Low temperature plasma for textiles disinfection

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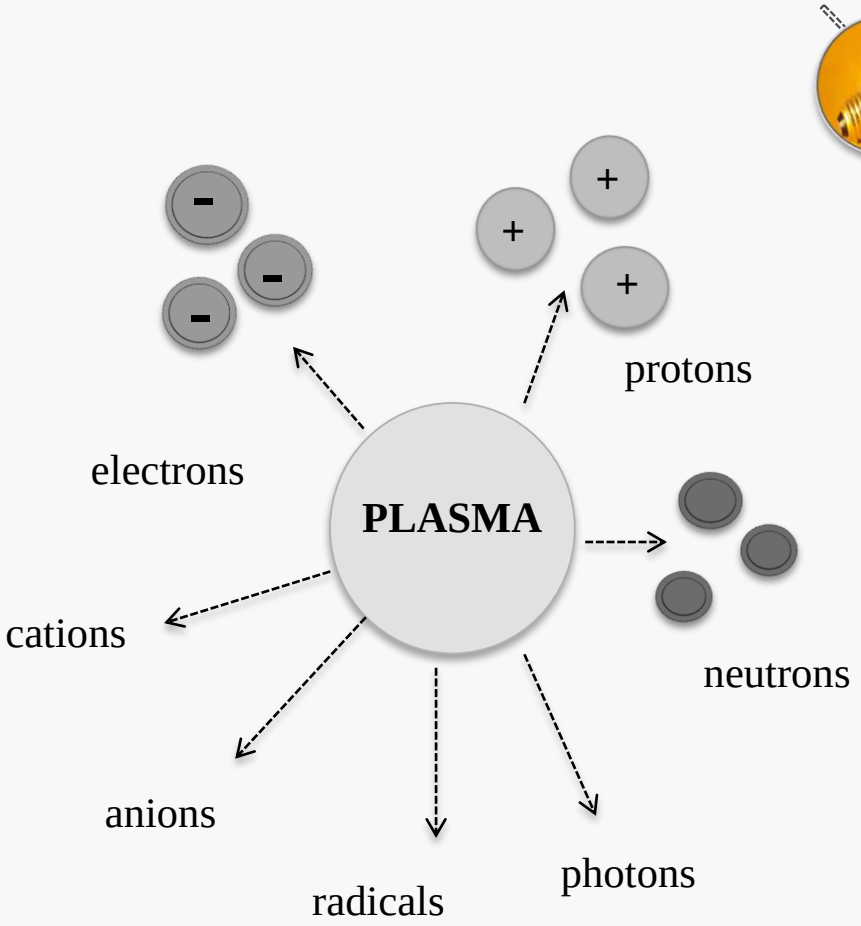
Low temperature plasma (LTP)



- Energetics
- Metallurgy
- Materials coating
- Air, soil, sewage treatment
- Waste management
- Medicine
- Package and food product sterilization

Low temperature plasma
T< several thousand K

Aim and scope

The aim of the study was to evaluate the low temperature plasma disinfection effectiveness and its impact on textiles properties

I
- Optimization of LTP disinfection

II
- Determination of the effectiveness of LTP textiles disinfection in model conditions

III
- Evaluation of LTP impact on the mechanical, structural and optical properties of textiles

IV
- Assessment of the LTP disinfection effectiveness of historical textiles

Materials

Textiles

Fiber	Mass per unit area (g/m²)	Thickness (mm)	Porosity (%)	Finishing	Manufacturer
Cotton	278	0.76	76	Unbleached	Andropol S.A. (Poland)
Linen	285	0.70	73	Natural colour	Świat Lnu (Poland)
Silk	52	0.12	67	Natural colour Degummed	Fei–Long Inc. (China)

Pillowcase
(embroidered cotton, 1950)

Ribbon (polyester, 1980)

Microorganisms

	Species	Source	Textiles
Bacteria	*Bacillus megaterium*	ŁOCK 105	Silk
	Pseudomonas fluorescens	ŁOCK POM2123	
	Streptomyces sp.	ŁOCK 0894	
Moulds	*Aspergillus niger*	ATCC 16404	Cotton Linen
	Penicillium funiculosum	ŁOCK 0587	
	Trichoderma viride	ŁOCK E153	

ATCC – American Type Culture Collection; ŁOCK – Łódź Pure Culture Collection

Trousers
(cotton, 1940)

Coif
(starched silk, 1918)

Historical textiles – Museum of Archaeology and Ethnography in Lodz, Department of Costume and Folk Textile

Methods

Test	Standard	Parameter	Equipment
Textiles ageing	Feller (1994)	140°C, 26h (70 years)	Thermal Ageing Oven UTS-1 (Uni-Tech)
Antimicrobial effectiveness	AATCC 100:2012	Reduction (%)	CD 400PLC ROLL CASSETTE (Europlasma)
Mechanical properties	ISO13934–1:2002	Elongation at break (%) Breaking strength (N)	INSTRON Model 4204 (Instron)
Optical parameters	ISO 105-J01:2002	CIEL*a*b*	V–670 UV–Vis–NIR Spectrophotometer (JASCO)
Structural changes	ATR FTIR	Absorbance	Nicolet 6700 (THERMO Scientific)
	SEM	Microscopic changes	Nova NanoSEM 230 (FEI)

AATCC – American Association of Textiles Chemists and Colorists

Low Temperature Plasma disinfection parameters:

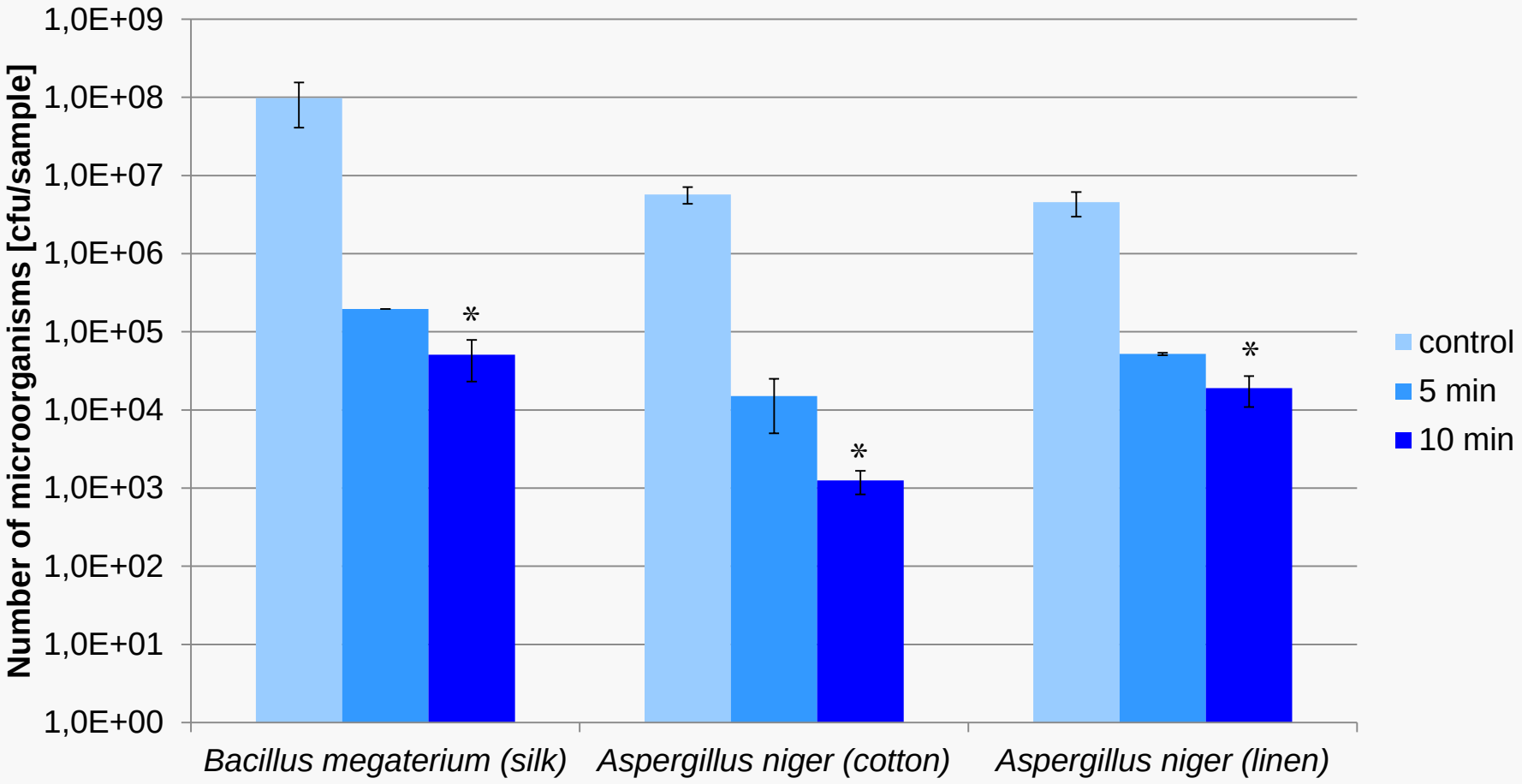
Time (min)

- 5
- 10
- 40

Gas

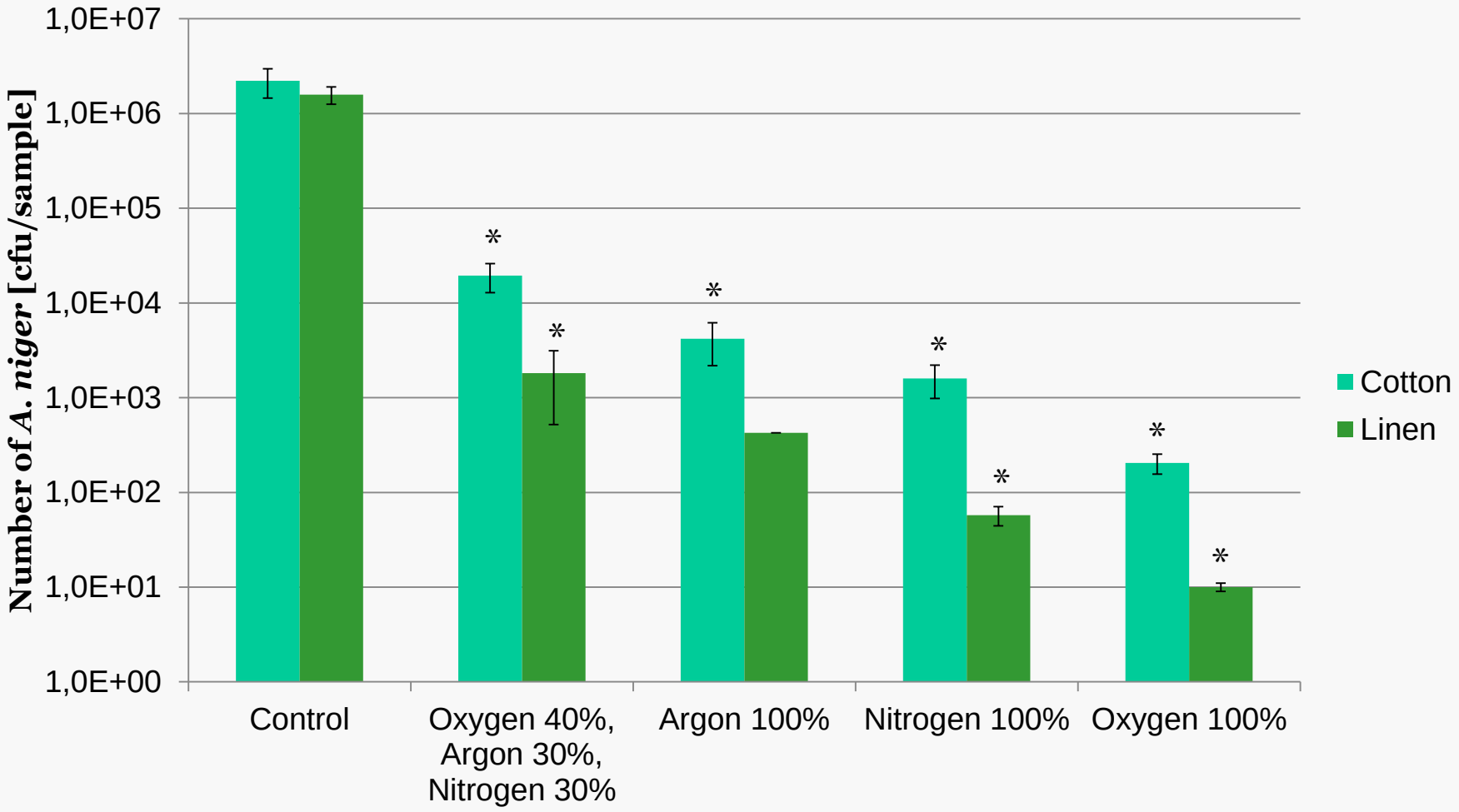
- oxygen
- nitrogen
- argon
- oxygen : nitrogen (20:80; 50:50)
- oxygen : nitrogen : argon (30:40:30)

