preveni vopsirea neuniformă și diferența de culoare, urmat de spălare (7.79E + 05 l) și finisare (8.11E + 03 l). Dintre toți poluanții chimici rezultați, eterul polioxietilen nonilfenilic (1,37E + 06 l) a cauzat cel mai sever impact de ecotoxicitate asupra mediului, din cauza bioacumulării sale ridicate și a toxicității ridicate pentru ecosistem, urmat de acidul sulfuric (1,03E + 06 l). Clorura de sodiu și peroxidul de hidrogen au fost cele două substanțe care au cauzat cel mai mic impact asupra mediului. Incertitudinea generală cauzată de datele de predicție a toxicității a reprezentat 20,2% din totalul ChF, iar incertitudinea procesului de spălare a fost cea mai mare. Rezultatele sunt disponibile pentru producătorii de materiale textile din lână pentru a îmbunătăți gestionarea produselor chimice textile.

Cuvinte-cheie: *amprentă chimică, evaluarea impactului mediu, vopsire și finisare, impact asupra mediului, fire de lână*

INTRODUCTION

Textile industry is one of the most important manufacturing industries in the world with long industrial chain and many subsectors. In 2017, the global production of fibers exceeded 90 million tons and the global trade in textiles and apparel exceeded 745.9 billion dollars [1–2]. Chemicals play a vital role in the production of textiles. In 2018, the global market size of textile chemicals exceeded US$ 10 million, and thousands of textile auxiliary agents were widely used in various sub-industries of the textile industry [3]. Taking China as an example, the world's largest producer of textiles, more than 700 kinds of dyes and 1500 kinds of textile auxiliary agents are daily used [4]. The uncombined dyes and auxiliaries are discharged into the environment with waste water, waste gas and waste residue [5]. These discharged dyes and auxiliaries, even contain harmful chemicals such as heavy metals and nonylphenol, cause serious impact on the environment [6].

Chemical footprint (ChF) was first proposed formally by Panko and Hitchcock in 2011 [7]. ChF provides a new perspective to quantify and evaluate the effect on ecosystem caused by chemical pollutants. This solves the problem of inadequate chemical representation in traditional footprint methodology [8]. The Characteristic factor method based on USEtox model to show the environmental load in the form of Comparative Toxic Units (CTU) were widely used in ChF assessment. For example, Bjørn et al. [8] calculated the ChF of agriculture in Europe and Denmark, and showed the distribution of ChF in time and space respectively. Sörme et al. [9] used European Pollutant Release and Transfer Register as a database to calculate the ChF of 54 substances discharged into the air and water in the national region of Sweden. The definition of ChF based on CTU reflects the toxic effect of chemicals with the help of integrated model in the field of environment, and comprehensively reflects the potential impact of chemical emissions on species. On the premise of knowing the time period of environmental load, the ChF based on CTU can be transformed into volume form [10]. Based on the concept of safe operating space, another concept of ChF was defined as the ratio of required to available water volumes in a given geographic area [11]. The discussion of the challenges in improving the relationship between security boundaries and natural thresholds providing ideas for later researchers. With the help of volume-weighted mixture toxic pressure, Zijp et al. [12] calculated the ChF of 630 organic chemicals in Europe and pesticides in the rivers Rhine, Meuse, and Scheldt (RMS). The results showed that the ChF of organic was within the natural carrying capacity of the area, while the ChF of pesticides was far beyond the natural carrying capacity of RMS. Du [13] introduced the assessment of mean impact (AMI) method into ChF and defined the chemical pollution index. Based on the ecotoxicity threshold of freshwater, 21% of China's basin ChF exceed their available freshwater resources by calculated 36 antibiotics which are commonly detected in China's river basins. The essence of this definition of ChF was to check whether the environment in the study area had enough dilution capacity to ensure the ecosystem safety [12]. This can reflect the differences between different regions, and the quantified results were intuitive enough to facilitate the popularization of the theory and understanding of public cognition.

Wool textiles are deeply loved by consumers because of their excellent wearing properties. The statistics show that the global wool textile production exceeded 1.16 million tons in 2017 [1]. The processing (e.g., scouring, dyeing, finishing) of wool textiles consumes large quantities of chemicals and discharges high concentration waste water that contains many kinds of chemical pollutants [14]. Nevertheless, there is negligible literature published on the assessment of impacts caused by the discharged chemical pollutants in the production of wool textiles. Therefore, we aim to investigate the potential ecotoxicity impacts of woollen yarn production with ChF methodology.

In our current study, we applied ChF methodology to quantify the ChF of woolen yarn. Then the impacts caused by chemical pollutants discharged in the production processes were analysed and discussed. What distinguishes this study is that it can provide a specific reference for wool textiles producers to reduce the environmental impacts and carried out sustainable production with green textile chemicals.

EXPERIMENTAL APPROACH AND DATA

Experimental approach

The AMI is a method used to quantify the toxic effects of chemical pollutants, which has the characteristics of compatibility of acute and chronic toxicity data [15]. In contrast to the character factor method, which requires highly integrated USEtox model, the AMI method does not need to rely on limited characteristic factors for accounting. At least three groups of organisms (typically one plant, one invertebrate, and one vertebrate) are selected to represent the three basic nutrition levels in the food chain during the average toxicity assessment process according to AMI method. This means that the AMI method is more feasible in calculating the ChF of new chemicals.

The calculation results of AMI method, which show the environmental load in the form of volume, are more intuitive and convenient for comparison with the environmental space in the follow-up study.

The ChF of a product based on AMI method can be calculated as:

$$ChF = \sum_{i}^{n} \frac{C_{Wi}}{HC_5(NOEC)_i} \cdot V \quad (1)$$

where V (in l) is the volume of chemical pollutants that discharged into the water body. C_{Wi} (in g/l) is the exposure concentration of substances i in water phase. $HC_5(NOEC)_i$ (in g/l) is the safety threshold of aquatic ecosystem.

C_{Wi} can be regarded as the steady-state concentration distributed in the natural water body of the study area after its fate. It can be calculated as:

$$C_{Wi} \cdot V = F_{Wi} \cdot Q_i \quad (2)$$

where F_{Wi} is the mass proportion of substance i in the water phase after its fate (dimensionless), Q_i (in g) – the emission quality of substance i.

To improve the feasibility of accounting, convert $HC_5(NOEC)_i$ to $HC_{50}(EC_{50})_i$ whose data is relatively easy to obtain, $HC_{50}(EC_{50})_i$ can be calculated as:

$$HC_{50}(EC_{50}) = \gamma \cdot 10^{2.94\beta} \cdot HC_5(NOEC) \quad (3)$$

where $HC_{50}(EC_{50})_i$ is the concentration value corresponding to 50% of the potentially affected fraction of species on the curve of species sensitivity distribution based on EC_{50} fitting, and log $HC_5(EC_{50})$ is approximately equal to that of log EC_{50}. γ is equal to 9.8 [16], and β is equal to 0.4 [17].

System boundary and data

The system boundary in this paper was from raw wool to dyed yarn, as shown in figure 1. The whole production process from wool scouring to dyeing was in one enterprise. In this study, only dyestuffs and auxiliaries (e.g., detergent, bases, bleach, levelling agent, smoothing agent etc.) that direct consumed in the production process of coloured yarn were considered for ChF calculation. The data of discharged chemical pollutants in the accounting inventory was provided by the manufacturing enterprise. Toxicity

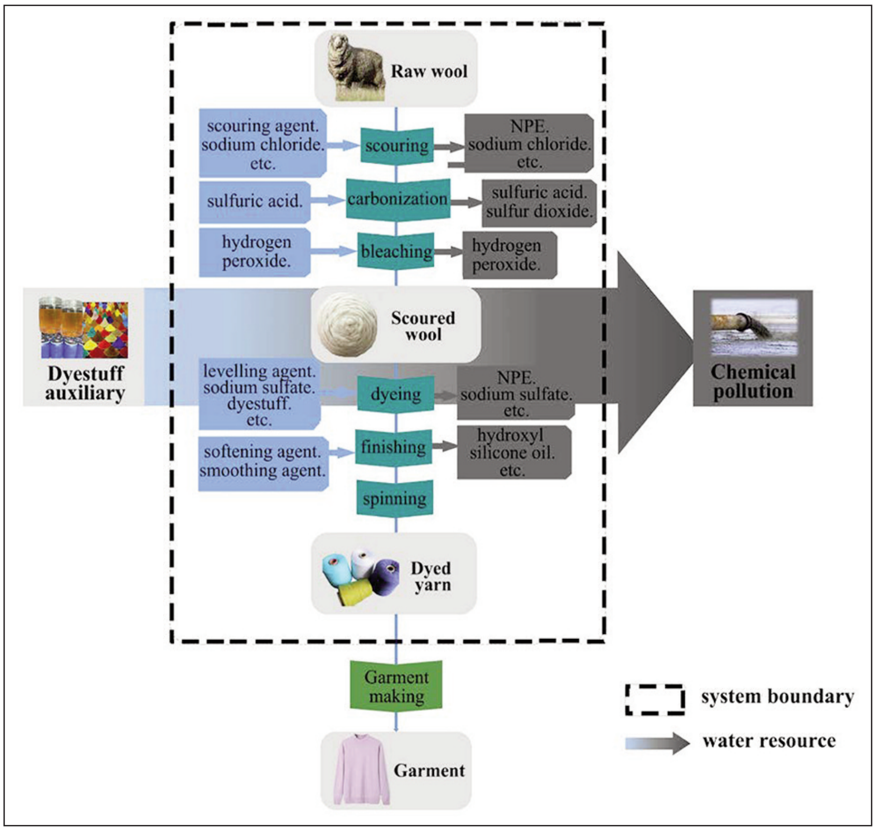

Fig. 1. The system boundary of dyed woolen yarn

combine the dyes before they are absorbed by the fiber, but also pull the dye from the excessively dyed part of the fiber back into the dye bath and transfer it to the insufficiently dyed part of the fiber. Therefore, a huge amount of levelling agent is used in the dyeing process to control the dyeing speed and transfer the dyes, which is the main reason for the great contribution of the dyeing process to the environmental load [19]. This process also requires a large amount of acid solution which maintains an acidic environment, to ensure that functional chemicals such as acid dyes can bind to the amino groups in the wool fiber molecules [20].

The main reason for the great environmental impact of the scouring process is that the ecological toxicity and dosage of the scouring agent used in the process are relatively large. In the scouring process, the raw wool is washed to remove the non-wool contaminants (natural fats, sweats and other impurities) [21]. Sweat and sand impurities can be removed physically, while natural fats are emulsified by scouring agent and pass into suspension. A large quantity of sulfuric acid is used in the carbonization process in order to separate the plant impurities from raw wool [22]. As the main by-product of carbonization process, sulphur dioxide has undesirable effects on the environment [23]. However, the auxiliaries used in the finishing, carbonization, and bleaching processes and the

experimental data of chemical substances were mainly collected from USEtox model and Pesticide Action Network Pesticide database (http://www.pesticideinfo.org). A few toxicity data that cannot be collected from the two sources were predicted by quantitative structure activity relationships (QSAR) model which approximating the often complex relationships between chemical properties and biological activities of compounds [18]. The functional unit in this study was 1 ton of dyed woollen yarn.

RESULTS AND DISCUSSION

Figure 2 shows the calculated ChF of each production process. From figure 2 it can be seen that the ChF of 1 ton of dyed woollen yarn was approximately 4.89E+06 l. The dyeing process contributes the most to ecological toxicity of the dyed yarn with a result of 4.10E+06 l, followed by scouring (7.79E+05 l). The ecotoxicity effects caused in the finishing, carbonization, and bleaching stage were much smaller than those of the above two processes.

In the dyeing process, because the scale layer on the surface of wool is compact and hydrophobic, and given the difference of wool fibers itself, the affinity of wool fibers to dyes is different, which can easily lead to uneven dyeing and colour difference between hair tips and roots [19]. The levelling agent can not only

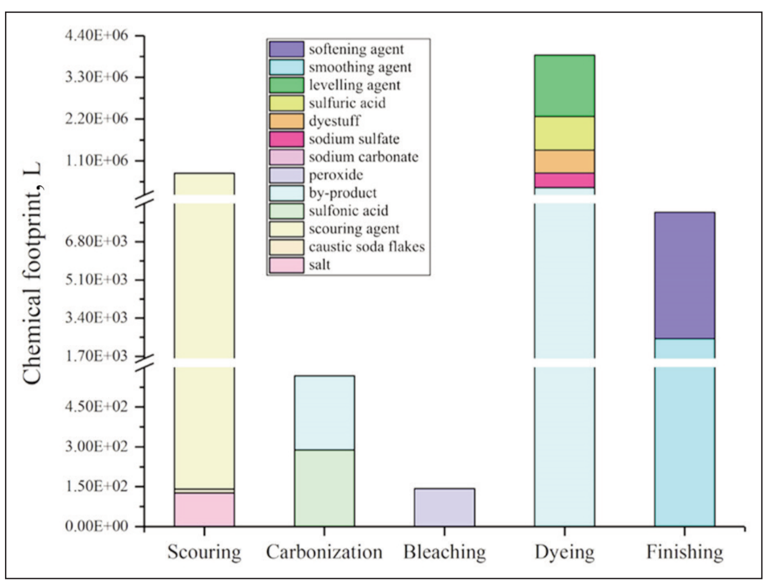

Fig. 2. ChF of process chain segment of dyed woolen yarn

by-products produced in the production process are relatively less toxic, and the types of chemical pollutants contained in the auxiliaries used are relatively less. Therefore, the ChF of these three processes account for a small proportion of the total ChF.

Among all the discharged chemical pollutants, polyoxyethylene nonyl phenyl ether (NPE) was the most ecotoxicity to the environment. The ChF of NPE was approximately 1.37E+06 l, accounting for 28% of the total ChF. The ChF of sulfuric acid was the second largest, accounting for 21% of the total ChF. OctaphenylPolyoxyethyiene and sodium sulphate also caused considerable ecotoxicity impacts. Sodium chloride and hydrogen peroxide were the two substances the caused the least environmental load in this study.

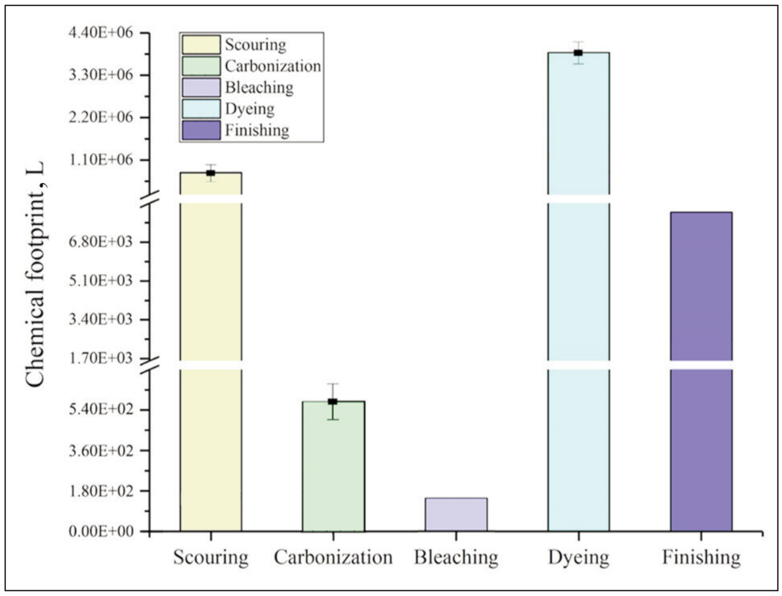

Fig. 3. Uncertainty of process chain segment of dyed woolen yarn

In this case study, NPE mainly comes from levelling and scouring agents. Although its distribution in the water phase after fate is relatively low, NPE belongs to a class of environmental estrogens, which means that it affects the sexual development of organisms and shows toxicity to the reproductive system [24]. Moreover, nonylphenol, the metabolite of NPE after biodegradation, possessed simultaneously estrogenic activities and mutation effects, which easily accumulates in organisms due to its high fat solubility and difficult degradation, thus having a serious impact on the environment [25–26]. In order to improve the product's pigmentation effect, a lot of inorganic salts are needed in the dyeing process. The retarding effect of sodium sulphate in the dyeing process is similar to that of levelling agents. Sulphates have higher fixation rates than anions in dyes, which primarily binds to amino groups in wool fibers. Even though the ecotoxicity of sodium sulphate per unit dose is two orders of magnitude less than that of sulfuric acid, the amount of sodium sulphate used is the largest, which is why the ChF of sodium sulphate is almost the same as that of sulfuric acid. Hydrogen peroxide has a certain carcinogenicity, due to its instability, but it is still considered as a green and environmentally friendly additive since its products of decomposition are oxygen and water.

Compared with the experimental data, the toxicity prediction data obtained by QSAR model have prediction uncertainty. Figure 3 shows the ChF uncertainty of calculated results of each process segment. The overall uncertainty accounting for 20.2% of the total ChF (4.40E+06 l to 5.38E+06 l). The uncertainty of scouring process was the most affected by the prediction data. In the scouring process, the proportion of uncertain value in the process was more than 54% (5.64E+05 l to 9.93E+05 l). Carbonization process was less affected by the uncertainty of prediction data, only 27.4% (4.86E+02 l to 6.40E+02 l). Because the ChF of dyeing process was so large that the uncertainty has little impact on it (3.82E+06 l to 4.38E+06 l), although the uncertainty values of dyeing and scouring processes were in the same order of magnitude. The two processes of bleaching and finishing were not affected by the uncertainty from the prediction data, because the toxicity data of the two processes in the accounting inventory were the experimental data.

CONCLUSIONS

The chemical pollutants discharged in the process of wool textile production have severe impact on biological health and ecological environment. ChF can quantify environmental load from qualitative perspective and control pollution from the original production processes. In this paper, the ChF of dyed woollen yarn were quantified and assessed. The total ChF of selected 1 ton of woollen yarn was 4.89E+06 l. The dyeing process caused the most severe ecotoxicity impact (4.10E+06 l), followed by scouring (7.79E+05 l). The main reason is that a huge amount of levelling agent was used in the dyeing process to control the dyeing speed and transfer the dyes, and a huge amount of scouring agent was used in scouring process to remove natural fats in raw wool. The ChF of the finishing, carbonization, and bleaching stage were much smaller than those of the above two processes.

