# WP T2 – INNOVATION ON TEXTILE WASTE MANAGEMENT

## ACTIVITY A.T2.3 PILOT CASES

### D.T2.3.3 PILOT CASES TECHNICAL REPORT

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## ENTeR – Expert Network on Textile Recycling

ENTeR works in five central European countries that are involved in the textile business, to promote innovative solutions for waste management that will result in a circular economy approach to making textiles.

The project will help to accelerate collaboration among the involved textile territories, promoting a joint offer of innovative services by the main local research centres and business associations ("virtual centre"), involving also public stakeholders in defining a strategic agenda and related action plan, in order to link and drive the circular economy consideration and strategic actions.

The approach of the proposal and the cooperation between the partners is oriented to the management and optimization of waste, in a Life Cycle Design (or Ecodesign) perspective.

## CONTENT

# 1. Pilot case description – aim and scope

The aim of the Polish Pilot Case was to find a way of effective post-production textile waste management. There is an urgent need to find solutions, e.g. recycling possibilities. The costs of waste storage and disposal are very substantial for the textile and clothing companies.

The main needs to be solved in the pilot case were finding the solution for recycling and/or reuse of production waste. The main steps of the Pilot Case comprised:

- **Waste analysis**: collection of different kinds of post-production textile waste, their identification and characterization in terms of their structure and the raw material composition
- **Solution for recycling and reuse**, including the **development of new value chains** through identification of Polish textile companies with similar waste streams, in terms of their processing possibility and, on the other hand, **searching for market available technologies for waste pre-treatment,** for recycling purposes in Poland and textile waste recycling technologies tested in Polish companies.

The first textile company involved in the Polish Pilot Case implementation is the manufacturer of woolen carpets and artificial grass. Their generated post-production textile waste consists of remains of yarns, cutting waste and dust from the carpet and artifical grass production. Within Pilot case management of the different waste streams, among others, scraps/waste collected from the production of traditional woollen carpets and artificial woven grass, based mainly on polypropylene and jute were considered.

The second textile company involved in the Polish Pilot Case implementation is the thread manufacturer. Their offer includes also quilting of fabrics and knitwear comprising quilting of outer fabrics and linings, quilting in the production of mattresses or quilting for the production of bedcover and products for tableware. Within Pilot case management quilted textile wastes based mainly on polyester were considered.

**Experts on textile material engineering/processing** were invited to **cooperation**, including textile waste processing plants.

# 2. Mapping of the market available technologies for waste pre-treatment in partner region

EU consumers discard about 11 kg of textiles per person per year[1]. Considering global material flows for clothing in 2015, only 13% of the total material input was recycled after end of use with less than 1% of clothing worldwide remaining in the production cycle[2]. According to the European Commission, European consumers discard around 5.8 million tonnes of textiles every year and only 26% is being recycled. The most of textiles waste goes to landfills and incinerators[3].

According to European Environment Agency 34% of all municipal waste in Poland was recycled or composted, 42% was landfilled and 24% was incinerated in 2017.[4] Polish consumers discard 328 kg of municipal waste per person in 2018.

In Poland textile waste generated by all NACE activities and households in 2018 increased over 65% from 2004 (**Fig.1**).

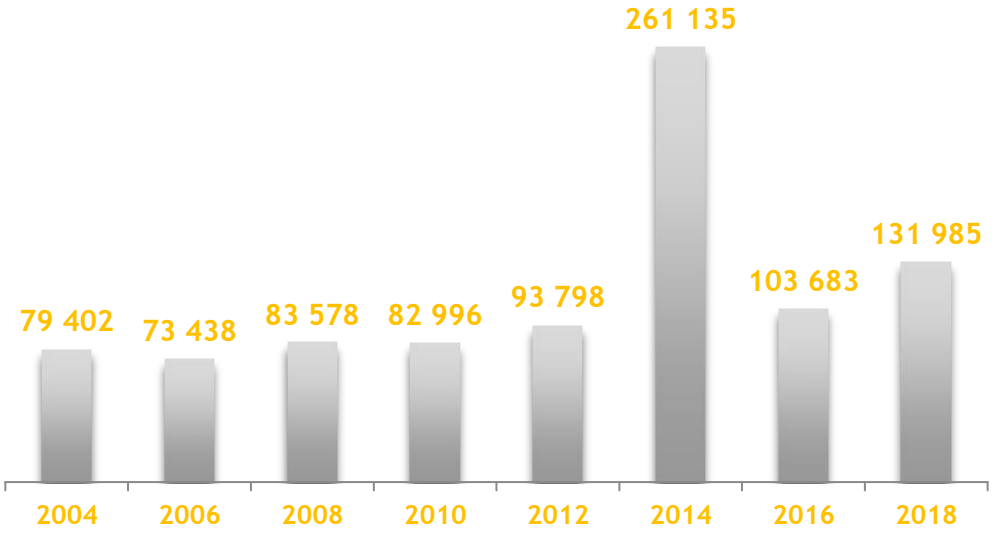


*Fig. 1. Textile waste generated by all NACE activities and households in Poland in the period 2004 - 2018, in tonnes (based on Eurostat data)*

