

Protective Properties of Health Care Materials Influenced by the Application Conditions

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ABSTRACT

The aim of the paper is to investigate protective function changes of reusable fabrics used for standard (operations where these risks for penetration by liquids are lower) and high performance clothes (for operations with a high risk for penetration by liquids) after a certain number of washing and sterilisation cycles. The absorbency test method and test method of obtaining penetration, absorption and repellency indexes of fabrics, were used to create an impression about the protective function of health care fabrics after 10, 20, 30 and 50 cycles. Protective properties of fabrics used in hospitals for standard performance after real application (washing and sterilization) have changed and it could affect the protection of medical workers. Therefore, it should take into consideration a period of use of fabrics intended for standard performance. The most important property for surgical gowns is repellency index, which for Laminate PES/PU/PES fabric, used for surgical gowns, is maximum and remains unchanged even after 50 washing and sterilization cycles, providing complete protection of medical workers.

KEYWORDS

Medical fabrics, washing and sterilization cycles, absorbency test, absorption, penetration and repellency index

INTRODUCTION

According to the Textile Institute, medical textiles are defined as “textile structure which has been designed and produced for use in any of a variety of medical applications, including implantable applications”. Healthcare textiles can be defined as textile structures designed and produced for use in the various healthcare sectors. Although there are differences between medicine and healthcare practices, medical and healthcare textiles are often used together or synonymously. Healthcare and medical textiles are continuously expanding and growing fields in technical textiles [1].

Based on end users, technical textile market is categorized into packtech, protech, agrotech, meditech, cloth-tech, hometech, buildtech, sportech, indutech, mobiltech, and others, which includes geotech and oekotech. Population growth, rise of an aging population, increased birth-rate and better awareness about hygiene among women in developing countries stimulates medical textile market. Also healthcare facilities and medical tourism development will boost the growth rate of medical market in the future (Figure 1) [3].

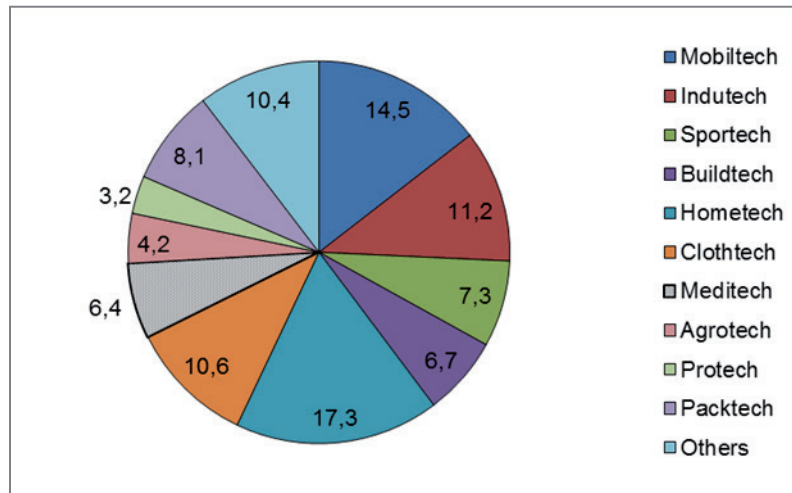


Figure 1. Global Technical textile market share in percentage categorized according to end users in 2011 [2]

In same time, medical textile industry improves existing and creates new products using novel materials and innovative designs, increasing market share of medical, surgical and sanitary products in total share of technical textile [4]. Due to overall progress in textile field, such as novel fibers and their modification for better properties and performance (including biocompatible and biodegradable polymers), development of production processes and fibrous materials known as nonwoven fabrics and electrospinning technology development (that allows production of ultrafine fibers), are now available for advanced products development design for many technical textile fields, including healthcare and medical applications. Generally, fibers can be made of natural or manmade polymers, as well organic or inorganic compounds, which can give a wide range of properties and performance. Properties can vary from highly hydrophilic (wool) to zero absorbent (polypropylene), from exceptionally elastic (spandex) to very stiff (carbon). The material is characterised by the ability of the fibres to absorb water and humidity into its nanostructure, making it less prone to the development of microorganism. While cotton, which is most often used for underwear, keeps most of the water at fibre surface, and is thus more susceptible to develop microorganisms, Tencel® is different and is being increasingly used in medicine and postoperative situations on the expense of cotton and other materials. Tencel® does not let off particles (textile dust) as opposed to cotton, which is prone to such shedding and is for this reason being removed from medical applications [5].