The discharged NPE (1.37E+06 l) caused the most severe ecotoxicity impact on the environment due to its high bioaccumulation and high toxicity to ecosystem, followed by sulfuric acid (1.03E+06 L). Sodium chloride and hydrogen peroxide were the two substances that caused the least environmental load in this study. The main reason is that the toxicity of sodium chloride is very low and hydrogen peroxide is easy to decompose. It is considered as a green and environmentally friendly additive as its products of decomposition are oxygen and water.

This study also analysed the uncertainty of calculated results due to the toxicity prediction data. The overall uncertainty accounted for 20.2% of the total ChF. The uncertainty of scouring process was the largest, which contributed more than 54% of the total ChF. The data used in the dyeing and scouring processes was experimental data, so they were not affected by the uncertainty of the prediction data.

ChF meet the biological and ecosystem health-oriented policy, so ChF theory can provide policy-making basis for related departments. The results of calculated ChF can help textile enterprises identify priority pollution and show the priority order of improvement. The way of quantitative evaluation of products and processes can guide enterprises to carry out targeted technical improvement and material selection.

At present, the quantification of chemical pollution in textile industry is facing some challenges. The formulation of many auxiliaries is opaque, and the main components are difficult to be determined. An efficient and transparent ChF database is needed. When considering regional differences, it is difficult to obtain toxicity indicators based on local species. The application of ChF in current research is mainly direct ChF, while indirect ChF need further study.

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The effects of government expenditure on sustainable economic growth in India: assessment of the circular economy

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ABSTRACT – REZUMAT

The effects of government expenditure on sustainable economic growth in India: assessment of the circular economy

Government expenditure is linked to the economic growth and is the driving force of the every country. In the post liberalization era, India has been exposed to the dynamics of the world economy due to which India has witnessed a significant impact of Government spending on its economic growth. The objective of this paper is to investigate the effects of the Central Government spending on the growth of the Indian economy over a period, from 2006 to 2016. The online data disclosures of the various ministries have been the major source of secondary data. Co-integration analysis is adopted to evaluate the effect of individual sectorial spending on the economic growth and gross domestic product. The economic spending is classified into 5 sectors namely: General Services, Social Services, Economic Services, Grants in Aid & Contribution and Public debt & Loans for analysis, as disclosed by the sources. The analysis gives us an idea of the various sectors which have a positive impact and the sectors which have a negative impact. The results would play an instrumental role in exploring the sectors in which the government should invest more, thereby contributing to an enhancement in the country's growth.

Keywords: *government expenditure, economic growth, circular economy, Gross Domestic Product (GDP), integration analysis, emerging economies*

Efectele cheltuielilor guvernamentale asupra creșterii economice durabile în India: evaluare în contextul economiei circulare

Cheltuielile guvernamentale sunt legate de creșterea economică și reprezintă forța motrice a fiecărei țări. În era post-liberalizării, India a fost expusă dinamicii economiei mondiale, datorită căreia India a asistat la un impact semnificativ al cheltuielilor guvernamentale asupra creșterii sale economice. Obiectivul acestei lucrări este de a investiga efectele cheltuielilor guvernului central asupra creșterii economiei din India pe perioada 2006–2016. Datele online ale diferitelor ministere au fost sursa principală de date secundare. Analiza co-integrării a fost adoptată pentru a evalua efectul cheltuielilor sectoriale individuale asupra creșterii economice și a produsului intern brut. Cheltuielile economice au fost clasificate în 5 sectoare și anume: Servicii generale, Servicii sociale, Servicii economice, Subvenții pentru ajutoare și contribuții și Datoria publică și împrumuturi pentru analiză, după cum se arată în surse. Analiza ne oferă o idee despre diferitele sectoare care au un impact pozitiv și sectoarele care au un impact negativ. Rezultatele joacă un rol instrumental în explorarea sectoarelor în care guvernul ar trebui să investească mai mult, contribuind astfel la o îmbunătățire a creșterii economice a țării.

Cuvinte-cheie*: cheltuieli guvernamentale, creștere economică, economie circulară, produsul intern brut (PIB), analiza integrării, economii emergente*

INTRODUCTION

Economic growth is pivotal to the sustainable progress of a country, especially in the case of emerging economies. Bökemeier and Greiner [1] suggested that a fundamental feature of emerging market economies consists in a high economic growth performance. The quality of life of the citizens of the country and the economic growth are intricately linked. Ghițuleasa et al. [2] suggested that a sustained growth is based on lowering carbon emissions and supporting environment-friendly farming practices. Investment in education, infrastructure development, improvement in health and medical services, agriculture, housing sector, encouraging local and foreign investments, environmental-friendly measures and proliferation of business-friendly policies would drive the economic growth of the country. Addressing these sectors and the issues relating to it would stimulate the economic activity at the grass root level of the country, thereby driving economic growth from bottom to the top of the economic pyramid. This will also lead to the creation of a lot of jobs in the country and thereby increase employment. The various activities in the country are intertwined together. Altering any phenomenon in one sector of the country affects the other, thereby the government needs to make judicious investment decisions to drive sustainable economic growth.

The per capita income in India had increased only by a meagre 1% until 30 years' post-independence. It was termed as the "License Raj". Very few licenses would be given for business operations which majorly included electrical power, Steel and communications. The growth rate started to increase as India moved towards the idea of liberalization. The Liberalization, Privatization and Globalization reforms of 1991 was the game changer for the Indian economy. A very huge public sector had emerged in the country which made continuous losses. At the same time business owners who had last licenses built up vast empires without much competition. Investments in public infrastructure were very weak due to the prevalence of public sector monopoly.

From the line chart below, it can be observed that the GDP growth in the country is mediocre until 1991. Once the LPG measures were introduced in 1991, subsequently many other policy changes followed. The reforms ended the License Raj, lead to the reduction of interest rates and various tariffs. This again led to the demise of public monopoly and the approval of foreign direct investment in many sectors in an automated manner. The country took nearly 10 years to adjust to the changes and assimilate the new drivers of economic growth. India started to move towards a free market economy. The major change and increase in GDP is observed from 2001 and the growth rates of the Indian economy started to grow faster at 9% from 2003 to 2007. But again, the global financial crisis hit the Indian economy and the growth rate moderated in 2008.

According to the analytics designed by Goldman Sachs, India is predicted to become the 3rd largest economy by 2035 only behind the US and China. Since the start of 2012 India entered a period of reduced growth at 5.6% economic growth. From 2014 India started to recover again entering a phase of accelerated growth of 6.4% and by 2017 the growth rate became 8%. Even though there were many ups and downs in the economic growth rate of the country it was observed that the growth rate almost doubled every 5 years. Through the years, the spending patterns of the government has changed drastically, as observed in the pre LPG era, the government spending wasn't focused much into infrastructure development, education, health and business creation. The investment was more into public sector undertakings, which happened to fail with huge losses. Later on, as the years progressed and the policies were liberalized, the government went more into a regulatory mode, thereby letting private businesses do the business operations part. The government started to act more as a policy supervisor to create an environment conducive to productivity than doing business itself. It started to invest in social services so as to elevate the lifestyle of the citizens of the country. There was a major shift in the spending patterns, boosting the country's growth. This paper investigates the link between the nature of the government expenditure and its spending patterns and its impact on the country's economic growth. This research attempts to empirically validate the link between government disbursements and economic growth witnessed by India in the past decade. This paper also attempts to establish the association between revenue and capital account governmental expenditure and the Gross Domestic Product (GDP).

LITERATURE REVIEW

It has been postulated that public spending can directly influence the economic growth of the country by the Keynesian macroeconomic model. Multiplier effects on aggregate demand are known to trigger an increase in the profitability, employability and investment due to an enhancement in government spending. The human capacity is ultimately elevated due to investments in healthcare, training and social and social services leading to be an economic contributor [4, 5]. Expenditure multipliers provoke an increased

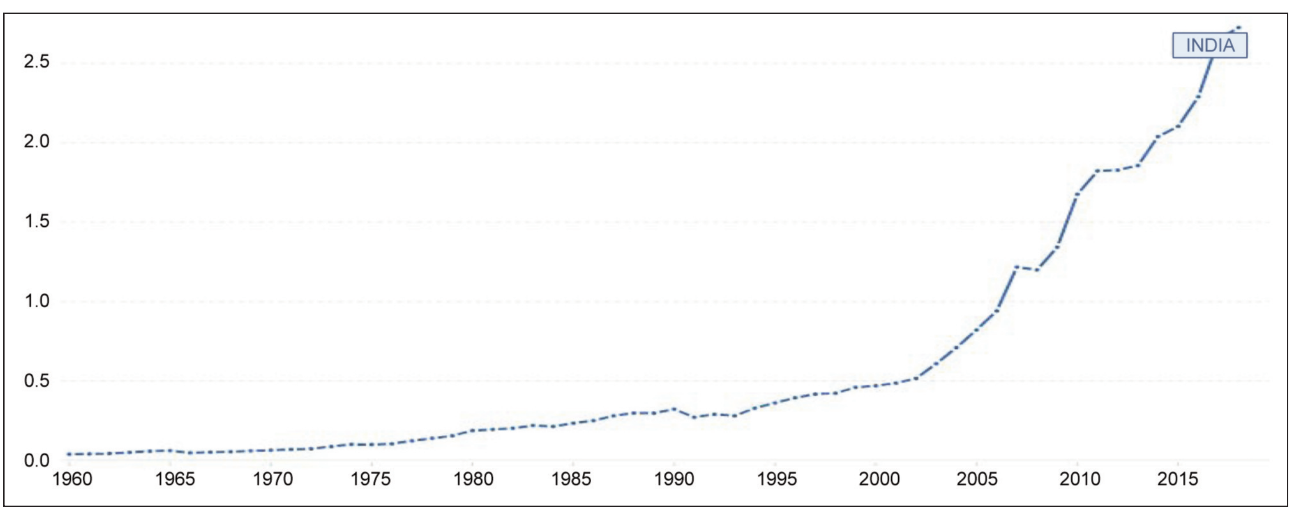

Fig. 1. GDP of India for the sample period from 1980 to 2016 in USD (Trillion) [3]

output when the aggregate demand is augmented by the government spending. The opponents claim that such an approach diminishes the accumulation of capital in the country in the long run and hinders the growth of the economy in the short run [6]. The Government expenditure have been classified as productive and unproductive, and it has been observed that unproductive expenditures have either indirect or no impact on the rate of economic growth. Whereas, productive expenditures have a positive impact on the rate of the economic growth of the country [7]. It has been understood that basic infrastructural spending has an effect on the country economic growth. Consider spending on railway and road network so as to move the goods across the country. Such expenditures ensure that there is an enhancement in the connectivity between various parts of the country and thereby promote trade leading to a contribution to economic activity.

According to Lee and Gereffi [8] developing economies have an opportunity to upgrade in both social and economic terms by linking into global value chains. On the other hand, Hendriks [9] argued that developing countries need to attract the "right kind" of foreign investment in line with their short- and long-term goals. Many countries are victims to poor public spending on medicine and healthcare. The spending patter is such that, the disbursed amount assists hospitals and people in the cities who are in minority rather than the majority located in semi urban and rural areas. This leads to poor health causing decreased productivity, which in turn affects economic growth and productivity. The heavy proportion of the poor relies on traditional medicine and home remedies [10]. Moreover, it has been observed that when the quality of the labor force plays a pivotal role in the country's growth and leads to more economic activity. This originates from the fact that labor force is an essential production factor for determining the production level. Thereby, if the labor force and its quality is elevated the production levels will spur up, contributing to economic growth. There would be a great impact on innovation and productivity [11, 12].

The quality of the human capital is determined by the education in the country. Economic growth has one pivotal influencer, which is education. The nation's wealth has two critical components; physical and human capital [13]. The latter is a very important production factor, which contributes to economic growth. Up-liftment of the lives of people can happen by the development of human capital, which leads to growth in the country by triggering economic activity, as people can lead a higher quality of life. Strategies should be designed to induce a change in the pattern of the spending of the government [10]. Studies have found that there is a negative impact on the education and health development programs in the country when governments design budgets that intensive in defense spending [14]. Previous studies conducted on the impact of government spending pattern that are intensive in defense budgets have led to inconclusive results. It is observed that some studies have displayed that defense expenditure has had a positive effect on the economic growth of the country [6, 15]. On the contrary, a few other studies have found that defense expenditure has a negative impact on the economic growth [16]. Spulbar et al. [17] argued that low-and middle-income countries are distinguished by certain features such as: fast technological change, demographic dynamics, poverty, but also unsustainable economic growth. Moreover, Birau et al. [18] revealed that inequality of chance, in the case of an overpopulated emerging country like India, involves negative effects such as economic and social disequilibrium due to inefficient distribution of resources. Hawaldar et al. [19] highlighted the importance of economic sustainability based on a case study for India based on economic production and long-term economic growth, but without any negative influence on environmental, social, or cultural aspects.

RESEARCH METHODOLOGY

The impact of components of Governmental expenditure on GDP is attempted in this research endeavor. Secondary data is gathered from various government portals and the website of the Reserve Bank of India. The data for the variables considered in the study was obtained from the annual financial statements of the Central Government of India.

Data on Gross Domestic Product is gathered from the website of the Ministry of Statistics and Programme Implementation, Government of India. The independent variables considered for the study are Revenue Account and Capital Account disbursements. In the Revenue Account the subcategories considered are General services, Social services, Economic services and Grants. In Capital Account, the variables considered are General services, Social services, Economic services and Public debt & Loans. The data for a period of 2 decades, ranging from 1996–2016, is collated and analyzed. Data captured is analyzed in two stages. Most of the economic variables falls into the category of non-stationary variables. Firstly, unit root test is conducted to check whether the variables are stationary or not. Subsequently, Cointegration analysis with the help of EViews software. Times series data considered here is first tested for stationary using Augmented Dickey Fuller (ADF) test and then Johansen test is conducted for testing cointegration in the data.

EMPIRICAL ANALYSIS

Time series data from the period 1998 to 2016 has been used in this study. The respective variables under consideration are General Services, Social Services, Economic Services and Grants in Aid & Contribution. The data has been compiled and constructed from various bulletins and data disclosures of the Reserve Bank of India and Government of India. All the variables in consideration are in real terms. Descriptive statistics of the data considered are discussed in table 1.

Table 1

DESCRIPTIVE STATISTICS OF THE ECONOMIC VARIABLES					
Measure	**Revenue Account Disbursements**				
	GSR	**SSR**	**ESR**	**Grants R**	
Minimum	97671.76	9014.15	73437.45	39806.16	
Maximum	924736.15	131471.07	614201.15	344032.49	
Mean	365627.94	54337.6395	291051.4	127085.0835	
SD	252026.172	41180.53	194799.396	98761.98182	
Measure	**Capital Account Disbursements**				
	GSC	**SSC**	**ESC**	**PDLC**	**GDP**
Minimum	9328.58	3377.76	5717.27	199485.3	1301788
Maximum	99183.05	4903.24	182500.8	5738835	15253714
Mean	43951.3	1899.893	46015.55	1800279	5681052
SD	31784.1	2007.372	47860.26	1638216	4508512

All the data for the respective categories and the descriptive statistics for the same are given in the above table. The figures are in cores. Under the **Revenue Account**, General Services averages at 365627.94 crores and it ranges from 97671.76 to 924736.15 with a standard deviation of 252026.172. Again, the Social Services average at 54337.6395 with a range of 9014.15 to 131471.07 with a standard deviation of 41180.53. Similarly, Economic Services averages at 291051.4 with a range from 73437.45 to 614201.15 with a standard deviation of 194799.396. Grants, average at 127085.0835 and range from 39806.16 to 344032.49 with a standard deviation of 98761.98182. Now, let us consider the **Capital Account**. Here, General Services averages at 43951.3 and ranges from 9328.58 to 99183.05 with a standard deviation of 31784.1. Social Services averages at 1899.893 and has a range of –3377.76 to 4903.24 and the standard deviation is 2007.37. When considering the Economic services, it averages at 46015.55 and ranges from 5717.27 to 182500.8 with a standard deviation of 47860.26. Public debt averages at 1800279 and it ranges from 199485.3 to 5738835 with a standard deviation of 1638216. Considering the GDP trends, they average at 5681052 and range between 1301788 and 15253714 having a standard deviation of4508512.

Unit Root Test

The variables involved in the unit root tests are Economic services, General services, Social services and Grants under the Revenue Account. Similarly, in the Capital Account the test is done for Economic services, General services, Social services and Public debt and Loans. The Augmented Dickey Fuller (ADF) Unit Root Test is done. This test enables us to understand whether the variables are stationary or non-stationary, that it's a unit root (table 2).

The null hypotheses for the Revenue account variables are the following:

Table 2

UNIT ROOT TEST OF REVENUE ACCOUNT VARIABLES			
Revenue Account			
Variables	**ADF t-Statistic**	**5% Significance**	**Probability**
ESR	–2.129502	–3.673616	0.4983
GSR	–2.719657	–3.759743	0.2433
SSR	–2.748037	–3.710482	0.2321
GRANTS_R	–1.783872	–3.673616	0.6721

– ESR has a unit root;
– GSR has a unit root;
– SSR has a unit root;
– GRANTS_R has a unit root.

The results show that the probability is more than 0.05. Thereby the null hypothesis cannot be rejected. It is conclude that, all the variables ESR, GSR, SSR are non-stationary.

Table 3

UNIT ROOT TEST OF CAPITAL ACCOUNT VARIABLES			
Capital Account			
Variables	**ADF t-Statistic**	**5% Significance**	**Probability**
ESC	–2.564322	–3.67362	0.2978
GSC	–1.939014	–3.673616	0.5955
SSC	–2.574695	–3.690814	0.2937
PDLC	–0.911926	–3.673616	0.9333

The null hypotheses for the Capital account variables are the following:

– ESC has a unit root;
– GSC has a unit root;
– SSC has a unit root;
– PDLC has a unit root.

The probability obtained is more than 0.05. The null hypothesis should be accepted. Thereby, all the respective variables ESC, GSC, SSC and PDLC are non-stationary.
For GDP, the null hypothesis is GDP has a unit root. It is observed that the probability is more than 0.05; hence the null hypothesis cannot be rejected. Hence, GDP is a non-stationary variable. The Augmented Dickey Fuller test indicates that all the variables being used are non- stationary at level.