Textile waste can be divided into:
• **post-consumer textile waste** which includes products such as clothing, home and household textiles generated during consumption of textile goods and
• **pre-consumig textile waste** generated during the production of textile goods, which includes also unsold textile goods.

[1] European Environment Agency (2019). Textiles in Europe's circular economy, Brief. No 10

[2] Ellen McArthur Foundation (2017). A new Textiles Economy: Redesigning fashion's future

[3] Bukhari M. A. B, Carrasco-Gallego R., Eva Ponce-Cueto (2018). Developing a national programme for textiles and clothing recovery Waste Management & Research 36, 321

[4] https://www.eea.europa.eu/data-and-maps/indicators/waste-recycling-1/assessment-1

Similar to other EU countries, there is no mandatory collection of textile waste in Poland. Currently textile waste in Poland:
• becomes part of mixed municipal waste; it is incinerated or disposed in landfills;
• is transported to the District Point of Municipal Waste Selective Collection operated by respective administrative bodies in municipalities (at least 1 per municipality) in cooperation with duly authorised sorting/recycling companies (the decision issued by the Environmental Protection Department), recovery is preferred;
• is collected by private companies or charity organizations such as Caritas.

The best quality post-consumer textile waste such as clothing is reused/re-worn. The current processing method for lower quality post-consumer and pre-consumer textile waste in Poland is mainly mechanical recycling. There is also possibility of physical (thermal) recycling. Textile waste is mainly processed for cleaning cloths (garages, machine factories, printing offices, the army and railroads), for fibre based insulation non-wovens (blankets, felt for soundproofing and yarns for carpets). The lowest quality textile waste is incinerated (energetical exploitation) or disposed in landfills.

There is **National Economic Chamber of Textile Recycling Materials** in Poland. Entrepreneurs consociated in the Chamber deal not only with the import and trade of second-hand clothes, but also second-hand clothes management from collecting up to processing into secondary raw materials/recycled materials, such as industrial cleaning cloth, interlinings, wadding, insulating materials as well as mats [ http://www.kigtsw.pl/ ].

**The key recycling leaders on Polish market are VIVE Textile Recycling and Wtórpol.**

**VIVE Textile Recycling** is one of the Polish leaders of the textile recycling industry in Poland and Europe.
The production process consists of many stages – from the acquisition of textiles, through sorting, to the wholesale and retail sale of second-hand clothing and industrial cleaning cloth, and other products resulting from the recycling process. For example, the raw material, which does not comply with quality requirements, is processed into industrial cleaning cloth, PE granulate, alternative fuel or composite boards. Finished products are delivered to customers in many countries in Europe, Africa, Asia and even North and South America.
The company uses modern, fully computerized lines for sorting clothes, allowing the processing of 500 tons of raw material per day while maintaining the highest quality standards ISO 9001 and 14001 [ https://www.vivetextilerecycling.pl/ ].

**Wtórpol** is one of the largest companies in the textile recycling industry as well as cleaning cloth manufacturing worldwide, which has been present for 28 years in Poland and on foreign markets. Wtórpol **collects used clothes** - containers into which people may throw unnecessary clothing are installed all over Poland. Thanks to that, every year millions of kilograms of textiles do not end up at landfills. The best quality clothing is delivered to their chain of second-hand stores under a common brand. Such clothing is also exported, among others, to 20 African countries. In 2017 a new technological line adapted to the production of high-calorific, environmentally safe fuel was launched.
In the company 300 tons of textiles during an eight-hour shift are processed [ https://www.wtorpol.com.pl/ ].

**Zakład Utylizacji Odpadów Przemysłowych (ZUOP Company)** offers comprehensive services for companies, institutions and individuals in terms of hazardous waste and other than hazardous waste management. The company is interested in collecting:

- production waste,
- used up items of clothing in the form of second-hand clothes,
- home furnishing textiles (curtains, heavy curtains, sheer curtains, etc.),
- clothing and footwear coming from customer complaints,
- textiles coming from vehicle equipment,

and other [ https://www.zuop.com.pl/pl/ ].