The Figure 2 shown structures used in medical sector, respectively conventional textiles and materials other than textiles (e.g. laminate fabrics). Conventional textiles like woven fabrics can be stable in dimension and low in elasticity, while knitted fabrics have high elasticity and elastic recovery. Nonwoven fabrics are produced by shorter processes comparing to woven and knitted fabrics, which results in lower costs. Textiles generally are versatile, where combinations of textile materials and structures can give end products with special properties and performances. For example, laminated fabrics can be designed to be waterproof for body fluid or bacteria, but breathable and thus comfort to use it for surgical gowns [6]. Laminated fabrics are composed of at least one layer of fabric and component like polymeric film or foam. Layers can be bonded by adhesive substances or with one laminated fabric layer which has adhesive properties.

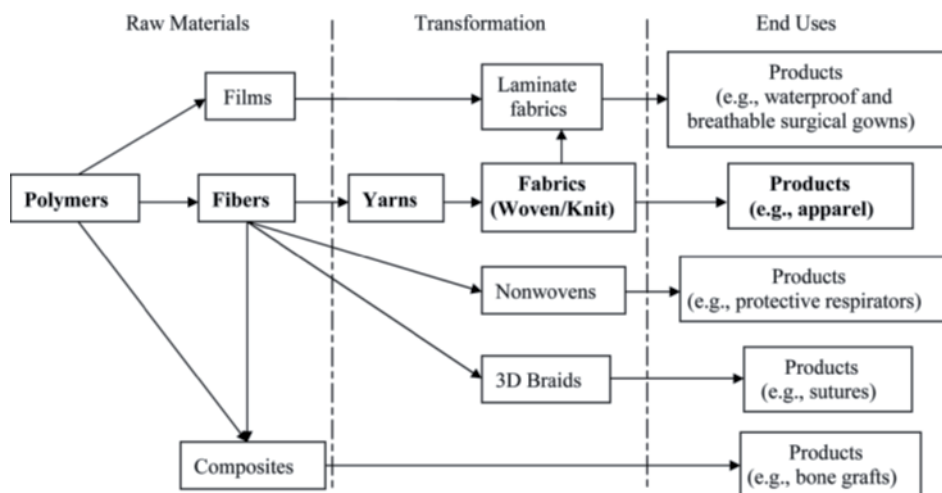


Figure 2. Materials and structures used for healthcare and medical textile products [6]

The health care products are not directly used in medical treatment but they are used for applications such as surgical clothing, surgical covers, beddings, clothing garments/uniforms and clothes/wipes.

The aim of the paper is to investigate protective function changes of reusable fabrics used for *standard* and *high performance* clothes after washing and sterilisation cycles. The absorbency test method and test method of obtaining penetration, absorption and repellency indexes of fabrics, were used to create an image about the protective function of health care fabrics after 10, 20, 30 and 50 cycles of washing and sterilization.

EXPERIMENTAL

Materials and Methods

Two woven fabrics used in hospitals for *standard performance* (operations where these risks for penetration by liquids are lower) and laminate for *high performance* (for operations with a high risk for penetration by liquids) are tested. Reusable hospital textiles PET/cotton and Tencel® are intended for manufacturing healthcare professionals' uniforms were three-layer textile laminate PET/PU/PET is used for surgical drapes. Investigated fabrics are used at the Clinical Hospital Center - Rebro Zagreb as medical uniforms at the clinical departments and surgical gowns in the operating rooms.

Two specific test methods, absorbency test method and test method of obtaining penetration, absorption and repellency indexes of fabrics, have been used. The purpose of using these methods was to create an image about the protective function of fabrics based on the ability of fabrics to penetrate, absorb and repel fluid from its surface. The combination of absorbency methods and method for determination penetration, absorption and repellency index can be used to specify the protective role of the fabrics for medical use in a hospitals. By using the AATCC test method for absorbency, time needed to fabric absorb the liquid is obtained [7]. The result itself does not specify fabric ability to let the fluid pass from the face to the reverse side, respectively the protective role of fabric considering a surgeon [6]. Using the test method for protective clothing ISO 6530: 2005, three obtained indexes describes the ability of a fabric to allow fluid to penetrate into, ability of a fabric to absorb liquids and ability of fabric to repel liquid from the fabric surface [8]. In above mentioned test methods, water as testing medium is used, since it is considered to be a satisfactory indicator. The liquids in real applications (water, blood, serum, urine and similar body fluids) that medical stuff and surgeon meet, has higher viscosity than water.