Cointegration Test

Since the variables are non-stationary Johansen cointegration test is performed, which is as follows. The test will help understand whether the variables are cointegrated or not. The test is separately run for revenue account and capital account. An insight on the type of effect is gained, namely; positive or negative effect, which the variables have on the GDP and economic growth of India.
The null hypothesis is the following: "The variables are not correlated".
Table 5 reports the trace statistics. A* denotes the rejection of the hypothesis. In the table Critical Value denotes the standard value, whereas the Trace statistic is the value obtained from the test. The variables where the Trace Statistic is higher than the Critical Value are rejected. This means that the variables are correlated. The results show the cointegration equations at the 0.05 level.
The null hypothesis is: The variables are not correlated.
The table 6 reports the statistics for Max-Eigen value. A* denotes the rejection of the hypothesis at the 0.05 level. In the table Critical Value denotes the standard value, whereas the Max-Eigen Statistic is the value obtained from the test. The variables where the Max-Eigen Statistic is higher than the Critical Value are rejected. The Max-Eigen value test indicates the cointegration equation at the 0.05 level.
The equation of utility is presented in table 7. All the equations where the hypothesis is rejected are of value from the results of 5 and table 6. But, the only equation of primary importance to us is in table 7. It gives the perspective as to what are the various effects of the variables of the Revenue account on the GDP of the country. The effects of the variables on GDP are considered by reversing the signs before them. It can be observed that the Economic services, General services, Social services and the Grants all have a positive effect on the GDP of India.

Table 4

UNIT ROOT TEST OF GDP			
GDP			
Variables	**ADF t-Statistic**	**5% Significance**	**Probability**
GDP	0.322608	–3.673616	0.9971

Table 5

UNRESTRICTED COINTEGRATION RANK TEST (TRACE TEST) – REVENUE ACCOUNT				
Hypothesized no. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.955294	111.9149	69.81889	0.0000
At most 1*	0.744908	55.97709	47.85613	0.0072
At most 2*	0.640186	31.38671	29.79707	0.0325
At most 3	0.387159	12.98770	15.49471	0.1153
At most 4*	0.206966	4.173998	3.841466	0.0410

Table 6

UNRESTRICTED COINTEGRATION RANK TEST (MAXIMUM EIGEN VALUE) – REVENUE ACCOUNT				
Hypothesized no. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.955294	55.93781	33.87687	0.0000
At most 1	0.744908	24.59038	27.58434	0.1154
At most 2	0.640186	18.39901	21.13162	0.1156
At most 3	0.387159	8.813701	14.26460	0.3020
At most 4*	0.206966	4.173998	3.841466	0.0410

Table 7

COINTEGRATION EQUATION – REVENUE ACCOUNT				
GDP	**ESR**	**GSR**	**SSR**	**GRANTS_R**
1.000000	–0.171270	–0.752644	–0.006418	–0.249400
	0.04327	0.02456	0.01783	0.01483

Table 8

UNRESTRICTED COINTEGRATION RANK TEST (TRACE TEST) – CAPITAL ACCOUNT				
Hypothesized no. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.998230	193.5376	69.81889	0.0000
At most 1*	0.972168	85.81014	47.85613	0.0000
At most 2	0.524192	24.92338	29.79707	0.1642
At most 3	0.470966	12.29678	15.49471	0.1432
At most 4	0.082991	1.472847	3.841466	0.2249

The null hypothesis is: The variables are not correlated.
The table 8 reports the trace statistics. A* denotes the rejection of the hypothesis. In the table, Critical Value denotes the standard value, whereas the Trace statistic is the value obtained from the test. The variables where the Trace Statistic is higher than the Critical Value are rejected. This means that the variables are correlated. The results show the cointegration equations at the 0.05 level.
The null hypothesis is: The variables are not correlated.
The table 9 reports the statistics for Max-Eigen value. A* denotes the rejection of the hypothesis at the 0.05 level. In the table Critical Value denotes the standard value, whereas the Max-Eigen Statistic is the value obtained from the test. The variables where the Max-Eigen Statistic is higher than the Critical Value are rejected. The Max-Eigen value test indicates the cointegration equation at the 0.05 level.

Table 9

UNRESTRICTED COINTEGRATION RANK TEST (MAXIMUM EIGEN VALUE) – CAPITAL ACCOUNT

Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None*	0.998230	107.7275	33.87687	0.0000
At most 1*	0.972168	60.88675	27.58434	0.0000
At most 2	0.524192	12.62660	21.13162	0.4872
At most 3	0.470966	10.82394	14.26460	0.1632
At most 4	0.082991	1.472847	3.841466	0.2249

Table 10

COINTEGRATION EQUATION – CAPITAL ACCOUNT

GDP	ESC	GSC	SSC	PDLC
1.000000	–3.409982	–0.052223	0.347668	1.706816
	0.05739	0.07328	0.03134	0.04567

All the equations where the hypothesis is rejected are of value from the results of table 5 and table 6. But, the only equation of primary importance to us is in table 7. It gives us the perspective as to what are the various effects of the variables of the Revenue account on the GDP of the country. The effects of the variables on GDP are considered by reversing the signs before them. It can be observed that the Economic services and General services have a positive impact whereas Social services and Public debt & Loans have a negative effect on the GDP of India.

DISCUSSION AND CONCLUSIONS

The objective of the paper is to investigate the various effects of the respective components namely; Economic services, Social services, General Services, Grants and Public debt & Loans on the GDP of the country. The spending patterns of the government have seen tremendous variation over the years, especially from 2000. To investigate the effect of changing patterns of spending and its effect on the economic growth from an economic perspective the Johansen cointegration test has been used. The test has been used over the period of 1996 to 2016. Unit root test is used to identify if the variables are stationary or not, which is then followed by cointegration test to understand the respective relationships. In the long run spending on Economic services, General services, Social services and Grants has proved to have a positive effect on the GDP of the country from the perspective of the Revenue Account. In Capital account, the Economic services and General services have a positive impact on the Economy but Social services and Public debt & Loans display a negative effect on the GDP of the country. The results are significant from a policy perspective. The findings are pivotal especially from the point of view of an emerging (developing) country such as India. In, such countries, the government has to judiciously allocate limited resources in the most beneficial way. The allocation should stimulate economic activity and drive the production of more goods and services within the country.

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Characteristics of textile and clothing sector social entrepreneurs in the transition to the circular economy

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ABSTRACT – REZUMAT

Characteristics of textile and clothing sector social entrepreneurs in the transition to the circular economy

The limits of the present take-make-waste business model are extremely visible when examining the textile and clothing industry. The concept of circular economy gained traction, which has led to the creation of policy actions throughout the life cycle of a product and at disposal. Transitioning from linear to circular economy business models requires significant value-chain changes in both production and consumption patterns. Existing circular business models are paving the way towards a paradigm shift. However, the literature has not retained much empirical evidence about these sustainability-oriented innovators which are invisible and work in anonymity. This study provides a simple, yet rich and unique overview of the characteristics of circular economy business models in the textile and clothing sector in Romania, identified through qualitative analysis performed on the entire population of sustainability-oriented innovators identified in Romania in the textile and clothing sector in a previous study done by the same author. The data was collected using a structured questionnaire with 37 questions connected to four areas: human resources, legal and fiscal framework, customers and communication, and materials, tools or technology employed. With a 100% response rate, the real significance of this paper is that it may have discovered the real contribution of these agents of change in the circular economy, functional circular business models which have never been studied before as a population.

Keywords: *circular economy, innovation, social enterprise, sustainability-oriented innovators, sustainable entrepreneurship, textile and clothing sector*

Caracteristicile antreprenorilor sociali din sectorul textile și îmbrăcăminte în tranziția către economia circulară

Limitele prezentului model de afaceri preia-produce-consumă sunt extrem de vizibile când examinăm industria textilă și de îmbrăcăminte. Conceptul de economie circulară a câștigat tracțiune, ceea ce a condus la pollitici publice care vizează tot parcursul ciclului de viață al unui produs. Trecerea de la modelele de afaceri bazate pe liniaritatea resurselor folosite la modele circulare necesită modificări semnificative ale lanțului valoric atât în modelele de producție, cât și în cele de consum. Modelele circulare de afaceri existente deschid calea către o schimbare de paradigmă. Cu toate acestea, literatura de specialitate nu a reținut multe dovezi empirice despre acești inovatori orientați spre durabilitate, care sunt invizibili și funcționează în anonimat. Acest studiu oferă o imagine de ansamblu simplă, dar bogată și unică, a caracteristicilor modelelor de afaceri circulare din sectorul textil și de îmbrăcăminte din România, identificate prin analiză calitativă efectuată asupra întregii populații de inovatori orientați spre sustenabilitate identificați în România în domeniul textile și îmbrăcăminte într-un studiu anterior realizat de același autor. Datele prezentului studiu despre caracteristicile inovatorilor din domeniul textile și îmbrăcăminte au fost colectate folosind un chestionar structurat, cu 37 de întrebări legate de următoarele subiecte: resurse umane, cadru juridic și fiscal, clienți și comunicare, materiale, instrumente sau tehnologie utilizate. Cu o rată de răspuns de 100%, importanța acestei cercetări este că prezintă contribuția reală a acestor agenți de schimbare în economia circulară, modele funcționale de afaceri circulare care nu au mai fost studiate până acum ca populație.

Cuvinte-cheie: *economie circulară, inovare, întreprindere socială, inovatori orientați spre sustenabilitate, antreprenoriat durabil, sectorul textile și de îmbrăcăminte*

INTRODUCTION

The transition to a circular economy is associated with circular businesses, models concerned with the sustainability of materials, processes, mainly sustainability of the value chain [1–3]. Despite the lack of circular strategies, existing business models are steadily shaping the textile and clothing sector. These innovators are contributing to the transition to the circular economy through incremental and transformational innovation. Studies about incremental business models [4–7] are already being discussed in the public space and studied by academia. Sustainability approaches to the textile and clothing sector are shifting from incremental to transformative business models, in an effort to engage in the transition to the circular economy innovations which produce accelerated change [8]. However, transformational innovation has not gained the same momentum, although these are offering real business models of applied circularity.

In Romania, a roadmap to circular economy has not yet been formulated despite of a variety of models available from other Member States, but a tentative proposal for a Circular Economic Strategy is being developed [9]. At this time, the literature related to Romanian circular business models is scarce and best practices in terms of circularity are absent. Most reports narrate about Romanian social entrepreneurs in general without a sectoral classification [10–11]. These innovators are practically invisible and no empirical data has been gathered to document their activities related to circularity. However, these models certainly exist since they appear mentioned in various reports. To summarize, these sustainable business models in the textile and clothing sector in Romania, with environmental and social sustainability in their core business [12] are invisible in the public discourse and their characteristics and achievements are not being promoted. The purpose of this research study was to explore the dimension of these sustainability-oriented innovators in the textile and clothing sector in Romania. To achieve the scope, the researcher identified the characteristics of the sustainability-oriented innovators in the textile and clothing sector by studying four areas related to the business model.

LITERATURE REVIEW

The transition towards a circular economy offers an opportunity to reduce Europe's environmental footprint through measures of diminishing raw material consumption and reducing waste generation [13–16]. In the past decade, the circular economy model has recently gained worldwide attention from business people, authorities and academia [2, 17, 18]. In the perspective of the urgent need for change, the circular business models are gaining traction, which has led to the creation of bi-directional policy actions: throughout the life cycle of a product and at disposal [14, 19, 20, 22]. However, these policies cannot succeed if the business models are not aligning the value chain to the circularity principles. If designed properly for circularity, innovative business models could thrive and contribute to reducing the need for new products and raw materials as well as the efficient use of assets [23]. Textiles waste is relatively small in terms of weight as compared to other waste streams, but it has a large impact on human health and environment [24–27]. The limits of the present take-make-waste business model are extremely visible when examining the textile and clothing industry [6, 7, 28]. Transitioning from linear to circular economy business models is not simple and requires significant value-chain changes in both production and consumption patterns [29, 30]. The shift from a linear to a circular model in the textile and clothing sector is associated with the need to implement innovative business models, but the adoption of circular business strategies in the industry has been scarce [31–33, 9].

Thus, studies are being developed on the innovations in the field, the majority of them are dedicated to incremental innovators, companies dedicated for the mass-market [34]. However, only a few sustainable business models emerged from the population of sustainability-oriented innovators whose mission is environmentally and social driven, with insignificant value attributed to the profit [35–37]. These sustainability-oriented innovators are being recognized for their circular business models and best practices in the transition to the circular economy [8, 38, 39] Recent research [40, 41] identified the population of sustainable-oriented innovators in the textile and clothing sector in Romania: eleven social enterprises are pioneering circular economy. This is the population concerned by this study.

METHODOLOGY

In motivating the decision to use qualitative research, it is important provide a definition and to justify the use of qualitative research methodology. Creswell [42] defined qualitative research as a process of understanding based on different methodological traditions of inquiry that explore a social or human problem. According to Patton [43], through qualitative research methods, researchers produce a wealth of detailed data about a much smaller population. In this particular case, it is important to understand that the population being investigated qualifies for "a hard to reach" or "hard to capture" population [44] characterized by low numbers, members hard to identify, difficulty into identifying commonalities among the members, information about them rarely recorded and available for consultation, and not entirely known behaviour which leads to a poor choice of places or spaces in which to approach them [45].

The data was collected using a structured questionnaire, technique considered particularly useful when the sample size is relatively small [46–49]. It is important to mention that the researcher itself is an active participant in the field under investigation through its role of social entrepreneur in the field of clothing manufacturing at Atelier Merci, a social enterprise based in Bucharest, Romania. Based on prior literature review, the researcher defined the game-changers targeted by this research which are the object of previous research published by the author [40, 41]: small and medium-sized sustainability-oriented innovators, with a business model and mission aimed at contributing to diminishing environmental and social problems. Throughout this study the researcher employed four association of words to which assigned the same significance "game changer", "sustainability-oriented innovator", "social entrepreneur", "agent of change". Eleven Romanian sustainability-oriented innovators were asked to participate in the survey: Made in Roșia Montană, Asociația D'Avent, Iuliana Pîslaru Design, Asociația Mai Bine – REDU, Mesteshukar ButiQ, Cup & Candle, Upside Down, Crucea Roșie, Sector 6 – Bine Boutique, Asociația Viitor Plus – Atelierul de Pânză, Yard Sale, Asociația Merci Charity – Atelier Merci. The response rate was 100%. The questions were designed by combining the findings resulted from previous work [40, 50] and

Table 1

THE SECTIONS OF THE QUESTIONNAIRE			
Section	**Description**	**Number of questions comprised**	**Type of questions (open-ended or closed-ended)**
Profile of the social enterprise	Legal form of the SE, year of creation, number of employees, field of activity	5	closed-ended and open-ended
Current context in Romania for developing a social business	Perceptions on the conditions for starting a SE in Romania, public policies, funding, non-financial support, access to market, workforce, consumers, awareness of SE.	12	closed-ended
Human resources in the social enterprise	Typology of the employees, skills required at employment, difficulties in recruitment, employee training	9	closed-ended and open-ended
Legal and fiscal measures for the social enterprise	Incentives for business development, legislation related to social entrepreneurship	5	closed-ended
Customers and communication of the social enterprise	Typology of customers, collaboration with other SE, marketing.	7	closed-ended
Raw materials and tools or technology in the social enterprise	Type of raw materials and procurement, collaboration with textile plants, product design, tools or technologies, barriers in business development.	11	closed-ended and open-ended
Personal information about the respondent	Name, e-mail, age, gender, education, work experience	9	closed-ended and open-ended

questionnaires from relevant national studies dedicated to social entrepreneurship developed. An e-mail was sent to the SOI database [41] after the content was uploaded in the Google Forms platform for hosting surveys. The response rate was 100%.

The questionnaire applied comprised thirty-seven questions structured into four areas under investigation: human resources, legal and fiscal framework, customers and communication, raw materials and tools or technology. Apart from these categories, the questionnaire comprised two other sections regarding the profile of the respondent and the profile of the social business (table 1). The questions were classified into three categories: open questions, open-ended questions, multiple choice questions. The answers were collected using a Web-based service entitled Google Forms and stored in the researcher's computer locked with a password.

Table 2

QUESTIONNAIRE SECTION: PROFILE OF THE SOCIAL ENTERPRISE		
Questionnaire section	**Question**	**Answer**
Social business profile	The legal form of my social business is:	Open question
	The year of setting up the social business is:	Open question
	Number of employees	Open question
	What does the social business do?	Open question
	The social business is focused on:	1. Production 2. Services

The profile of the social enterprise is composed of the answers provided to thirty-seven questions divided into four sections: human resources, legal and fiscal measures for the social enterprise, customers and communication of the social enterprise, raw materials and tools or technology in the social enterprise (table 2).

FINDINGS

Previous research performed in 2019 employing traditional and virtual sampling research methods determined the population of sustainability-oriented innovators in the textile and clothing sector in the transition to the circular economy in Romania [41]. This population is the subject of analysis of this current research.

Respondents' profile

Most of the respondents to the questionnaire were founders and co-founders of the businesses with 36% of each of the two categories. 45% of them were aged 31 to 35 years old, followed by 26 to 30 years old representing 36%. 83% of the respondents were female. Most respondents have a bachelor degree (55%), followed by a master degree (45%). 64% of the respondents have previous studies related to entrepreneurship. 73% of the respondents believe it would have been useful to pursue an entrepreneurship course before working in the social business. All the respondents have previous work experience. To summarize, the respondents are the creators of the social businesses analysed, majority females aged between 26 to 35 years old, with previous work experience and holding a bachelor or master degree, with previous studies related to entrepreneurship.

The characteristics of the sustainability-oriented innovators in the textile and clothing sector

Business profile

54% of the SOI are dedicated to textile recycling (figure 1). Analysing the eleven SOI, based on Smits [51], business models advancing the T&C sectors towards circularity, the Romanian SOI in the T&C are based on the "circular" which by definition is a model of creating value from waste [51] and "sufficiency" models which by definition are models based on effective use of resources. The majority of the business models (82%) are circular models of creating value from waste, followed by 73% of business models encouraging effective use of resources 73% of the SOI are dedicated to production.

73% of the SOI respodents are dedicated to production (figure 2).

Legal forms

Four categories of legal forms resulted from the respondents' answers: Non-governmental organisation society with limited responsibility, Authorized person and Social Economy Structure (table 3).

Table 3

REGULATIONS RELATED TO THE LEGAL FORMS ACCEPTED IN ROMANIA		
Legal form	**Acronym**	**Regulated through**
Non-governmental organization	NGO	Official Monitor – 26/2000, 2000
Society with limited responsibility	SRL	Official Monitor – 31/1990, 1990
Authorized person	PFA	Official Monitor – 182/2006, 2006
Social Economy Structure	SES	Labour Ministry – 219/2015, 2015

Most of the SOI were registered as societies with limited responsibility (45%), followed by NGOs with 27%. Only 9% of the SOI were registered as a structure of the social economy, structures developed especially for enterprises acting for the social greater good.

