WP T2 INNOVATION ON TEXTILE WASTE MANAGEMENT

ACTIVITY A.T2.

Deliverable: Annex Technical report on comparison

Additional ENTeR pilot case: Textile waste coming from medical devices concerning COVID-19 emergency

Version 1

09/2020

Responsible partner:

PP7 INOTEX (Czech Republic)

This document has been issued within the project ENTeR (CE 1136) thanks to the funding received from the European Union under the Interreg Central Europe Programme (2nd call 2016)

This document reflects only the authors' view and neither the European Commission nor the Interreg Central Europe Managing Authority are responsible for any use that may be made of the information it contains.

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 Pilot case "Textile waste coming from medical devices concerning COVID-19 emergency"

The COVID-19 pandemic has revealed the urgent need for large number of disposable textile medical devices both for the healthcare workers (surgical gowns, medical masks, respirators, surgical drapes, gloves) as well as for the citizens (protective face masks). The dramatic increase in their use is leading to significant increase of waste production worldwide.

The additional pilot case of the ENTeR project "Textile waste coming from medical devices concerning COVID-19 emergency" aims to define a potential new way for medical textile waste management in order to favour their recycling and /or reuse. The aim is to study the medical textile waste materials (material, chemicals, biological contamination), to define current procedures for medical textile waste management, to study removal of chemicals and biological decontamination, to evaluate economic and environmental benefits of it´s reuse / recycling and to create guidelines and best practices for a new and more sustainable waste management

In Czech Republic, wearing of the face masks was mandatory from 19th March 2020 till end of June 2020 and is mandatory again after the summer break from 1st September 2020. As there was a lack of the the disposable face masks in Czech Republic at the beginning of the covid-19 pandemic situation, this product was not available on the market and the emergency supplies were restricted by the government to be supplied exclusivelly to the hospitals, doctors at ambulances and to other first response health services. To be compliant with the obligations according to the government action, the Czech citizens proactively started to sew the face masks from textile fabrics (100% cotton strongly preferred) at home.

Outside the ENTeR project, INOTEX in cooperation with external partners has developed the textile fabric with special treatment which is used for production of the textile face masks „FreshDye“. These masks work on principle of the fotoactive dyestuff which after irradiation with common daylight generates the short-term reactive forms of oxygen; thanks to that, the mask is protected against the pollutants including aproved antibacterial effect. Thanks to that effect, it is not necessary to wash the masks at 100°C to decontaminate them; textile can be washed at 60°C. The approved durability of the photocatalytic dyeing at minimum 50 washing cycles prolongs the service life in comparsion to 100% cotton masks and significantly reduces amount of waste in comparison with disposable masks.

Within the pilot case, reduction of generated textile waste from disposable masks thanks to the „FreshDye“ face masks will be evaluated.

2. Cloth face masks as an alternative to disposable ones

2.1. Use of the cloth face masks during COVID-19 pandemic

To deal the global health threat posed by the COVID-19 pandemic, the main health measures and safety protocols were adopted. It includes e.g. the distance measures, hygiene and the use of personal protective equipments, such as masks or gloves.

According to WHO, the current evidence suggests that most transmission of COVID-19 is occuring from symptomatic people to others in close contact when not wearing the appropriate PPEs.

There is also possibility of pre-symptomatic transmission from people who are infected but have not yet developed symptoms; also the asymptomatically-infected people are likely to transmit the virus. (1)

Wearing a medical maks is part of a comprehensice package of the prevention measures that can limit to spread of certain respiratory viral diseases, including COVID-19, according to the WHO. Masks can be used either for protection of healthy persons (to protect oneself when you are in a contact with an infected person) or to prevent transmission from infected person (worn by infected individual). However, the use of mask alone in insufficient to provide an adequate level of protection; other prevention measures should be adopted as e.g. hand hygiene, physical distancing and other measures. (1)

