Boosting the efficient use of resources in the textile industry by moving to a circular economy

Ivana Dorotić, univ.bacc.ing.techn.text.
Tea Tesla, univ.bacc.ing.techn.text.
Ajna Prstačić Vuković, univ.bacc.ing.techn.text.
Tena Margan, univ.bacc.ing.techn.text.
Karlo Golubić, univ.bacc.ing.techn.text.
Prof.dr.sc. **Sandra Bischof**
University of Zagreb Faculty of Textile Technology
Department for Textile Chemistry & Ecology
e-mail: sbischof@ttf.hr
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Review

Preservation of the Planet Earth and facing of global climate, environmental and societal challenges, require the harmonization of all human resources. The paper presents importance of The European Green Deal and its most important measures - improving resource efficiency by moving towards a clean, circular economy. The principles of the circular economy system, improvements, specialization and modernization of directions for its better and more efficient implementation in the economy and society are described. The situation of textile waste management and the application of the circular economy in the textile industry in the Republic of Croatia, as well as in the European Union, are presented. Additionally, possibilities of textile engineer's contribution to environmental issues through implementation of sustainability principles in the processes of textile technologies is presented.

***Keywords**: The European Green Deal, circular economy, textile industry, textile finishing, waste management*

1. Introduction

Improving resource efficiency in the textile industry by moving to a circular economy is in line with the main objective of The European Green Deal - to make Europe climate neutral by 2050. With this new strategy and responsible work on the preservation of the planet, Europe seeks to correct mistakes made during the past times, that have negatively affected the environment and climate. To achieve the goal, further efforts are needed to revitalize every segment of the European economy, including the textile industry.

The EU Green Deal will operate through a framework of regulations and legislation setting clear targets, where the most important one is carbon neutrality, namely CO_2 neutrality. To reach that goal, CO_2 emissions must be reduced 50-55 %, by 2030 [1]. The European Commission's Green Deal includes 10 main areas shown in tab.1.

The circular economy belongs to a newer model of 21st century economics and is considered to be the answer to climate change and environmental protection. The primary task of the circular economy is to reduce waste generation, which can be achieved by returning secondary raw materials to new production process, i.e. recycling of products, materials and natural goods. Collection, separation, processing and production of new products from waste materials are encouraged.

The trend of continuous increase of textile waste in recent decades raises the issue of its disposal and environmental protection. The gradual intro-

Tab.1 Main areas of the European Commission's Green Deal [2]

1. Climate neutral Europe	6. Strategy on greener and healthier agriculture
2. Circular Economy Action Plan	7. Emissions in transport
3. Energy renovation of buildings	8. Assistance to the regions and sectors most affected by the changes
4. Strategy on non-toxic environment	9. Research funds
5. Strategy on ecosystems and biodiversity	10. Foreign policy

duction of circular waste management would not only be a solution for significant decrease of textile waste, but would present sustainable strategy for a longer lifecycle of raw materials and products. By proper treatment of waste and specific treatment procedures it can be used as a secondary raw material with certain market value. The collected quantities of textile waste in Croatia, in relation to the world are small, but there has been a continuous increase in quantity of recycled textiles.

2. Textile waste - classification and management

The European Union classifies textile waste as biodegradable waste. Most likely due to the very definition of biodegradable fibers – which depicts biodegradable fibers as fibrous polymeric materials that can be degraded by the action of microorganisms (bacteria and fungi, etc.) [6, 7]. However, decomposition time is a very important factor. Some polymers, i.e. polymer fibers which require much longer degradation period, can only be classified as non-biodegradable (e.g. polyamide, polyester, polypropylene, polyurethane, etc.), and their textile waste is classified in most cases as inherently biodegradable. This raises the question of how to classify textile waste and how to define textile waste in general.

Textile waste is devided according to the time of its generation to textile waste generated *before the use* of a textile product, i.e. to by-product in the production or industrial waste. Industrial waste may be of different shape (fibres, yarn and fabrics, etc.), depending on the raw materials and forms of textile materials used in the textile and clothing production process. The second category is waste generated *after the use* of textile products, i.e. clothing, household or technical textiles that the user no longer wants (consumer waste) [3, 4].

Textile waste accounts for aprox. 5 % of total amount of waste. In general, waste should be managed as shown in figure 1. Therefore, majority of work that needs to be done to prevent waste occurrence includes eco-design, extension of service life, rationalization, increase of efficiency and environmental friendliness of production, so as the effort to avoid accumulation of waste at all. Next choices are reuse and recycling of textiles. Due to the difference in the quality of individual waste treatment procedures, a strict hierarchical order of waste disposal is defined by European waste policies and legislation.

The waste management hierarchy, i.e. the order of waste management, is known as 4R according to the first letters of the English names of waste management procedures [6]:

- Prevention of waste generation ***(Reduce)***,
- New use for same or different purpose ***(Reuse)***,
- Material recovery: recycling and composting ***(Recycle)***,
- Transformation, energy recovery ***(Recover)*** and
- Final disposal.