The constructional parameters of fabrics were tested according to ISO 2060 (yarn count), ISO 7211-2 (fabric density) and ISO 3801 (fabric mass) [9-11].

Field emission scanning electron microscope (FE SEM, Mira II LMU, Tescan, Brno, Czech Republic) was used for sample analysis. The samples were coated with a conductive Ag/Pt layer and scanned under the conditions of high voltage (HV 10.00 kV). Images of tested samples are shown on Figure 3.

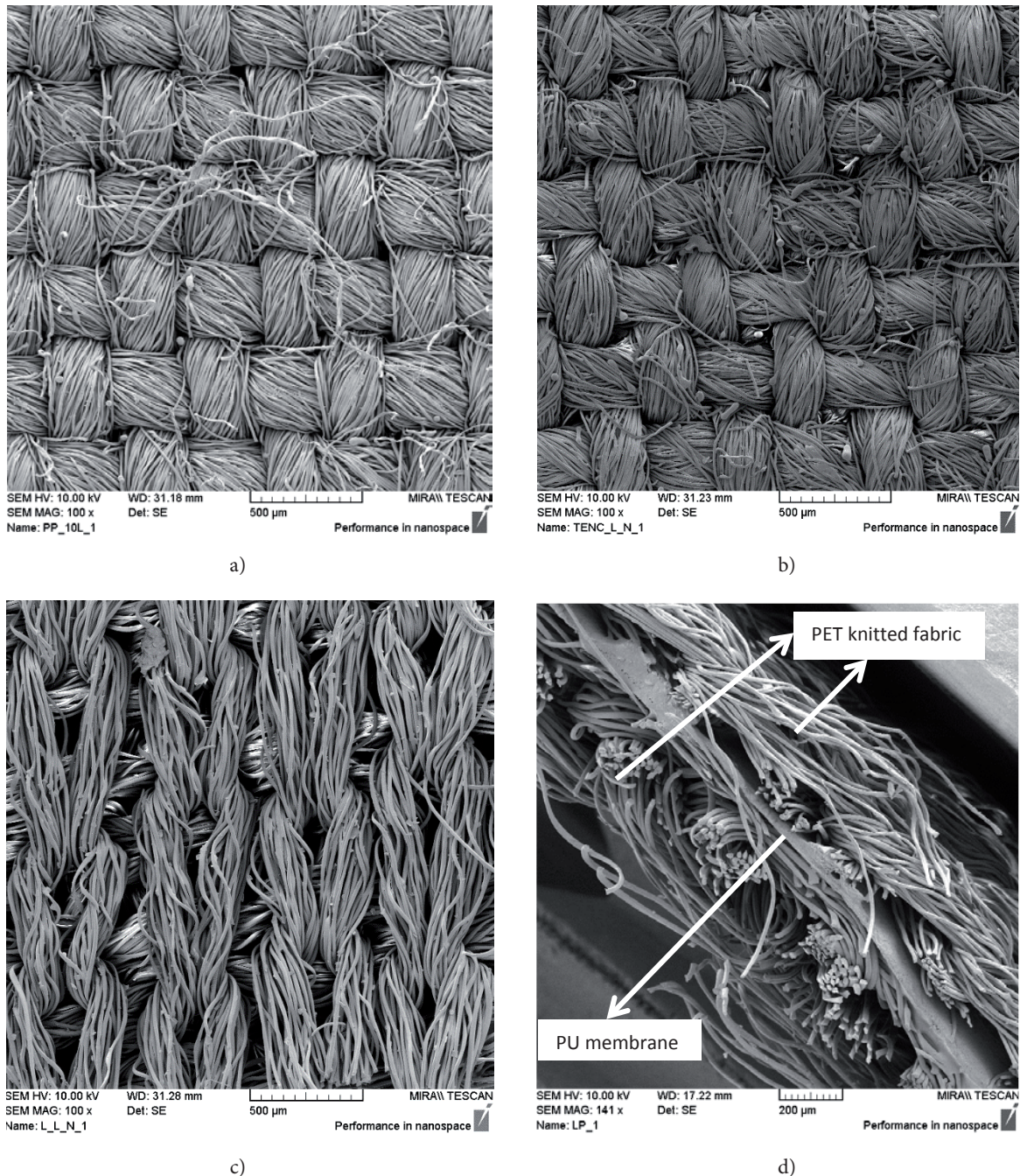


Figure 3. Scanning electron microscopy images of: a) face side of PET/cotton sample, b) face side of Tencel® sample, c) face side of Laminated PET/PU/PET sample, d) cross section of Laminated PET/PU/PET sample

AATCC test method 79 defines absorbency of a material, to take in and retain a liquid (usually water) in the pores and interstices of the material. A drop of water is allowed to fall from a fixed height (approx. 1.0 cm) onto the surface of the fabric which is firmly fixed in an embroidery hoop. The number of seconds required

for the drop to be completely absorbed by fabric is noted. Absorbency is easily judged visually by the loss of specular reflection of the water droplet (Figure 4) [7].