Longevity on the market

The population of the SOI questioned has 1–10 years' experience, with 2 of them having 7 years of experience. It is important to notice that these entities are active on the Romanian market in the last 10 years (starting 2009) though the law on social economy has been published only four years ago, in 2015.

Human resources

All the eleven SOI employed 34 people, ranging from 1 to 12 employees. 90% of the employees of these SOI become productive within the first 90 days of starting a job (figure 4 and 5).

Most SOI hire unemployed people (33%), followed by poor women, rural residents and people with disabilities (11% of SOI for each of the three categories). We should not ignore the other categories of employees which were belonging to vulnerable populations, among them young

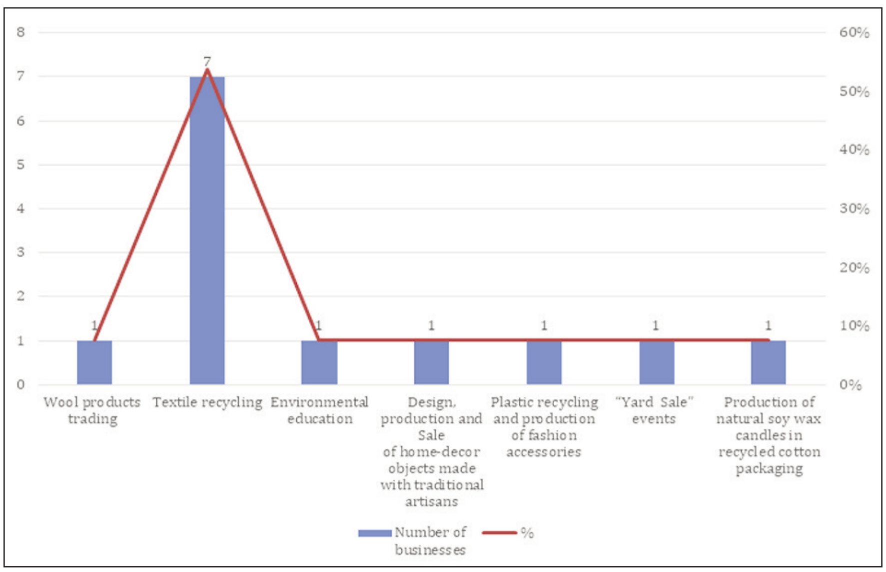

Fig. 1. Main activity of the SOI

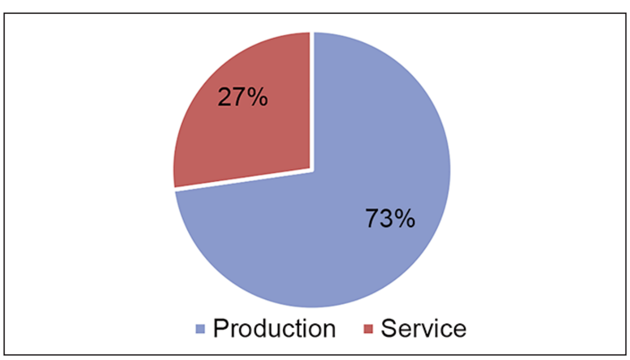

Fig. 2. Type of activity

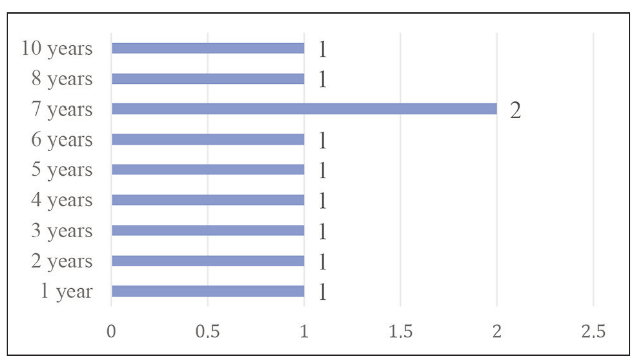

Fig. 3. SOI years of experience on the market

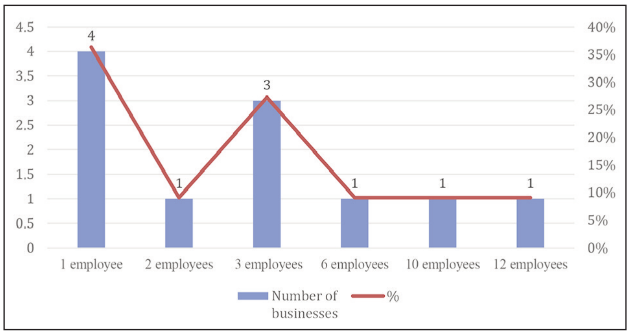

Fig. 4. SOI number of employees

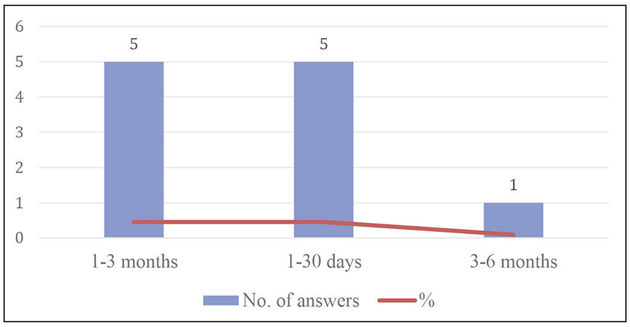

Fig. 5. Employee productivity timeline

people over 18 who are no longer included in the childless care system, Roma people in high-risk situations, women victims of domestic violence, monoparental families, young people and craftsmen. The answers to the question related to "Which skills are you searching for in future employees?" were collected and grouped into four main categories with 40% skills related to tailoring, and each of the following with 20%: skills related to knitting, skills related to product design and skills related to selling products/entrepreneurial spirit. One of the SOI mentioned that the skills related to product design are necessary because the products were purchased for utility and design. Moving to skills related to accountability, in equal percentages, the employer appreciates as being important: organizing abilities, meeting duties on time and being a team player. Third, the respondents highlighted mindset related skills searched in the future employees: the determination to keep a job (20%) while the determination to learn is 80%. The last categories of skills are related to personal values of the future employee, among these the most appreciated being cognitive flexibility (27%), seriousness (18%) and humanitarian values (18%). The people employed show interest in getting a job (44%), while only 25% have the qualification required.

Legal and fiscal framework

55% of the respondents do not have knowledge about the social economy law 219/2015 provisions.

Customers, product and communication

Most customers are individuals (64%) and it is important to signal that public institutions are not among the customers of SOI. The products of the SOI (figure 6) are purchased for design (32%), followed by the mission of the social enterprise (24%) and quality of the fabrics (20%). 82% of the respondents already collaborate with other social businesses. 64% of the respondents intend to collaborate with other SOI. I

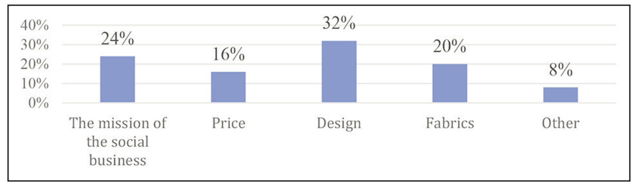

Fig. 6. The characteristics which determine the customers' purchase decision

91% of the respondents intend to launch the business of the international market and the same percentage promote their products through a website and have been mentioned in the media.

Raw materials and technology

42% of the raw materials employed are donated clothing, and only 8% recycled materials (figure 7).

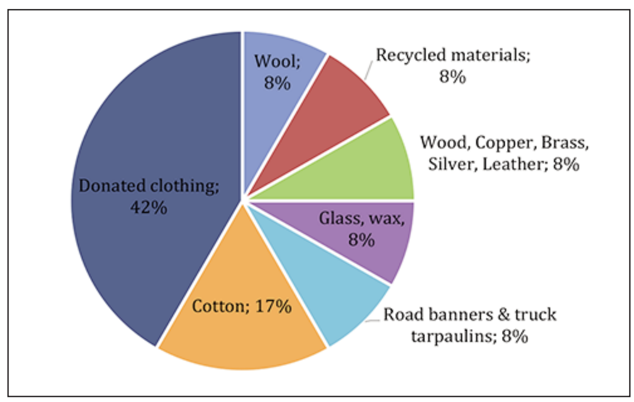

Fig. 7. Raw materials employed in the SOI questioned

Fig. 8. A snapshot of the characteristics of sustainability-oriented innovators in the T&C

The sources of the raw materials (36%) are various companies from Romania, followed by the textile stores and donations from individuals (36%). 47% of the respondents pay per kilo or per meter for their raw material and 40% obtain it without paying. In equal percentage (36%), the design is created in collaboration with a designer or by an employee. There is no collaboration with the Art University or students in the arts. 91% of the equipment is bought and 73% of it comes from Romania. The value of the equipment used is estimated between 2,000 and 5,000 EUR for 55% of the respondents. 64% of the respondents do not collect their used products from the customers as seen in figure 8.

CONCLUSIONS

This is the first exercise of obtaining empirical data about the Romanian sustainability-oriented innovators in the textile and clothing sector and provides valuable information about the distribution and dimension of this category of circular economy stakeholders. The following characteristics were discussed: experience on the market, legal form, main activity, human resources, materials and technology, and customer typology. Although this study was designed to provide preliminary research into the characteristics of sustainability-oriented innovators in the textile and clothing sector in their transition to the circular economy, its real significance may be the discovery of the real impact of these agents of change in the circular economy.

To sum up, the interpretation of the results gave **the following characteristics and contributions of the population of sustainability-oriented innovators in the textile and clothing in Romania**: the majority of the innovators in the textile and clothing sector are circular models of creating value from waste, followed closely by business models encouraging effective use of resources being mostly dedicated to production and less to providing services. Most of the innovators were legally registered as societies with limited responsibility followed by NGO's.

The population questioned has 1 to 10 years' experience, and it is important to notice that these entities have been active on the Romanian market for 10 years (since 2009) even though the law on social economy has been published in 2015. 90% of the employees become productive with the first 90 days of starting a job and most innovators hire unemployed people, followed by poor women, rural residents and people with disabilities.

Most of the characteristic skills related to these specific businesses were related to tailoring, followed by skills related to product design, sale of products and knitting in equal percentages. Next, moving to skills related to accountability, in equal percentages, the employer appreciates organizing abilities, meeting duties on time and being a team player. The last categories of skills are related to personal values of the future employee, among these the most appreciated being cognitive flexibility, seriousness and humanitarian values. 55% of the respondents indicated that they have no knowledge about the social economy law 219/2015 provisions.

Most customers are individuals, and it is important to signal that public institutions are not among these customers. The products are purchased for design, followed by the mission of the social enterprise, and quality of the fabrics. Most of the innovators already collaborate with other social businesses and intend to launch the business of the international market and promote their products through a website. The source of the raw materials are various companies from Romania, followed by the textile stores and donations from individuals. Less than half of the respondents pay per kilo or per meter for their raw material and 40% obtain it without paying. For a third, the design is created in collaboration with a designer or by an employee. There is no collaboration with the Art University or students in the arts. Most of the equipment is bought and three quarters is bought from Romania. The value of the equipment used is estimated between 2,000 and 5,000 Euro for more than half of the respondents. 64% of the respondents do not collect their used products from the customers.

Based upon the findings and the conclusions of the study, **there are two decisively important implications for the circular economy ecosystem sectors.** First, in order to facilitate the transition to circular business models, there are obvious **barriers to transitioning to circular business models signalled by the low scores in some questions which have to be alleviated or best eliminated in order for the circular business models to develop**. Second, **the Romanian textile and clothing sector has functional business models and their activity is not being studied enough.** Their characteristics can serve as best practices for the field of circular economy with the condition of being pulled from anonymity and invisibility, given a voice and placed at the table of discussion about the topic of circular economy. **It is imperative for these circular business models to participate in all conversations about circularity and be inquired about the facilities, which would help these models scale up their businesses.** So far, these circular business models have been only intrinsically motivated and it is the time for external stimulants.

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Clothing development process towards a circular model

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ABSTRACT – REZUMAT

Clothing development process towards a circular model

The textile and clothing industry uses many resources. It causes a lot of environmental problems: water pollution, consuming a massive amount of raw materials, energy, chemicals, etc. The garments are produced to be worn and cleaned several times, and their lifespan is considerably reduced. Over 60% of what the consumer buys, becomes unuseful (either the consumer forgot what he/she has, or the product is not fashionable anymore, or it does not fit). It is compulsory and essential to understand the necessity of creating a new balance between the use of resources, the lifespan of the products and consumer behaviour. Closing the loop and building a new understanding of how the textile and clothing industry can exist is the key to the future – to develop and implement the circular business model. This type of business implies some changes in the production flow: the materials are recycled in several rounds, the design process has to take into account several lifecycles of the items (with the same destination or a different one), the products are designed to be re-included in a system where it is possible, and the consumer has to be educated to accept these categories of products. Each stage of the production process has to be sustainable, environmentally friendly and with a low production cost. In terms of a sustainable design process, this paper presents the main stages of the designing process of a garment (leisure sports jacket), with a versatile shape and usage (garment/ backpack). The garment is designed and manufactured to allow and the vice-versa transformation without any technological modifications. By using a creative and feasible design and manufacturing solution, the waste of worn garments will be considerably reduced, and the product lifespan prolonged, as much as it is possible.

Keywords: *circular economy, versatile garment, design for durability, prolong the lifespan, detachable garment parts*

Dezvoltarea conceptuală a produselor de îmbrăcăminte adaptată unui model de economie circulară

Industria textilă și de îmbrăcăminte folosește numeroase resurse. Din acest motiv apar multiple probleme de mediu: poluarea apei, consumul unei cantități masive de materii prime, consumul de energie, consumul de substanțe chimice etc. Produsele de îmbrăcăminte sunt realizate pentru a fi purtate și curățate de mai multe ori, iar durata lor de viață este considerabil redusă. Peste 60% din ceea ce cumpără consumatorul devine inutil (fie consumatorul a uitat ce deține, fie produsul nu mai este la modă, fie nu se mai potrivește ca mărime). Este obligatoriu și esențial să înțelegem necesitatea creării unui nou echilibru între utilizarea resurselor, durata de viață a produselor și comportamentul consumatorului. Închiderea buclei și construirea unei noi înțelegeri a modului în care industria textilă și de îmbrăcăminte poate exista este cheia viitorului – dezvoltarea și implementarea modelului de afaceri circular. Acest tip de activitate implică unele schimbări în fluxul de producție: materialele sunt reciclate în diferite etape, procesul de proiectare trebuie să țină seama de mai multe cicluri de viață ale produselor (cu aceeași destinație sau una diferită), produsele sunt concepute pentru a fi reincluse în sistem, dacă este posibil, iar consumatorul trebuie educat să accepte aceste categorii de produse. Fiecare etapă a procesului de producție trebuie să fie durabilă/sustenabilă, ecologică și cu un cost de producție redus. În ceea ce privește un proces de proiectare durabil/sustenabil, această lucrare prezintă principalele etape ale procesului de proiectare ale unui produs de îmbrăcăminte (jachetă tip sport de agrement), cu o formă și utilizare versatilă (îmbrăcăminte/rucsac). Produsul de îmbrăcăminte este proiectat și fabricat astfel încât să permită transformarea versatilă, fără modificări tehnologice. Prin utilizarea unei soluții creative și fezabile de proiectare și fabricație, se reduce considerabil cantitatea de produse de îmbrăcăminte utilizate, iar durata de viață a produsului va fi considerabil extinsă.

Cuvinte-cheie: *economie circulară, produs de îmbrăcăminte versatil, design pentru sustenabilitate, prelungirea duratei de viață, repere detașabile ale produsului de îmbrăcăminte*

INTRODUCTION

The textile and clothing (T&C) industry is a diverse and heterogeneous field of activity. It is an essential part of the European manufacturing industry, playing a crucial role in the economy and social well-being of multiple regions of the EU.

In 2019, the entire EU-28 T&C industry represented a € 162 billion turnover. According to the Euratex Key Figures of the Textile & Clothing Industry 2019, the EU T&C industry is formed by 160.000 Textile & Clothing companies, most of which are SME's [1, 2]. The European Commission recently identified the significant potential of this sector to become part of

the circular economy, calling out textiles (apparel and fabrics) as a priority for future development [3].
EURATEX and European Technology Platform developed (October 2016) the document "Towards a 4th Industrial Revolution of Textiles and Clothing – A Strategic Innovation and Research Agenda for the European Textile and Clothing Industry" [4]. According to this document [4], the first seeds of the 4th Industrial Revolution are currently being shown in the European textile and clothing industry. However, significant investments in research and development, and worker education will be necessary for the coming years to achieve the goal of having truly smart textile and clothing factories.
One of the significant Strategic Innovation Themes and corresponding Research Priorities for the next years is Circular Economy and Resource Efficiency, along with:
- Novel flexible process technologies for saving water, energy and chemicals
- High-tech textile recycling for circular economy concepts
- Sustainable substitutes for hazardous and restricted textile processing chemicals or biochemistry based textile processing
- Bio-refinery concepts using European biomass or waste for textile fibres
- Greater use of EU-origin natural fibres.