3. Circular economy

Taking into the consideration population increase and the increase in average textile consumption per capita, it is necessary to consider waste as a possible secondary raw material for numerous products. Natural resources will not be sufficient for increased demands and continuous attention is paid to their controlled use with the purpose of preserving the environment and maintaining the nature balance. Global increase of industrial production cause increase of natural goods exploitation, energy consumption and CO_2 emissions, i.e. greenhouse gases, which have a major impact on climate, air quality and the environment in general. A circular economy would manage raw materials more properly, reduce the required amounts of energy and reduce the amount of harmful emissions and waste.

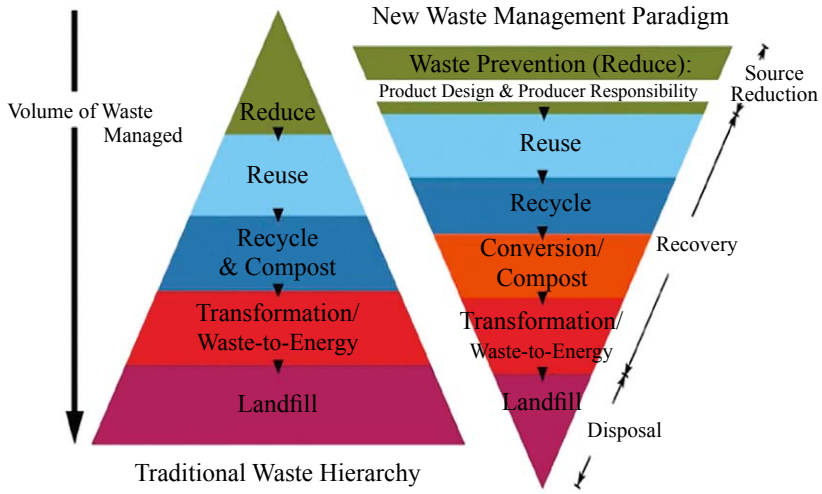

Fig.1 Waste management hierarchy [5]

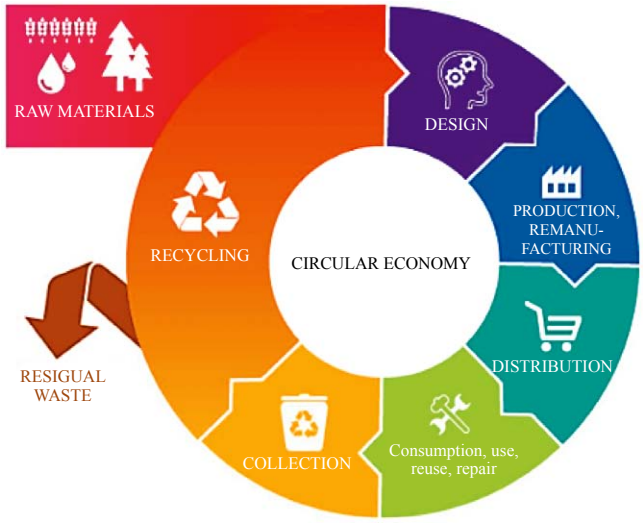

Fig.2 Phases of the Circular Economy [12]

Although textile waste and its environmental harm are not so largely addressed as e.g. plastics or electronics, textiles belong to the fourth category in terms of environmental impact (after food, household and transport), and in fifth in greenhouse gas emissions [8]. This classification is a result of overuse of primary raw materials and water in textile production. The knowledge that textile industry is one of the largest environmental pollutants and that, despite the legal regulations, it still represents a significant share of municipal waste is the reason for urgent introduction of circular economy in this sector [9].

3.1. Definition of the circular economy

Different views are related to the term circular economy, and many experts such as Wautelet [10] considered that circular economy mechanism was developed by environmentally conscious economists D.W. Pearce and R.K. Turner, whose model was based on scientific research by K. Boulding dated from 1966. It seems that the foundations of the circular economy originate from the ecological branch of the economy.

The Circular Economy Plan enables better exploitation of raw materials, recycling of products, job creation and conservation of renewable sources, while generating some financial profits. Four basic principles of the circular economy [11] are:

1. A real circular economy is a zero-waste economy. Nothing is thrown away because the product is designed so that it can be repaired, disassembled and reused;
2. Application of eco design, which includes detailed planning of applied materials. Disposable ingredients are those that can be degraded, such as paper or fabric, and durable ingredients are e.g. metal or plastic, which can be reused. More complex products should be designed so that at the end of their lifecycle they can be disassembled and reclassified into one of the above categories;
3. The energy used shall be fully renewable, for such an industrial cycle to be sustainable. It reduces the risk of depletion of resources or the impossibility of acquiring them;
4. Customers are no longer consumers but users. The product will have to be returned back to the economy when usage is complete, which means a greater incentive to return, rent or share the product.