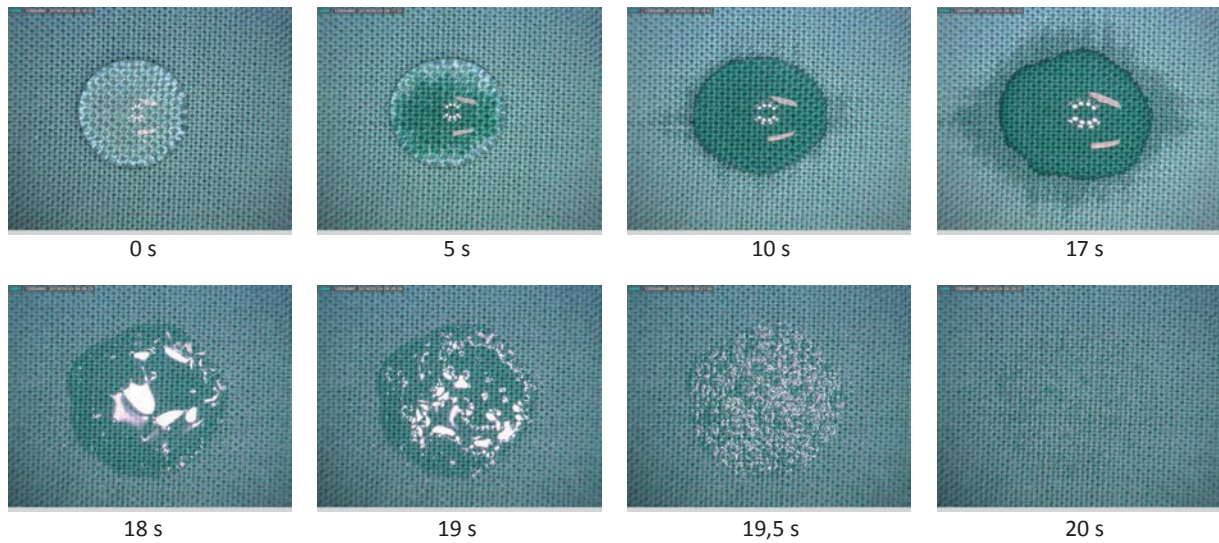


Figure 4. Display of absorption time of PET/Cotton fabric after 10 cycles of washing and sterilization according to Absorbency test (AATCC test method 79) recorded by Dino-Lite 25X

The standard ISO 6530:2005 was used to examine penetration, absorption and repellency of materials used for clothes and uniforms in hospitals for small and major surgery. Penetration is a process where liquid pass through pores, holes or openings of a fabrics or the garment. Absorption is a process where liquid moves through the material at the molecular level, including sorption, diffusion and desorption processes. Repellency is the ability to repel fluids from the material surface [1].

The tests samples were prepared in the warp direction, dimension of 360 mm long and 235 mm wide. Samples are weighted, following by transparent PVC foil resistant to test liquid and absorbent paper Whatman No. 1 which are weighed together. The order of laying in the half cylinder groove is transparent foil, absorbent paper and the test sample. The sample is placed on the top of pile where 10 cm³ of the test liquid in 10 second is sprayed on the tested fabric surface. The test period is 60 s, followed by re-weighing the absorbent paper, the transparent foil, the laboratory glass and the test sample [8].

Absorption index (I_A), penetration index (I_p) and repellency index (I_R) are calculated according to the equations (1) to (3).

$$I_A = \left(\frac{M_a}{M_t} \right) \cdot 100 \quad (\%) \quad (1)$$

$$I_P = \left(\frac{M_p}{M_t} \right) \cdot 100 \quad (\%) \quad (2)$$

$$I_R = \left(\frac{M_r}{M_t} \right) \cdot 100 \quad (\%) \quad (3)$$

where: M_a (g) - mass of the absorbed test liquid on the tested material; M_p (g) - mass of the collected test liquid on absorbing paper/foil; M_r (g) - mass of the test liquid collected in the laboratory glass; M_t (g) - mass of the test liquid discharged on the test sample.