Recently, the European Commission issued the novel "Industrial Strategy for a globally competitive, green and digital Europe", which mentions three key priorities: maintaining the European industry's global competitively and a level playing field (both locally and globally), making Europe climate-neutral by 2050, and shaping Europe's digital future [5].
In this context, innovation and market potential of the European textile and clothing industry are intimately related to what is known as "Circular Economy". The latter provides a guideline for making investments in production technology (cleaner and less resource-consuming), product development (more sustainable products, focus on recyclability, prolonged lifespan), and for the selection of textile materials (more focus on the use of sustainable fibres).
However, the industry still faces tough challenges in the transition from a traditional linear production and consumption model (take – make – dispose of) to a circular one. In this case, cooperating with all stakeholders in production, retail and waste processing is essential.
Forward, this sector is going to operate according to a globalised and efficient circular economic model (figure 1) that maximises the use of local resources, exploits advanced manufacturing techniques and are engaged in cross-sectoral collaborations and strategic clusters. It is also going to implement profitable and inclusive business models and attract skilled and talented entrepreneurs and employees [6].
Euratex is developing a successful EU Textile Strategy for Circular Economy as a solution for both

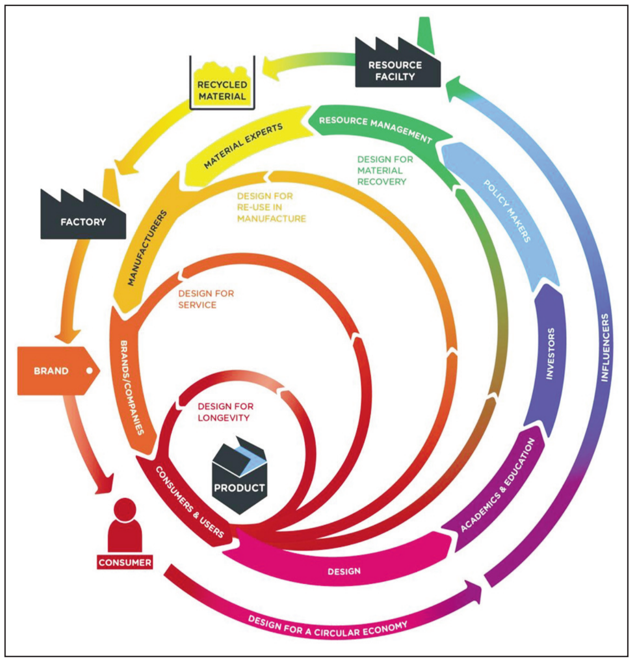

Fig. 1. Globalised circular economic model [7]

social and economic problems. It also aims at reconciling the Environmental-Social-Economic sides of sustainability in the sector and at providing resources for resource-decoupled growth, especially for the European SMEs and the employment they provide. 12 specific points were identified as necessary for making the EU textile circular economy a reality: partnerships between buyers (fashion brands/authorities) and makers (from fibres to finished products) needs, demand lowers cost, product design (or designed for circularity, which includes: i) design for recycling or ii) design with recycled or regenerated materials or iii) design for longevity), consumers, life cycle assessment (LCA), standards, collecting and sorting, green public procurement, the legacy of chemical, national barriers, public-private funding, and new services.
The principle of the circular economy is to minimise waste through cycles of reduction, reuse, and recycling with limited leakage and minor environmental impact [8, 9]. Even though the benefits of the circular economy are relatively well understood, there are still very few examples of companies that have implemented this paradigm [10]. Recent studies observed and analysed the circular economy business model of Eileen Fisher (EF), New York [11]. The study explored how the company had developed its take-back programme and how this programme led to the development of recycling operations at EF. Results were summarised in an analysis of the strengths, weaknesses, opportunities and threats (SWOT) to highlight the advantages and challenges the company faced when it adopted the circular economy concept. The results indicated that a circular economy approach in the luxury fashion industry is possible and is beneficial to extended business, and while both generating revenue and reducing environmental degradation.

PECULIARITIES OF THE DESIGN/MANUFACTURING PROCESS IN THE CONTEXT OF THE CIRCULAR BUSINESS MODEL

The clothing development process is defined as one which turns a concept/idea into a physical item with a specific destination. This process involves several stages of transforming textile materials by using different categories of textile equipment, IT tools, and trained labour force.

Traditional clothing manufacturing processes incur costs determined by the use of raw materials, force labour, energy, water supplies, and other sources.

The producers in the field of clothing, like any other goods manufacturers, must always be aware of the pulse of the market, its financial potential and resources. They should adapt their strategies to the new requirements of nowadays by adopting the circular business model, with a rethinking of the design and production processes, and extending of the product lifecycle, usage flexibility, and diversity.

Some manufacturers have already adopted some of these new measures; they collect the used products from the customers and turn them into raw materials and other final products.

Consumers must be aware of all of these issues; they have to learn to prolong the lifespan of textile products, which means that the latter must also be designed for this purpose. This goal can be accomplished by adhering to the following principles: a design for durability, design for long-lasting style and design for disassembly [12].

The first principle requires textile products to be manufactured in a way that enables them to be resilient to the usual wear and tear and to withstand abrasion and washing. The choice of durable, high-quality fabrics and other components is vital for this purpose, along with how seams are executed (so that they can withstand tearing) [13].

The second principle refers to the users' sensitivity to style and the changes in fashion trends. By carefully selecting colours and styles that are regarded as timeless and appealing to a wide range of customers, designers prevent the items from being perceived to be out-of-fashion and dispose of. Moreover, timeless items retain a higher value on the second-hand market, further encouraging prolonged use and reuse.

Finally, how a textile product is assembled determines how easily it can be disassembled to facilitate maintenance, component reuse and/or recycling. For this purpose, design-for-disassembly strategies choose to stitch over gluing, avoid fusible interfacing by using blind hemming and use low-density stitching.

DESIGN FOR DURABILITY

Its purpose and consumer habits influence the lifespan of a garment product. The lifespan of the product is variable and is determined by:

- the type of product: usual, for special occasions, sports, protective or with a particular destination (medical, technical, etc.)
- the shape of the customer's human body, which can be: standard (in terms of proportion, conformation and posture), particular (characterised by asymmetries or peculiar proportions, conformation, or posture), or with disabilities [14];
- how often is the product used;
- the quality of materials used in the production process and the technical accuracy of the operations involved;
- the storage, usage and maintenance conditions;
- the user's habits and background: level of education, financial resources, social status, purchasing habits (some customers might tend buying more frequently than necessary).

Figure 2 explains the circuit that a garment undergoes during its lifespan:

– branch A → using/cleaning (these actions are repeating), and disposal (when the item does not meet the consumer requirements);

– branch B → using/cleaning (these actions are repeating), transformation, reuse/cleaning (repeating), and disposal (in the end).

Branch A corresponds to a linear circuit, whereas branch B contains a loop that extends the lifespan of the product. The latter describes a circular model, in which the item is re-introduced in the usage circuit (with the same destination or with a different one) and used to the greatest extent possible.

The garment transformation process is conditioned by how the garment was designed and manufactured. Thus, several aspects have to be carefully considered:

- the structure and the complexity of the model (number of layers, pieces, category of accessories);
- the shape of the style lines (curvature, length, number, etc.)
- the properties and characteristics of the materials (physical, mechanical and surface properties, colours, types of structure, colours, motifs, etc.)
- the manufacturing technology (the type of stitches, assemblies, number of layers in an assembly area);
- the garment destination and style: casual, streetwear, ethnic fashion style, formal office wear, business casual, evening black-tie, sportswear, haute couture, modest fashion, etc.

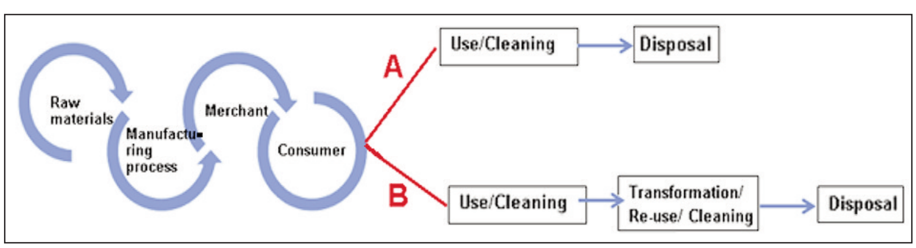

Fig. 2. The lifespan of garment products

- the category of consumers for which it is intended: children (all growing and development phases, teenagers), adults (different ages), etc.
- variants of design and manufacture solution to obtain the garment.

A garment transformation process can be carried out by either keeping the initial intended purpose of the object or by altering it:

- keeping destination → some parts or layers of the garment are replaced or removed;
- changing destination → the garment is used in different ways, without affecting its structure. In this case, we can say that the garment is flexible or versatile one: its transformation can last for a long or a short time, according to the user's preferences.

DESIGNING A VERSATILE GARMENT

In what follows, we are going to present a model of a versatile leisure sports jacket. This type of jacket can be used in two different ways: as a garment or as a backpack.

The design and manufacturing processes are approached to ensure its durability:

– the garment must have some detachable parts whose position can be changed;
– the materials, accessories and manufacturing process ensure the use of the item in both variants;
– the transformation process does not involve technological modifications.

The garment patterns and manufacturing process have to be developed while keeping in mind that the consumers should be able to transform the item by themselves by following precise and simple instructions.

The selected model is presented in figure 3. Because it is a leisure sports jacket, it can be made from fabric which contains cotton fibres. It is also meant to have different accessories placed in different positions to allow its uses. The model has-zippers, pockets with flaps, straps and special pressure staples.

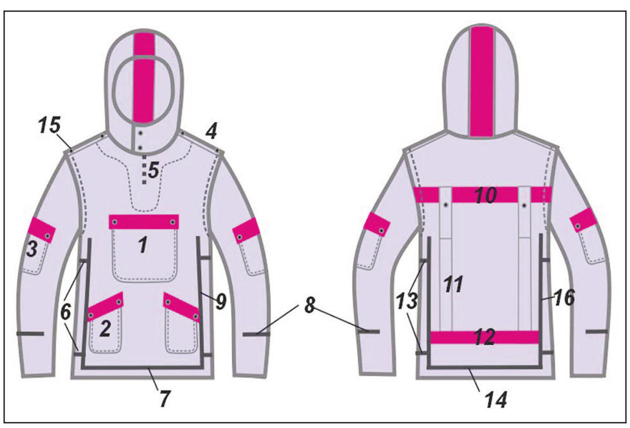

Fig. 3. Leisure sport jacket: *1* – central pocket; *2* – lateral pockets; *3* – sleeve pocket; *4* – shoulder strap; *5* – middle zipper; *6* – front longitudinal zipper; *7* – front longitudinal zipper; *8* – sleeve zipper; *9* – front vertical zipper; *10* – band; *11* – straps; *12* – band; *13* – back longitudinal zipper; *14* – back longitudinal zipper; *15* – pressure staples; *16* – back vertical zipper

Description of the front side

The front side is composed by one main piece with three pockets: one central (1/3 of the central pocket is above the bust line, and 2/3 below) and two other ones placed below the waistline (figure 3). The pockets have rounded corners, and they are also equipped with flaps at the opening line (rectangular-shaped for the upper pocket and parallelogram-shaped for the others). The jacket has a zipper, placed on the middle line, whose purpose is to dress and undress the garment. The facing corresponding to this area is shown in figure 3.

The jacket is also equipped with a hood, well-shaped around the head and the neck, which is made of three pieces (the central one has a rectangular shape). The hood is buttoned with two pressure staples.

The jacket is equipped with zippers covered by pleat facings at the shoulder level. The shoulder area is attached with two pressure staples (one on the right-hand side and one on the left-hand side).

The front is equipped with two vertical zippers (9) and other longitudinal ones (6 and 7), whose purpose is to allow the jacket to transform into a backpack.

Description of the backside

The backside consists of one piece that is equipped with two straps (11), placed symmetrically to the middle line of the backside. Each strap has a loop fixed with a pressure staple. The backside has also got two bands (10 and 12), whose purpose is to reinforce the vertical straps of the backpack. The band (10) is placed at the shoulder blades level, whereas the other one (12) is placed at the hip level. For fashion reasons, these two bands, the pockets flaps, and the central piece of the hood have the same colour.

The backside has zippers: two vertical one with the same length as the front side (16) and horizontal ones as well – the two zippers (13) (symmetric, placed on both the right and left-hand sides) are at the same level as the ones on the front side (6), and the zipper (14) is placed at the same level as the one on the front side (7).

The zippers (7 and 14) are detachable because they are meant to play a role in forming the bottom part of the backpack.

The description of the sleeves

Each sleeve consists of one piece and is equipped with pockets. The latter is placed on the middle line of the sleeve, and they have rectangular flaps. The sleeves are attached to the jacket with zippers and, covered by pleated facings.

The outer material contains 35% cotton and 65% PA, while the reinforcing bands and the middle piece of the hood are entirely made of PES (pink neon colour to ensure excellent visibility, figure 3).

Designing the patterns of the model

The shapes of the pieces of the jacket are designed by first drafting the patterns of the main elements (front, back, and sleeves) and by doing the same for the patterns of the other pieces afterwards (hood, pockets, flaps, straps and facings).

The 2D shape of the pattern blocks are drafted in the Modaris software environment (LECTRA Systems). The shape of the patterns is drawn using specific values. These values are calculated with mathematical relations, whose structure is determined by several factors: the size and shape of the garment (numerical values of lengths and widths), the shape of the human body (dimensions of the body, conformation, proportions), model cut lines, and ease allowances (see figure 4).

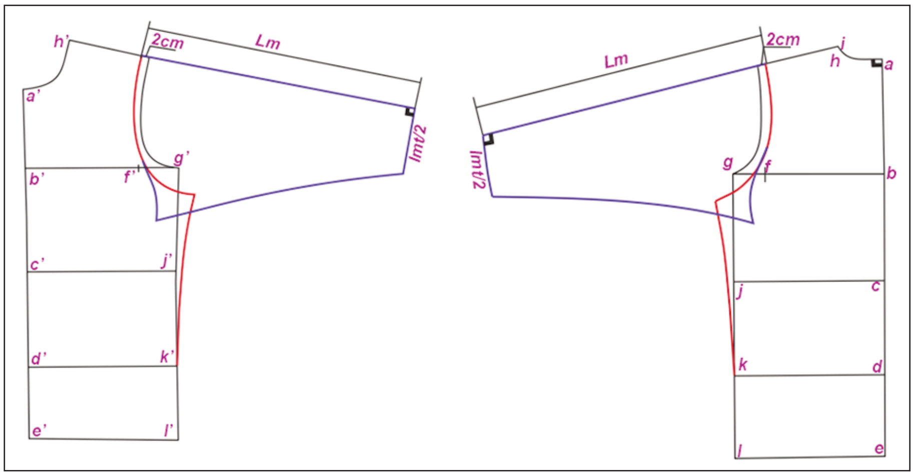

Fig. 4. 2D shape of the pattern blocks

The initial data used to draw the patterns are the body height (I_c), the bust perimeter (P_b), the jacket length (L_{pr}), the sleeve length (L_m), the sleeve width (l_{mt}), and bust ease allowance (A_b).

To be able to draft the hood pattern, one needs to know: the height of the head area (including the neck), the head perimeter neck and the characteristics of the desired hood model. The block starts from point (a) by drawing a rectangular angle.

Mathematical relations:

$(a-b) = P_b/10 + k_1$, k_1 = the value is influenced by the posture of the human body and by the structure of the garment;

$(a-c) = I_c/4 + k_2$, k_2 = the value is determined by the posture of the human body, the structure of the garment, silhouette and cutline;

$(c-d) = I_c/10 + k_3$, k_3 = the value is determined by the posture of the human body, the structure of the garment, silhouette and cutline;

$(a-e) = L_{pr}$ = initial data

$(b-f) = (P_b/8 \pm k_4) + c_1{*}A_b$, k_4 = the value is determined by the posture and conformation of the human body, the structure of the garment, silhouette and cutline;

c_1 = a fraction of the bust ease allowance intended for the backside; it is determined by the posture and the conformation of the human body, the structure of the garment, silhouette and cutline;

$(f-g) + (f'-g') = (P_b/8 \pm k_5) + c_2{*}A_b$, k_5 = the value is determined by the posture and the conformation of the human body, the structure of the garment, silhouette and cutline;

c_2 = a fraction of the bust ease allowance intended for the armhole; it is determined by the posture and the conformation of the human body, the structured garment, silhouette and cutline.

$(f'-b') = (P_b/4 \pm k_6) + c_3{*}A_b$, k_6 = the value is determined by the posture and the conformation of the human body, the structure of the garment, silhouette and cutline;

c_3 = a fraction of the bust ease allowance intended for the armhole; it is determined by the posture and the conformation of the human body, the structure of the garment, silhouette and cutline;

$(a-h) = P_b/20 + k_7$, k_7 = body posture and conformation of the human body, the garment structure, silhouette and cutline influence this parameter.

$(h-i)$ = constant value (2.5 cm)

The vertical distance between points (b') and (h') = $= (a-b) + 3.5$ cm.

The sleeve patterns are drafted in the blocks of the back and front, as it is explained in figure 4.

The chosen model implies the following changes in the main garment elements:

– change the position of the bust line (decreases by 3–5 cm), figure 4;
– increase the backside and frontside width, each by 2–4 cm, figure 4 (red line);
– lift the shoulder point by 2 cm.

Figure 5 shows the new armhole and sideseam lines (front and back). The style lines and design features (for the pockets, hood, facings, straps, flaps, and everything else that is necessary to ensure that the garment can be used for its intended purpose) are marked on the patterns.

