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STRUCTURAL CHARACTERISTICS OF TEXTILES COLLECTED FOR REUSE AND RECYCLING

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Abstract: *The circular economy is a new economic model for addressing human needs and fairly distributing resources without undermining the functioning of the biosphere or crossing any planetary boundaries. The research project carried out under the EU contract presents an analysis of 8720 pieces (1500 kg) of used clothing collected from the population for reuse and recycling, in terms of quantification and composition. A Near Infrared (NIR) scanner for the determination of textile fibre composition was used; other characteristics of the garment like product type, age group, colour and presence of disruptors were captured in the app on the electronic device through a short predefined multiple-choice survey, using an application designed by Matoha Instrumentation Ltd. Destination function four groups were selected: disposal (19%), re-wearable non-EU (32%), re-wearable EU(25%), and recycling (24%). The structure of used clothing for adults highlights the preference of consumers for pieces intended for the upper part of the body (42.0%) with a faster change dynamic. The fraction for the lower part of the body (skirts, pants, etc.) follows with 19.9% and underwear with 1.4%, which is characterized by a longer duration of use. The degree of wear and tear of used clothing items correlates with the fractions intended for export (57%), highlighting the main characteristic of the fast fashion phenomenon, namely the shortening of the duration of use of products. The high share of the recycling fraction (19%) highlights the potential of this type of waste for recycling through mechanical or chemical technologies. 14.7% of the pieces of clothing had a blue colour which expresses calm, and responsibility and 12.7% had a white colour which expresses purity, cleanliness and virtue. The predominant composition of the textile materials in used clothes is cotton 34.2% and the basic structure is specific to knitted items (55%).*

Keywords: *used textiles, sorting, reuse, analysis, recycling***.**

1. INTRODUCTION

The textile ecosystem, comprised of textile fabrics, clothing, leather, and footwear (TCLF), is one of the largest industries in the world, with one of the most globalized value chains that exist today [1]. The European textile ecosystem with more than 2.2 million workers faces strong international competition, being the world's second exporter of Textiles & Clothing after China [2].

In this context, the number of textiles & clothing (T&C) produced increased year by year, but the trend of "fast fashion", identified in the market determines the rapid obsolescence of these. As a consequence, T&Cs are discarded for a variety of reasons – a garment may still be wearable but no longer attractive to the consumer [3]. While the production of T&Cs contributes to the raw material deprivation, globally, around 87% of discarded textiles (about 92 million tons, globally) end up in landfills, while more than 90% of these are potentially reusable and recyclable. The

environmental impact caused by discarded textiles is huge impacting soil, water, and air [4]. The textile industry is the second most polluting industry, after the oil industry, and is responsible for 20% of the world's wastewater.

The year 2025 is a milestone for EU-27 countries to collect separately the textiles. The goal is to ensure that used textiles are sorted for reuse and that non-reusable textiles are prioritized for recycling. Even, more and more clothes may be passed on for further use via the second-hand market, having the African and Asian continents as the last destination (about 46% of the Europeans used textiles goes to Africa and about 41% goes to Asia), and finally, most of them end up in open landfills and informal waste streams [5]. Among all European countries, Romania recycles only 3% of the entire volume of waste it produces, the rest being thrown into the landfill.

The limitation of the textile waste flow is possible by applying a strategy in the context of the Circular Economy. The circular economy is a new economic model for addressing human needs and fairly distributing resources without undermining the functioning of the biosphere or crossing any planetary boundaries [6]. Implementing this will have a great impact on the research sector (promoting innovative technologies for sustainable textiles) and on new businesses involved in the collection and treatment of textiles (with opportunities and a larger market for used textiles for social enterprises).

2. MATERIALS AND METHODS

Several factors influence the amount, the structure, and the degree of wear and tear of the waste collected from a certain area. We took into account two main factors:

- Socio-economic conditions: The level of income highly determines the quality of textiles consumed, hence affects the potential destinations of collected textiles. Besides, neighbourhoods with citizens with high levels of environmental awareness tend to have higher collection rates than others.
- Demographic conditions: Consumption and disposal patterns can differ depending on the degree of urbanization and average population age.

For the research, we employ a quantity of 1500 kg of used textiles, respectively 8720 used garment pieces, that were classified and analysed in a specialized deposit from Romania, that are intended for reuse and recycling. The collection was carried out with the support of governmental organizations for social protection.

