WP T2 TEXTILE WASTE COMING FROM MEDICAL DEVICES CONCERNING COVID-19 EMERGENCY

ACTIVITY A.T2

Deliverable

Chemical removals and sanitation

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CONTENT

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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 are oriented to the management and optimization of waste, in a Life Cycle Design (or Ecodesign) perspective.

1. Scope

This report describes the methods and technologies studied for the sanitization of tissues in the medical field that are effective for the removal of the SARS-CoV-2 virus, with the aim of suggesting which are the best methods to decrease the viral load and to perform a recovery of the material that would otherwise be lost. In addition to the sanitization system, the report describes methods to remove the finishing that may be present on the masks, in fact, these finishing affect the recycling process of the material, decreasing the purity of the secondary material and therefore influencing the chemical-physical characteristics.

2. Sanitation

As seen in the deliverable D.T2.1 relating to the legislation on infectious risk waste, the law provides for the possibility of decontaminating the waste, but the decontamination takes place without separation, creating a sterile but mixed product, which inside can contain glass, plastic, paper, etc. The sterilization process involves a first phase of shredding the material to make it unrecognizable and reduce its volume, this procedure obviously implies that the sterile output material is impossible to separate. Furthermore, the legislation provides that the sterilized material must in any case be destined for thermal destruction, with the possibility of energy production. Being a widely used procedure in the management of potentially infected waste in the healthcare sector, there are various devices and technologies on a market for decontamination and processing of medical waste. Using these technologies, it is possible to process various types of medical waste including used PPEs.

As examples we can mention the devices produced by company Siemens: their device CONVERTER is a single-chamber shredder of a medical waste. It can be used for processing of the waste under the codes Waste is there shredded into small, unidentifiable particles. The shredder and knives are constantly rotating and their mechanical energy causes an increase in temperature at which the moisture contained in the waste evaporates. In case of processing the municipal waste without hazardous properties, the process ends after reaching the temperature 100°C; in case of processing the hazardous waste, the process continues till the temperature reaches up to 151 °C. The resulting shredded particles are subsequently cooled and removed to storage. The final waste product looks like the ordinary vacuum cleaner dust; it is completely sterile, dry odourless and does not contain the sharp components. The original volume of the waste is reduced by up to 70% and weight by almost the third. The resulting product can be used as an alternative fuel with a calorific value of brown coal.

According to the World Health Organization (WHO), in 2018 only 15% of hospital waste in the world was considered dangerous (10% infectious and 5% dangerous due to its chemical or radioactive properties). This number has increased exponentially during the pandemic due to the continuous use in hospital wards, but also to the use of these materials by the population during daily activities. Given this increase, the typical sanitation procedures used for infectious medical waste can cause damage to the environment. For this reason, research has begun to solve this problem, in some cases moving on to the production of social masks, which are more resistant than surgical masks during the maintenance phases (washing), but which need exchangeable filters or antiviral

finishing to prevent user contamination. Some, however, have sought a solution to be able to reuse the same surgical or respiratory masks by studying the effects of sanitization processes on the masks, in order to extend their life and allow greater use of the unit.

The following will describe the sanitation work performed on the respirators.

2.1. Hydrogen peroxide vapour

Hydrogen peroxide vapour (H_2O_2) has long been used as an industrial decontaminant, this has led several research institutes and industries in the sector to study it as a possible sanitization method for the reuse of masks. Recent studies conducted by the Dutch National Institute of Health have shown that this method is effective in inactivating viruses. Battelle recently received FDA approval for the use of its H_2O_2 steam generator and system in the decontamination of N95 masks. Similar approaches and technologies have been validated by Duke University.

In the study by the Dutch National Institute for Health, the polypropylene masks were subjected to sterilization with different processes:

- cleaning process at 60 ° C for 12 minutes and drying without chemical detergents or disinfectants
- cleaning process at 90 ° C for 5 minutes and drying without detergents
- cleaning process at 90 ° C for 5 minutes and drying with detergents
- low pressure hydrogen peroxide vapour applied up to 4 times
- sterilization with steam at 134 ° C

Treatments at 90 °C (including sterilization with steam at 134 °C) visibly deformed the mask making it unusable. In addition, 4 times H_2O_2 steam sterilization also deformed some masks. Masks that did not undergo deformation were analysed with adhesion tests. These tests have shown that H_2O_2 steam sterilization can be done a maximum of twice before rendering them unusable.