Washing and sterilization were performed in hospital laundry services under strict and controlled conditions. The samples were washed in a continuous assembly Jensen washing machine (Jensen-Group Belgium). After washing samples were dried in a drum dryer. The sterilization of samples was performed in a Seletomat PL MMM steam sterilizer (Münchener Medizin Mechanik, Deutschland) for five minutes at 134°C.

RESULTS AND DISCUSSIONS

Basic structural parameters of tested materials as surface mass, thickness, yarn count and density are shown in Table 1.

Table 1. Structural parameters of tested-materials

Sample		m (g/m ²)	t (mm)	Tt (tex)		d (threads/cm)	
				Warp	Weft	Warp	Weft
PET/cotton	Mean	178.6	0.3	28.6	42.3	34.0	25.0
	SD	2.1	0	0.4	0.7	0	0
	CV (%)	1.2	1.4	1.3	1.6	0	0
Tencel®	Mean	193.7	0.3	22.8	31.3	50.0	27.0
	SD	1.5	0	0.5	0.4	0.4	0
	CV (%)	0.8	2.4	2.3	1.4	0.9	0
Laminate PET/PU/PET	Mean	216.0	0.7				
	SD	0.4	0				
	CV (%)	0	0.5				

where: m (g/m²) – fabric surface mass, t (mm) – fabric thickness, Tt (tex) - yarn count, d (threads/cm) – fabric density

In order to investigate absorbency properties of tested fabrics, the samples were first subjected to AATCC absorbency test. Time until the water droplet is absorbed completely is recorded and the results are shown in Table 2.

Table 2. Results of absorbency properties by the water drop test

Sample	t (s)	Number of washing and sterilizing cycles				
		0	10	20	30	50
PET/cotton	Mean	77.6	20.1	5.8	4.6	3.8
	SD	11.4	6.6	0.6	0.7	0.6
	CV (%)	14.7	32.8	10.9	15.2	16.6
Tencel®	Mean	34.0	3.6	3.0	2.8	2.1
	SD	6.7	0.5	0	0.4	0.3
	CV (%)	19.7	14.3	0	15.1	15.1
Laminate PET/PU/PET	Mean	13.9	5.0	3.4	2.6	2.1
	SD	2.0	1.2	0.8	0.7	0.3
	CV (%)	14.2	23.1	24.8	26.9	15.1

where: t (s) - time of completely water drop absorption

The time required for complete absorption of water drop is the longest in initial (unwashed and unsterilized samples (0)), preferably in the PET/cotton fabric (Table 2). The reduction of water droplet absorption time by increasing the number of washing and sterilizing cycles is evident in all samples. Figure 5 shows increase of absorption rate i.e. decrease of time absorption between cycles (0-10, 10-20, 20-30, 30-50 cycles). The greatest change, or the largest increase in absorption rate, was observed in the range of 0-10 cycles in all samples, mostly in Tencel® sample which increases the absorption rate for almost 90 %. This indicates the greatest change of this material in terms of absorption properties after 10 cycles. This change can be explained by well-known fact that Tencel® absorb water through fibre, while cotton fibre absorb water only on surface [5]. By further subjecting fabrics to washing and sterilization cycles, there is no significant difference in the absorption rate, with total increase after 50 cycles compared to the initial (0 cycle) sample of only 4 % (total 94 %).

After a sudden increase in absorption rate after 10 cycles (for 74 %), PET/cotton sample further increases the absorption rate between 10-20 cycles (for over 71%), after which (from 20-30 cycles) the increase rate considerably decreases (to 20 %). This means that the PET/cotton sample experiences the highest degradation up to 20 cycles, after which degradation in the capacity of increasing absorption rate slows. The total amount of absorption rate increase, from 0-50 cycle's amount 95 %.

For Laminate PET/PU/PET sample, the rate of absorption between the cycles gradually decreases, although the highest increase is recorded after 10 cycles (64 %), while after 50 cycles the total absorption rate is 85 % higher.