The WHO recommends wearing of the medical masks to the health workers and caregivers. In case of general public, the WHO recommends the use of masks in case when people feel unwell with potential symptoms of COVID-19. Many countries have recommended the use of fabric masks/face coverings for general public; from the beginning of the COVID-19 pandemic, the WHO does not supported the use of masks by healthy people in the community, in general. (1)

However, their successful use in China, South Korea and the Czech Republic from very beginning, in addition to other measures, has demonstrated their benefits. Based on this experience, the use of masks has become widespread also other countries as Italy, Spain and others, despite the fact that the WHO still didn´t explicitly recommend it. (2) Taking into account the available studies ecaluating the pre- and asymptomatic transmission, a growing experience on the use of masks by the general public, individual values and preferences or difficulty of physical distancing in many contexts, in May 2020 the WHO has updated its guidance. Its last advice to the decision makers is that to prevent the COVID-19 transmission effectively, govenments should encourage the general public to wear masks – either medical or non-medical - in specific situations. (1) The European Center for Disease Prevention and Control also recognized that use of masks by the population could reduce the spread of the infection, together with other preventive hygiene measures; the Centers for Disease Control and Prevention recommend the use of cloth face coverings to help slow the spread of COVID-19. (2, 3)

This encouraging of the widespread use of the face masks by general public togehter with the mass use of masks by health workers and other professions has caused a shortage. With respect to that, companies and individuals are looking for solution at the best way, including the reuse, cleaning and disinfection of certified disposable masks and to manufacture of non-certified masks (homemade or not). (2)

Because of the lack of single-use face masks or their price in a sum when worn during the longer period, many people use the self-made cloth masks. The LCA studies confirm the positive environmental balance of the cloth face masks comparing to the disposable ones in terms of the amount of the generated waste or carbon footprint. Detailes are described in deliverable *D.T2.3.2_Pilot Cases_INOTEX medical devices covid-19.*

2.2. Technical requirements on cloth community face masks

2.2.1. The minimum permormance requirements

As already described in the *Deliverable D.T2.3.2.*, the non-medical masks may be made from a variety of woven and knitted fabrics.

The guidance document *CWA 17553* developed by European Committee for Standardization (CEN) proposes the minimum performance requirements:

- Two levels of masks in relation to filtration efficiency: ≥ 90 % and ≥ 70 %
- Breathability - differential pressure ≤ 70 Pa/cm^2 (~80 l/s/m^2 for vacuum pressure 100 Pa) or maximum inhalation resistance of 2,4 mbar and maximum exhalation resistance of 3 mbar or air permeability ≥ 96 l/s/m^2 (for vacuum pressure of 100 Pa) (1)

The combinations on materials and shapes result in variable filtration and breathability.

Breathability is the difference in pressure across the mask; it is reported in millibars (mbar) or in Pascals (Pa) or, for an area of mask, in mbar/cm^2 or Pa/cm^2. It is the ability to breathe through the material of the mask.

2.2.2. Influence of the used cloth material on filtration efficiency and breathability

As the filtration efficiency and breathability depend on the fabric used to make a mask, the selection of material is ans important first step.

In case of cloth masks, the filtration efficiency depends on the tightness of the wave, fibre or thread diameter. The filtration of cloth fabrics masks has been shown to vary between 0,7% and 60%. The higher filtration efficiency means the more of barrier provided. (1)

The commercial cotton fabric masks are very breathable, in general, but they offer lower filtration. (1)

The used filtration quality factor “Q” is a function of filtration efficiency and breathability. The higher values indicate the better overall efficiency. The recommended minimum Q factor is three (3), according to experts. (1)