Duke University used a Bioquelltm Clarustm C with a 35% hydrogen peroxide solution and a dispensing system which is used to achieve a uniform concentration of 480 ppm throughout the decontamination room. The HPV cycle included a 10 minute conditioning phase, a 30-40 minute gassing phase at 16 g / min, a 25 minute soak phase, and a 150 minute aeration phase. The test was conducted on 100 respirators hung on a metal rack in the centre of the decontamination chamber. Biological indicators loaded with Geobacillus Stearothermophilus spores were used to validate this method and a 6-log reduction was found and no significant degradation of the respirator filter was found until 50 cycles were performed, making it a method effective. However, after 20 cycles a degradation of the laces was detected. A major concern with H_2O_2 vapour decontamination is the escape of hydrogen peroxide gas from the inner layers of the mask after completion of the decontamination cycle. The Duke University study conducted a qualitative and quantitative study of gas leaking from the masks during the procedure and after four hours the detectable H_2O_2 level emanating from the masks dropped below the detection level of the sensor used.

Ideally you can think of using the same technique in the aqueous phase, the resistance of polypropylene to H2O2 is high as regards the 10% aqueous solution, with a 30% solution the

polypropylene resists up to 40 ° C, at a temperature of 60 ° C begins to degrade. Same results for PET, it is resistant to 30% H2O2 in aqueous phase.

2.2. Heat and humidity

There is a growing body of evidence supporting the potential viral inactivation of SARS-CoV-2 through the use of heat, relative humidity and time.

Dutch researchers performed autoclaving processes at temperatures of 121 °C, found that 3M's FFP2 masks were able to be processed up to 5 times without loss of filtration efficiency or adaptation. Viral inactivation studies have not been conducted as tests with commonly accepted steam sterilization parameters have been performed. However, when tests with similar parameters were performed on different masks made of polypropylene, the results showed unacceptable physical deformation that prevented proper fit and a reduction in filter efficiency below acceptable limits.

In a recent article, Peter Tsia, inventor of the electrostatic charge technology that produces N95 face mask filters, discussed acceptable temperature ranges for the electret. The test data provided show the integrity of the filter after steaming it at 125 °C for 5 minutes; however, no experimental data on mask shape retention performance are available.

Tests performed at temperatures lower than 65 °C with humidity (85% RH) or humid air for 30 minutes showed at least Log 4.8 viral inactivation of two influenza strains. The Centers of Disease Control and Prevention has highlighted the use of 60 °C and 80% relative humidity, or 65 °C and 85% relative humidity.

These temperatures are difficult to implement for polypropylene, too high to be processed, there is a risk that the material softens and consequently the mask loses its filtering properties, but also a potential deformation. For PET however, these temperatures are not problematic. The logarithmic value of viral decrease is encouraging for a good sanitization in this way, which if carried out for the PP should lead to a recycling of the material and not reuse.

2.3. Steam generated by microwaves

Microwaves are a source for the immediate production of steam, for this reason the effects of the steam generated by microwaves on different masks have been studied. Plastic tanks were placed inside the microwave with perforated tops filled with about 50ml of water at room temperature, with the contaminated masks positioned in the centre of the top and exposed to radiation for two minutes (one minute each side of the mask). The use of this method resulted in a mean log reduction of the virus of 5.06. Many mask designs feature metal nose pads which when exposed to microwave radiation melt the surrounding area of the mask, rendering it unusable. However, mean aerosol penetration and airflow resistance was not shown to change significantly for masks subjected to this disinfection method that did not contain metal components. It is important to note potential significant problems with this approach. As noted, the metal nose piece can damage the mask and can also create a fire hazard. Microwaves come in a variety of powers and the ability to turn. This study also did not identify whether any of these parameters are important in achieving viral inactivation while maintaining filter integrity.