All the above mentioned waste is disposed of by the company through waste shredding and mixing in the process of alternative fuel production from waste.

Other example of Polish sustainable company is **Nowy Styl Group**, the 3rd biggest office furniture manufacturer in Europe. The company developed 'less waste' or 'zero waste' solutions as well as an environmentally-friendly office chair in line with CE approach. About 96% of all materials of an environmentally-friendly office chair can be recycled after the end of the chair life. This chair has been designed to be used for a long time. In another chair line, the seat can be detached from the backrest easily, and the selected model of seat upholstery (the fabric with the EU Ecolabel certificate) has no inserts or stitching of any kind. The wall claddings at office can be made of panels made by Nowy Styl Group, which have been upholstered with the fabric made from fibres obtained from 100% recycled PET bottles. [https://uk.nowystylgroup.com/en/]

Other recycling companies present on the Polish market are listed in the Table below (see also **Fig.2**).

***Table 1.*** *Recycling companies dealing with textile waste in Poland, by voivodships*

| **The Łódzkie Voivodship** | |
|---|---|
| BIOMATEX (Zduńska Wola) | Collection and processing of textile waste mainly for nonwovens. Cotton, viscose, wool, polyester, acrylic, polyamide, cashmere, silk waste. |
| MK-TEX (Łódź) | Purchase and recycling of textile waste from knitting and sewing factories. Production of various types of cleaning cloths made of cotton and artificial fibers (polyamide, polyester, polyacrylonitrile and others). |
| TOMCOTTON (Tomaszów Mazowiecki) | The possibility of needled nonwovens production from textile waste. |
| TPO sp. z o.o. (Łódź) | Collection and recycling of textile waste, including the utilization and processing of waste from wool, horse hair, artificial fibers and the processing of rags. |

| | |
|---|---|
| **The Małopolska Voivodship** | |
| ARKA sp. z o.o. (Tarnów) | Collection and recycling of textile waste, services, collection and recycling of used clothing. |
| CLIF sp. z o.o. (Skawina) | Collection and recycling of textile waste, including the utilization and processing of waste from wool, cotton, linen, jute, hemp, artificial fibers and the processing of rags. |
| SINOMA recycling (Kraków) | Collection, sorting and baling of post-production textile waste from polyester, acrylic, polyamide, polypropylene, cotton and wool. |
| Zakład Utylizacji Odpadów Przemysłowych, ZUOP Company (Kraków) | Collection of post-production textile waste, used clothing, interior textiles (curtains, drapes) and from vehicle equipment. The waste is torn up and mixed, and the produced granulate is used as an alternative fuel. |
| **The Mazowieckie Voivodship** | |
| PAWEX PAWEŁ TRĘTOWSKI (Turzyn, Brańszczyk) | Collection of plastic including PP nonwovens, regranulation and grinding of plastic. |
| **The Śląskie Voivodship** | |
| BRECO sp. z o.o. (Bielsko-Biała) | Collection and recycling of textile waste, services. Utilization and processing of artificial fiber waste. Yarn waste processing. Textile waste processing for upholstery needs. Textile waste carding. Processing of textile waste into plastic fillers. |
| KONTAKT DSS RECYKLING sp. z o.o. (Dąbrowa Górnicza) | Collection and recycling of textile waste, services, collection and recycling of used clothing. |
| Makpol Recykling (Lubliniec) | Production of alternative fuel also from textile solid waste.Textile waste processing. |
| **The Świętokrzyskie Voivodship** | |
| VIVE TEXTILE RECYCLING sp. z o.o. (Kielce) | Collection and recycling of textile waste, services, collection and recycling of used clothing. |

| | |
|---|---|
| Wtórpol sp. z o.o. (Skarżysko-Kamienna) | Collection and recycling of used clothing, services. Production of cotton wipes with high absorption properties, primarily for machine maintenance and cleaning. Production of composites with high resistance, insensitive to weather conditions from the combination of fragmented clothing with other materials for use in construction, agriculture and households, including composite boards and painting mats. Production of high-quality alternative fuel from textile waste. |

*Fig.2 Recycling companies dealing with textile waste*

# 3. Results and conclusions

Different kinds of textile waste were collected from the production of two main assortments: traditional woven carpets (from natural and synthetic yarns) and artificial grass and were assessed at Ł-IW in terms of their structure and the raw material composition, including FTIR analysis.