Material	Source	Structure	Initial Filtration Efficiency (%)	Initial Pressure drop (Pa)	Filter quality factor, Q ** (kPa^{-1})
Polypropylene	Interfacing material, purchased as-is	Spunbond (Nonwoven)	6	1.6	16.9
Cotton 1	Clothing (T-shirt)	Woven	5	4.5	5.4
Cotton 2	Clothing (T-shirt)	Knit	21	14.5	7.4
Cotton 3	Clothing (Sweater)	Knit	26	17	7.6
Polyester	Clothing (Toddler wrap)	Knit	17	12.3	6.8
Cellulose	Tissue paper	Bonded	20	19	5.1
Cellulose	Paper towel	Bonded	10	11	4.3
Silk	Napkin	Woven	4	7.3	2.8
Cotton, gauze	N/A	Woven	0.7	6.5	0.47
Cotton, handkerchief	N/A	Woven	1.1	9.8	0.48
Nylon	Clothing (Exercise pants)	Woven	23	244	0.4

* This table refers only to materials reported in experimental peer-reviewed studies. The filtration efficiency, pressure drop and Q factor are dependent on flow rate. ** According to expert consensus, three (3) is the minimum Q factor recommended.

Table 1: Non-medical mask filtration efficiency, pressure drop and filter quality factor (1)

For making masks, the non-elastic materials should be preffered because the mask material may be stretched over the face during wear which may result in the pore size increasing and therefore lower filtration efficiency. The elastic materials are sensitive to higher temperatures during washing and also may degrade over time. (1)

2.2.3. Number of layers

According to WHO, a minimum of three (3) layers is required for non-medical masks, depending on the used fabric. Fabric cloths (e.g.nylon blends and 100% polyester) used in two layers, provide 2-5 times increased filtration efficiency compared to a single layer of the same cloth; when folded into four layers, the filtration efficiency increases 2-7 times. The masks made of cotton handkerchiefs made of four layers achieved only 13% filtration efficiency. Very porous materials, such as gauze, achieved only 3% filtration efficiency and do not provide sufficient filtration.

But with more tightly woven materials, the breathability may be reduced with increased number of layers. (1)

2.2.4. Combination of materials

According to WHO, the ideal combination of material for non-medical masks should include a minimum of three layers, as following:

- the inner layer of hydrophilic material (e.g. cotton or cotton blends)
- the outer layer of hydrophobic material (e.g. polypropylene, polyester, or their blends); this layer aims to limit external contamination from penetration through to the wearer´s face

- a middle hydrophobic layer which may enhance filtration or retain droplets (synthetic non-woven material, e.g. polypropylene) (1)

2.2.5. Mask shape

The mask shape may include flat-fold or duckbill. Theshall be designed to fit closely over the nose, cheecks and chin. When the masks does not fit well to the wearers face because of the size and shape of the mask, an internal / external air penetrates through the esges of the mask and is not filtered through the fabric. (1)

Fig.1: The flat-fold mask shape (4)

Fig.2: The duckbill mask shape (5)

2.2.6. Coating of fabric

The fabric used to make a masks may be coated e.g. to give it hydrophobic properties and to increase the barrier. On the other hand, such coatings may block the pores; thanks to that, it may be difficult to breathe through the mask and the unfiltered air may more likely escape the sides of the mask when exhaling.

Therefore, coating is not recommended. (1)

2.2.7. Mask maintenance

To make a cloth masks, the fabric washable at water warm at least 60°C, with soap or laundry detergent. Natural fibers may resist high temperatures during washing and ironing. The combination of on-woven PP spunbond and cotton can resist high temperatures, masks mad of combination of these materials may be steamed or boiled (PP itself may be washed at temperatures up to 125°C).

To make the masks, the stretchy materials should be avoided because they are sensitive to washing at high temperatures. (1)

2.3. Comparison of the filtration efficiency of medical and cloth face masks

Protective effect of face masks has been already extensivelly studied for example during the SARS or influensa epidemics. The results of the study published by Dutch scientis (6) concluded that in adults, the professional FFP2 respirators reduce risk of infection 66x to 113x, medical (surgical) face masks 4,1x to 5,3x and the homemade communioty masks made from dishcloth 2,2x to 2,5x. In children they provide less protection.