Optimization of LTP disinfection - time



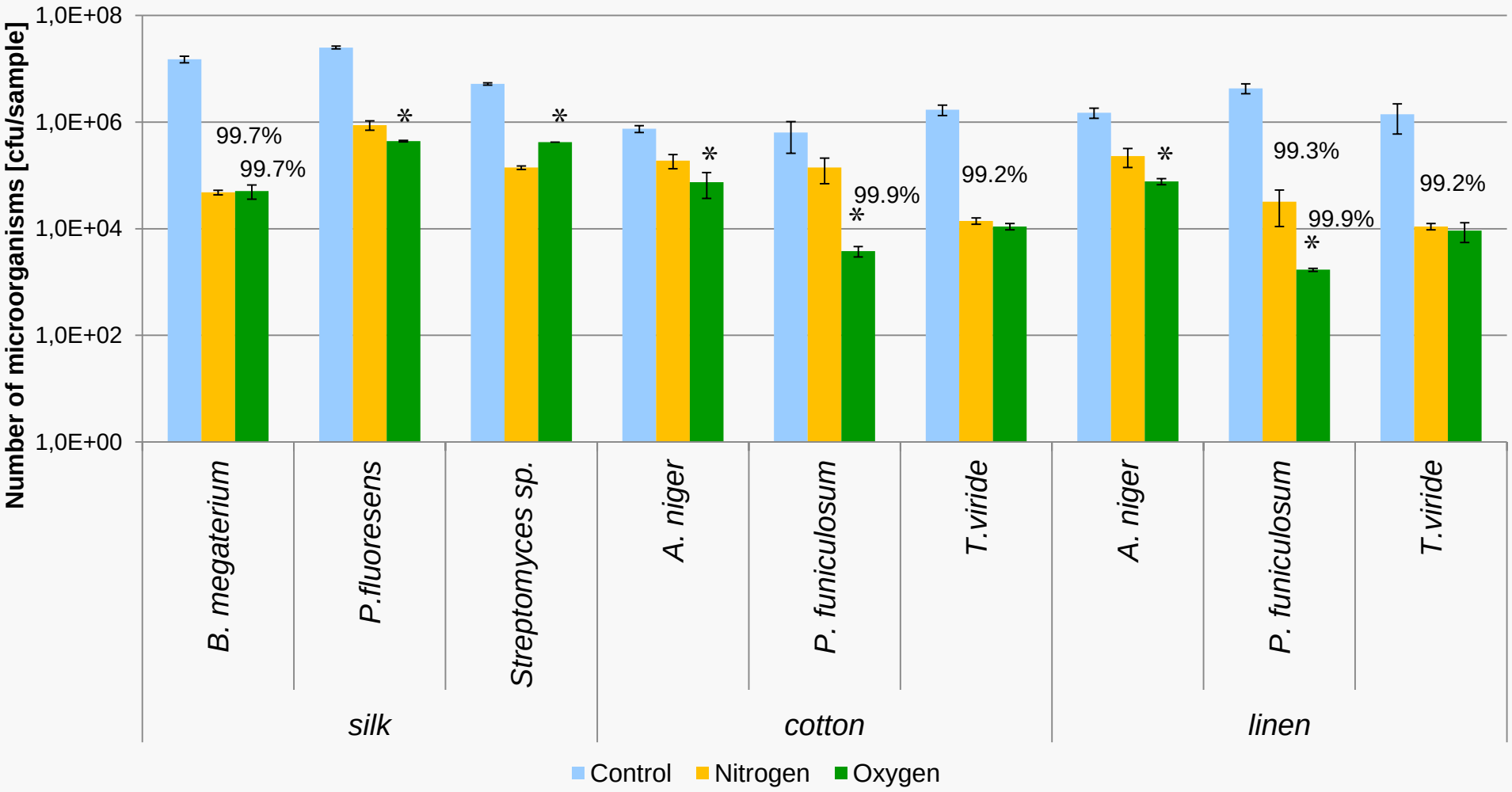
Gas: oxygen : nitrogen (50:50)
*statistically significant difference between the number of microorganisms after 5 and 10 min. disinfection (One-Way ANOVA, $p<0.05$)

Optimization of LTP disinfection - gas



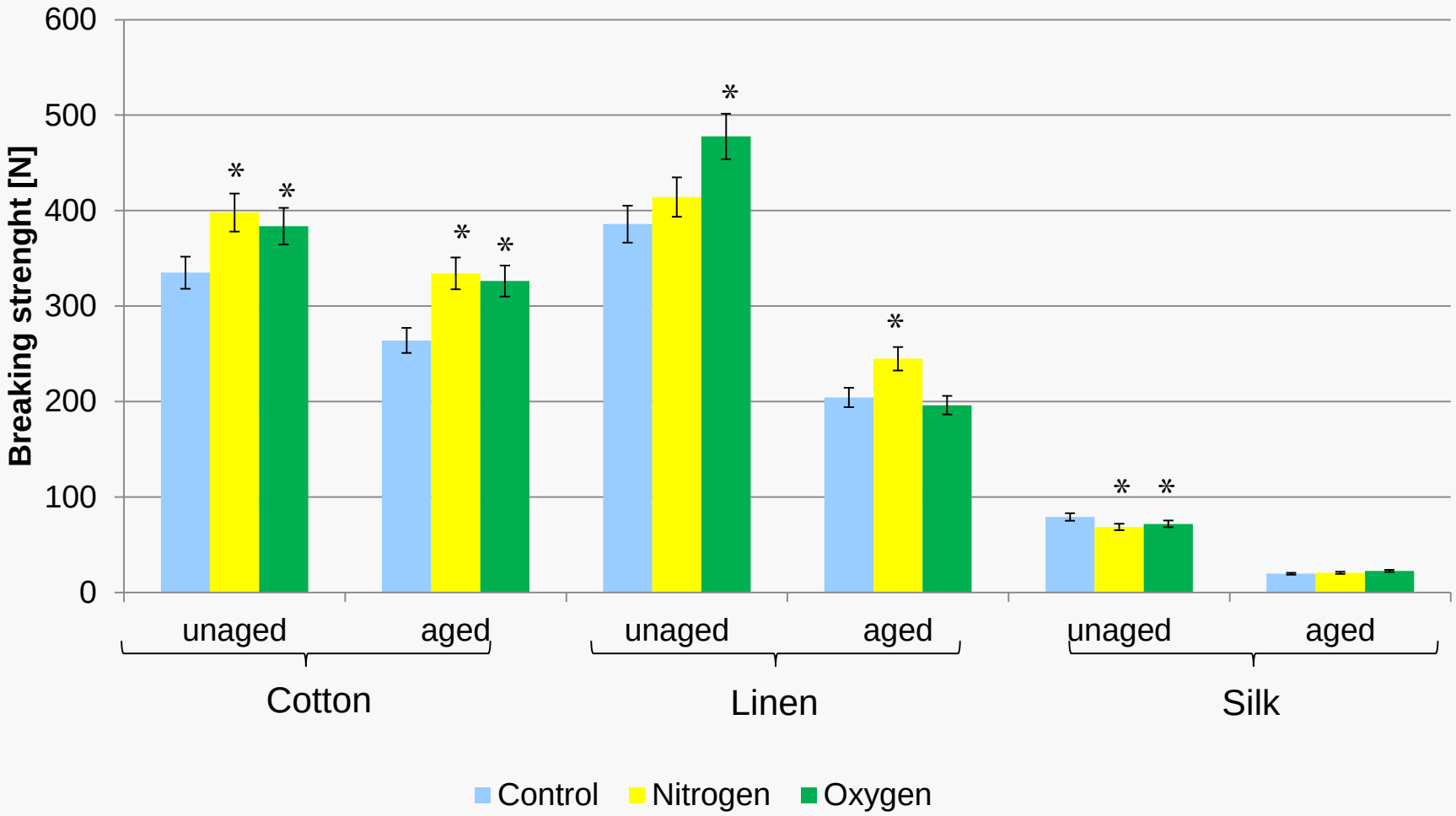
Time: 10 min
* statistically significant difference between the number of *Aspergillus niger* number in control and disinfected samples (One-Way ANOVA, $p<0.05$)

