Environmentally friendly sanitation mats made of fiber obtained from hemp grown on remediated areas

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Introduction

In 2012, the Institute of Natural Fibres and Medicinal Plants together with an agricultural cooperative in Kazimierz Biskupi launched a multiyear project under the EU Life+ program "The new method of restoration of degraded land in the region of Konin Coal Mine using hemp cultivation." Completion of the project is expected in 2018.

One of the objectives of the project, is development of a novel, environmental friendly technology of hemp straw processing for environmentally friendly uses.

The Institute has conducted research on the use of hemp fibers in the production of disinfection mats due to cyclical emerging infectious diseases that afflict especially the agricultural sector. Infectious diseases are spreading through the movement of people, vehicles, farm tools and machinery. Suspending the transport completely and isolating farms completely is difficult to implement and brings severe consequences for the farmer. Therefore, it is important to disinfect vehicles by installing disinfectants at the entrance to the farm.

As the carrier of disinfecting solutions the following solutions are used currently:

- straw mats of relatively low effectiveness. These mats are rapidly disintegrated by moving vehicles, plus straw with a proper structure is difficult to obtain due to harvesting by combine and growing short-straw cereals,
- shavings and sawdust, which due to the flow ability under the influence of passing vehicles provide poor contact of the tires with a disinfectant,
- shallow tanks of disinfectant solution that require efforts to build a tight structure for vehicles. The solution is not suitable for disinfecting footwear,
- mats made of petroleum-based fibers that are a problem for the environment. These mats are difficult in a disposal and a serious ballast to the environment.

Hemp is a plant that produces large amounts of biomass (ca 10 t/ha) which allows to use it for cultivation in post-mining areas. It is estimated that hectare of hemp, accumulates about 2.5 tons of CO_2 from the atmosphere. Additionally, hemp has a well-developed tap root system, which ventilates and loosens the soil.

A new crop rotation was introduced in the Project, that includes two crops: hemp and alfalfa. During the reclamation activities both crops are plowed after mowing. A biological composite is formed in the soil that contributes to the development of soil flora and fauna and accelerates restoration of humus layer in the post-mining degraded areas. Hemp is mowed using a mower equipped with three cutter bars, which cut the stem in three places which facilitates plowing the biomass, which is additionally sprayed with the preparation accelerating the decomposition of post-harvest residues (Mańkowski J. et al. 2014).

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Description of the work

The preliminary studies have shown that the developed disinfection mat should consist of three layers. The bottom layer should prevent the leakage of disinfectant to the soil, the inner layer must be a reinforcement of the non-woven, and the top layer absorbs the maximum amount of disinfectant. The lower layer contains a flexible natural resin, the middle layer is made of jute fabric and the outer layer is made of a nonwoven composed of 80% hemp and 20% flax fibers.

The first stage of the work was to obtain fiber. To process the raw material a decortication unit was selected. The unit is equipped with stem breaking hardened elements able to disintegrate the structure of the stem. Broken straw is arranged in a uniform layer on the feeding table and moved to a tearing drum by a belt conveyor. Extraction of the fibers takes place by the action of steel tearing blades on clammed straw located in the tearing drum. In a further process when decortication is completed, the fiber is cleaned and pressed into bales for later use in disinfecting mat production process (Cierpucha W. 2013).

Photo 1. Compact decortication unit

When processing on decortication unit was finished, a qualitative tests on obtained decorticated fiber was carried out. The basic laboratory quality parameters analysis was carried out at the Textile Raw Materials Technological Assessment Laboratory of the Institute of Natural Fibres and Medicinal Plants.

The analysis covered:

– determining the level of impurities,
– determining the fiber length distribution,
– determining fiber divisibility,
– determining fiber strength.

The study confirmed that the obtained decorticated hemp fiber is suitable for the production of disinfectant mats.

The next stage of the research was to determine the method of forming the non-woven fleece and stitching. For this purpose, a research station for forming mats was assembled.

Table 1

Average quality parameters of obtained decorticated hemp fiber

Raw material	Imputities [%]			fiber length distribution [%]				Divisibility [tex]	Metric number [Nm]	Average breaking force [N]
	total	durable	loose	< 20	21–50	51–100	101–150			
				mm						
Hemp decorticated fiber	40.0	30.0	10.0	9.5	31.2	46.2	13.1	14.0	71.4	114.2

The process of disinfecting mat production involves mechanical method of fleece forming by means of a carding machine equipped with suitably modernized working elements. This method provides a well fiber separation and mixing of the individual components of the mat which have different properties and geometric dimensions. Formed fleece is then needled. Needling process involves dragging a fibers through the fleece with special steel needles. This process leads to formation of three-dimensional arrangement of the fibers fixes them within the fleece. The production process is run at the fleece movement speed of 0.8–1.0 m/min, needle density number of 20, and number needle punches of 50 per cm^2.

Photo 2. Needle punching machine used in the manufacture of disinfecting mats

Having obtained the needle-punched fleece, the tests were carried out in the next step, which allowed selection of the suitable reinforcing fabric, constituting a layer of disinfectant nonwoven. It was assumed that the jute (instead of linen) fabric reinforcing the mat will have a surface weight of approx. 120 g/m^2, mainly due to the large price difference. Better strength parameters were obtained with linen fabric, but because of the price competitiveness the jute fabric was selected. It turned out that the fabric of mesh structure introduced in the mat, contributed to the tearing strength increase of nonwoven and prevented the mat shape deformation.