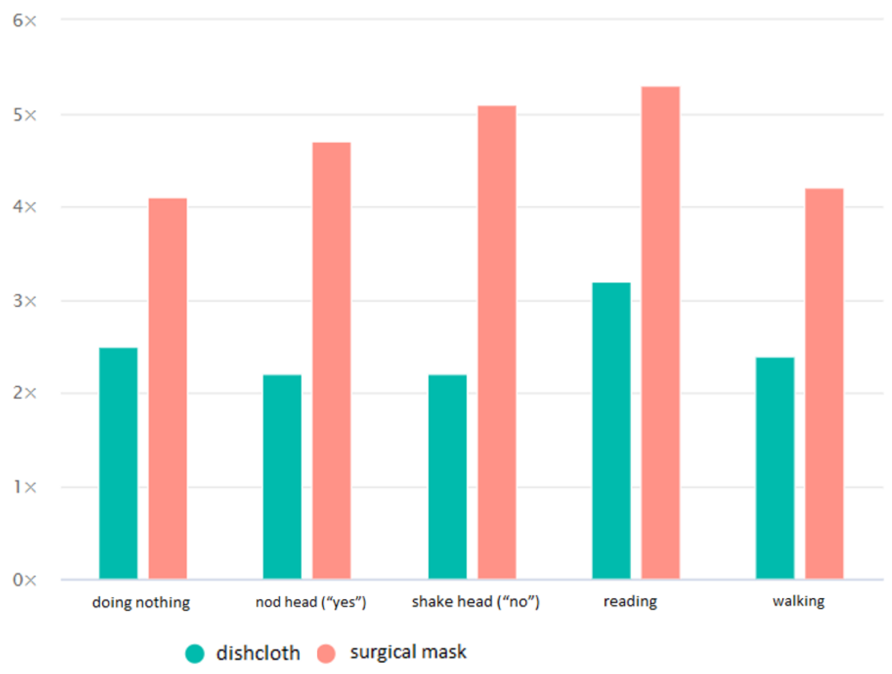

Fig. 3: Reduction of the infection risk – comparison of dishcloth and surgical masks (6,7)