The manufactured item has to ensure the use in both ways; from this reason, the category of accessories, sewing threads, sewing parameters and manufacturing stages were attentively established:

– the sleeves are attached with zippers, covered by pleat facings and fixed with special pressure staples;
– the jacket is equipped with zippers on the shoulder line (to attach the front and the back sides), covered by straps and fixed with pressure staples;
– the jacket is equipped with vertical and horizontal zippers (placed on the front and the back sides) to cover some folded parts of the jacket;
– the zippers placed on the sleeves are meant to cover some of their folded parts;

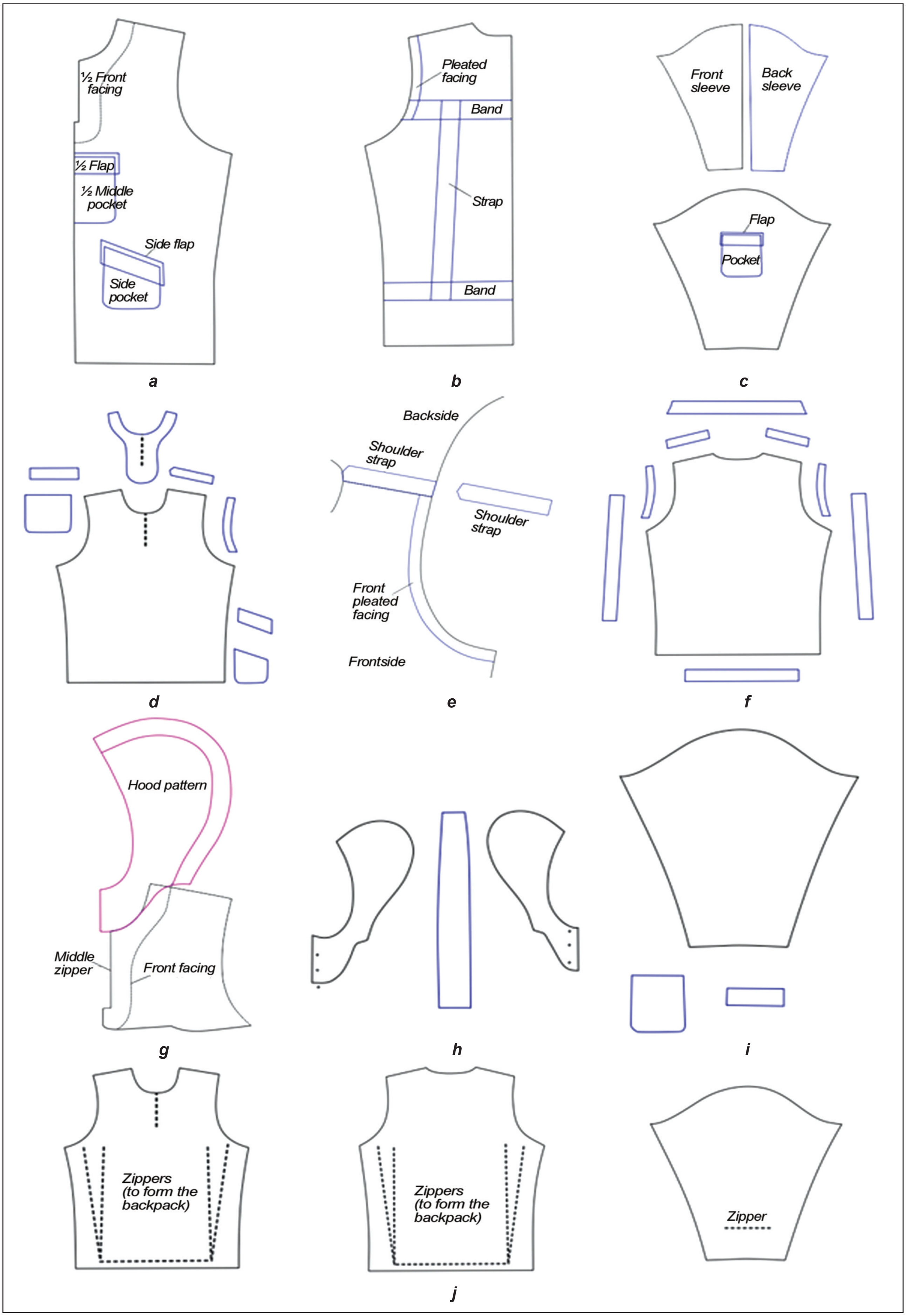

Fig. 5. The final 2D shape of the pattern blocks *a* – frontside; *b* – backside; *c* – sleeve; *d* – pieces of the frontside; *e* – designing the shoulder strap; *f* – pieces of the backside; *g* – hood positioning; *h* – pieces of the hood; *i* – pieces of the sleeves; *j* – placement of the zippers

a *b* *c* *d*

Fig. 6. Jacket transformation into a backpack: *a* – front; *b* – back; *c* – lateral side; *d* – cover

– the hood is folded so that it can become a backpack cover.

Figure 6 shows some stages of the process which transforms the jacket into a backpack.

The customers can use the garment for its initial destination (leisure sports jacket). However, they can also transform it into a backpack by executing a set of simple instructions described below:

– open the pressure staples of the shoulder straps and then open the zippers which fix the front and the back sides on the shoulder lines;
– open the zippers attaching the heads of the sleeves (the ones sewn on the armholes);
– fold the sleeves and fasten them by closing the removable zipper: one side on the middle line (14 cm from the hemline) and the other side on the lateral part, above the zippers attaching the bottom of the backpack;
– close the vertical zippers (front and back);
– close the zippers attaching the sides of the bottom of the backpack;
– close the detached zipper;
– fold the remaining part of front side inside the backpack;
– close the two pressure staples on the folded lines of the front and back sides;
– fold the hood inside the backpack;
– fold the remaining part of the backside to obtain the cover of the backpack;
– close the pressure staples of the pleated facing on the shoulder line and the front fold line;
– open the pressure staples placed on the straps (backside).

The consumer can transform the backpack into the jacket and vice-versa, anytime he wants, or the situation requires.

CONCLUSIONS

The novel circular business model is an incentive for finding proper solutions of reducing the input of primary resources and the production waste, and of cutting down on the environmental impact and quantity of disposal.

The product design stage is essential in developing soft goods with an enhanced lifespan through reuse, maintenance, and recycling.

A longer active lifespan of the item is ensured by proper maintenance and repair services. At the end of their lifecycle, textile products can be used as materials for new fibres/yarns/fabrics and other products.

Clothing development process towards a circular model requires creativity, flexibility and diversity. The customer needs and behaviour, the sources of materials (recycled materials), and the designer knowledge, skills and competencies have to meet together to produce original and fashionable items, with lower productions costs. By integrating the customer in the garment design process, suggesting him different details, understanding his profile, the designer can think to multiple or versatile usage of the product. He can convince the customer about his achievement: with one investment, he gets more than one useful product, without disassembling or destroy it.

The designer has to have the ability to visualise the same item with new possible usages, to understand which materials and technology are necessary to use for producing it and try to exploit its physical characteristics to achieve its versatility.

Designing and producing textile products with an enhanced lifespan (with initial or different destination) will raise awareness and loyalty among consumers. By making a change in their education and habits (which consists of starting to use the same product for more extended periods of time), the consumer will be more responsible. This approach could also be beneficial for the customers, as they will better understand the manufacturing stages of the desired product, the resulting amount of waste, energy, water, and chemicals involved in this process.

By closing the loop of "garment travel", the clothing industry will become more sustainable, it will be able to have a positive impact in terms of economic competitivity, dependence on natural resources and waste reduction.

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Considerations regarding the purchase behaviour for clothes made from recycled textile waste in Turkey

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ABSTRACT – REZUMAT

Considerations regarding the purchase behaviour for clothes made from recycled textile waste in Turkey

Today, more than ever, the increasing levels of recycled textile waste ratios in Turkey make a significant contribution to the development of a sustainable future at global level. This research paper aims to present the attitudes, motives and experiences of the Turkish purchase intention related to textile products coming from the recycling of unused, old or faulty textile products. A quantitative marketing research was carried out on a sample of over 650 participants on the data provided by the questionnaire which focuses on studying the consumer behaviour of textile products coming from the recycling of unused, old or faulty textile products, influenced by endogenous (psychological) and exogenous (sociological) variables. A series of general hypotheses and statistical assumptions were made, the results of which were presented through testing using a series of econometric formulas. The results show important aspects regarding the purchase intention of the textile products coming from the recycling of unused, old or faulty textile products and they also describe the evolution of the market shares of green textile products, based on the perceptions of the Turkish population.

Keywords: *Turkish textile sector, environmentally friendly, eco-friendly clothing, financially sustainable, sustainability*

Considerații privind comportamentul de cumpărare a hainelor confecționate din deșeuri textile reciclate din Turcia

Astăzi, mai mult ca oricând, nivelurile în creștere ale raporturilor de deșeuri textile reciclate din Turcia contribuie semnificativ la dezvoltarea unui viitor durabil la nivel global. Această lucrare de cercetare își propune să prezinte atitudinile, motivele și experiențele intenției de cumpărare a populației din Turcia în raport cu produsele textile provenite din materiale textile neutilizate, vechi sau defecte. O cercetare de marketing cantitativă a fost efectuată pe un eșantion de peste 650 de participanți la datele furnizate de chestionar care se concentrează pe studierea comportamentului consumatorului produselor textile provenite din reciclarea materialelor textile neutilizate, vechi sau defecte, influențate de variabile endogene (psihologice) și exogene (sociologice). Au fost făcute o serie de ipoteze generale și ipoteze statistice, ale căror rezultate au fost prezentate prin testare folosind o serie de formule econometrice. Rezultatele arată aspecte importante cu privire la intenția de cumpărare a produselor textile provenite din reciclarea materialelor textile neutilizate, vechi sau defecte și descriu, de asemenea, evoluția cotelor de piață ale produselor textile verzi, pe baza percepțiilor populației din Turcia.

Cuvinte-cheie: *sectorul textil din Turcia, prietenos cu mediul, îmbrăcăminte ecologică, durabilitate financiară, sustenabilitate*

INTRODUCTION

In the last years, the international market of green textile and clothing products, during the last years, has been in a continuous process of structural mutations [1–3]. As a consequence, the changing of the fundamental elements of the market had a significant influence on the exports from many less developed countries and with economies in transition, where the national incomes depend a lot on the export of green textile and clothing products. The clearest tendency in Europe for the next period is the focus of the retail trade in specialized chains, with an impact on the independent traders (they will represent about 44% of the green textile products distribution) [2].

On the other hand, increased competition and trade liberalization should contribute to the overall objective of sustainable development in all its dimensions (economic, social, and environmental). This poses challenges, such as how to avoid a race to gain or defend market shares resulting in a deterioration of the working conditions – already fragile – of some of the poorer people in the poorer countries: such non-respect of basic labour rights or a worsening of environmental standards should not be considered as part of the comparative advantages of any country [3–5].

In addition, the promotion of sustainable development should be done, as far as possible, through specialized international institutions where they exist, through enhanced cooperation between the EU and these institutions, and using proactive means and compliance with international standards.

Turkey has achieved significant success in improving its textile recycling framework and reforming its public expenditure management system as well as key green textile product markets. The new Stand-by Arrangement and the EU accession create twin anchors for economic policies but strong implementation of the "Zero Waste" reforms is a necessary condition for maintaining the current policy performance [4].

The contribution of the textile industry at the growth of the Turkish economy is tremendous, having in mind the variety of the green products used in the most diverse activity fields. Among the foremost types of green textile products, we name part of an ambitious new waste management initiative [5]. On the other hand, success depends on the recycling technologies used, the high level of textile wastes collection and management.

The importance of the green material is huge, as presently the green technologies are in transition to a domain of green materials. They are multi component recycling materials, with ordered and specific structure, fact that pushes up the existent limits [5].

In order to reduce the gaps in the reuse and recycling of textile waste, the Turkish Government must provide the necessary resources to develop and implement effective textile waste management policies, to provide the necessary infrastructure for their collection and recycling, to set up business partnerships to collect them and recycle better [6]. From this point of view, Turkey intends to align itself with resolving issues related to textile waste management in the European Union.

In recent years, researchers pay more attention to textile products coming from the recycling of unused, old or faulty textile products and identified the following eco-friendly clothing purchase intention: (1) economically purchase motivated; (2) environmentally purchase motivated; (3) economically oriented reuse; (4) environmentally motivated reuse; and (5) awareness-based purchasing [7–11].

Other authors interpreted their analyses in the way that the purchase intention was a more influential factor for environmentally oriented eco-friendly clothing than was one's self-reported actual recycling behaviour of textile waste [12–15]. Also, the results showed that purchase intention is more driven by monetary or economic reasons. Furthermore, gender and age were significant factors predicting to oriented eco-friendly clothing behaviours. Various studies suggest that the communities with a collection programme for recyclable textile waste had a 24% higher participation rate than communities which not oversees the recycling campaign [14–18].

On this background, the statistical hypotheses underlying this research are as follows:

H_1: There is a significant relationship between environmentally friendly attitude and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

H_2: There is a significant relationship between financially sustainable and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

H_3: There is a significant relationship between social Influence and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

H_4: There is a significant relationship between behavioural intention and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

RESEARCH METHODOLOGY

The methodological principles that underpinned the research were the Cartesian principle of analytical division and decomposition and the principle of deductive logical reasoning. Carrying out this research study (at the level of 650 respondents who answered a questionnaire with 35 items with simple and multiple answers), thus contributing to revealing the recycling textile products spirit existing in Turkey, as well as the advantages and disadvantages conferred by the manifestation of the spirit among young people in Turkey, including the risks arising from the implementation of a green business in the context which the Turkish Government aims to increase its textile recycling rate to 35 per cent over the next five years [19–20].

Obviously, it was taken into account that the manifestation of the recycling textile products spirit is directly and indirectly dependent on the conditions of the entity's environment of action (internal and external), as well as on the approach to the risks arising from the following implementation of a business, including different ways of perceiving the green business environment in Turkey.

The quantitative marketing research ran from June to September in 2019 on a sample of over 650 people and used a survey based on questionnaire appropriate to the research objectives. Using the survey, according to the research interests, it was possible to build a sample of individuals with characteristics close to those of the reference population. The criteria for structuring the population included age, gender, and background. In determining the sample size, a random sampling had to take into account both the accuracy level of the estimation (admitted error) and the confidence interval.

At the level of the population surveyed, a sample size (n) of 850 subjects was found and the share of those aged between 40 and 49 the level of the sample it was 16.62% while the share of the female population at the level of the sample was 72.77% (table 1).

The probability with which the results were guaranteed was p = 95%; therefore, the theoretical value corresponding to the coefficient t in the standardized normal distribution table, specific to a bilateral test, must be 1.96. It has been found that $t\ calc$, the population structure criteria (age 40–49 years = 2.87 and sex f = 2.06) were higher than their theoretical value (1.96); therefore, the sample in this structure could be validated, and the sample was verified by correcting the criteria so that they coincide with the structure of the population surveyed (table 2).

Table 1

DISTRIBUTION OF ADULT POPULATION AND VALIDATION SAMPLE				
Criteria	**Groups of subjects investigated sample (P)**	**%**	**t calc.**	**t**
Age				
18 – 29 years	156	24.00	0.26	1.96
30 – 39 years	182	28.00	0.95	
40 – 49 years	108	16.62	**2.87**	
50 – 59 years	135	20.77	0.33	
over 60 years	69	10.62	0.14	
Total	**650**	**100**	-	
Gender				
Male	177	27.23	**2.90**	1.96
Female	473	72.77	**2.06**	
Total	**650**	**100**	-	

Table 2

SAMPLE REDRESSING STRUCTURE				
Criteria	**P_0 (%)**	**P - redressed**	**t calc.**	**t**
Age				
18 – 29 years	23.53	23.92	0.20	1.96
30 – 39 years	27.41	27.58	0.32	
40 – 49 years	20.55	19.14	0.08	
50 – 59 years	20.96	21.58	0.11	
over 60 years	7.55	7.78	0.04	
Sex				
Male	47.81	48.42	0.09	1.96
Female	52.19	51.58	0.09	

RESULTS AND DISCUSSION

The respondents were asked to assess the importance attributed to the purchase intention related to textile products coming from the recycling of unused, old or faulty textile products based on the perceptions of the environmentally friendly, financially sustainable, social Influence and behavioural intention. Their answers are quantified by an ordinate scale with a five-semantic differentiation, where (+1) represents “insignificant” and (+5) “extremely important”.

Testing of the H_1 hypothesis: There is a significant relationship between environmentally friendly attitude and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

The results of the survey show that over 50% of the valid responses of young people, adults and the elderly have indicated that environmentally friendly is an important factor in the decision-making process of purchasing textile products coming from the recycling of unused, old or faulty textile products (figure 1).

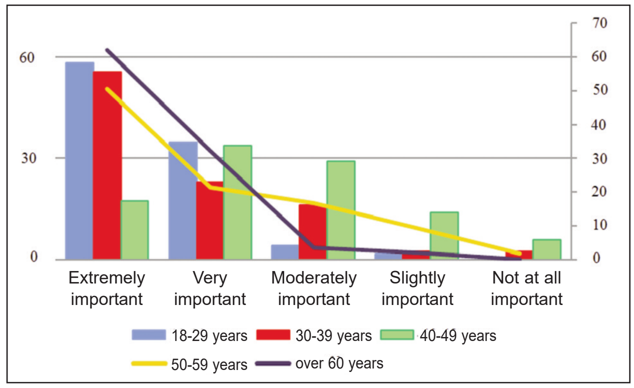

Fig. 1. The environmentally friendly factor on the criterion purchase intention

The first null hypothesis of research states that the respondents’ age and environmentally friendly does not significantly affect statistically the importance of the purchasing textile products coming from the recycling of unused, old or faulty textile products.

Verification of the hypothesis was performed using the x^2 test for two independent variables. Under conditions of a significance level of 0.05 and of 10 specific categories of variables investigated (n = 5, k = 5), 16 degrees of freedom {$n=(r-1)(k-1)$, n = 16} result in an $x^2_{0.95}$ of 28.70. From the comparison $x^2_{calc.} > x^0_{0.95}$ (125.88>28.70) it results that the null hypothesis cannot be accepted.

Testing of the H_2 hypothesis: There is a significant relationship between financially sustainable and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

The second null hypothesis indicates that the gender and financially sustainable of the respondents does not significantly and statistically influence the importance of the purchasing textile products coming from the recycling of unused, old or faulty textile products.

Again, the x^2 test for two independent variables was used to verify the statistical hypothesis. At a significance level of 0.05, where r = 2 and k = 5 and specific categories of variables are examined, it results in four degrees of freedom {n = (r – 1) (k – 1), n = 4} to give $x^2_{0.95}$ of 9.44. As $x^2_{calc.} > x^2_{0.95}$ (16.33 > 9.44), it appears that the alternative hypothesis is accepted, the gender and financially sustainable of the respondent significantly influences the importance of the purchase intention criterion (figure 2).

Testing of the H_3 hypothesis: There is a significant relationship between social Influence and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

In order to verify the null hypothesis indicating that the social Influence factor did not significantly and statistically influence the importance of the purchase intention criterion, the x^2 test for two independent variables was used (figure 3).

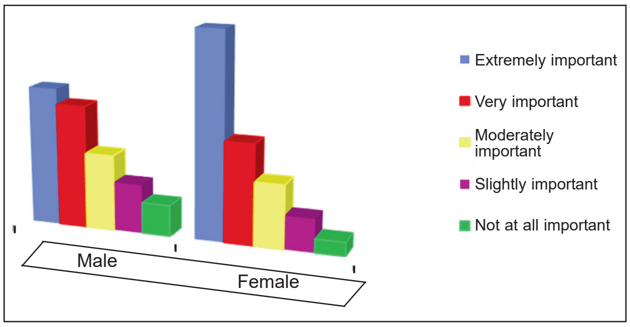

Fig. 2. The financially sustainable factor on the criterion purchase intention

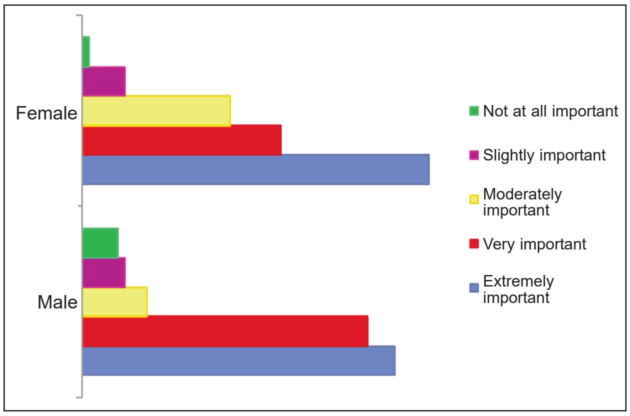

Fig. 3. The social Influence factor on the criterion purchase intention

Testing of the H4 hypothesis: There is a significant relationship between behavioural intention and purchase intention of textile products coming from the recycling of unused, old or faulty textile products

The following null hypothesis refers to the influence of the behavioural intention on the surveyed population in regard to the purchase intention of textile products in the previous year. Because $x^2_{calc.}$ (9.80) is higher than $x^2_{0.95}$ (5.20), the null hypothesis was rejected; therefore, the variable behavioural intention is influenced by the respondents 'purchase intention of textile products coming from the recycling of unused, old or faulty textile products. Cramer's coefficient Φ_c was used following the identification of the surveyed population's opinions on behavioural intention and the way they are influenced by the purchase intention of textile products criterion. Figure 4 shows that to meet the minimum condition of this test, the age variable was grouped into three distinct categories: young people (18–29 years), adults (30–59 years), and the elderly (over 60 years).