2.4. Ultraviolet radiation

A UV-C lamp (80 W, 254 nm) is used to expose contaminated FFRs to UV radiation (≥1 J / cm2 total dosage) for 15 minutes on each side of the mask (external and internal). The use of this method resulted in a mean log reduction of the virus of 4.81. Both the dosage and the wavelength of the UV light are critical for inactivation, in fact a problem is that any part of the mask in the shade will not be disinfected. Additionally, it is critical to ensure that UV dosage is measured on the mask as dosage can be significantly reduced as distance from the source increases. A potential problem with implementing UV disinfection is penetration into the inner layers of some mask designs, which may not be exposed to the same dosage. Some twist-prone strap designs may also inhibit UV disinfection and may require a secondary disinfection step applied only to the mask straps.

Tests have shown that UV exposure does not reduce aerosol penetration above 5%, while statistically significant increases in UV penetration occur, which means that repeated use of this disinfection method will degrade the masks over time. However, evidence from the University of Nebraska where reuse of masks has been fully implemented using UVGI light disinfection protocols suggests that repeated use of the mask leads to degradation much faster than the disinfection protocol. The average number of times masks were reusable is 3 times before negative results were observed on mask deformation tests, while masks subjected to the UV disinfection protocol were reused 50 times before significant degradation was observed the structural integrity of the mask.

3. Chemicals removal

According to the experts from NGO Health Care Without Harm (HCWH), many PPE, produced to be used during the COVID-19 pandemic, are likely to contain hazardous chemicals. The medical textiles used for production of medical masks, may probably be treated with perfluoroalkyl substances (PFASs) to give them oil- and hydrophopbic properties.

The perfluorinated substance widely used in textile industry for water- and oil resistant treatment of materials, was perfluorooctanoic acid (PFOA), along with its salts and PFOA-related compounds. Due to its persistent, bioaccumulative and reprotoxic properties, its production, placing on the market and use in EU was banned from 4th July 2020 by Annex XVII of Regulation 1907/2006/EU (REACH). In adition to this, from 4th July 2020 its´use has been also globally banned under the UN´s Stockholm Convention (implemented in EU by Regulation 2020/784/EU). The short-term exemptions were approved for several applications, including the three-year exemption on use of PFOA and its related compound in textiles for oil- and water- repellency for the protection of workers from dangerous liquids that comprose risks to their health and safety (till 4th July 2023); till 3th December 2020, there is also the exemption on its use for medical devices other than implantable which are under the scope of Regulation 2017/745/EU.

With respect to these exemptions, the medical masks produced during this COVID-19 pandemic in 2020 (before 4th July 2020) may be legally treated with C8-based perfluorocarbons and may contain PFOA, however it is criticized by NGOs.

Yuyun Ismawati from Indonesian NGO Nexus3 and her team carried out the home tests on widely used facemasks: they soaked the spunbond nonwoven facemasks in water to see how long it takes them to become wet, and they tried to burn them. It took 26 hours till the masks were getting wet indicating that a surfactant was applied to achieve water-repellency, and they didn´t burn completely which points that flame retardants were used.

To replace the PFOA and othe C8-based perfluorinated substances in oil- and water resistant applications, the textile producers started to use the other short-chain PFAS like e.g. C6-based fluorocarbons. Though they are less bio-persistent than long-chain perfluorosubstances and their use is still legal, they are also under the pressure to be banned; some studies suggest they affect the same organs like the longer ones – the liver and the thyroid. These finishing also make it difficult to recycle the material with the commonly used methods.

Centrocot in cooperation with external partners is developing a methodology to remove finishing on textile. The REACT project funded by H2020 program is focused of elimination of impurities on acrylic textile used for awnings and outdoor furniture, some of the finishes on acrylic awnings are fluorocarbon based which prevent recycling. One of the aims of the project is to extend this methodology to other finishes, other fibres and other productive sectors. The situation created could allow the REACT technology to be translated within the healthcare sector, exploring the potential of the removal protocol in another sector, and improving the management of masks at the end of life, which at this moment is a great challenge for ideologies of Europe and the plan to reduce waste and refusals. The methodology that is being developed in REACT could allow the water repellent finishing to be removed from the masks with systems designed to be as eco-friendly as possible. The system based on conditions that are extreme for the SARS-CoV-2 virus and therefore it can simultaneously decrease the viral load on the fabric, acting as a further process of sanitizing, which can then be processed for recycling without health problems. With introducing a circular economy process in the healthcare sector, which is currently poorly developed, bringing the elimination by thermal destruction of potentially infectious materials.