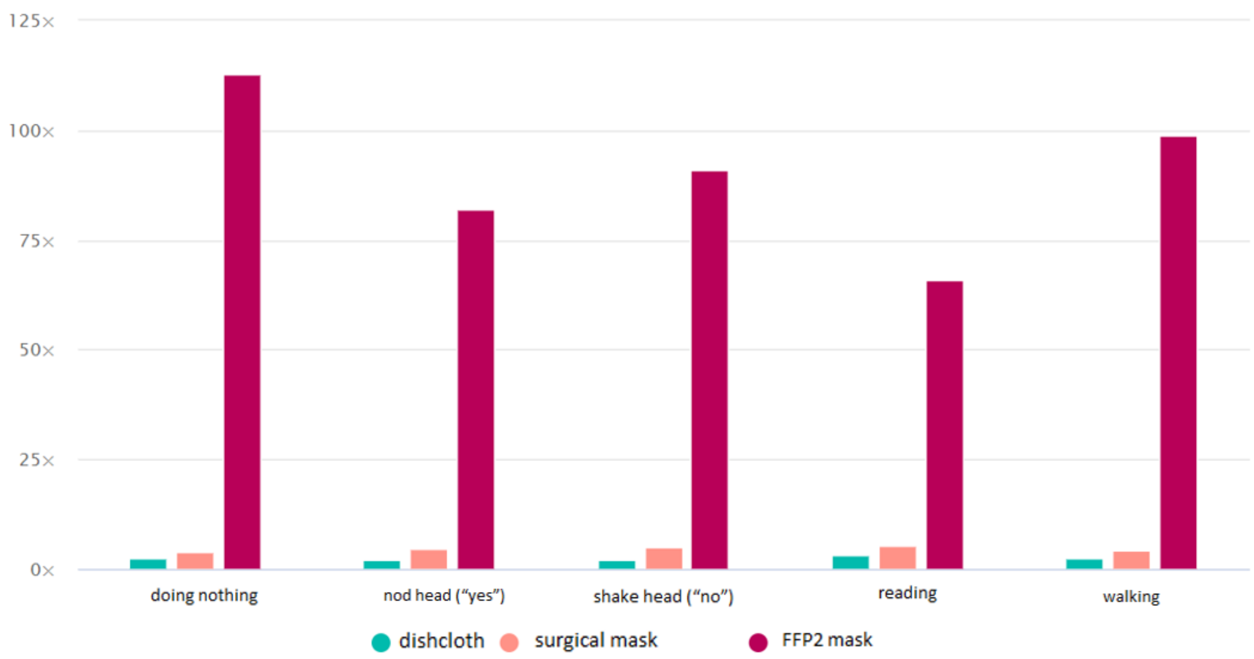

Fig. 4: Reduction of the infection risk – comparison of dishcloth, surgical and FFP2 masks (6,7)

However, experts including WHO are not in agreement on the effectiveness of preventive wearing of face coverings by general public.

2.4. Use of the cloth community face masks from the waste generation point of view

As already mentioned in deliverable *D.T2.3.2_Pilot Cases_INOTEX medical devices covid-19*, from the beginning of 2020 the consumption of disposable face masks during the pandemic has dramatically increased worldwide. Whereas in health care facilities, use of the single-use face masks cannot be avoided due to the safety reasons (high risk of infection); when wearing the masks from the preventive reasons by general public, the disposable masks could be replaced by the cloth community masks. That way, hudge amount of the municipal waste from single-use face masks could be avoided.

However the studies comparing efficiency of the disposable medical masks and cloth community masks conclude that the cloth community masks are less efficient that the disposable medical ones (see chapter 2.3.) but acceptable, there is an evident positive environmental impact of the cloth mask comparing to the disposable single-use face masks. Details are described in deliverable *D.T2.3.2_Pilot Cases_INOTEX medical devices covid-19* (chapter 3) and in deliverable *D.T2.3.4_Pilot Cases Feasibility Study_INOTEX medical devices covid-19* (chapter 3).

3. The “FreshDye” cloth face mask

3.1. Photoactivity of the phtalocyanine compounds

The commercial phtalocyanines are well known blue-green textile dyes; their central atom is usually copper. When aluminium or zinc are incorporated as a central atom, these compounds show photocatalytic properties; it means they produce singlet oxygen when exposed to the light. The singlet oxygen is very reactive and is able to kill majority of microorganisms and destroy some pollutants. It´s lifetime is only several microseconds and its effect is limited only to form 20 nm thick layer on the textile surface. It means that it is limited to the textile surface without any impact to the environment when bound to the fibre. (8)

These unique properties of photoactive phtalocyanines were used for manufacturing of the antimicrobial / self-cleaning textile materials with long-lasting wash-permanent barrier effect. It represents the safe and less environmentally risky alternative of conventional antimicrobial systems.

3.2. Functional dyeing of cotton and Co/PES blends based on photocatalytic phtalocyanines

Different phtalocyanine derivates containing zinc and aluminium in the structure were synthetised by Centre for Organic Chemistry, Pardubice, Czech Republic within the project ALTERBIO (TE02000006, TAČR, 2014-2019). INOTEX, which was also one of the project participants, suggested and verified the dyeing technologies for different textile fibers, including dyeing of mercerized cotton 120 g/m^2 and 50/50 cotton/PES blend 140 $g/m^{2.}$ For improvement of the colour-fastnesses and different colour-shades ate reduced costs, combination of the photoactive phtalocyanine dyeing technology with commercial vat dyeing (two-steps dyeing) and with reactive dyeing (one-bath) was optimized by INOTEX in industrial scale (jigger dyeing). Resulting colour-fastnesses were evaluated according to the relevant standards.