Wastes generated during the production process of traditional carpets contain natural fibres (wool, jute), staple yarns made of a blend of polyester and cotton fibres, as well as polyacrylonitrile fibres. Artificial grass wastes contain polyethylene monofilaments and polypropylene fibrillated tapes.

The potential possibilities of processing or other use of separated waste streams (polyolefins, natural fibers) were assessed and analyzed in cooperation with external experts. As a result the first ideas of managing and processing of post-production textile waste from production of carpets, artificial grass and quilted textile materials were developed, including pre-treatment for recycling purposes. The possibility of mechanical recycling was considered: waste cutting and then their defibering, and subsequent nonwovens and ropes production, according to KEMAFIL® technology.

The potential application areas for manufactured products were proposed. **Potential areas for the use of cut edges of woolen carpets can be as follows:**

- direct use of the cut edges in the agro area, in the area of geo-products,

- use of cords in the geo area,

- use of nonwovens from a cut edges in the geo area,

- use of nonwovens from linen in the furniture industry.

**Nonwovens made of textile waste:**

- for production of rolling lawns,

- for absorbing oil and oil-in-water emulsions,

- as geo products

- for the furniture industry.

The potential application areas of new products obtained from post-production textile waste result mailny from their structure and the secondary raw material composition and comprise:

- geotextiles,
- **construction industry,**
- heavy industry (sorbents),
- forestry,
- **transport,**
- decorations,
- sealing used during construction of wooden houses.

The developed solutions were tested in cooperation with processing plant **TOMCOTTON in Tomaszów Mazowiecki** and **University of Bielsko-Biala**.

As part of the *Pilot case*, the following separated waste streams were used: waste in the form of jute cuttings from the production of woollen carpets, polypropylene cuttings from the production of artificial grass (both types from the first textile company) and waste in the form of scraps and cuttings after quilting, containing polyester fibres (from the second textile company), (**Fig. 3**).

a)  b)  c) 

***Fig. 3****. Post-production waste used for the production of nonwovens: a) jute selvedges, b) polypropylene selvedges, c) quilted cuttings - polyester*

Based on expert analysis on the potential for processing or other use of separated waste streams as well as developed concepts for the management and processing of post-production textile waste, in the first stage, this waste was processed mechanically at Tomcotton in Tomaszów Mazowiecki. Processes of waste cutting and defibering / unravelling were carried out.

The possibility of obtaining needled nonwovens made from selected post-production textile waste was tested in the company. The needled nonwovens made of such a waste were composed of:

**I** - 100% defibred jute selvedges,

**II** - 50% defibred jute selvedges / 50% defibred polypropylene selvedges

and

**III** - 33% defibred jute selvedges, 33% defibred polypropylene selvedges and 34% defibred cuttings after quilting (polyester) - **Fig. 4**.

I 

II 

III

*Fig. 4. Needled nonwovens made of defibred post-production waste: I - 100% defibred jute selvedges, II - 50% defibred jute selvedges / 50% defibred polypropylene selvedges, III - 33% defibred jute selvedges, 33% defibred polypropylene selvedges, 34% shredded polyester waste*

As initially assumed the produced needled nonwovens would be used as geotextiles, acting as anti-erosion protection for slopes. For this reason, tests of manufactured nonwovens were carried out in accordance with applicable harmonized standards for geosynthetics. The basic properties of newly produced nonwovens were characterized. Their thickness, mass per unit area (**Table 2**), strength properties (**Table 3**) and hydraulic properties - water permeability, water flow velocity at a given height of hydraulic pressure, characteristic pore size in nonwovens (**Table 4, Fig. 5**) were evaluated.

It has been shown that nonwovens containing jute fibres, regardless of their percentage/share in the fleece, have very good filtration properties, confirmed by a high permeability value perpendicular to the surface of the product, ranging from 76.7 to 87.7 mm/s. The nonwoven fabric composed of jute selvedges (50%) and polypropylene selvedges (50%) is characterized by the highest water permeability and also the highest porosity. Based on the results obtained, it was found that the values of strength parameters are relatively low compared to the currently used biodegradable geotextile materials. As a result, the produced nonwovens cannot independently act as anti-erosion protection on slopes or embankments.