4. Recycling of non-woven textiles

There are the commercial technologies for recycling of non-woven available on a market. Many of the nonwovens producers are recycling edge trim material, rejected rolls or materials sent back from their customers. The material is reprocessed and reused as a raw material in production.

As an example, the Starlinger recycling technology using their “recoSTAR” line can be mentioned. The non-wovens scraps (either one type of plastic material or mixture of materials) can be processed and recycled into pellets; to separate the components of polymer mixtures (PES/PE, polymer/cellulose, etc.), special filtration is applied. In some cases, certain viscosities pose a challenge during pelletisation. Starlinger offers two machines for the nonwovens recycling: “recoSTAR universal” line is a shredder/extruder combination mostly for recycling of polypropylene materials; and “recoSTAR dynamic” is a SMART feeder/extruder combination mostly for the recycling of polyester nonwovens.

There is also the experience with recycling of absorbent hygiene products (AHPs). Bellow, several examples are mentioned.

The company Knowaste has been researching and developing technology for recycling 100% absorbent hygiene products (AHPs) since the mid-1990s. The Absorbent Hygiene Products include the disposable diapers, adult incontinence products (pads and pants) and feminine hygiene products. AHPs are made from combination of several materials: fibres to absorb moisture, super absorbent polymers to retain moisture and plastic membranes and tabs keeping the user dry and secure. Through the recycling process, the company converts the AHP waste into two valuable resources — fibre and plastics which can be then reused in various products. The patented process introduces also the advanced thermal treatment which sterilises the waste stream prior to separation. The waste is sent to an autoclave where it is shredded, separated and then sterilised using advanced thermal treatment technology and sorted to remove any contaminants. The resulting plastics are then granulated, pelletised and reprocessed offsite for reuse. The superabsorbent polymer is left in the fibre and deactivated, though the product should retain about 30% of its absorbent capacity. Fibres produced by the process are treated for use as a pet litter. The company cooperates with local, regional and national hygiene, healthcare or sanitary disposal companies and their customers. Thanks to the system of increased identification and source segregation, also the non-infection waste from the hospital sector can be recycled. The UK-based Knowaste was forced to close its 70,000 tonne-per-year recycling plant in Holland in 2007 after a new incinerator beat it on cost; also it was unable for Knowaste to find markets for the final product. In 2011, Knowaste opened first AHPs treatment facility in UK (West Bromvich) and have planned to open another one in West London. Unfortunatelly, the Knowaste´s AHP recycling facility in West Bromwich was closed down in 2013; the planned new plant in West London was rejected because of the odour emissions issues and concerns with regards to the impact on the nearby residentials and schools. In 2017, the company announced the plans to launch its recycling service in South Africa and to establish there a recycling plant.

In 2019, Procter & Gamble opened a pilot plant for recycling of old nappies in Treviso, Italy. After going into full industrial scale with annual capacity of 10.000 tonnes, the second pilot facility in Amsterdam, Netherlands was launched; as a part of this project, the smart blue recycling bins are placed in couple of neighbourhoods. At present, the AHPs collected in Amsterdam are transported to the Italian facility in Treviso but it is planned to build a facility as well in the Netherlands. There are discussions about the facilities also in number of other countries. The nappies are processed by the patented process to reclaim plastics and fibres. The first step is washing out the contaminants and sterilisation, including the analysis to make sure that no contamination remains. Then the waste material is broken down into three categories of materials: cellulose, super absorbent polymers and mixed plastics. Each metric tonne of waste produces on average 150kg of cellulose, 75kg of plastic, and 75kg of super absorbent polymer. The plastics then may be used to make e.g. school desks, bottle caps or urban playgrounds, cellulose can be used for production of viscose fabrics or specialty paper and super-absorbent polymer can be used in gardening and flood barriers or as a litter.

The PHS Group company´s facility in UK uses a different process than Knowaste, converting AHP waste into refuse-derived fuel which can be burnt to produce energy. The process is named LifeCycle; it uses mechanical separation combined with chemical treatment. The wet products are shredded to break them down into components parts; after they are compressed to remove liquid. The waste is then chemically treated to keep it stable.