Colourfastness	Standard	100% cotton 126 g/m^2	50/50 cotton/PES 140 g/m^2
Water	EN ISO 105-E01	4/4/4	4/4/4/-5
Washing 60 °C	EN ISO 105-C06 (C1S)	3-4/4/4-5	3-4/4/4-5
Perspiration alkaline	EN ISO 105-E04	4/4/4	4/4/4-5
Perspiration acid	EN ISO 105-E04	4/4-5/4-5	4/4-5/4-5
Rubbing dry	EN ISO 105-X12	4	4-5
Rubbing wet	EN ISO 105-X12	4	3-4
Light Q-SUN	EN ISO 105-B02	4K	3-4
Active chlorine	EN ISO 20105-N01	3	3-4

Table 2: Colourfastness of PTC dyed fabrics (8, 9, 10)

Testing of photoactivity of the finished textiles was conducted by Centre for Organic Chemistry by means of an iodide method. (8, 9, 10)

Fig. 5: Dyeing and measuring of the fabric with photocatalytic phtalocyanine dyestuffs

(Source: INOTEX Ltd.)

3.3. Antimirobial efficiency

Antimicrobial activity of the finished fabrics was determined according to a modified standard EN ISO 20743 after repeated washing (°C) and chemo-thermo-disinfection maintenance cycles which is a prescribed maintenance procedure for textiles used in health-care sector. For the microbial tests, the proper light sources were necessary to be used, to initiate the photocatalytic effect; the illumination shall simulate the indoor and outdoor conditions. Testing was conducted in the National Institute of Public Health, Prague.

Testing of the antimicrobial efficiency of the textiles (100% cotton, 50/50 cotton/PES) dyed with photoactive phatocyanine dyestuffs confirmed the high antibacterial efficiency against G-positive (*Enterococcus faecalis*) and G-negative (*Escherichia coli*) bacteria strains. The antibacterial activity of the dyed fabric is stable in minimum of 50 manitenance cycles performed in commercial laundry. (8, 9, 10)

Thanks to the produced very active singlet oxygen, also the antiviral efficiency is expected to be confirmed. Due to the full testing capacity of the laboratories during the COVID-19 outbreak at the beginning of 2020, the antiviral efficiency of the dyed fabrics will be tested in autumn 2020.

3.4. Skin irritation and senzibilisation testing, physiological parameters

The dyed cotton and cotton/PES fabrics were tested and showed good mechanical-physical and physiological parameters (moisture management)

Lso the skin irritating and senzibilising potential of the dyed fabrics were tested in the National Institute of Public Health, Prague according to EN ISO 10933-10 (Medical devices). The results of the tests (Skin sensitization: test with examination of local lymph nodes; Tests for irritability and hypersensitivity of the remote type) show that these textile materials dyed with photoactive phtalocyanine dyestuffs are not significant skin irritants and don´t have senzitizing potential.

3.5. The cloth face masks manufactured from the fabrics dyed with photoactive phtalocyanines

The unique properties of the fabrics dyed with photoactive phtalocyanines, developed by INOTEX and other partners within the project TE02000006 ALTERBIO (9) offer the successful use of these materials for various kinds of medical textiles (clothing of the health care workers, hospital bed linen). This topic became very topical also during the COVID-19 pandemic. With respect to the urgency of solving the problem as well as of the registered acute lack of face coverings in Czech Republic at the beginning of the COVID-19 outbreak , INOTEX early at the beginning of the emergency state has mobilized other cooperating organizations and has started the small-scale production of this textiles with protective self-cleaning effect.

Fort its use as a material for production of face masks, it is very important that testing confirmed no irritating or sinzitizing potwential of this textiles; thereofre, its use as material in contact with face skin is safe.

For manufacturing of the “FreshDye” face masks were used both kinds of the dyed fabrics – cotton and blend of cotton with PES: 100% cotton (120 g/m^2) or blend cotton/PES 50/50 (140 g/m^2). The amount of 1.000 running meters of the fabric dyed with phtalocyanine dyestuff is sufficient for manufacturing of 40.000 pcs of face masks (fabric width 160 cm) or 50.000 pcs (fabric width 180 cm). The face mask is made from two layers of textile; the outer layer is made from photocatalytic “FresDye” fabric, the inner is made from common textile (use of the photocatalytic textile for inner layer does not make sense because it is not enlightened with light). Also the type of the mask with “pocket” for inserting replaceable filter material was made.