*Table 2. Basic parameters of needled nonwovens made of defibred post-production waste*

| **Needled nonwoven made of:** / **Tested parameter** | | 100% defibred jute selvedges | 50% defibred jute selvedges<br>50% polypropylene selvedges | 33% defibred jute selvedges<br>33% polypropylene selvedges<br>34% polyester waste |
|---|---|---|---|---|
| **mass per unit area PN-EN 29073-1:1994** | | 208 ± 10 g/m$^2$ | 202 ± 9 g/m$^2$ | 215 ± 7 g/m$^2$ |
| **Thickness PN-EN ISO 863:2007 at load** | **2 kPa** | 4.07 mm | 3.28 mm | 3.28 mm |
| | **20 kPa** | 2.43 mm | 1.67 mm | 1.67 mm |
| | **200 kPa** | 1.19 mm | 0.77 mm | 0.79 mm |

*Table 3. Strength properties of needled nonwovens made of defibred post-production waste*

| Needled nonwoven made of / Tested parameter | | | 100% defibred jute selvedges | 50% defibred jute selvedges<br>50% polypropylene selvedges | 33% defibred jute selvedges<br>33% polypropylene selvedges<br>34% polyester waste |
|---|---|---|---|---|---|
| Tensile strength PN-EN 29073-3:1994 | Average maximum breaking strength | lengwise | 2.9 ± 0.8 N | 3.1 ± 1.4 N | 4.6 ± 0.9 N |
| | | crosswise | 4.4 ± 0.7 N | 4.2 ± 0.8 N | 7.4 ± 2.5 N |
| | Relative elongation at maximum breaking | lengwise | 39.0 ± 13.0 % | 41.5 ± 17.0 % | 67.5 ± 13.0 % |
| | | crosswise | 22.5 ± 3.5 % | 43.5 ± 5.5 % | 60.0 ± 15.5 % |
| Static puncture test (CBR test) PN ISO 12236:2007 | | | 14 ± 5 N | 13 ± 5 N | 23 ± 21 N |
| Dynamic perforation test (cone drop test) PN-EN 918:1999 | | | 44.75 ± 3.0 mm | 42.80 ± 3.0 mm | 31.60 ± 4.9 mm |

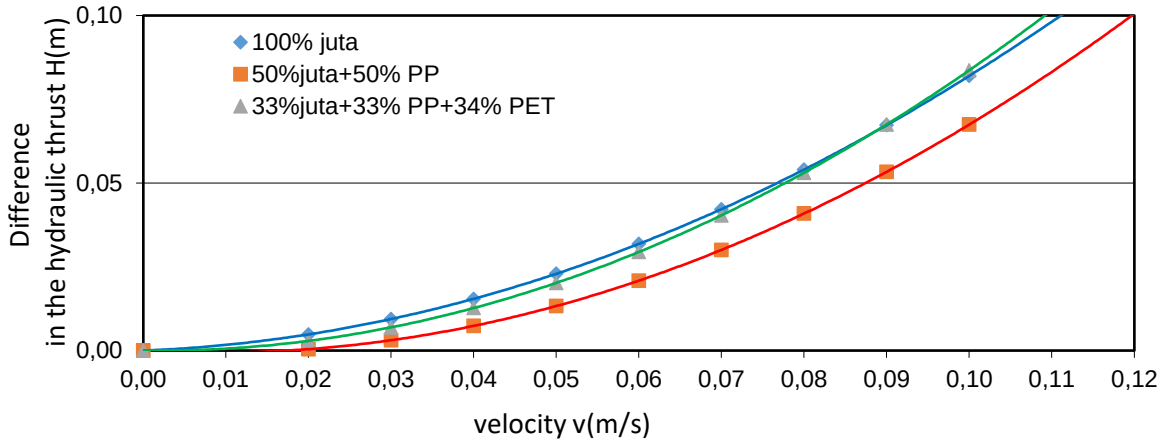


*Fig. 5. Diagrams of water permeability perpendicular to the surface of the geotextile without load for needled nonwovens made of defibred post-production waste*

*Table 4. Hydraulic properties of needle-punched nonwovens made of defibred post-production waste*

| Needled nonwoven made of / Tested parameter | 100% defibred jute selvedges | 50% defibred jute selvedges<br>50% polypropylene selvedges | 33% defibred jute selvedges<br>33% polypropylene selvedges<br>34% polyester waste |
|---|---|---|---|
| **Water permeability characteristics normal to the plane, without load PN-EN ISO 11058:2011** | 76.7± 3 mm/s | 87.7± 4 mm/s | 77.8 ± 19 mm/s |
| **Determination of the characteristic opening size (the wet-sieving principle) PN-EN ISO 12956:2010** | 150 µm | 260 µm | 170 µm |

In the next stage, newly produced nonwovens were used to make nonwoven composites using materials, provided by the University of Technology and Humanities (ATH) in Bielsko Biała, the contractor of an expert service under Pilot case. These materials are: jute mesh, woollen nonwoven made of wool waste together with spun-bonded polypropylene nonwoven fabric, as well as wool dust, by-product in wool rugs production. Newly produced nonwovens and nonwoven composites were used to make cords using the Kemafil® technology - developed and patented at the the Dresden Institute for Industrial Textiles with the firm Rothe, Berthold & Thoma in 1975.