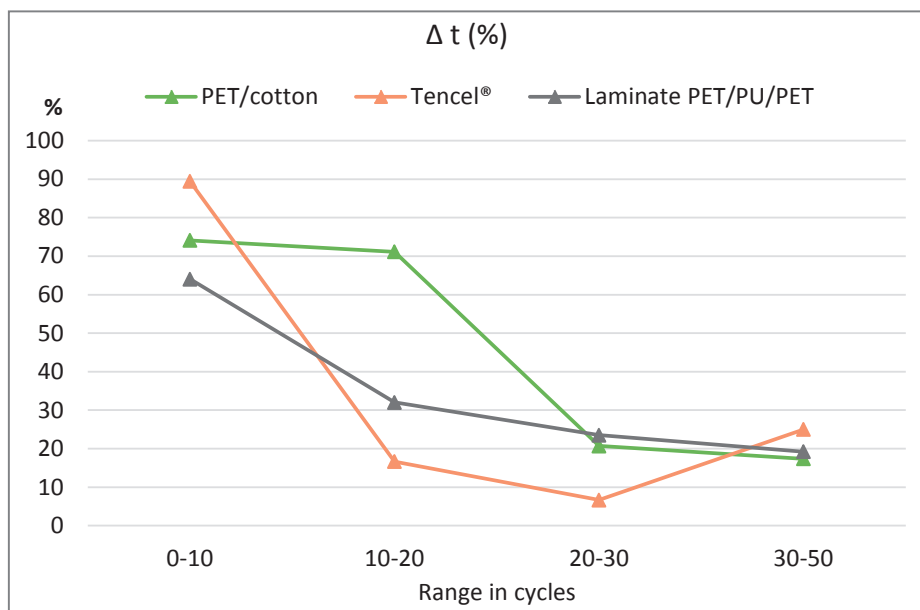


Figure 5. Percentage increase of absorption rate (decrease of time absorption) between cycles

In Table 3, test results of absorption, penetration and repellence indexes of all three samples after various numbers of washing and sterilizing cycles, are shown. Generally, by increasing the number of washing and sterilization cycles, the absorption index (I_A) and the penetration index (I_p) increase, while the repellence index (I_R) decreases.

Among the initial samples (0 cycles), the highest absorption index (I_A) was observed in the Laminate PET/PU/PET sample, which also has a remarkable property of non-penetration ($I_p=0\%$), which is retained through all cycles. It is also important to note that this sample, after 50 cycles of washing and sterilizing, retains the best repellence properties compared to other materials.

The lowest I_A of the initial samples was recorded with sample PET/cotton (15 %), which at the same time has the highest $I_R=76$ %, but after subjecting to washing and sterilizing cycles, it decreased to 7.5 %. For Tencel® sample I_A through the cycle's increases in relatively similar proportions as I_p , while the I_R gradually decreases and after 50 cycle's amounts 0 %.

Table 3. Results of absorption, penetration and repellence measurements

Properties	Sample	Number of washing and sterilizing cycles				
		0	10	20	30	50
I_A (%)	PET/cotton	15.0	38.4	58.4	59.0	59.5
	Tencel®	24.5	41.0	49.0	52.6	58.8
	Laminate PET/PU/PET	52.0	61.0	63.0	65.0	67.0
I_p (%)	PET/cotton	9.0	9.4	29.4	32.0	33.0
	Tencel®	19.9	39.0	40.0	40.6	41.2
	Laminate PET/PU/PET	0	0	0	0	0
I_R (%)	PET/cotton	76.0	52.2	12.2	9.0	7.5
	Tencel®	55.6	20.0	11.0	6.8	0
	Laminate PET/PU/PET	48.0	39.0	37.0	35.0	33.0

where: I_A (%) - absorption index, I_p (%) - penetration index, I_R (%) - repellence index

Figure 6 shows the percentage increase of absorption index (I_A) through cycles of washing and sterilizing. The highest increase after 10 cycles shows PET/cotton sample (even 156 %), followed by an increase of 52 % between cycles 10-20. Interestingly, by further increase of cycle's number, I_A stays almost unchanged (1 %). For Tencel® sample, the most significant increase of I_A , is also after 10 cycles (67 %), while by further increase, it remains within the range of 10-20 %. The Laminate PET/PU/PET sample retains the best absorption properties, where after 10 cycles I_A increases for only 17 %, while subjecting it to further washing and sterilizing cycling's, retains an increase of 3 %.