2.1 Method

The study took place in a city with approximately 4 million inhabitants, characterized by a high degree of pollution, a continental climate, a very dynamic lifestyle and an average annual income of approx. 13,850 euros/inhabitant, which is 86% higher compared to the residents of other areas of the country and 8% below the European average. The average age of the inhabitants is 42.3 years. The capture of garment characteristics was made in two steps:

• the garment was scanned by a volunteer using the NIR handheld device, to assess its composition;

• other characteristics of the garment like product type, age group, colour and presence of disruptors were captured in the app on the electronic device through a short predefined multiple-choice survey, using an application designed by Matoha Instrumentation Ltd.

Destination function four groups were selected: disposal, re-wearable non-EU, re-wearable EU, and recycling.

3. RESULTS

3.1 Garment type

The analysis of the batch of used clothes highlighted the results presented below.

- Garment type according to users (Fig.1): 22.9% garments for children, 67% garments for adults, 8.29% other textile products, 1.2% blank, accessories such as hats, gloves, medium and small accessories 4.7%.

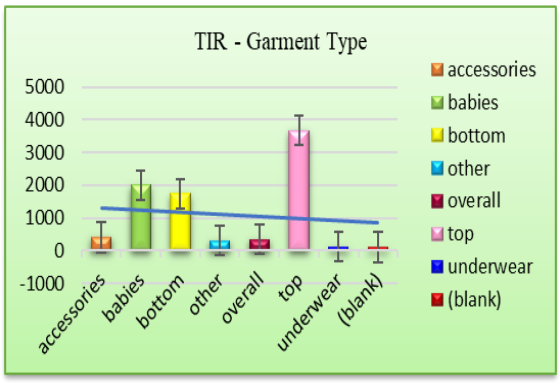

Fig. 1: *Fractions of the batch*

The structure of garments for adults highlights the consumers' preference for pieces intended for the upper part of the body (42.0%) with a faster change dynamic. Next, the fraction for the lower part of the body (skirts, pants, etc.) with 19.9% and underwear, with 1.4%, which is characterized by a longer duration of use. Other types of garments mean 36.7%.

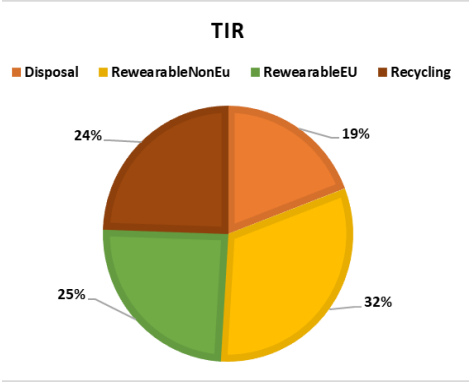

Fig. 2: *Garment type per batch*

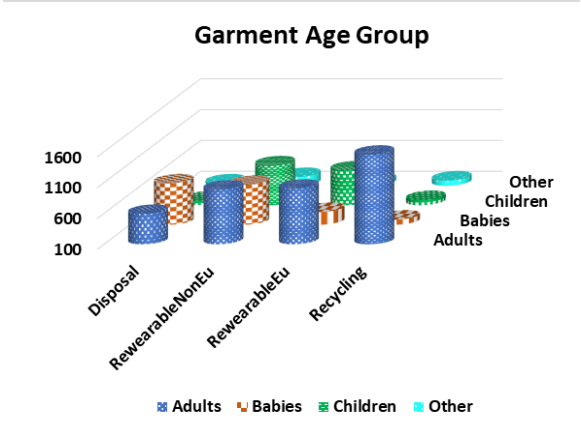

Fig. 3: *Fraction per garment type*

Fig. 2-3 present the share of each type of garment by destination group after collection. From the whole batch, 19% represents the disposal fraction, 24% the recycling fraction, 32% the fraction intended for export to non-EU countries and 25% the fraction intended for export to EU countries. It is noted that the largest share of the recycling fraction is from used clothing for adults. This orientation is correlated with the degree of wear (Fig.4 and 5), respectively: degree 1: pieces with multiple stains and holes, missing buttons and /or broken, zippers, including clothes impossible

to identify; degree 2: pieces with multiple stains and holes, missing buttons and/or zippers but the garment possible to identify; degree 3: pieces with few and small stains or holes and/or some discolouration and pilled or thinned to a major extent; degree 4: the item is visibly worn with minor hole(s) or stain(s) or fabric being to a minor extent thinned or pilled (not all of these factors together); degree 5: new items with tags, without tags or like new, no visible damage.