Fig.2 shows the phases of the circular economy. The consumption of raw materials decreases with optimization and use of by-products (industrial waste) and recycling of waste or used products. Those measures contribute to reducing the consumption of primary sources and overall reduction of pollution. The circular economy prioritizes the production of longer-lasting products, which can be repaired or easily disassembled and recycled, thereby aims to reduce and completely replace the linear model of cheap and fast production and disposal [8]. The circular economy model should not be mixed with the waste collection and recycling plan, since it is essentially different and much more complex. Reorganization, new ways of governance, modernization of economic activities are very important in order to enable changes in organizational structures by changing numerous processes. The concept of a circular economy assumes the success of the enterprise, but foresees improvements for the environment and society as a whole, not just for buyers and investors.

The Europe 2020 strategy [13] foresees the positive effects of the circular economy, and one of the priorities of EU development is to promote more efficient resource use for an economy that is becoming "greener", more competitive and therefore needs to reshape the linear models of the economy into a circular one.

3.2. Transformation from linear to circular economy

Overexploitation, impoverishment of natural resources, and the daily accumulation of waste that pollutes the environment and creates more and more ecological problems, requires an urgent change of the model of linear economy to circular one [14].

Currently, the focus in the world is still on the highest possible production of lower cost items. This approach is described with take–make–consume–throw pattern and represents a linear economy. Thus, the linear system consists of utilization of resources, production, distribution, market placement, use of products and ends up discarding the product in waste. Although the system seems to

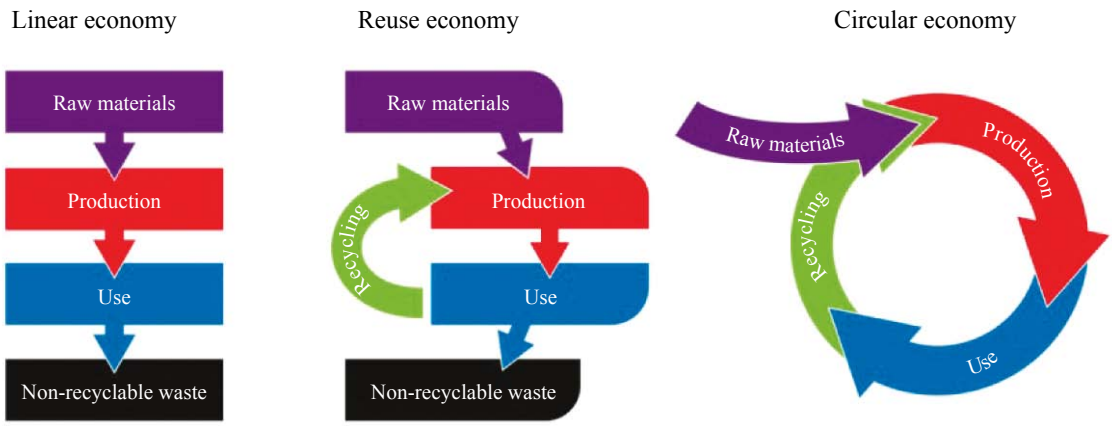

Fig.3 Change from a linear to a circular economy [15]

be good and simple, it is actually very limited because it is one-way and unsustainable cycle, due to the limited resources. Therefore, it is necessary to move from a linear model to a circular one, as shown in Figure 3.

Industrial waste and used textile materials (clothing, home and other technical textiles) have excellent reusability. There are many ways of reusing where organized implementation significantly reduces adverse environmental impacts. The importance of reuse is significantly increasing, year after year, due to the economic and environmental concerns. Globalization processes have resulted with a mass dislocation of the textile industry to less developed countries, but this has not reduced the problem of textile waste in Europe at all. Industrial waste has decreased, but due to the lower price of textile products and the high purchasing power of the European population, most of the textile products, contrary to legal regulations [16] end after use on waste. On the other hand, product lifetime is shorter and average is 3 years. However, the lack of natural and productive resources in Europe and therefore the overall rise of resources prices impose textile recycling and the transition to a circular economy as a priority.

3.3. Advantages vs disadvantages of the circular economy

The advantage of circular economy concept within the textile industry lies in the benefits for the environment, but the economic benefit is equally important. Recycling of textile waste contributes to the creation of new jobs in the economy, where opportunities are created for the new recycling facilities, recycled products or the production of items related to recycling. Thus, the benefits of the circular economy in the textile industry are manifested in environmental, resource, economic and social benefits. An example of business practice according to the circular economy model in the Republic of Croatia is a practice carried out by an increasing number of companies, e.g. Regeneracija and Humana Nova.

The disadvantage of this concept is high requirement of energy. Further unfavorable fact is higher price of recycling yards and low investment of cities in managing of recycling schemes. Recycling costs vary on type of recycled material, so as on application schemes and demand for recycled material.

Most people agree that a circular economy has significant benefits, even if it is not the perfect solution to all environmental problems. Numerous projects are financed with the purpose of increasing environmental protection, reducing waste, stimulating socially responsible entrepreneurship, where educational institutions are becoming important stakeholder. One example of a successful recycling project is *How you separate matters – make Karlovac better*,

Fig.4 Sustainable economy according to the scheme developed as part of the project [17]

which envolved the primary school population.