Effectiveness of LTP disinfection



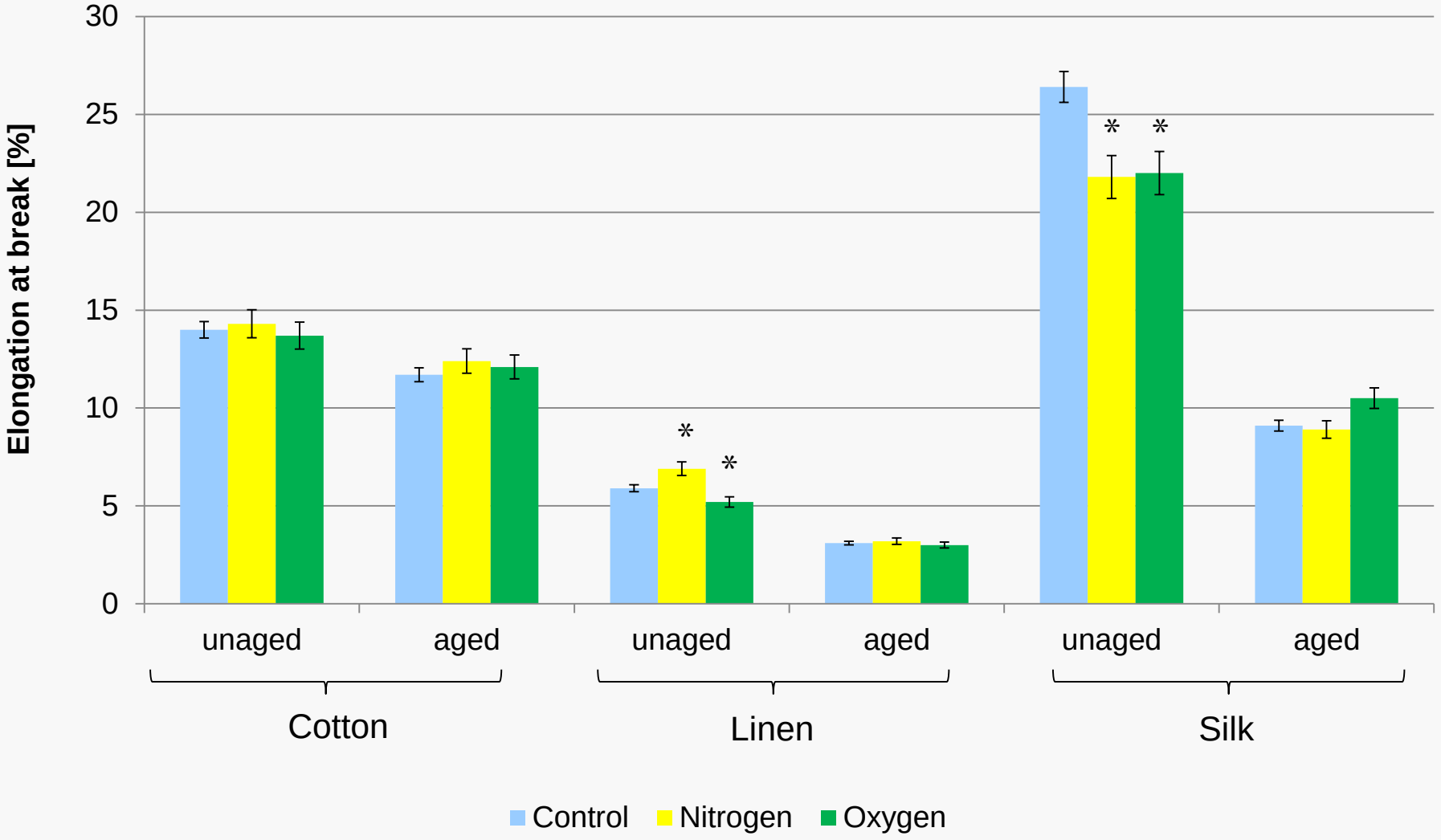
Time: 10 min
*statistically significant difference between the number of microorganisms after nitrogen and oxygen disinfection (One-Way ANOVA, $p<0.05$)