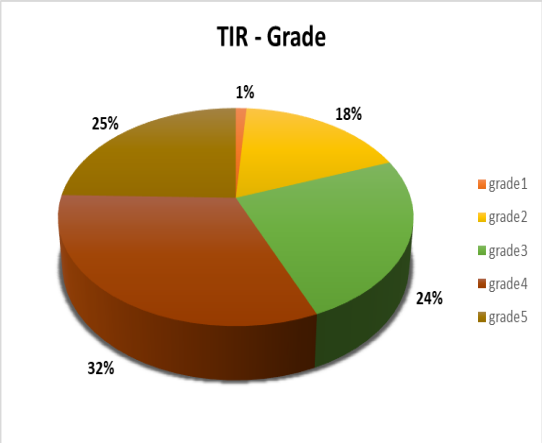

Fig. 4: *Degree of wear per batch*

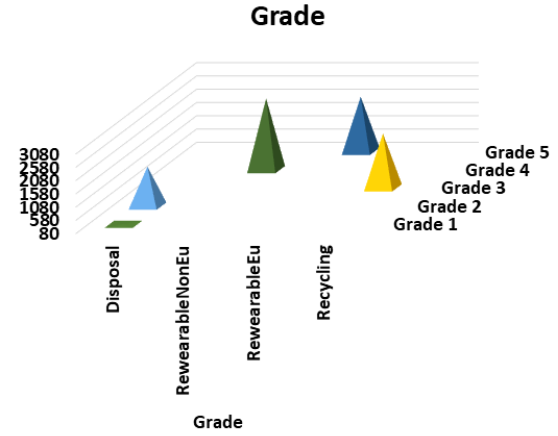

Fig. 5: *Degree of wear per fraction*

More than 32% of used clothing pieces have grade 5 of wear, being almost new and 25% grade 4. These percentages highlight the phenomenon of fast fashion that has led to the shortening of the use of products.

3.2 Composition

People are becoming increasingly aware of the importance of the composition of the clothing they wear. Apart from the key aspects related to environmental protection and moving towards a more eco-friendly life, it is essential to remember how important the fabric composition is for skin and comfort of use. The composition is a classification of materials, fabrics and knitted fabrics by what type of fibre they are made of. Every fabric or knitted fabric of a given composition has its uses. There are no bad ones or good ones – the important thing is to apply them appropriately to our needs. In addition, it is essential knowledge to properly care for the item so that it can serve for years. Therefore, it is useful to know the specifics of different materials, and then make an informed choice when shopping. In the spirit of environmental protection, we are keen to bet primarily on materials made of natural fibres, if only because synthetic ones such as polyester take a long time to decompose.

In our study:

✓ 34.2% of the garments are made from cotton (Fig. 6-7). Its characteristics are that it absorbs moisture very well retains heat, is breathable and does not crease. Another very positive property is that it is non-sensitizing– which is great news for allergy sufferers.