The European Commission will propose a simple framework to monitor the main elements of the Circular Economy Action Plan. It is important to have a set of reliable indicators to assess progress towards the circular economy and the effectiveness of action at EU and national level. On this basis the Commission, in close cooperation with the European Environment Agency (EEA) and in consultation with Member States, will work to propose as simple and efficient framework for monitoring the circular economy. The indicators will be published in line with the Commission's reports on the social development goals (SDGs) and will cover new indicators on food waste, as well as other official data of key raw materials supply, repair, reuse, waste generation and management, trading of secondary raw materials in the EU and with third countries, and the use of recycled materials in products. Five years upon the adoption of the Circular Economy Action Plan, the Commission is projected to report the progress of its implementation [18].

3.4. Socially responsible textile industry

The modern age and development of all segments of the textile industry has caused the need for global, social responsibility for development in accordance with the needs of people and nature and the knowledge that the Earth must stay suitable for current and future generations [19, 20]. Tab.2 presents various economic, social and environmental possible negatively impacts of the textile industry. With a stronger impact of political, economic and financial development on the textile industry, the intensity of change becomes much more noticeable. Over the past few decades, these changes have triggered the relocation of production, losing hundreds of thousands of jobs in industrialized countries, which were then created in developing countries. Many studies have shown that the garment industry faces major problems due to lack of state regulation, inadequate working conditions, low average wages, occupational diseases and injuries of textile workers. There are also numerous initiatives involving a growing number of European clothing manufacturers who want to distance themselves from labor rights violations and put emphasis on socially responsible entrepreneurship (CSR). As an example, *we* highlight the *Circular Fibres Initiative*, launched in 2017, which aims to contribute to society, environmental protection and the economy while reducing the negative industrial impacts of pollution and waste. The initiative works closely with the Ellen MacArthur Foundation, which makes numerous publications on environmental topic [11, 21].

4. European Union and circular economy

The EU Circular Economy Action Plan provides instructions and measures to preserve the resources currently available [18, 23]. These plans replace a linear economic growth model which is no longer appropriate given the societies' needs today. Resources need to be handled in a smart and sustainable way to preserve them and to reduce waste to as low level as possible. The EU wants to develop a sustainable and competitive, low-CO_2 economy through such measures. The Green Action Plan provides proposals and solutions on the application of the circular economy.

A circular economy will increase EU countries' competitiveness, reduce the risk of resource scarcity and thus price volatility. Fostering sustainable activity in key sectors will contribute to the formation of new business opportunities and the creation of more innovative and efficient ways of spending. The introduction of new measures and activities will enable the creation of safe jobs of different qualifications that will ensure higher competitiveness. Increased level of protection for people and the environment will be ensured, and consumers will be able to purchase more durable products that will ensure money savings and a higher quality of life. The circular economy also looks at ecology and provides solutions on plastics, excessive food waste, key raw materials and their consumption, so as on green public procurement [24].

4.1. Production

In a linear economy, more lower cost items with shorter service life are produced. Those products often cannot be reused or recycled and most of them are disposable.

Tab.2 Economic, social and environmental possible negatively impacts of textile industry [19]

Economic impact	**Social impact**	**Ecological impact**
Global realocation of production from developed industrial countries to developing or underdeveloped countries	Low workers' wages, low work standards, temporary work contracts and child labor	Large amounts of energy, water and chemical use
Decline in export prices of textile and clothing products, fast fashion	Sex discrimination	Increase in textile waste
Penetration of lower-priced producers into the international market	Exposure to health risks of the local population	Non-renewable raw materials
Abolition of textile and clothing agreements	Lack of fair trade - subsidies and regulations prevent fair trade in textiles	Impact on climate change

The application of the circular economy begins already with the design of products and production lines, because the purchase and utilization of resources and production with as little industrial waste as possible have a big impact, and continues throughout the lifecycle, i.e. the duration of the product.

The EU eco-design directive aims to increase the efficiency and environmental friendliness of products. Regards to the directive, the Commission has developed binding product design and labelling requirements to make dismantling, reusing and recycling e.g. electronic displays simpler and safer. Production processes, despite ingeniously designed materials, can generate significant amounts of waste due to inefficient resource exploitation. Reference documents on the best available techniques have been introduced (eg. *Best Available Techniques – BAT for the Textiles Industry)* in member states to be accepted before issuing a permit for industrial plants [22]. Innovative industrial processes such as industrial symbiosis will be promoted, allowing the waste from one industry to serve as a resource for another industry.

4.2. Use

Information on the application of circular economy principles which are available to users (consumers, customers) influence their decisions. A large amount of eco-labels is present and decisions on the choice of the best and most reliable environmentally friendly products are not easy. Voluntary environmental sign *EU Ecolabel* ensures that the product has less impact on the environment during its lifecycle.