Mechanical properties of textiles after LTP



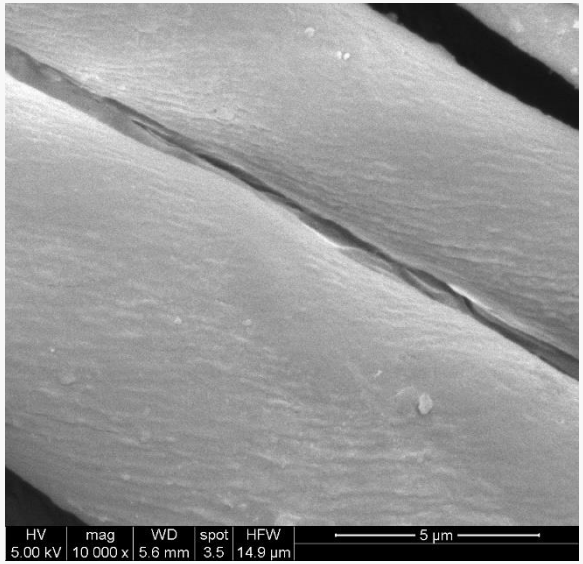
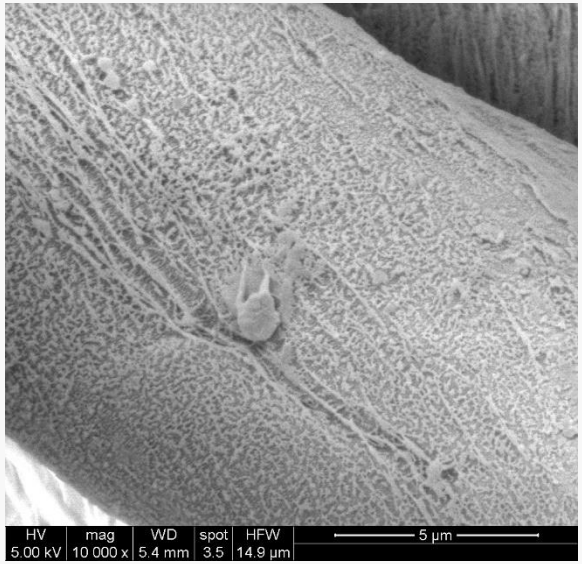
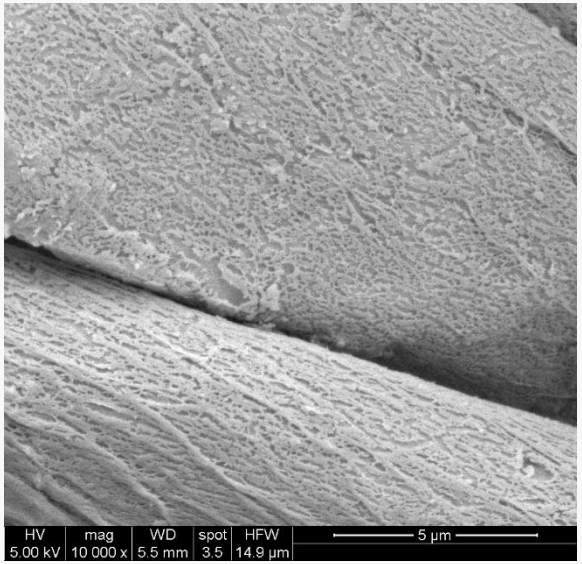
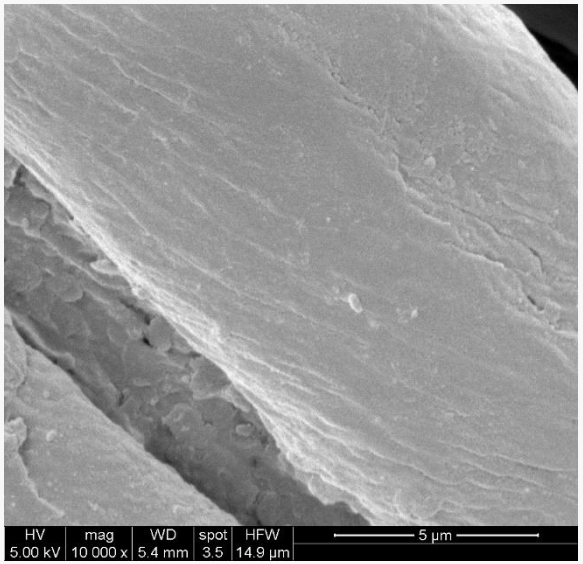
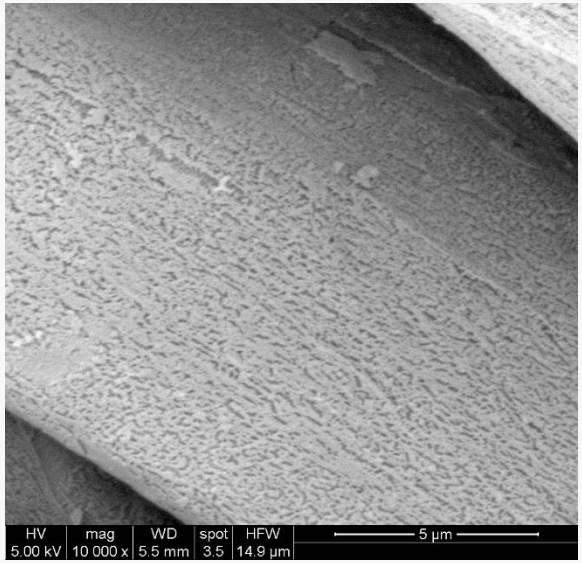
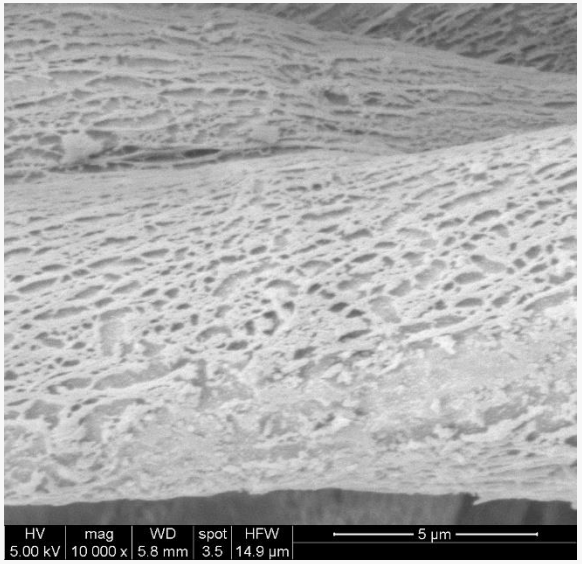
Time: 10 min
* statistically significant difference between the elongation at breaking streanght for control and disinfected samples (One-Way ANOVA, $p<0.05$)

Mechanical properties of textiles after LTP

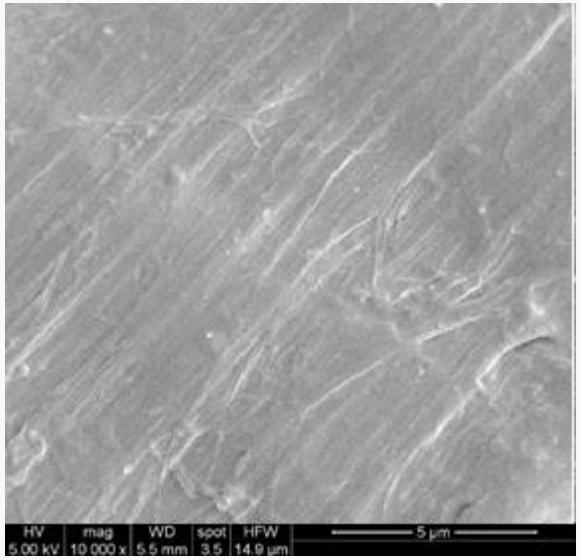
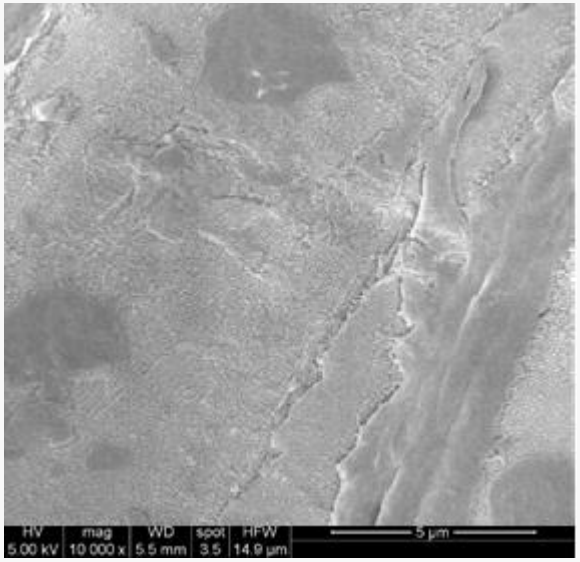
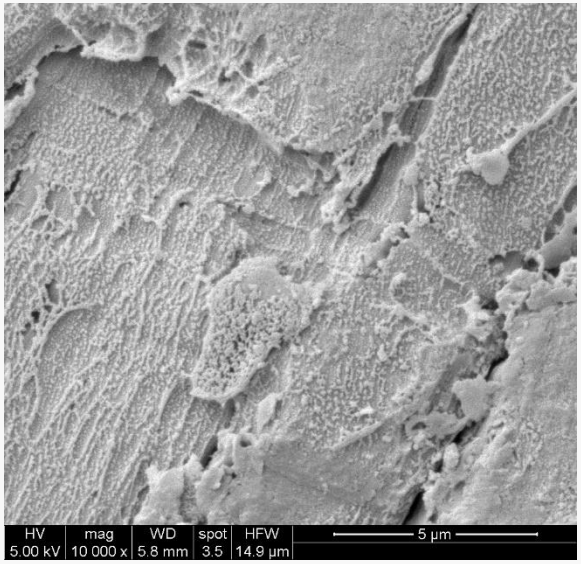
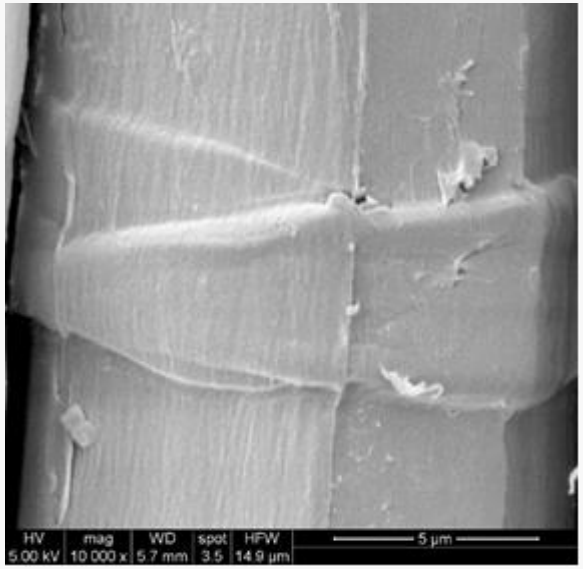
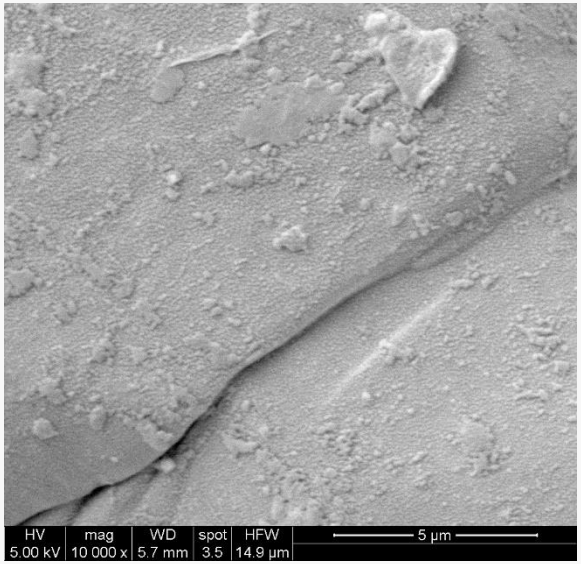