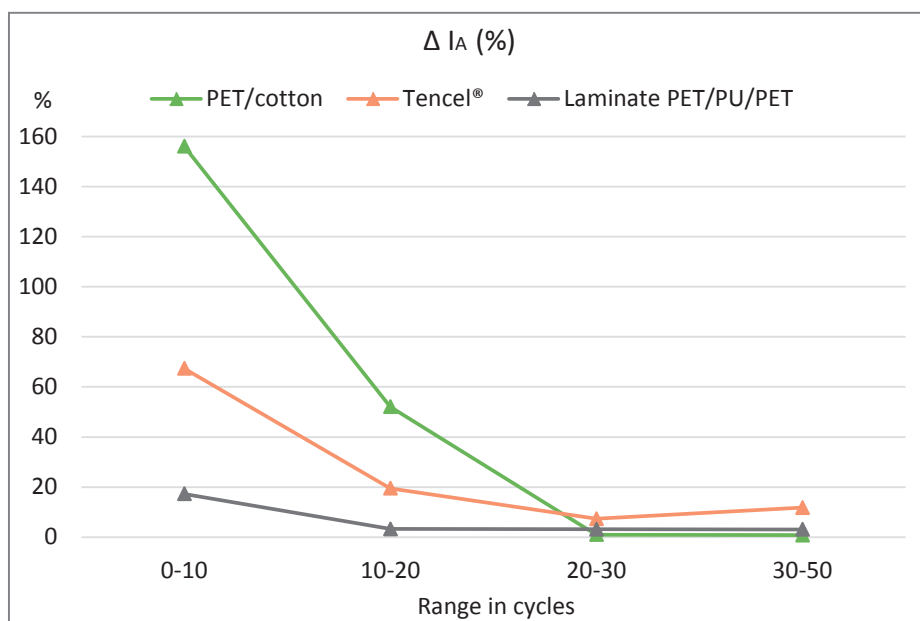


Figure 6. Percentage increase of absorption index (I_A) through cycles

By observing penetration index (I_p) (Figure 7) it is interesting to note a significant increase in the PET/cotton sample that occurs after 20 cycles and amount even 212 %, compared to the minimum increase of 4 % after 10 cycles, confirming the above-mentioned degradation of this material after 20 cycles of washing and sterilizing. Furthermore, Tencel® sample shows a significant increase of I_p after 10 cycles, while further submission of washing and sterilization does not affect the changes of this property.

Decrease of repellence index (I_R) through cycles increase, indicates a decline of the material properties (Figure 8), which is strongly emphasized in the Tencel® sample, in which, after 10 cycles I_R decreases by 64 %