Fig.5 EU Ecolabel Sign [23]

As price is often a key factor in the adoption of a purchasing decision, Member States are encouraged to provide incentives and apply economic instruments such as taxation. This would reflect environmental costs in prices. The Commission promotes waste prevention and reuse by sharing information and best practices, so as funding projects at local and regional level. Public procurement can play a key role in the circular economy, as it accounts for a large part of European consumption. The Commission will encourage this role through 'green' procurement measures, which develop EU-wide criteria applied by public authorities on a voluntary basis. In the next period, the emphasis will be on durability and the possibility of repairing the product. The Commission will also, by its own example, ensure that "green" public procurement is applied as broadly as possible and will strengthen the role of the Public Procurement Process in EU funding.

4.3. Waste management

Europe loses around 600mt of materials a year that could be recycled and reused. The recycling rate in some areas is 80 %, while in other is lower than 5 %. Waste management determines how the EU waste hierarchy is applied in practice. The hierarchy determines the order of priority: from waste prevention, recycling applications, recycling and energy recovery, to landfilling. The results of waste collection can give high recycling rates and result with the return of valuable materials to economy. On the other hand, irresponsible management can result in the most landfilled waste or indiscriminately taken to incinerators, which can have a detrimental impact on both the environment and the economy. Achieving good results requires removing barriers on the ground, such as underinvestment in infrastructures for separate collection and recycling and illegal transport of waste within the EU and third countries. In 2014, a revised waste consignment regulation was adopted to make it easier to detect illegal shipments [24].

Waste can often be repurposed and thereby a new lifecycle can be given to the product. Recovery and general recycling of waste is a vital sector, which creates new jobs and thus stimulates growth. Furthermore, if waste management is carried out properly it improves quality of life.

Recyclable materials are returned to the economy as new raw materials. Secondary raw materials are still under represented in the EU, but improved waste management directly affects the quantity and quality of the secondary materials. The problem faced by operators when using secondary raw materials is its questionable quality. The development of standards should increase confidence in these sources and in recycled materials in order to support and expand their market. The revised legislative proposals on waste lay down more harmonized rules to facilitate the setting of conditions where the raw material should not be legally considered as waste. Quality standards should be developed when it comes to recycled nutrients that are an important category of secondary raw materials. Their sustainable use in agriculture reduces the need for environmentally harmful mineral fertilizers. Water scarcity is also a growing problem, and the reuse of industrial production water in agriculture can also contribute to the recycling of nutrients instead of the use of solid fertilizers. The problem is the presence of chemicals in the water which need to be removed appropriately, but often poses a significant problem. This is the main reason why new initiatives go towards promoting the use of non-toxic materials and improving monitoring of the use of chemicals in order to facilitate recycling and increase the use of secondary raw materials [24].

Fig. 6 Cyrcular economy in company Regeneracija [26]

4.4. Priority areas

The transition to a circular economy requires an increase in plastic recycling rates. Less than 25% of the plastic collected is recycled and around 50% ends up in landfills. As a solution, the Commission is offering a strategy on plastics in the circular economy, which is under the construction. Its aim is to address issues such as recycling, biodegradability, the presence of hazardous substances in certain types of plastics and marine litter issues. It will also propose more ambitious targets for recycling plastic packaging through a revised legislative proposal on waste management. The implementation of such legislation foresees a reduction of marine litter by a minimum of 25 %. Concrete measures are proposed to reduce marine litter by 2030 by implementing the SDGs [24, 25].

4.5. Textiles

Textiles are the fourth category in terms of impact on the use of primary raw materials and water (after food, household and transport) and fifth in greenhouse gas emissions. It is estimated that less than 1 % of all textiles in the world are recycled. The textile value chain is quite complex and in 2021 the Commission will propose a comprehensive EU textile strategy based on data from industry and other participants. The aim of the strategy is to boost competitiveness in industry by strengthening the market for sustainable and circular textiles, including the EU textile reuse market, tackling fast fashion and launching new business models. This will be achieved by forming a set of measures such as: developing eco-design measures to ensure that the product fits into the circular economy using secondary raw materials, addressing the presence of harmful chemicals and encouraging business and private consumers to choose sustainable textiles. Easy access to reuse and repair should also be provided. In addition, guidance will be given to achieve high levels of separate collection of textile waste, which member states must provide by 2025 [23].

5. Croatia and Circular Economy

One of the world's biggest ecological and industrial problems is also a problem in Croatia - the disposal of waste textiles. The circular economy model should be applied to a greater extent throughout Croatia. With this model, textile waste is converted into raw material which passes various treatments to become the final product which can be reused. Some of the Croatian companies have already established this model, moreover this concept was actually applied as the main business strategy of the company Regeneracija already in 1954. The fact is that textile component currently accounts for a relatively small share (aprox. 4%) of municipal waste composition, but in absolute quantity it is actually a large amount of textile waste. Nevertheless, it should be noted that it is a material that has a high degree of recyclability and a wide possibility for the reuse. Since littering is prohibited and incineration is a very demanding procedure, the most favorable option is recycling of textile waste [3].