Time: 10 min
* statistically significant difference between the elongation at break for control and disinfected samples
(One-Way ANOVA, $p<0.05$)

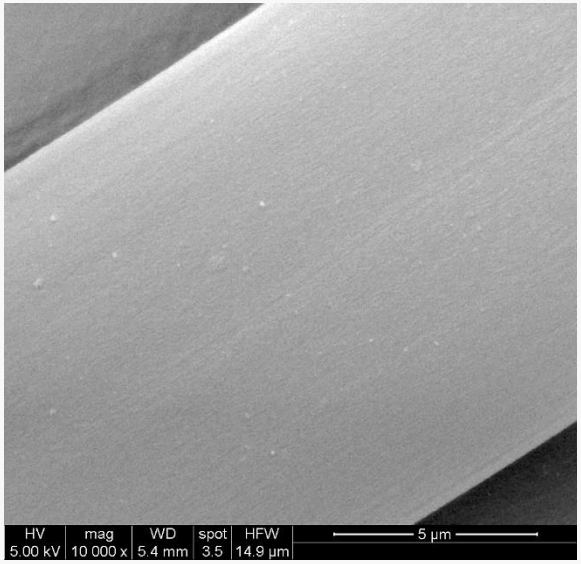
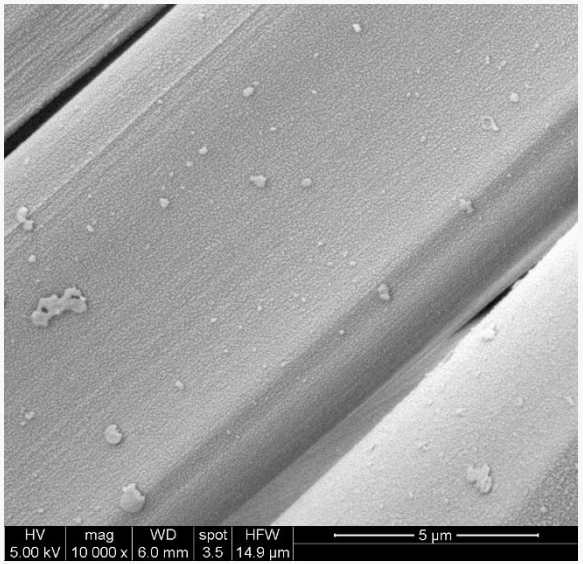
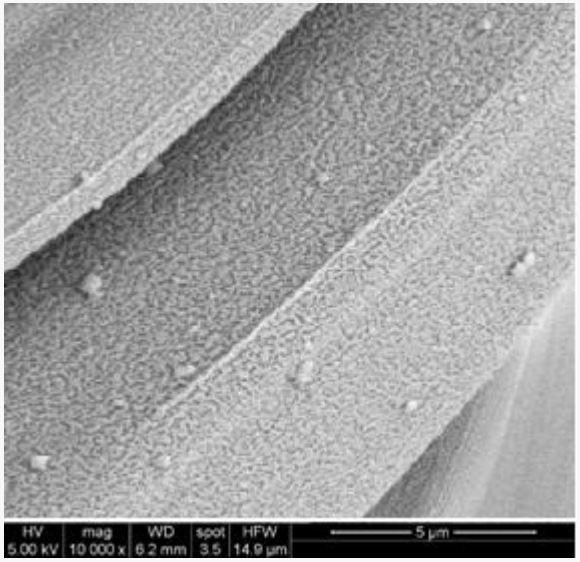
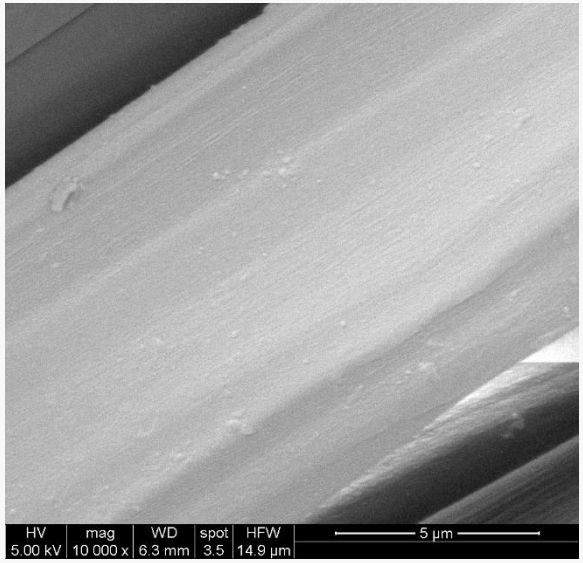
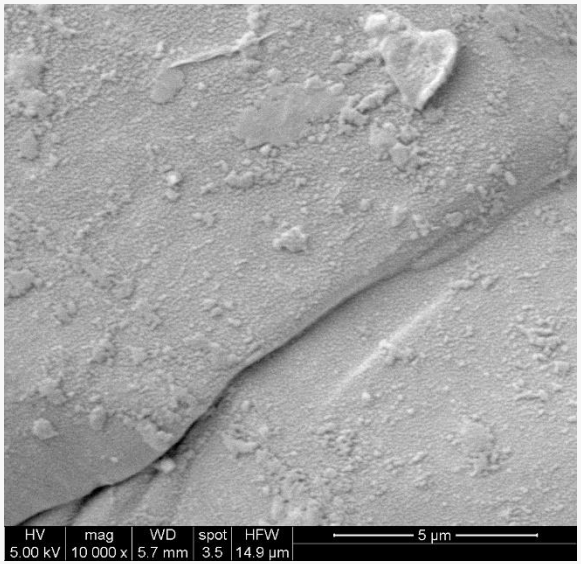
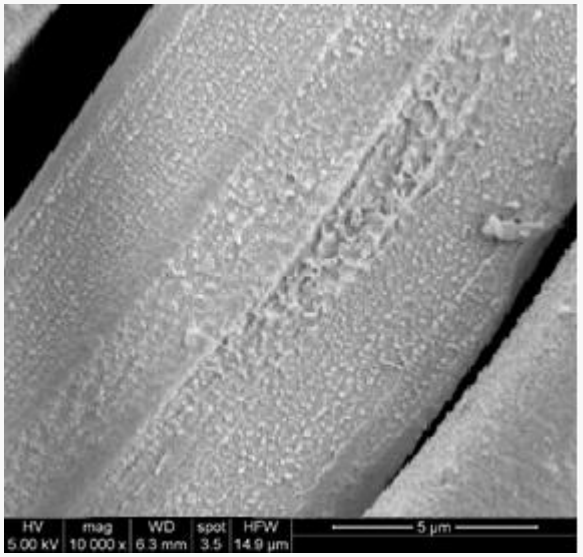
Morphological properties of textiles after LTP - cotton