Other factors like environmentally friendly [0.248, $p<0.05$], financially sustainable [0.152, $p<0.05$] and social Influence [0.105, $p<0.05$] too showed significant and positive paths to the behavioural intention of purchasing green textile, in their order of influencing strength.

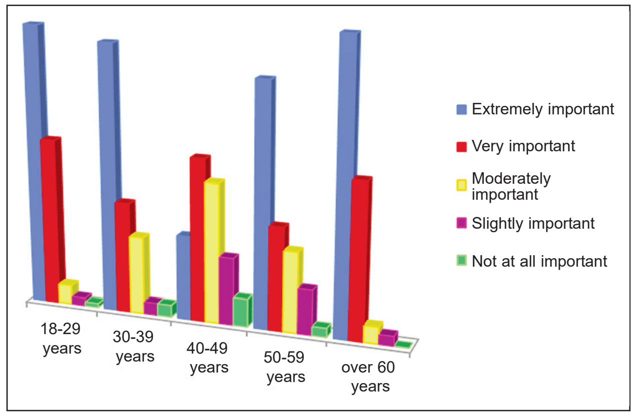

Fig. 4. The behavioural intention factor on the criterion purchase intention

CONCLUSIONS

Understanding behavioural intention and knowing customers is never a simple job because consumer behaviour regarding purchase intention of textile products coming from the recycling of unused, old or faulty textile products is dynamic, constantly changing and evolving.

The results of this quantitative research show important aspects related to the attitudes, motives, and experiences of the population regarding the purchase intention of textile products coming from the recycling of unused, old or faulty textile products and describe the evolution of the textile market shares of products analysed based on the perceptions of the population from Turkey.

After analysing the data, the present research also illustrates that necessary condition for studying behavioural intention to preserve the company's textile market share. Our work contributes to this important issue by demonstrating that the textile products coming from the recycling of unused, old or faulty textile products does not depend only on the age of the population.

At the same time, the results of our study can be a real support for the Turkish Ministry of Environment and Urbanization, which oversees the textile recycling campaign, in supporting the partnerships between public and private companies to establish a textile waste collection system as part of nationwide campaign.

Moreover, the findings are especially useful because the Turkish manufacturers can take into account them in view improving their activity, in order to eliminate the shortcomings and discrepancies in the client-client relationship. Improving this relationship will attract potential customers, allow customer loyalty and, implicitly, increase credibility.

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Digitalization of garment in the context of circular economy

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ABSTRACT – REZUMAT

Digitalization of garment in the context of circular economy

One of the principles of the circular economy is to recycle used or unused materials, in order to reuse them in the creation of new objects or the restoration of old ones. But due to the fragility, some of these materials, such as old textiles and clothing, are quite difficult to handle. This study presents a completely digital method with the help of which two pieces of clothing of different ages and physical properties, have been restored and stylized; the two pieces are made up of a traditional Romanian women's shirt about 100 years old and a modern sports t-shirt. For the application of the principles of the circular economy, the restoration-stylization processes of the pieces were based on the material and ornaments collected digitally from a series of old Romanian towels, which are currently no longer used. For this we considered the creation of 3D models of all the materials considered by the method of photogrammetry in Agisoft Metashape 1.6.2 Professional Edition and their processing in MeshLab 2020.2, as well as the vectorization of traditional motifs in ArcGis 10.6. Such an approach limits to the minimum the numbers of attempts that the restores have at their disposal while also allowing the obtaining, storage and transmission of information about traditional textiles, aimed at capturing the imagination of modern artists and designers to restore them for future generations.

Keywords: *ethnographic textiles, photogrammetry, 3D modelling, digitalization, garment, digital design*

Digitalizarea articolelor de îmbrăcăminte în contextul economiei circulare

Unul dintre principiile economiei circulare este acela de a recicla materialele uzate sau nefolosite, în vederea reutilizării lor, în crearea de obiecte noi sau restaurarea celor vechi. Dar datorită fragilității, unele dintre aceste materiale, precum materialele textile vechi, sunt destul de greu de manipulat. Acest studiu prezintă o metodă complet digitală, cu ajutorul căreia două piese vestimentare de diferite vârste și proprietăți fizice au fost restaurate și stilizate; cele două piese sunt alcătuite dintr-o cămașă tradițională românească pentru femei de aproximativ 100 de ani și un tricou sportiv modern. Pentru aplicarea principiilor economiei circulare, procesele de restaurare-stilizare a pieselor s-au bazat pe materialul și ornamentele culese în mod digital dintr-o serie de prosoape vechi românești, care în prezent nu mai sunt folosite. Pentru aceasta s-a avut în vedere crearea de modele 3D pentru toate materialele luate în considerare prin metoda fotogrametriei în Agisoft Metashape 1.6.2 Professional Edition și prelucrarea acestora în MeshLab 2020.2, precum și vectorizarea motivelor tradiționale în ArcGis 10.6. O astfel de abordare limitează la minimum numărul de încercări pe care restauratorii le au la dispoziție, permițând totodată obținerea, stocarea și transmiterea informațiilor despre materialele textile tradiționale, menite să capteze imaginația artiștilor și designerilor moderni pentru a le reabilita pentru generațiile viitoare.

Cuvinte-cheie: *textile etnografice, fotogrametrie, modelare 3D, digitalizare, articole de îmbrăcăminte, design digital*

INTRODUCTION

The exacerbation of the environmental problems of the last period requires serious efforts from all the factors involved (social, economic, political, etc.) in identifying, testing and applying optimal solutions with effects in diminishing the anthropic impact on the environment. In this context, a special role is played by the concepts of sustainable development, sustainability and circular economy. The circular economy represents the frontier of environmental sustainability [1], a limit of the support capacity, which translates simply through the six R [2], reduces [3, 4], repair [5], reuse [6], recover [7], remanufacture [7, 8], recycle [9, 10].

In a circular economy, the products and materials contained are highly valued, as opposed to the traditional linear economic model, based on a "take-make-consumption-throw-away" model [11]. The transition to a circular economy could bring benefits such as: reduced pressures on the environment, increased security of supply of raw materials, increased competitiveness, innovation, etc., but also challenges: financial, consumer behaviour, etc. [12]. Therefore, sustainable development is a milestone, while sustainability is a driving force of the circular economy, with major implications for the economy, environment and society [13, 14].

In this context, considering that the textile industry is one of the largest industries with a negative impact on the environment, solutions are sought in order to reduce it. Applying the concept of circular economy to the textile industry is a challenge to which all stakeholders are called to make their contribution, starting with the academic environment and ending with the simple man, as the main beneficiary of the textile industry.

In essence, man is a creative being with an emphasized artistic-aesthetic spirit. Over time, he has tried to express his inner beliefs and experiences through art [15, 16]. In this context, special attention was paid to the decoration of textile elements, especially clothing. Thus, they have been adorned with a series of plant motifs (leaves, flowers, plants, etc.), abstract (anthropomorphic, zoomorphic or cosmic), geometric (dots, straight lines, squares, triangles, etc.) with a very diverse chromatic specific to each community [17–20]. Clothing persons dressed in the former time played the most important "identification" function: it was possible to determine not only his gender and age, but also his social status, gender affiliation etc.

Given the fact that textiles face a limited lifespan [21] and are most often accessible to a limited number of people, digitization seems to be the best solution for preserving, restoring, viewing and promoting these vestiges of the past [22]. The information obtained by digitizing the various textile elements and the embroidered motifs, can be stored together with other types of information (textual, graphic, photographic, audio-visual etc.) to be transmitted over generations or to be used today in the textile industry (traditional motifs, taken as sources of inspiration for designers in this field and beyond), audio-visual, constructions, etc.

The digitization of ethnographic textiles is sometimes more special, due to the fragility and the difficulties of manipulation and it can be carried out using certain investigative techniques. The digitization of heritage objects includes the acquisition of spatial data, geometry modelling, digital archiving and posting in the online for the purpose of viewing by the general public, but also of studying, without interacting directly with the object [23]; thus, being able to easily follow the evolution of surface morphology as well as the evolution over time of some important processes for preservation, conservation etc., the details being very accurate [24].

As methods of digitization, photogrammetry and 3D modelling represent an important working tool that offers an overall, three-dimensional perspective [25], with implications in faithfully reproducing structural elements, as well as methods and techniques of obtaining and joining them.

Also, the 3D model offers a useful tool for designing and redesigning similar elements, with applicability in the preservation and informational rendering of cultural heritage [26–29], on the one hand, and in its use in the textile industry, on the other. The fashion industry is also increasingly attracted to the Virtual Prototype (VP) of clothing products, which allows designers to make quickly changes to their design, saving time and costs, in an increasingly competitive world [30, 31].

Vectorization of traditional motifs and ornaments, as a technique of ethnographic digitization on textile products, is a very important operation, due to the fragility and the difficulties of manipulation, which implies certain specific working techniques [23, 24]. The results obtained after the vectorization can be used in the conservation, promotion and exploitation of the material cultural heritage.

Considering the ones listed above, the present study aimed at the digitally reutilization of some common elements compiling the Romanian textile heritage, it is about a series of old traditional peasant towels (60–70 years old) specific to Bihor County, Romania, decorated with traditional motifs. Thus, through processes of vectorization and 3D modelling based on photogrammetry technique, the material from which the traditional peasant towels are made and the traditional motifs with whom they are embellished represented the support for the reconstruction and stylization of two garments of different ages and uses; a traditional Romanian shirt and a sports t-shirt belonging to F.C. University of Oradea.

MATERIALS AND METHODS

The materials used to carry out the present study were made up of a number of four traditional Romanian peasant towels, an old traditional shirt and a t-shirt designed for sports activities.

For the digital reconstruction, a 3D model was created for each of the pieces considered. The models were created using a typical photogrammetric pipeline, based on creating 3D models by aligning and densely matching sets of 2D images [32, 33], using Agisoft Metashape 1.6.2 Professional Edition. The data was acquired with the help of a Canon EOS-1D Mark III camera, equipped with a 28.1×18.7 mm sensor and having a resolution of 10.7 megapixels. The photos thus obtained were sorted and preprocessed with the help of the Build-in option, in order to eliminate the inferior quality data which could affect the final texture; lining up for the creation of the models being only those photos considered optimal. To define the correct scale of each project, real manual measurements previously performed on the considered pieces were used, on the basis of which the correct calculation algorithms were then established for the two software so as to capture the actual dimensions of the objects.

The second digital operation aimed at vectorization [16, 34, 35] of the traditional geometric motifs on the four traditional peasant towels in order to preserve the models and promote them by applying them on new materials. This was achieved by processing in ArcMap 10.6 of some very good quality 2D images focused on accurately presenting the details of the ornaments on the towels. This software was chosen due to the fact that it allows fast, very easy and accurate copying of the contours of the ornaments, due to the point-line-polygon type shape files it works with, these being also the main geometric shapes used in the traditional creation of these ornaments. At the same time, it allows different analysis, the change of colours and making patterns in case of repetitive motifs. The compatibility of this software with another from the ArcGIS package, namely ArcScene 10.6, allowed the export of models thus made in.wrl format, making them visible for the three-dimensional reconstruction program MeshLab.

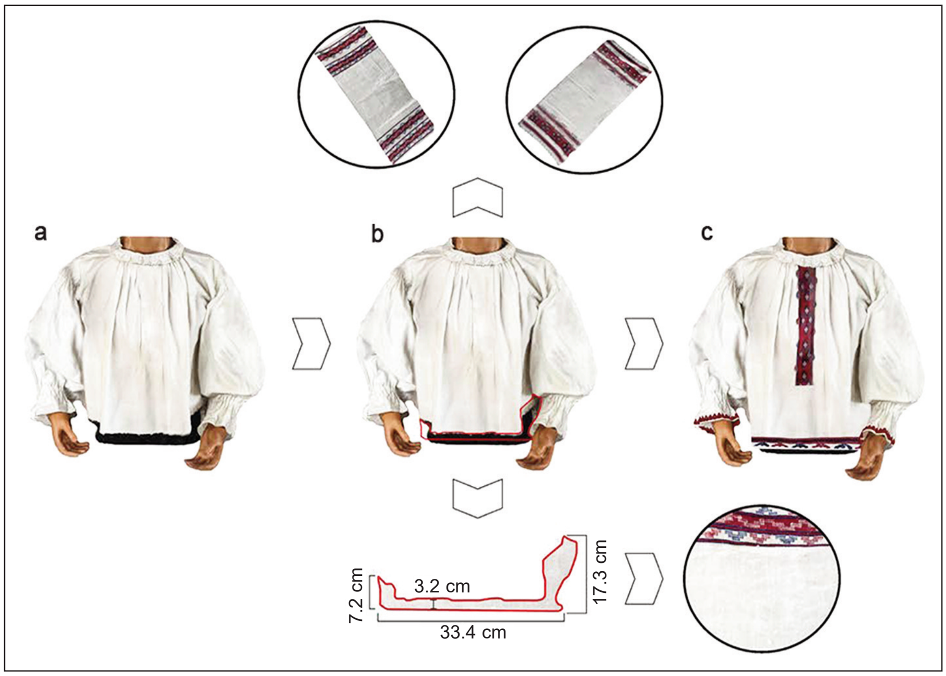

Fig. 1. The main stages in the process of restoration and stylization of traditional women's shirts "ie": *a* – initial appearance of the traditional shirt; *b* – model of restoration of the traditional women's shirts by digital reassembly of missing parts and stylization with traditional Romanian motifs present on other materials; *c* – the final model

Finally, the 3D models and the traditional motifs created were important in MeshLab 2020.2, where the applicability of the techniques of rebuilding and styling the traditional shirt and the sports t-shirt brought on a real scale, based on the material taken from the traditional peasant towels, was tested in the context of the circular economy. Further on, the two 3D models depicting two clothing objects of different ages and uses, metric and volumetric operations were performed.

RESULTS AND DISCUSSIONS

Due to the large number of photographic data processed, their quality and the orientation of all photogrammetric processes to obtain a good texture, 3D models have free from noise, missing data or holes. For a proper presentation and to facilitate the analysis to be performed, the traditional shirt and the t-shirt were placed on a mannequin.

Reconditioning-styling the traditional women's shirt "ie"

With the help of modern digital techniques, the traditional female shirt without motives (figure 1, *a*) was processed in such a way that she was given a new look using pieces from traditional peasant towels. For this, a 3D image model was created for each of the targeted materials. Known as the fragility of textile materials and the fact that they are quite difficult to manipulate, such an approach was chosen because it limits the direct contact with the objects, allowing an unlimited number of analyses and attempts of restoration and/or stylization, without the initial appearance suffering.

The process of restoration and stylization of the traditional shirt (figure 1, *b*) was channelled in two main directions. Due to the fact that at the bottom was missing a piece of fabric, the first operation involved the identification of a material that can be reused and which is also similar in terms of its nature, colour, pattern, age, etc. All these characteristics were identified in an old traditional towel. In the MeshLab 2020.2 program, the part of the missing fabric was measured digitally, creating a virtual model of the portion of material needed for the shirt re-assembly. This portion was cut from the traditional towel, after its 3D model was created in Agisoft Metashape 1.6.2 Professional Edition and then imported into MeshLab 2020.2. The piece of material thus generated was manually fixed in the correct position within the shirt model.

The stylization process consisted of reusing the traditional motifs cut from the traditional peasant towels and applying them on the shirt, so that the final model (figure 1, *c*) resulted is an object built entirely on the basis of the principles of circular economy.

Vectorization and reuse of traditional motifs

The second case study focused on the vectorization of the models (figure 2) from the embroidery sewn on the old traditional peasant towels originating in Bihor County, Romania. This approach plays a decisive role in the creation of databases containing traditional Romanian ornaments, in order to preserve and promote them, while increasing their accessibility and

Fig. 2. Traditional motifs, specific for Bihor County (Romania), vectorized from traditional peasant towels

Fig. 3. Stylizing the 3D prototype of the sports shirt using the traditional Romanian motifs vectorized from the traditional peasant towels

visibility among young people, artists and modern designers to integrate them into their creations, bringing them back, the fame from the past. The great advantage of these models is that they offer the possibility of performing operations such as changing the colour, size, restructure of the whole model or combining several models. At the same time, by vectorization you can get an ornament which is very difficult to achieve in the case of handmade motifs.

Considering that the old ornaments are an authentic source of inspiration for the production of modern textiles, the vectorized motifs represented the basis of the digital stylization of a polyester t-shirt dedicated to sports activities (figure 3).

In the MeshLab 2020.2 program, after importing the 3D model of the t-shirt and the vectorized motifs, it was proceeded to the manual positioning of the last ones at the level of the garment. This operation is a great time consuming considering that for the development of a model with a high accuracy it is necessary to take into account the colour of the parts, the angles of the models and the texture of each one. Figure 3 depicts the 3D prototype obtained from the assembly of old traditional elements on a support made of new/modern material; thus, the motives used to acquire the true sense of inheritance transmitted to future generations, through renewal of the past.

CONCLUSIONS

As techniques related to digitization, 3D modelling and vectorization of textile materials are shown as efficient and integrated ways of data analysis and processing in the context of the circular economy. Creating prototype garments based on material obtained from old or unused textiles in a fully digital format is a first step in the process of restoring these pieces. By reconstructing the digital stylization of the garments, the number of test samples necessary to finalize a final model is drastically reduced. At the same time, the techniques used offer easy access to objects and collections far away, they limit the direct contact with the pieces, at the same time being characterized by low costs of data acquisition and processing; opportunities that prove vital in the field of textile heritage research. This approach can be very useful both in terms of analysis on heritage textiles in order to preserve them, and in the fashion industry to streamline the creative process. The prototypes thus obtained, can be used in the creation of online content, adequate visualization, reconstruction of real pieces and creation of similar copies using 3D printing, preservation and promotion among the population samples that appreciate the authentic.