Fig.6 : “FreshDye” face mask

(Source: INOTEX Ltd.)

The recommended maintenance of the “FreskDye” masks is the following:

- wash at 60 ° C (can withstand boiling, but it is unnecessary)
- **do not disinfect with products containing active chlorine (hypochlorite, SAVO…) !!!!**
- in commercial laundries, washing under the hospital laundry regime is usually followed by chemothermodisinfection as part of the final washing (rinsing) by addition of Persteril (peracetic acid); this sterilization does not matter to face masks, does not reduce photocatalytic activity. This

sterilization with Persteril is possible, not necessary - the face mask disinfects itself in daylight and artificial light. However, do not disinfect and do not wash with active chlorine!

- normal drying in the dryer is possible
- ironing at max. 150 ° C (higher temperature is not harmful, but it is unnecessary)
- P - permanent in dry cleaning

When used as a material for production of the face masks, there is still another advantage together with the others mentioned above: the described photocatalytic reaction is catalyzed by water. Therefore, the "FreshDye" face mask can be used during the whole day and it is not necessary to change it when it is damp (as recommended in case of disposable face masks from non-woven textiles); the moisture catalyzes the photocatalytic process and improves the self-cleaning function of the mask.

3.6. Use of the "Fresh Dye" face masks from the textile waste point of view

The details are discused in the deliverable *D.T2.3.4_Pilot Cases Feasibility Study_INOTEX medical devices covid-19.*

4. Bibliography

(1) Advice on the use of masks in the context of COVID-19. Interim guidance. WHO, 5th June 2020. WHO reference number: WHO/2019-nCov/IPC_Masks/2020.4 https://apps.who.int/iris/bitstream/handle/10665/332293/WHO-2019-nCov-IPC_Masks-2020.4-eng.pdf?sequence=1&isAllowed=y

(2) Carlos Rubio-Romero, J., Del Carmen Pardo-Ferreira, M., Antonio Torrecilla García, J., & Calero-Castro, S. (2020). Disposable masks: Disinfection and sterilization for reuse, and non-certified manufacturing, in the face of shortages during the COVID-19 pandemic. *Safety science*, *129*, 104830. Advance online publication. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7218384/

(3) https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/diy-cloth-face-coverings.html

(4) https://www.banner-eshop.cz/cz/katalog/ostatni-sortiment/rouska/rouska-1-ks-1604

(5) http:// /Rouska-s-kapsou-cerny-folk-d3645.htm

(6) Professional and Home-Made Face Masks Reduce Exposure to Respiratory Infections among the General Population. Van der Sande, M., Teunis, P., Sabel, R.; *PLoS One*. 2008; 3(7): e2618. Published 9th July 2008. doi:10.1371/journal.pone.0002618 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2440799/

(7) https://www.irozhlas.cz/zpravy-domov/rousky-koronavirus_2003180839_jab

(8) Functional Reactive Dyeing of Cotton Based on Photoactive Phthalocyanines. Martinková, L., Kořínková, R., Vrkoslavová, J. Book of Abstracts – 9th Central European Conference 2017, s 67-68 (english), publisher: Technical University of Liberec, date of issue: August 2017, Edition: First, No. of pages: 169, publication no.: 55-035-17; ISBN: 978-80-7494-356-0

(9) Results of the project TE02000006 ALTERBIO, , TAČR, 2014-2019
(10) L. Martinková, R. Kořínková, M. Karásková, V. Špelina, M. Vrtalová : „ALTERBIO – Environment friendly functional barrier textiles based on photoactive phthalocyanine dyeings“, VLÁKNA A TEXTIL, Vol. 23, č. 3, 2016, s. 133-137, ISSN: 1335-0617