5.1. Company Regeneracija Ltd.

The company Regeneracija d.o.o. was founded in Zabok in 1954 as a company that collects, sorts and processes textile waste. Already after 10 years they managed to install the first line that deals with the production of non-woven textiles based on regenerated textile fibers. In 2005 they refocused on the production of technical nonwoven textiles and protective insulation materials. They use materials that do not harm the environment and humans. Natural gas and electricity derived from renewable sources are key energy sources for their production. Their goal is to reduce the amount of waste and to collect created waste to be recycled. Waste that can't be processed in any way should be disposed in the least hurtful way for the environment and humans. The company finalized textile recycling project "EKO-EKO" in two phases: the ECOnomy phase where the production of raw materials was enabled (waste emissions to the environment and waste of other textile industries were reduced) and the ECOlogy phase, which included the processing of collected textile waste in Croatia, which accounts for 135.000 t. Company Regeneracija annually processes 8 k tons of textile fibers and produces 30 million square meters of

Fig 7. Humana Nova Čakovec [27]

different nonwoven textiles. Through 50 years of production of nonwoven textiles, various products have been made and incorporated into clothing, footwear, furniture or cars. The undergoing phases of waste textiles are the following: collection and storage of textile waste, shredding and mixing of waste, obtaining semi-finished products, adding connective substances and obtaining a finished product (which undergoes needle punching, calendering, thermal bonding and mashing). This way of recycling and reuse has several positive environmental and economic impacts: it saves water, energy and reduces the amount of chemicals which will be used to produce new raw materials [26].

5.2. Humana Nova Čakovec

Next example of a successful company is Humana Nova, founded in 2011 in the form of a social cooperative, as part of the ESCO project "Education for Social Cooperatives that provides new opportunities for people with disabilities". It was implemented by the Autonomous Center (ACT) Čakovec. Their work starts with sorting of collected used clothes in various categories:

- Clean and undemaged clothes go for further sale at affordable prices in second hands shops in Čakovec, Zagreb and Labin
- Clean and partially demaged clothes go to the sewing step for repairment, and then to greenware stores
- Clean and demaged clothing is used in the production of new products - *patchwork* blankets, handbags, clothing which are sent to stores in Čakovec, Zagreb and Labin
- Worn and stained clothing is recycled into industrial wipe cloths. Prior to that step buttons and zippers are removed and reused
- Textiles that are no longer for use and textile waste are sent to recycling companies for decomposition.

The cooperative has collected more than 200 t of clothing and footwear so far. The production of this quantity of raw materials will have significant release of carbon dioxide into the atmosphere and will require usage of 1,140 million l of drinking water, 57 t of artificial fertilizers and 38 t of pesticides. The cooperative operates in three locations: Zagreb, Čakovec and Labin.

In view of the requirements of the European Union, every member state, including the Croatia, has the obligation to establish as many of such collection centers as possible. This organization is considered as positive measure for the prevention of waste.

6. Circular economy in the textile sector

Textile markets indicate that the circular economy is already applied in this industry. This form of the economy is not only about recycling, it is much more than that. The models include the efficient use of the material already in the design of the product itself, and a number of services have been developed to extend the product lifetime and reuse it.

6.1. Possibilities to reduce and dispose textile waste through circular economy concept

According to 2015 data, the carbon footprint of textiles consumed in EU was 195 million tones of CO_2 and the water footprint was 46.4 million m^3 [29]. The increase in the carbon footprint is mostly influenced by energy and raw materials, where the recycling and reuse significantly reduce those quantities and thereby contribute to less environmental impact. The water footprint can be reduced by optimizing processes; reducing the use of chemicals, including pesticides, artificial fertilizers, by waste water treatments and their reuse. In general, the circular economy achieves rationalization of production costs and reduction of waste volumes in addition to environmental well-being. The EU has a good recycling system for textile materials where reuse of textiles increase resources in production. Circular economy is much more than recycling, and starts already in the design phase where materials can be effectively selected and continues with different services which can extend product lifetime or ensure its reuse. The implementation of the circular economy requires knowledge, innovations and dedication of participants. The concept of circular textiles creates numerous opportunities and EURATEX is suggesting 12 specific points for better absorption capacity for EU Textile Cyrcular Economy [28]:

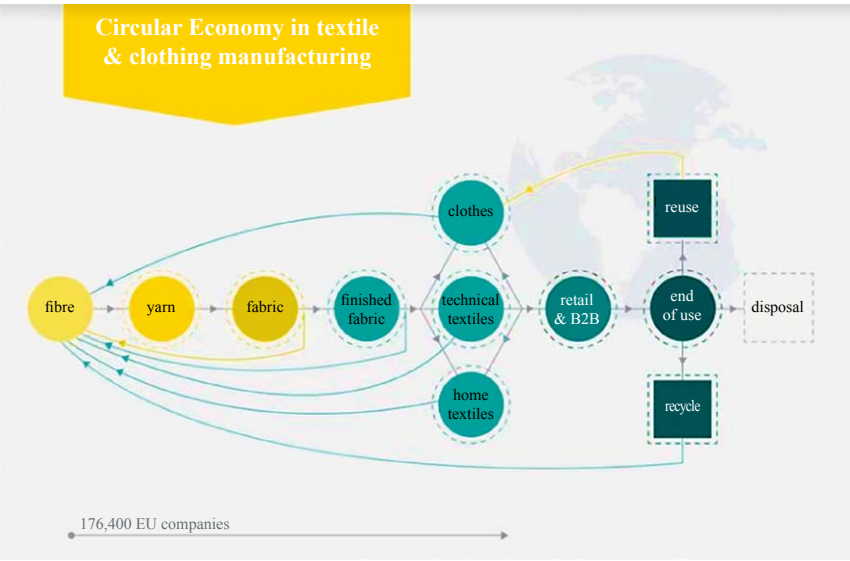

Fig.8 Circular economy in the EU textile and clothing industry [28]

- Partnership between buyers and makers for mutual education and better communication;
- Price reduction requirements - recycled material has a higher price than virgin ones, which leads to the unprofitable use of recycled materials for many companies;
- Product design (design for circularity) including design for recycling, design with recycled or regenerated materials and design for longevity;
- Consumers need to educate themselves to be aware of which products are better for themselves and the environment;
- Prices and eco-labels must encourage consumers to buy recycled products, and the benefit of such products should exceed expectations. Life Cycle Assessment (LCA) should be considered to make objective decision weather some products/waste shall be recycled or used for energy recovery;
- The need to develop European standards for recycled materials;
- The need to develop and apply new technologies for collecting and sorting of discarded textiles, so as logistical improvements to facilitate the collection from end-users and factories;
- Focus suppliers' interest in innovation, with the main decisions taken by state, regional and local suppliers in order to stimulate the work of other companies;
- Legacy of chemical substances in recycled textiles where composition and health safety of recycled materials can be easily controlled and REACH compliance can be reached;
- National barriers need to be reviewed in order to establish better legislation for a simpler flow of goods/waste between EU countries;
- Triggering public-private funding for development and marketing of new ecological solutions;
- Encouraging consumers and textile industry to implement new circular economy services.

Since textile waste is a major global problem, it is important to implement measures to reduce and/or dispose it. Recycling is an important for today's society, but also for business organizations whose general aim is to reduce unnecessary waste disposal and achieve better "eco" image by investing in recycling models. In addition to recycling, significant results are achieved through the reuse of textiles [29]. J.M Hawley found that as much as 48% of used textiles are sorted and then donated to charity [30]. Recycled textiles also have many application options that have been paying more attention lately. Some of the applications of recycled textiles include the construction sector where they can serve as thermal insulation because they have just as good properties as conventional insulation agents [3]. Textile waste has the possibility for secondary application in the production of textile fibers. L.V. Haule et.al. investigated the characteristics of regenerated cellulose fibers obtained by processing cotton fabrics waste. The results show that depending on the treatment and twisting process, the fibers obtained from the waste have similar or even better properties of tensile strength and wet strength, compared to conventional lyocel fibers [31].

Sorting procedures are important in the disposal of textile waste and greatly facilitate the recycling and application of further processes. Most often after sorting the mechanical procedures of tearing and shredding follow. Mechanical proceses lead to fibrous materials used to obtain new non-woven textile materials bonded with various firming techniques.

It is interesting to point out an example of the research of the use of waste PP flooring, which are sorted and shredded. After that, the residual impurities are dissolved and thermoplastic polymers are melted into granules. Zamani et.al. found in their research that this recycling process reduces CO_2 emissions and saves energy in quantities needed to produce around 1 t of textile material [32]. However, not all waste can be recycled in this way, another way is to use waste flooring as fuel for thermal power plants [33, 34].

6.2. Application of the circular economy in textile finishing

According to a United Nations report, humanity is projected to face a 40% shortage of water supplies by 2030. Demand in most sectors will grow, especially in the agricultural and industrial sectors. Projection is that increase from 2000 to 2050 will be 400 % [35]. Therefore, sustainable com-

panies will invest in technologies aimed at reducing water consumption. This is of utmost importance for the textile industry, especially for textile finishing companies. Pre-finishing, dyeing and finishing uses significant amounts of water and energy and therefore have a great impact on the environment. The circular economy should be applied at all production stages, starting from the reuse of energy (e.g. heat exchangers) and water, all the way to savings of chemicals and process optimization (reducing time and temperature). Waste water must be purifyed by applying physical, biological and chemical treatment procedures to obtain physico-chemical characteristics of water suitable for reuse in certain textile processes. Novel design of wastewater treatment systems combines various systems: membrane bioreactors (MBR), filters with ion exchange resin, reverse osmosis (RO) and nanofiltration (NF). Water after those treatments is of so high-quality that it can be reused in preparing baths for dyeing or bleaching and other finishing processes required by textile companies.