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Influence of environmental factors on the working rhythm in a clothing industry

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ABSTRACT – REZUMAT

Influence of environmental factors on the working rhythm in a clothing industry

The working environment is an essential element for the health and safety of the work and for the improvement of productivity. So, the conditions in the clothing industry are the most productive of occupational diseases such as MSDs, deafness and eye diseases. In this paper, we made an analysis of the environment in a clothing industry for each workplace using the NF EN ISO 2612 standard to analyze the level of sound exposure, the standard NBN EN 12464-1 is used to analyze the level of light for a sewing workplace. The noise level varies between 73 dBA and 90.5 dBA depending on the type of workplace. The lighting at the working zone varies between 240 lx and 1100 lx. The average temperature level varies between 28°C for the ironing stations and 26°C for the other stations and the average humidity level is 50%. The percentage of quality varies between 0 and 5%. An objective method was developed to determine the general pace of a sewing post which contains the atmosphere factors with regard to the noise level, the lighting level, the level of quality, the temperature level and the humidity. According to these parameters, the average pace of the studied group decreased from 98 to 78.

Keywords: *lighting level, noise level, temperature, humidity, quality, workplace*

Influența factorilor de mediu asupra ritmului de lucru în industria de îmbrăcăminte

Mediul de lucru este un element esențial pentru sănătatea și siguranța muncii și pentru îmbunătățirea productivității. Astfel, condițiile de lucru din industria de îmbrăcăminte sunt cele care produc boli profesionale, cum ar fi MSD, surditatea și bolile oculare. În această lucrare, s-a realizat o analiză a mediului din industria de îmbrăcăminte pentru fiecare loc de muncă, folosind standardul NF EN ISO 2612 pentru a evalua nivelul de expunere la zgomot și standardul NBN EN 12464-1 pentru a evalua nivelul de iluminare aferent locului de muncă de la mașina de cusut. Nivelul de zgomot variază între 73 dBA și 90,5 dBA în funcție de tipul locului de muncă. Iluminatul din zona de lucru variază între 240 lx și 1100 lx. Nivelul mediu de temperatură variază între 28°C pentru stațiile de călcat și 26°C pentru celelalte stații, iar nivelul mediu de umiditate este de 50%. Procentul de calitate variază între 0 și 5%. O metodă obiectivă a fost dezvoltată pentru a determina ritmul general al unui post de coasere, care conține factorii atmosferici în ceea ce privește nivelul de zgomot, nivelul de iluminare, nivelul de calitate, nivelul de temperatură și umiditatea. Conform acestor parametri, ritmul mediu al grupului studiat a scăzut de la 98 la 78.

Cuvinte-cheie: *nivelul de iluminare, nivelul de zgomot, temperatura, umiditatea, calitatea, locul de muncă*

INTRODUCTION

The sewing operations are very varied, which induces different procedures with high and repetitive rhythms. The lasts decrease the motivation of the workers, which diminish production on the one hand and influence their health and cause several types of occupational diseases, which the most recognized are musculoskeletal disorders TMS [1–3]. The work environment still influences the health of the worker and may be a source of other types of occupational diseases such as hearing diseases due to prolonged sound exposure to a high noise level. According to the U.S. Occupational Noise Exposure Regulation, 90 dBA is the maximum dose for a period for 8 hours [4]. In Turkey, the maximum dose should be less than 75 dBA for a period for 7.5 hours [5]. A survey was conducted by the European Agency for Safety and Health at Work indicates that 67% of French workers are disturbed by noise at their place of work. According to the Sumer study (2010, France), long-term exposures and more than 20 hours per week with high levels (more than 85 dB) concern 16.8% of employees in industries. Deafness is the second most common occupational disease and 750 cases are reported each year [5]. As well as the lighting not in accordance with the requirement may be the cause of dazzling eyes, headaches and work will be boring and not stimulating which decreases productivity [6]. The objective of this study is to carry out an analysis of the working environment in a clothing industry by using the NF EN ISO 9612 [7] standard to analyze the level of sound exposure, the standard NBN EN 12464-1 [8] is used to analyze the level of light for a sewing post. According to this analysis, an objective method must be developed to determine the general appearance of a sewing workplace which contains the environmental factors with regard to the noise level, the lighting level, the temperature level and the humidity.

METHOD

The analysis of the environment in this study was made in an assembly line of articles prepared in the manufacture of jackets men. The chain is consisted of 50 workers at the similar conditions. The simple sewing machine, buttonhole, button pressing, welt pocket, ironing, simple table for the control and cleaning are used in our study. According to the standard "NFEN ISO 9612" [7], the study was begun with an analysis of the noise exposition level. The method consists of measuring the level of noise by the following approach:

– An analysis of the work while observing the workstation and measuring the cycle duration by the method of measuring stitching time [9].
– A selection of the measurement strategy: The chosen strategy is based on a full day measurement.
– Measure the noise level for each activity by breaking down the task into two levels; when the machine is running and the machine is stopped when the worker is performing manual tasks. The measurement was realized by a portable digital sound level meter HD600. The noise level was measured in the head position of the employees, for each post 5 measurements were taken at a period of 2030 seconds [10].
– Treatment of errors and calculation of daily exposure level according to the following equation:

$$Lex{,}8H = LP{,}A{,}T_e + 10\lg(T_e/T_0) \qquad (1)$$

where $LP, A, \mathrm{eq}T_e$ is the continuous acoustic level of pressure balanced equivalent, A calculated by the average, T_e is the effective duration of the working day, T_0 – the standard duration (T_0 = 8 hours). A calculator was used to estimate the sound and total exposure for each workplace [11].

The second analysis was made according to the standard NBN EN 12464-1 [8] in order to measure the lighting level for each workplace. The approach taken for this analysis is as follows:

– Measurement of lighting level in the immediate surrounding zone which was defined by a band of at least 0.5 m around the working zone in the field of vision.
– Measurement of lighting level of the bottom zone which is defined by a band of at least 3 m width adjacent to the immediate surrounding zone. The measurement was made by a digital luxmeter TES 1332. Illumination was measured at the work site at a height of 0.85 meters above ground level [12].
– Determination of the ratio of illumination between the work area, the surrounding area and the bottom area.
– Determine the uniformity of the lighting according to the following equation:

$$U_0 = \frac{L_{min}}{L_{max}} \qquad (2)$$

The analysis of the atmosphere was ended with the measure of the level of the temperature by a thermometer and a level of humidity by a hygrometer. To develop a method one realized objectify to determine the general pace of a worker the following steps has been performed:

– Determination of the immediate speed of the worker according to the following equation:

$$IP = \frac{ST \times 100}{AT} \qquad (3)$$

where IP is the instantaneous pace, ST – the standard time and AT – the average time of task.
– The reference time is determined by the sewing time measuring method [9]. The average time of the operation is determined by the average of 20 statements for each post.
– Determination of percentage of defect; which is calculated by comparing the number of defects due to the workforce with regard to the number of pieces worked during a day.
– Determination of ambient coefficient that depends on the temperature and humidity level according to the BTE [13].
– Determination of the sound coefficient according to the standard NFEN ISO 9612.
– Determination of the lighting coefficient according to the NBNEN standard 12464-1.

A new method was developed to determine the general pace of a worker according to the following parameters; instantaneous pace, ambient coefficient, sound coefficient, lighting coefficient and percentage of defects.

RESULTS

The analysis of noise level was done on a group of 47 workers. The made tasks are repetitive and continuous during all day with a break of 30 minutes. The sources of noise are due to machines and to ventilators used for the ironing. The noise level was measured for each post when the machine is out of work that is the worker executes a manual task and when the machine is working. The results are summarized in the table 1.

According to the table 1, the percentage of manual task and technological time varies from a task to another one according to the complexity and to the operating procedure of every task. The noise level depends on the speed of the machine, on sound noise of the machine and on level of the noise accumulated by the nearby machines. The noise level varies between 73 dBA and 90 dBA when the machine is operating. For the posts of ironing, the noise level depends on the use or not of the ventilator. The average exposure level for the "pressing button" and "pressing buttonhole" positions is equal to 85 dBA, which means that there is a risk. For the cleaning station, the average exposure level is 76.5 dBA, so no risk for this post. For other posts; Simple sewing machine, zigzag, ironing and Welt pocket, the

Table 1

RESULT OF THE NOISE LEVEL MEASUREMENT FOR DIFFERENT POSTS									
Machine/ task	**Number of posts**	**Time (s)**	**% of manual task**	**% of tech-nological time**	**Level noise (dBA) (manual task)**	**Level noise (dBA) (machine on works)**	**LAeq,Te (average)**	**LEx,8H (average)**	**% compared to 85 dBA**
Simple sewing machine	31	2724.38	48.57	51.43	76.7	89.5	86.8	87.3	3%
Zigzag stitch machine	1	80	27.5	72.5	75	89	87.8	88.2	4%
Ironing	9	648.125	42.23	57.77	84.4	88.2	87.8	88.3	4%
Pressing buttonhole	2	79.125	63.65	36.35	76	90	84.6	85.1	0%
Pressing button	1	34	76.5	23.5	79	90	84.7	85.2	0%
Cleaning	2	228	100	0	76	76	76	76.5	–10%
Welt pocket	1	40	62.5	37.5	75	90	86	86.5	2%

difference compared to the limit given by the standard varies between 2% and 4%. So, the risk is very high which leads to a danger on the eye and therefore a risk of deafness [14].

According to the standard NBN EN 12464-1, the maximum lighting for a stitching post is equal to 750 lx, for ironing must be equal to 300 and for control the maximum illumination is equal to 1000 lx. According to the French association of lighting, the lighting level varies between 250 lx and 850 lx [15]. Therefore, the lighting does not conform to the standard and the level of illumination is higher than, what is required by the standard which causes negative effects on the health of the worker such as the dazzle of the eyes, headaches and fatigues which decreases the concentration and increases the risk of work accidents and therefore lowers productivity. According to the figure 1, the ratio (Lz/Ls) varies between 0.69 and 4.11 and the ratio (Ls/Lb) varies between 2.18 and 17.12 which does not meet the standard which requires that the ratio between the level of the lighting of the working zone and the surrounding zone (Lz/Ls) shall be 1.5 and the ratio of the lighting level of the surrounding zone to the bottom zone shall be 3.

The analysis of the atmosphere showed that the temperature level varies between 26°C for the stitching posts and 28°C for the ironing posts. This means that the ambient coefficient varies between 1.1 and 1.25 [13]. To determine the general pace *GP* of each worker, the following model is proposed:

$$GP = \frac{IP \times (1 - \%D)}{C_A \times C_S \times C_L} \qquad (4)$$

The instantaneous pace must be corrected by the sound coefficient C_S according to the following formula:

$$C_S = \frac{L_{EX,8H} - 85\,\text{dB}}{85\,\text{dB}} \qquad (5)$$

According to the results of the noise analysis, the exposure level varies between 10% and 6.5% compared to 85 dB so a sound coefficient between 09 and 1.065.

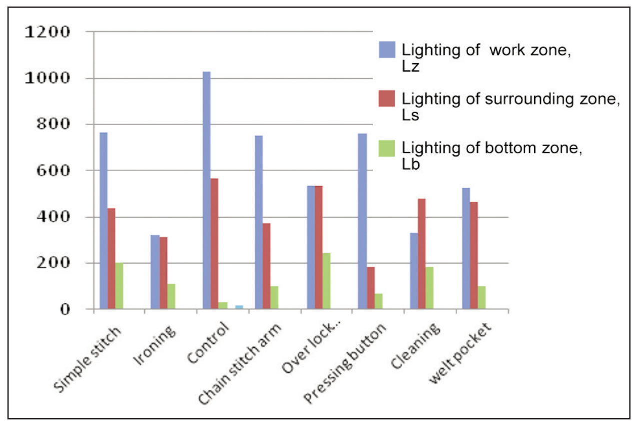

Fig. 1. Variation of the lighting level for different workplaces

The best lighting according to the French association, the lighting level varies between 250 lx and 850 lx [15]. For stitching stations and according to the standard NBN EN 12464-1 the maximum acceptable lighting is 750 lx. For the ironing post the maximum lighting is 300 lx and for the control post is 1000 lx. To calculate the lighting coefficient C_L the following formulas are used:

For the sewing posts:

$$C_L = \frac{L_{Max} - 700\text{ lx}}{700\text{ lx}} + 1 \qquad (6)$$

For the ironing posts:

$$C_L = \frac{L_{Max} - 300\text{ lx}}{300\text{ lx}} + 1 \qquad (7)$$

For the control posts:

$$C_L = \frac{L_{Max} - 1000\text{ lx}}{1000\text{ lx}} + 1 \qquad (8)$$

where L_{Max} is the lighting level for working zone.

Table 2

PERCENTAGE OF VARIATION OF THE GENERAL PACE COMPARED TO THE INSTANTANEOUS PACE				
Variation	**Minimal**	**Maximal**	**Average**	**% compared to IP**
Instantaneous Pace IP	69	113	98	0.66%
% of defects	0%	5%	1%	
Pace 1	68	112	97	
Ambient coefficient C_A	1.1	1.25	1.13	11.92%
Pace 2	62	99	86	
Lex,8H	76.5	89.5	87	
Sound coefficient C_S	0.9	1.06	1.02	13.79%
Pace 3	60	100	85	
Lmax	240	900	649	20.66%
Lighting coefficient C_L	1	1.33	1.09	
General Pace GP	60	93	78	

The case study showed that the lighting level for the stitching posts varies between 240 lx and 900 lx, namely the lighting coefficient varies between 1 and 1.33 depending on the type of workplace.

The percentage of defect is also an element that influences the pace *P* of the worker. This pace must be corrected for this default percentage as follows:

$$P = IP \times (1 - \%D) \quad (9)$$

The case study in the same group of work showed in table 2.

DISCUSSIONS

The best organization of workplace reduces the risk factors for diseases of MSDs in the hands, wrists, elbows, shoulders, neck and at the level of lower back, feet and legs [1–3]. But this organization does not reduce other risk factors because the noise exposure at a high noise level exceeds then 85 dB for 8 hours per day of work [16]. Noise effects are in the order of three groups: acoustic trauma, temporary hearing loss and permanent hearing loss [17]. Noise promotes health problems such as hearing fatigue, deafness which is irreversible fatigue because of the sound exposure for a slow period. The noise also causes cardiovascular disorders which are especially hypertension and therefore a loss of concentration and increase in absenteeism [18]. Noise also promotes sleep disorders; it is also an unpredictable and uncomfortable work stress factor. It can also cause fatigue, irritability, headaches and decreased hearing [19, 20]. Noise causes discomfort or stress vector disorders and pathologies that affect not only the health of the worker but also productivity by lowering the concentration [18]. The non-traumatic effects of noise are manifest at the physiological and behavioral level, which increases the risk of an accident at work since it disturbs verbal communication and distracts attention [21].

According to the regulations of the National Institute of Health and Safety (NIOSH) the daily exposure level for a day of 8 working hours should not exceed then 85 dB [16] otherwise the risk becomes higher. In addition, beyond then 85 dB for an extended period, the risk of hearing loss increases exponentially [22]. To reduce the risk of noise, it is essential to apply a preventive solution to the exposure of noise: acoustic treatment of work premises, partitioning and enclosure of machines (enclosure built around the machine to reduce the noise level), soundproofing of ceilings and walls, these are the most effective preventive actions [11].

Noisy machines will be equipped with a noise-canceling system is a method to prevent the spread of noise by the ground. Better machine maintenance and regular lubrication are ways to reduce the level of noise [11]. Personal protections such as ear muffs and ear plugs are short-term solutions to the problem of noise [19]. Workers must be trained in noise and its effects on human health [14].

The ergonomics of lighting makes possibilities to avoid the under lighting and the over lighting of workplace. The lighting of a work zone must be neither too much lighting to avoid glare of the eyes, nor with low lighting to avoid the boring and not stimulating work. Indeed, the best lighting avoids eye fatigue and also allows having a visible task and avoiding the risk of errors and improving productivity in the best visual comfort. Bad lighting can increase the risk of error, increases stress, and produce visual discomfort therefore risk of dazzling eyes [23]. Fluctuating lights can cause visual disturbances and increases the risk of work-related accidents [24]. Symptoms caused by a bad lighting are: rapid fatigue, headaches, visual fatigue, decreased ability to concentrate and stress, degeneration of sharpness of vision [6]. To optimize the lighting level, it is necessary to measure and control the lighting and distribute the lighting system evenly for all stitching posts.

The level of humidity and temperature has an effect on the work rhythm and the health of the worker. Studies have been done to give the optimal environment zones for the comfort of the human being, with a temperature of 22°C and the optimum humidity zone varies between 40% and 65% [25]. According to this study, the average temperature level varies between 28°C for the ironing stations and 26°C for the other stations and the average humidity level is 50%, so the ambient coefficient varies between 1.1 and 1.25. Pace judgment is an estimate by which the speed of work of a performer is judged in relation to the base speed called the reference pace (100) [26].

Indeed, the pace depends on several parameters such as the qualification of the worker, the quality of his work obtained, his physical effort, his physical and mental state still the pace depends on the physical environment of the work (noise, light, temperature …) [26].

The majority of innovations and research in the apparel industries have been made on the improvement of management processes [27], as well as on the comfort of the garment and the creation of products meeting specific requirements and aesthetics. This article is directed towards organizational research by proposing an objective method of the pace of a worker according to ambient parameters and the percentage of defects.

CONCLUSIONS

The clothing industry is the most important source of occupational diseases with regard to TMS disorders, deafness diseases and eye diseases. This study was done in order to analyze the workplace for a stitching post to develop a method that allows determining the general pace of a worker according to percentage of quality and the ambient parameters in terms of regarding the sound level, the lighting level and the temperature and humidity level.

The lighting level varies between 240 lx and 1100 depending on the type of workplace that is to say a coefficient that varies between 1 to 1.33; the sound level 75–90.5 dB and the sound coefficient 0.9–1.06 and the ambient coefficient 1.1 to 1.25 depending on the type of workplace. The percentage of quality varies between 0 and 5%. According to these parameters, the average pace of the group decreased from 98 to 78.

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