	control	nitrogen	oxygen
Unaged			
Aged			

Morphological properties of textiles after LTP - linen

	control	nitrogen	oxygen
Unaged			
Aged			

Morphological properties of textiles after LTP - silk

	control	nitrogen	oxygen
Unaged			
Aged			

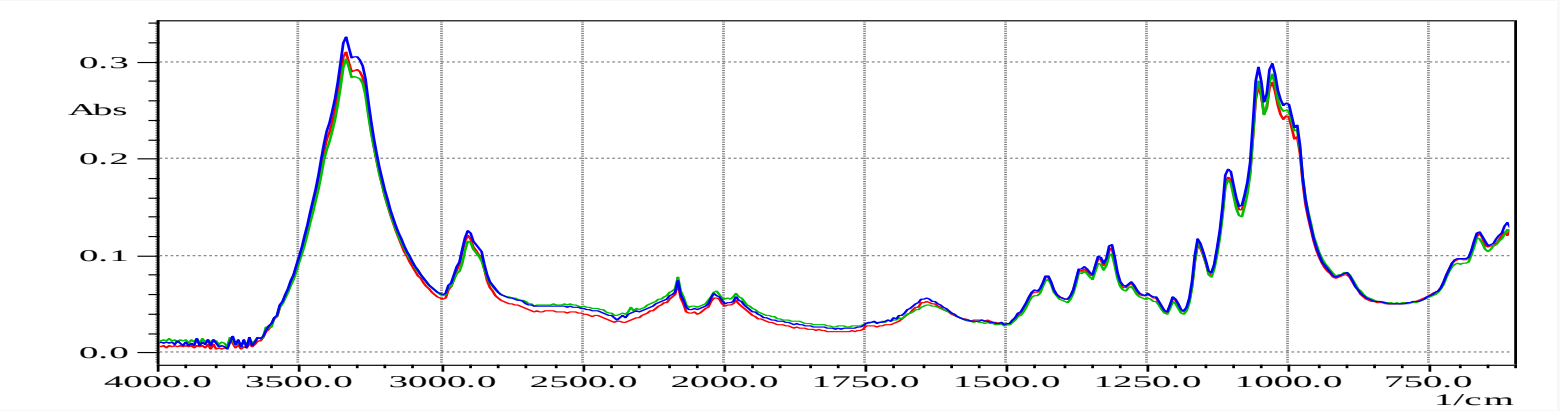
Optical properties of textiles after LTP

Sample		Parameter			
		Δ L*	Δ a*	Δ b*	Δ E
Unaged	Linen				
	Nitrogen	-0.99	0.13	0.47	1.10
	Oxygen	-0.48	0.08	0.05	0.49
Aged	Control	-10.65	4.95	4.95	12.74
	Nitrogen	-1.97	-0.17	-0.28	2.00
	Oxygen	-3.83	0.60	-0.41	3.90
Unaged	Cotton				
	Nitrogen	1.52	-0.12	0.64	1.66
	Oxygen	2.87	-0.14	-0.08	2.87
Aged	Control	-7.15	2.79	7.76	10.92
	Nitrogen	1.10	-0.15	-0.05	1.11
	Oxygen	2.17	-0.09	0.27	2.19
Unaged	Silk				
	Nitrogen	-0.76	-0.25	1.10	1.36
	Oxygen	0.38	-0.12	0.17	0.43
Aged	Control	-18.05	5.44	17.31	25.59
	Nitrogen	4.77	-1.79	-0.50	5.11
	Oxygen	4.46	-1.21	-0.09	4.63