According to studies, 90% of industrial water can be reused, which would significantly contribute to the conservation of the environment and water resources. Savings on water consumption (up to 65%) also leads to energy savings (up to 64%) associated with its preheating (the most common starting temperature for finishing processes is 30 °C, which is the temperature of re-used water). In addition to preserving the environment by application of re-used water in the process of finishing, better results of softness and more dyeing resistance are often achieved. This method of wastewater treatment, under the name Wasatex (*Water Saving Processes for Textile Production*), was funded by EU project and used by Olimpias Tekstil from Osijek. The treatment allows water to be reused at various stages of production almost up to 100%. For their positive environmental results company Olimpias received the National Energy Globe Award in 2017 [37].

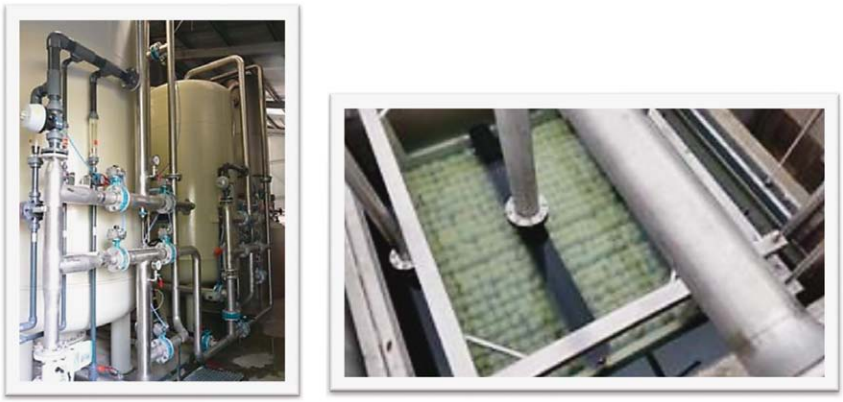

Fig 9 Waste water purification with ion exchange resin and membrane bioreactor (MBR) in Olimpias Tekstil d.o.o. [36]

6.3. Monitoring the implementation of the Circular Economy Action Plan

In order to achieve maximum effectiveness of the measures proposed by the European Green Deal, it is necessary to adopt a framework for monitoring the main elements of the Circular Economy Action Plan. It is important to have a set of reliable indicators in order to assess progress towards the circular economy and the effectiveness of actions both at national and EU level. The European Commission, in close cooperation with the European Environment Agency (EEA) and in consultation with Member States, will work to propose simple and efficient framework for monitoring the circular economy. The indicators will be published in line with the Commission's reports on the SDGs and will also cover new indicators on food waste, as well as other official data in the areas of supply of key raw materials, repair and reuse, waste generation and management, trading of secondary raw materials in the EU and with third countries, so as the use of recycled materials in products. In the five years following the adoption of the Circular Economy Action Plan, the Commission is obliged to report on the progress of its implementation [18].

7. Conclusion

The transition from linear to circular economy is necessary, primarily due to the conservation of natural resources and the reduction of environmental pollution. In a circular economy, products remain in use longer, and at the end of their lifecycle they are reused, repaired, processed, transformed or recycled. The application of this model also achieves numerous social and economic advantages.

In general, public awareness on textile waste needs to be continuously upgraded. It is important to familiarize ourselves with the possibilities of sustainable separation of textiles, encourage the local community to adopt and apply techniques for reuse and disposal, and promote more environmentally friendly products and procedures. The implementation of the circular economy requires synergy between the economic sector, educational and scientific institutions and government. Investments and modernization of technologies in the industry are necessary, primarily from the point of view of increasing energy utilization and reducing the negative impact on the environment.

The knowledge possessed by a textile technology engineer, which includes knowledge on the composition of materials and their mechanical, chemical, thermal, optical and/or

other properties, is of great importance for textile employers. Additionally, engineering knowledge includes capability to solve production problems, human relations, market problems, so as textile waste disposal problems. Textile technology engineer is ready to meet market requirements under specific conditions and quickly decide on the choice of textile finishing, as well as other processes in production. They are trained to design, organize and manage any part of the textile processes and manage the entire production process in textile companies. The goal of textile technology engineers is to contribute with their creative and professional work to the development and rapid transfer of modern technologies. Equally important is the preservation of the environment, so the role of the engineer is to consider and apply the most economically efficient and environmentally friendly methods and technologies. Together with the leadership of the company, legislative acts and new sectoral strategies should be monitored and production harmonized to meet all set requirements.

In 2020, the European textile and clothing industry, coordinated by the European Commission, is preparing a new textile strategy to achieve a better application of the circular economy. More than 40 textile companies in the EU have already adopted the Circular Economy Action Plan, and in 2021 significantly better business results can be expected within the textile, clothing, leather and footwear sectors.

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