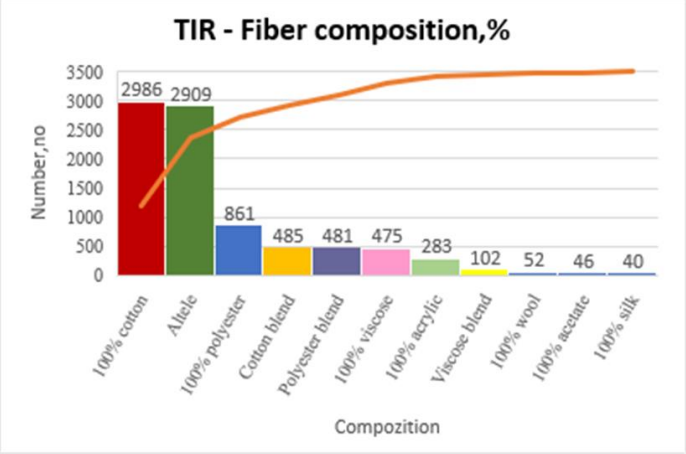

Fig. 6: *Composition per batch*

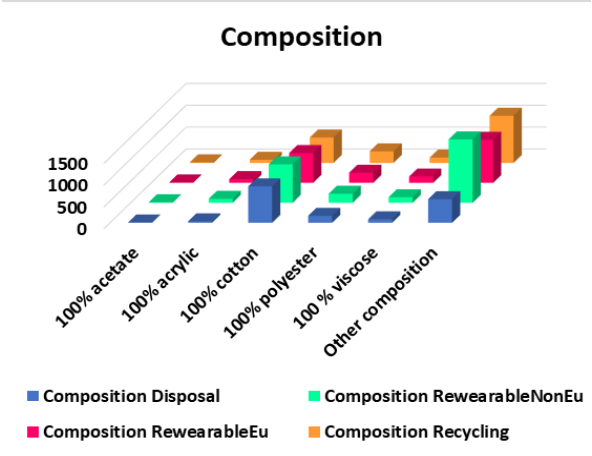

Fig. 7: *Composition per fractions*

✓ 9.8% of the garments are made from polyester. Polyester is noted for its exceptional durability and resistance to wrinkling, shrinkage and stretching. It withstands regular wear and tear, making it suitable for durable garments. Initially, consumers were enthusiastic about the improved durability profile of polyester compared to natural fibres, and these benefits are still valid today. In recent decades, however, the harmful environmental impact of this synthetic fibre has come to light in great detail, and the consumer stance on polyester has changed significantly.

✓ 5.45 of the garments are made from viscose: Viscose is an artificial fibre that is made from naturally occurring raw materials, such as wood cellulose. It has properties similar to cotton, it is a pleasant and soft material. Unfortunately, it is also characterized by low durability and the fact that it creases a lot.

In general, mixtures of 2 or more fibres aim to capitalize on the positive comfort and durability characteristics of each fibre. The most well-known are those made of cotton/polyester.

In our study:

✓ 10.8 % of the garments are made from cotton/polyester blend - because polyester fibres are so tough, unlike cotton and other natural fabrics, they do not easily rip, stretch, or pill. When blended with cotton, polyester improves the shrinkage, durability, and wrinkling profile of this widely-produced natural fibre. Because of its durability, polyester clothing doesn't need special

maintenance and can easily withstand damage from machine washing. Polyester fabric is particularly well-liked for outdoor apparel due to its resilience;

✓ 39.75% of the garments are made from the other fibrous mixtures.

One major limitation of the use of NIR is its limited ability to recognise the presence of elastane. Elastane is often added to cotton garments to optimise comfort and fit. Pure cotton may contain small amounts of elastane.

3.3 Colour

Few things in design are more subjective, or more important than the use of colour. A colour that can evoke one reaction in one person may evoke the opposite reaction in another, due to culture, prior association, or even just personal preference. In our study: the colour of used garments was considered the solid or dominant colour. If it wasn't possible to define the same dominant colour, the article was considered multicoloured.

Based on this were obtained:

✓ 14.7% of the pieces of clothing had a blue colour that expresses calm, responsibility and sadness. Blue is a primary colour across all models of colour space. It is the colour of the ocean and the sky; it often symbolises serenity, stability, inspiration, or wisdom (Fig.8).

✓ 12.7% of the pieces of clothing had a white colour that expresses purity, cleanliness and virtue. White is often associated with purity, perfection, honesty, cleanliness, and beginnings. Surveys in Europe and the United States repeatedly link the colour white to forms of purity.

✓ 10.6% of the pieces of clothing had grey colour express grey moody, conservative and formal. In Europe and North America, surveys show that grey is the colour most commonly associated with neutrality, conformity, boredom, uncertainty, old age, indifference, and modesty.

✓ 10.2% of the pieces of clothing had a black colour that expresses mystery, elegance and evil. It can be linked with death, mourning, evil magic, and darkness, but it can also symbolize elegance, wealth, restraint, and power. As the first pigment used by artists in prehistory and the first ink used by book printers, black played an important role in the development of art and literature.

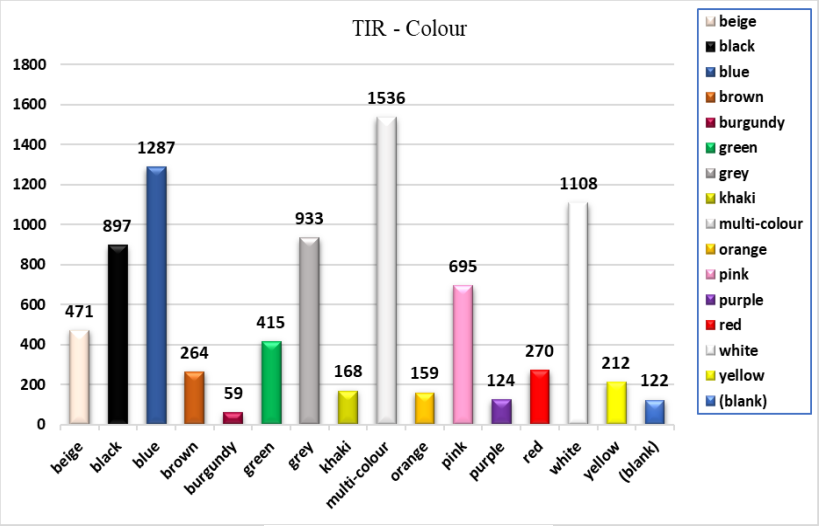

Fig.8: *Colours per batch*

Fig.9 shows that the share of colours on the fractions is similar to that identified on the whole batch of used clothes.