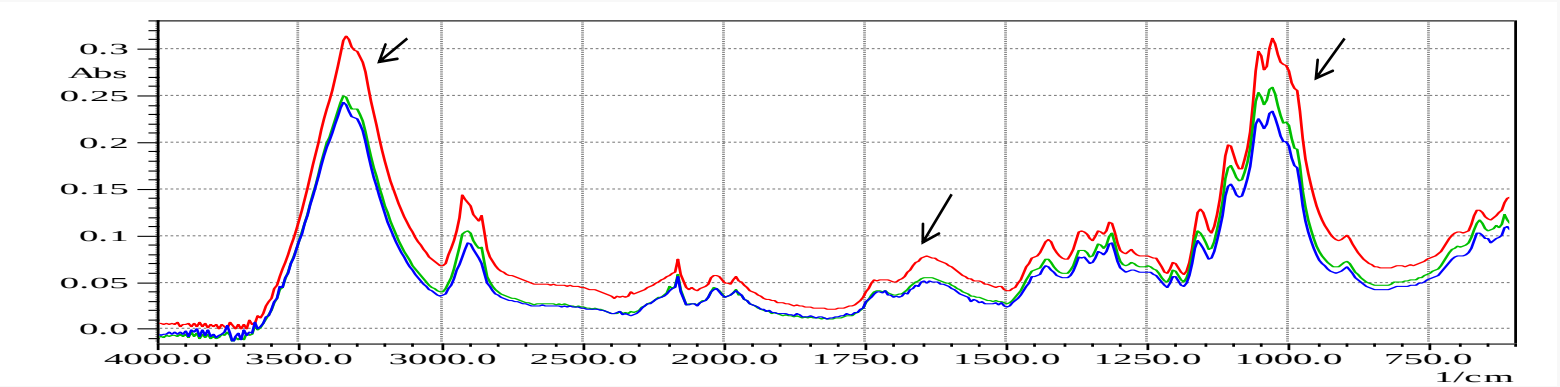
Time: 10 min

Structural properties of textiles after LTP

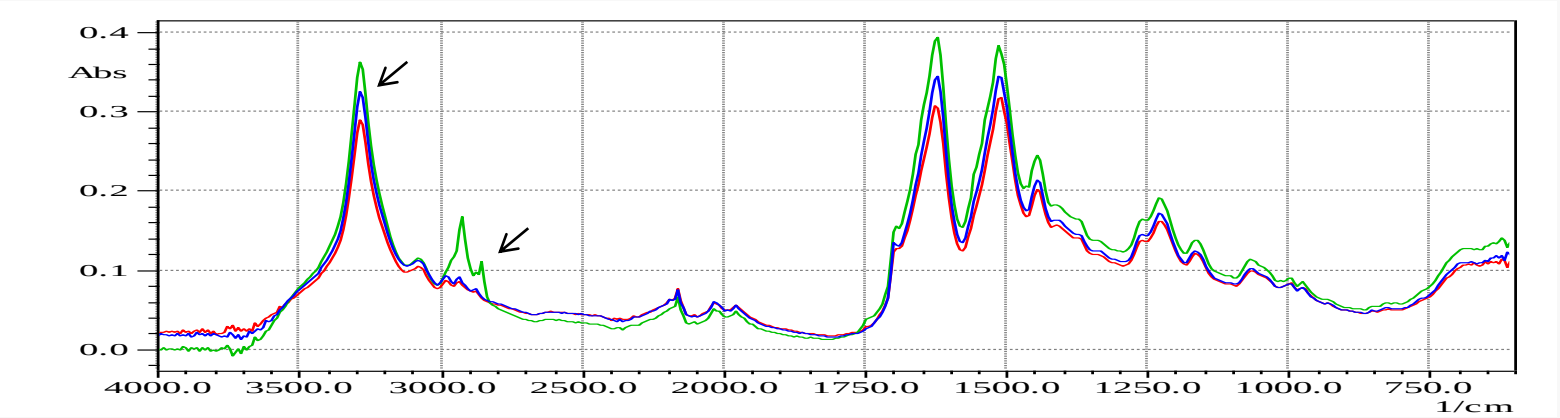
Cotton



Linen



Silk

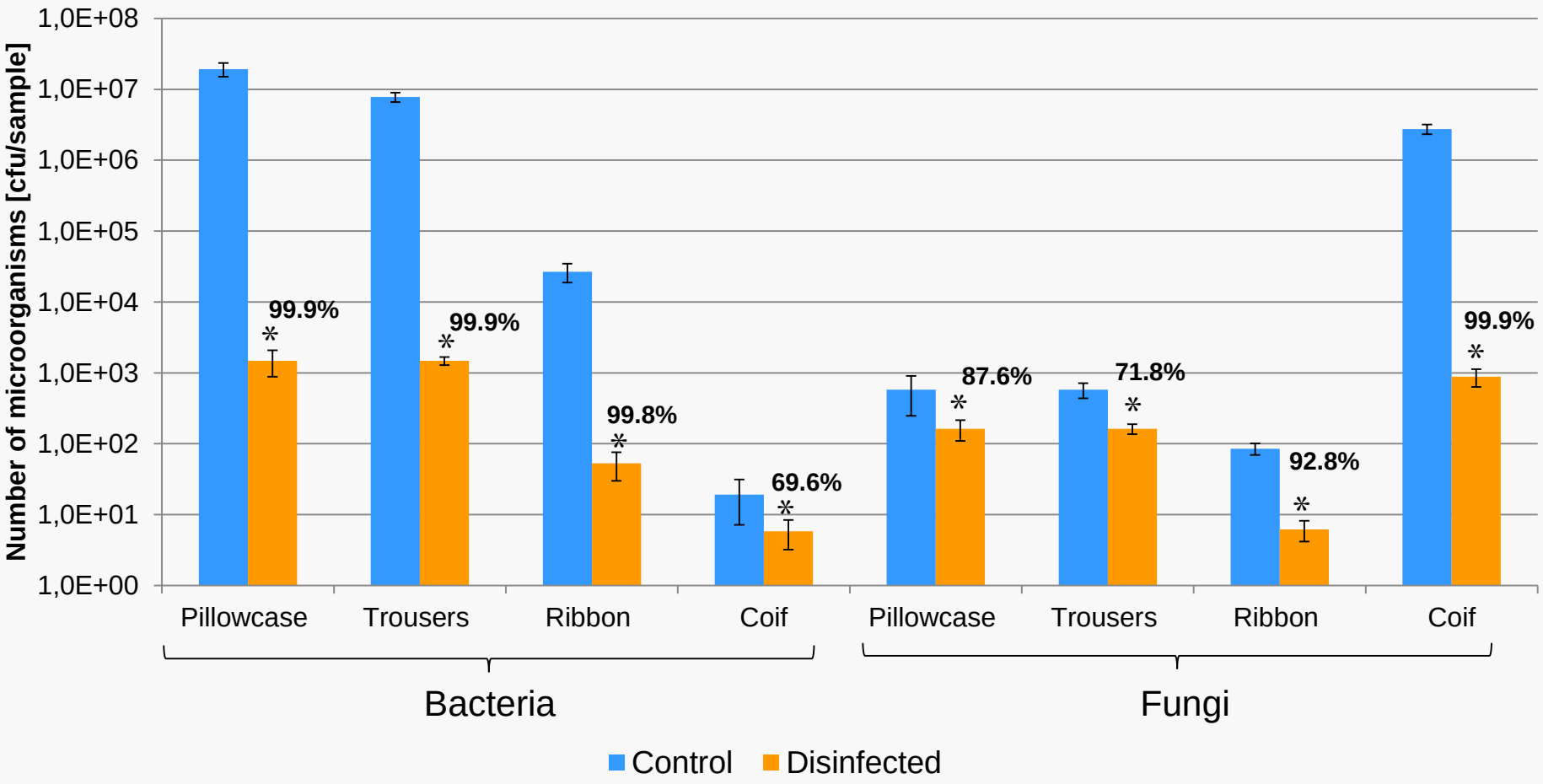


Control

Nitrogen

Oxygen

Effectiveness of LTP disinfection of historical textiles



Time: 10 min; Gas: oxygen
* statistically significant difference between microorganisms number in control and disinfected samples (One-Way ANOVA, $p<0.05$)

Summary

1. The highest antimicrobial efficiency of low temperature plasma disinfection was obtained for 10 min and oxygen or nitrogen as reactive gas.

2. Low temperature plasma disinfection enables to achieve the reduction of microorganisms number from 84.00% to 99.96% under the model conditions and from 69.64% to 99.99% for historical fabrics.

3. The highest antimicrobial activity of LTP disinfection was reported for *Penicillium funiculosum* (cotton and linen) and *Bacillus megaterium* (silk). *Aspergillus niger Pseudomonas fluorescens* and *Streptomyces* sp. were the least sensitive to this disinfection method.

4. Low temperature plasma increased breaking strength of cotton and unaged linen, decreased mechanical properties of silk. Plasma also caused morphological microdamages of tested fibers and a noticeable colour changes in cases of aged textiles. Moreover, structural changes after plasma disinfection were observed for aged linen and silk.

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