Given the need to maintain the requirement of biodegradability, in order to counteract leakage of disinfectant into the soil, a flexible and resilient base insulation was developed, made of natural resins. Tests results showed that the best method to apply the natural resin on the nonwoven is by spraying. In the method of spraying an aqueous suspension of natural rubber is sprayed on the web by the nozzle. An aqueous suspension of 20–30% of natural rubber was used. After the process of applying natural rubber the nonwoven goes to a dryer, where the mat is vulcanized at a temperature of 90–100°C.

Having optimized the structure of disinfectant mat its properties were analyzed in the laboratory. The parameters important during the use of mats were analyze, namely: the strength of the mat and its biodegradability. Non-woven fabrics with extreme surface weights were chosen: 900 and 1350 g/m^2.

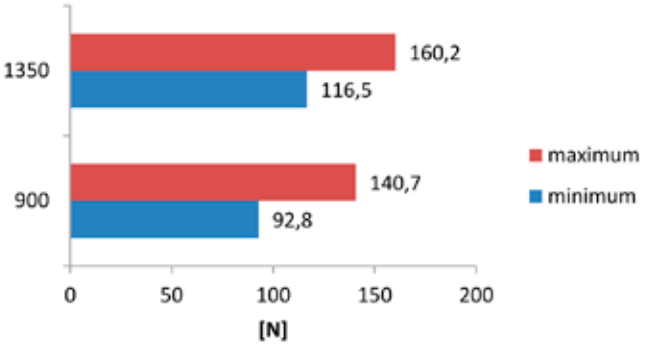
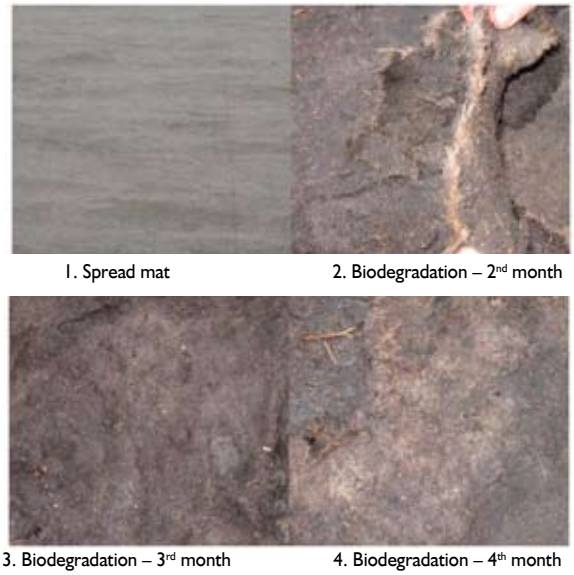


Fig. 1. Breaking strength of disinfectant mats with a surface weight 900 and 1350 [g/m^2]



1. Spread mat — 2. Biodegradation – 2nd month

3. Biodegradation – 3rd month — 4. Biodegradation – 4th month

5. Biodegradation – 5th month — 6. Biodegradation – 6th month

7. Biodegradation – 8th month — 8. Biodegradation – 10th month

9. Biodegradation – 12th month

Photo 3. Disinfection mat biodegradation process

The maximum breaking strength of the mat with a surface weight of 900 g/m^2 was only 12% lower than the breaking strength of the heavier nonwoven. Similarly, the minimum breaking force to the mat with a weight of 900 g/m^2 was lower but only by approx. 20% than that of 1350 g/m^2. The thickness of non-woven has no direct effect on the strength disinfectant mats but type of reinforcement fabric, which constitutes the layer of the mat.

Developed disinfectant mats were subjected to biodegradability testing. For this purpose, the samples of manufactured mat were exposed to atmospheric conditions for 12 months, while conducting strength tests of the samples. The advancement of biodegradation was evaluated by the changes in the strength of nonwoven.

Conducted observations and studies have shown that after 10–12 months the disinfectant mats completely lost their structure. Strength tests are shown in Figure 2.

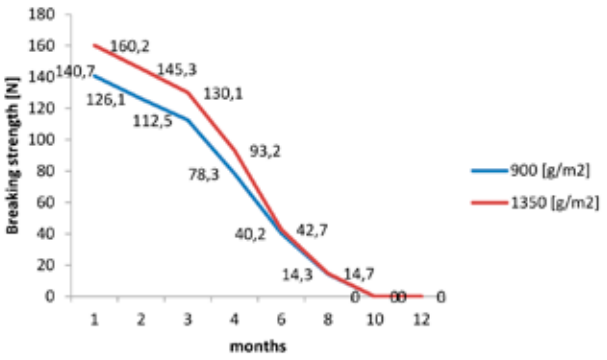


Fig. 2. Strength of disinfection mats in different stages of biodegradation

Resume and conclusions

At the current stage of the project the crop biomass produced on reclaimed land is plowed. Agricultural treatments conducted in the first three years of remediation contributed to improvement of the agronomic conditions on post-mining areas and increased in the humus level in the soil by approx. 20–30% (Mańkowski, J. et al. 2015). Reconstruction the humus layer will allow for the subsequent use of reclaimed land for the cultivation of hemp for hemp fiber and its use in the manufacture of disinfection mats.

Photo 4. Disinfection mats made of natural fibers

Developed mats can be spread to form a barrier to the migration of pathogens carried by the transportation equipment, livestock, or humans on the surface of the footwear. The mats are successfully used at crossings and passageways within the sheds, barns, piggery, dairy, feed mills, slaughterhouses, food processing plants, apiaries, livestock collection points, mushroom farms, border crossings, where they are used to create buffer zones to prevent the spread of infectious diseases such as the avian flu.

Spread mat is impregnated with a disinfectant solution, so that the surface of the wheels, shoes or other items can be washed and soaked with an appropriate agent acting against bacteria, viruses or fungi. Unlike previously used solutions, studies have demonstrated that these mats are completely biodegradable, so that they use are not a burden the environment.

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