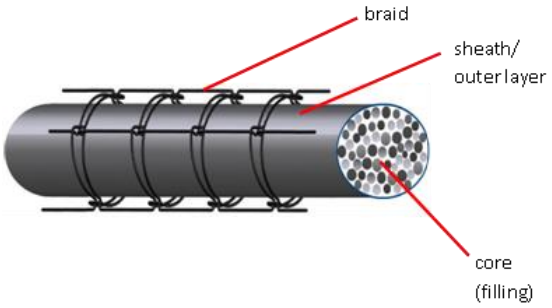


*Fig. 6. Scheme – structure of cord/rope*

In recent years, this technology has been studied and developed at the University of Technology and Humanities (ATH). It uses a specialized, cylindrical knitting machine, equipped with four curved loops, braiding a 4-thread mesh around the outer cover of the cord. Currently it is possible to obtain cords with a diameter of 50 mm to several tens of centimeters. Cords of this type, consisting of a core, sheath and braid (**Fig. 6**), can be made of any textile materials, both synthetic and natural. Potential areas of their application include: agriculture and gardening - as drainage and irrigation elements, transport - as protective and securing cords, construction - as insulation

and sealing materials, as well as anti-erosion protection systems on slopes and embankments. At ATH, a meandering system made of ropes was developed to stabilize the soil on steep slopes. A special method of attaching cords creates a network of microtams that stop the flow of water along the slope and causes that excess rainwater is absorbed and stored. This increases the germination rate of seeds and promotes plant growth, and consequently prevents surface erosion of slopes and embankments.

As part of the Pilot case at ATH, cords were tested having the following composition:

| Sample name | Sheath | Core (filling) | Braid |
|---|---|---|---|
| **ROPE 1** | nonwoven 100% jute | | PP yarn |
| **ROPE 2** | nonwoven 100% jute | PP selvedge un-shredded | |
| **ROPE 3** | nonwoven 100% jute | 100% nonwoven jute + strips with sorbent | |
| **ROPE 4** | nonwoven 33% jute + 33% PP + 34% PET | 100% nonwoven jute | |
| **ROPE 5** | nonwoven 33% jute+33% PP+ 34% PET | | |
| **ROPE 6** | composite 1: woollen nonwoven from wool waste + PP spunbonded nonwoven + nonwoven 100% jute | Wool dust | |
| **ROPE 7** | composite 2: nonwoven 100% jute + woollen nonwoven from wool waste + PP spunbonded nonwoven | Wool dust | |

Examples of ropes, made of nonwovens and nonwoven composites made from post-production waste, are shown in **Fig. 7**.

a)  c) 

b)  d) 

***Fig. 7****. Examples of ropes made (as part of Pilot case) of needle punched nonwovens and nonwoven composites made of post-production waste: a) - outer sheath made of jute nonwoven, core - unprocessed polypropylene beads, b) outer sheath made of non-woven 33% jute + 33% PP + 34% PET, core - 100% jute nonwoven, c) outer cover made of waste wool nonwovens with spunbonded polypropylene nonwoven and 100% jute nonwoven, core - wool dust, d) outer cover and core made of 100% jute nonwovens and waste wool nonwovens together with spunbonded polypropylene nonwovens.*

The ropes, containing woollen nonwovens from waste wool, were used for experimental, laboratory grass cultivation, due to the fact that the wool decomposes in the soil, it generates nitrogen, which is a fertilizer for many plants. Photographic record of this crop is shown in **Fig. 8**.

a)  b) 

c)  d) 

***Fig. 8****. Pictures from experimental cultivation of grass on the ground containing soil and woollen nonwovens from wool waste - made in ATH (on the left side of each photo) or rope containing in the outer covering woollen nonwovens from wool waste and a core of wool dust (on the right side each photo): a) on the day of sowing, b) 6 days after sowing, c) 10 days after sowing, d) 22 days after sowing.*