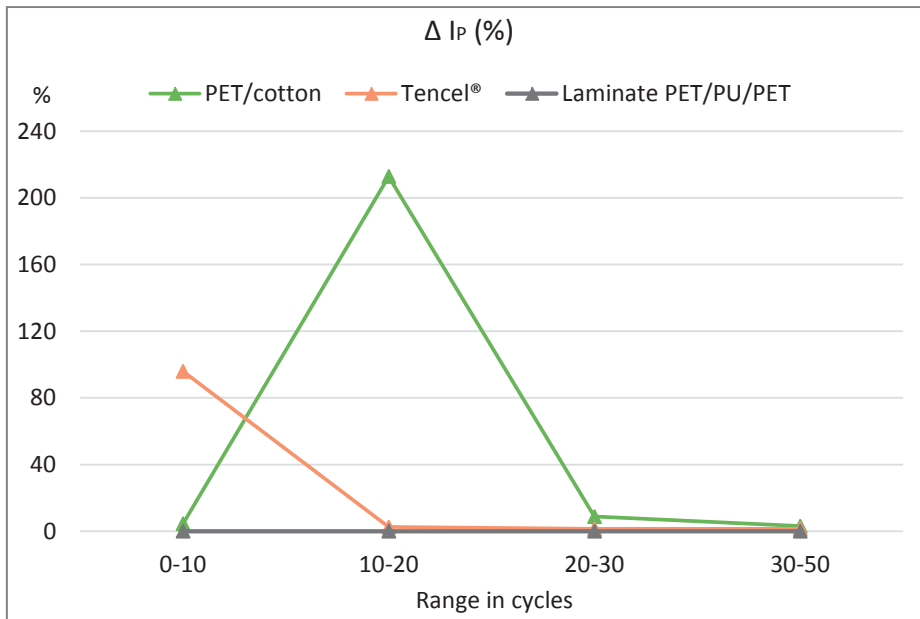


Figure 7. Percentage increase of penetration index (I_p) through cycles

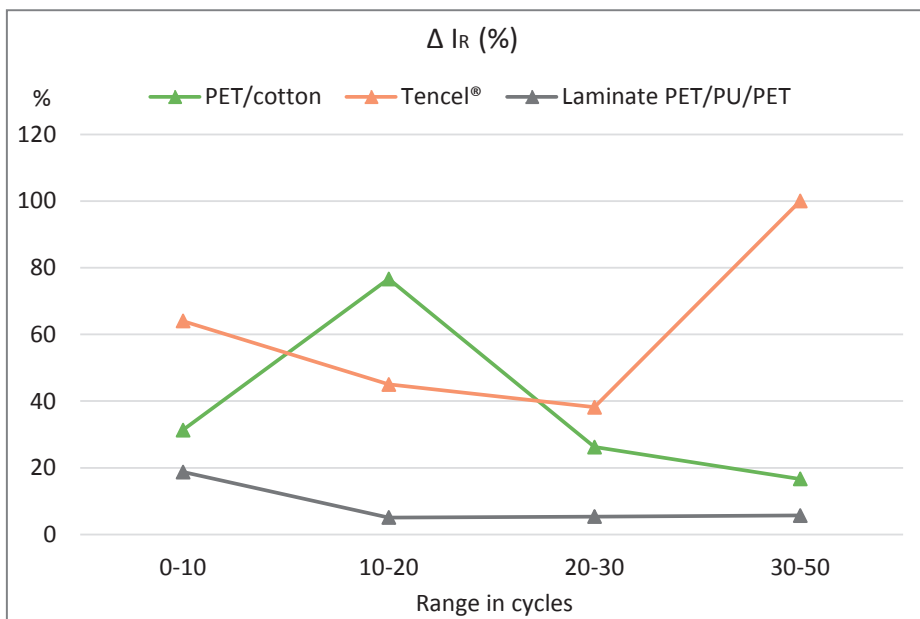


Figure 8. Percentage decrease of repellence index (I_R) through cycles

and further between 10-20 cycles by 45 %, while after 50 cycles this decrease is 100 % or $I_R=0$ %. The PET/cotton sample gradually loses the property of the repellence, where the most pronounced decrease of I_R has been obtained after the 20 cycles. Conversely, for Laminate PET/PU/PET fabric decrease of I_R between 0-10 cycles is only 19 %, while further reduction is minimal (about 5 %), and it is important to point out that total I_R decrease after 50 cycles is only 31 %.

CONCLUSIONS

According to obtained results it can be concluded that time required for complete water drop absorption is the longest for unwashed and unsterilized fabrics. Absorption increase i.e. decrease of water droplet absorption time is highest, for PET/cotton fabric, followed by Tencel® and Laminate PET/PU/PET fabrics. PET/cotton fabric absorption properties significantly decrease already up to 10 cycles and additionally decrease up to 20 cycles, after which doesn't change significantly. Tencel® and Laminate PET/PU/PET fabrics up to 10 cycle lose a significant part of the absorption property, which by further subjecting to additional washing and sterilization cycles does not considerably change.

Absorption index for unwashed and unsterilized Laminate PET/PU/PET fabric is the highest and by subjecting to washing and sterilization cycles changes only for 29 %. For woven fabrics used for *standard performance* absorption indexes are considerably lower, but with real application conditions (washing and sterilization) remarkably change its properties (in sense of fabrics degradation), where after 50 cycles increase is even 140 % for Tencel® and 300 % for PET/Cotton. These changes are most evident after 10, i.e. 20 cycles of washing and sterilization.

Penetration index is higher for Tencel® comparing to PET/Cotton fabric, but remarkably differences between fabrics are visible through washing and sterilization cycles. For Tencel® fabric, the largest penetration index change is visible up to 10 cycles, after which penetration index remains almost the same. Contrary to Tencel® fabric, the largest penetration index change for PET/Cotton fabric is noticeable after 20 washing and sterilization cycles, after which values almost does not change. Laminate PET/PU/PET fabric is distinguished by the exceptional properties of impermeability, where after 50 washing and sterilization cycles penetration index remain at 0 %.

Repellence index is the highest for unwashed and unsterilized PET/Cotton fabric, which significantly decreases already after the 20 cycles, to reduce after the 50 cycles by as much as 90%. For Tencel® fabric trend is similar; by increasing number of cycles, repellence index significantly decrease, where after 50 cycles is 0 %. Contrary to that, Laminate PET/PU/PET fabric retains its repellence index even after 50 washing and sterilization cycles.

Based on the above, it can be concluded that protective properties of two woven fabrics used in hospitals for *standard performance* (operations where these risks for penetration by liquids are lower) after real application (washing and sterilization) are changed and it may affect the protection of medical workers. Therefore, it should take into consideration a period of use of fabrics intended for *standard performance*. The most important property for surgical gowns is repellency index, which for Laminate PES/PU/PES fabric, used for surgical gowns, is maximum and remains unchanged even after 50 washing and sterilization cycles, providing complete protection of medical workers.

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