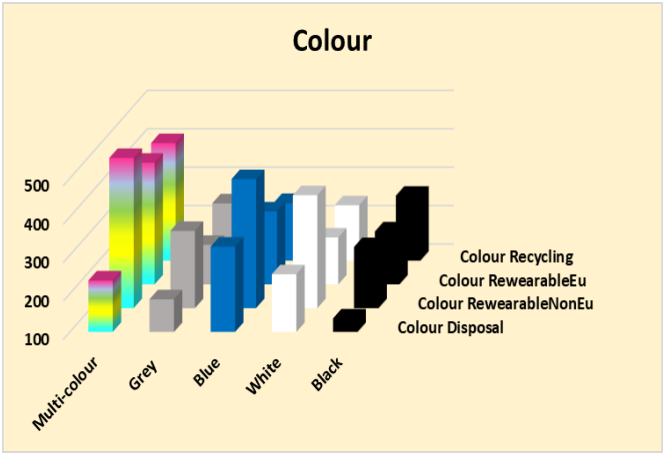

Fig. 9: *Colours per fractions*

In our study, 17.6% of the pieces of clothing had a combination of colours (Fig. 8-9) that was nominated as multicolour. The other colours mean 34.2%.

Structure of the raw material

Fabric structure is most relevant to assess the potential use of textiles as feedstock for mechanical recycling. Specific characteristics make a difference between them. The knit fabric is looped together. The woven fabric is interlaced at right angles. Woven fabric does not stretch across the width but along the length. Knitted fabrics stretch easily across the width and slightly lengthwise. Knitted fabrics keep their shape when pressed, while woven fabrics show folds on the surface when pressed. Examples of knit are single jersey, interlock, pique, rib and ponte roma and woven fabrics are twill, chiffon, denim and poplin. Out of 8720 pieces of clothing analysed, 55% are made of textile materials obtained by knitting technology, 44% of textile materials are made by woven technology and 1% are unidentified (fig. 10-11).

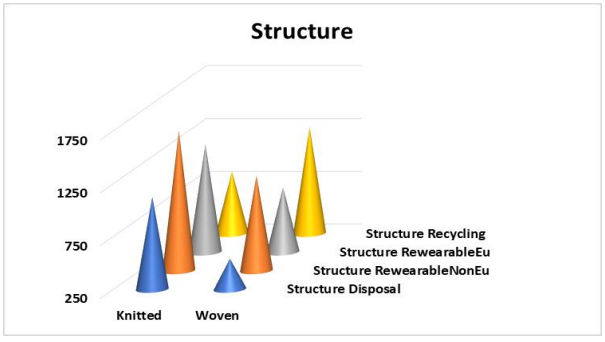

Fig. 10: The structure of raw material per batch

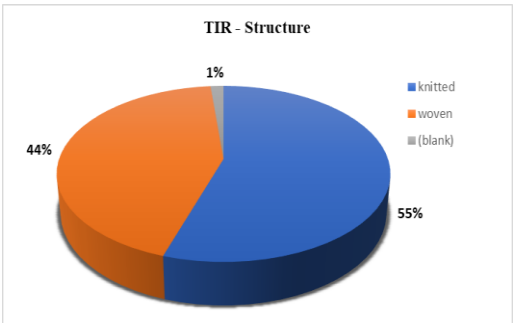

Fig. 11: The structure of raw material per fractions

5. CONCLUSIONS

- A batch of 8720 pieces of used clothing collected from the population in 4 fractions, weighing approx. 1500 kg, was analyzed.
- The share of wear grades 4 and 5 correlates with the fractions intended for export (57%), highlighting the main characteristic of the fast fashion phenomenon, namely the shortening of the

product lifespan. The high share of the recycling fraction (19%) highlights the potential of this type of waste for recycling through mechanical or chemical technologies.

- The predominant colours of the pieces of clothing are blue colour (14.7%) which expresses calm, responsibility, and sadness and white colour (12.7%) which expresses purity, cleanliness and virtue.
- The predominant composition of textile materials in used clothes is cotton (34.2%) and the basic structure is specific to knitted items (55%).

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