



Universidade do Minho
Escola de Engenharia



**CENTRO DE CIÊNCIA E
TECNOLOGIA TÊXTIL**

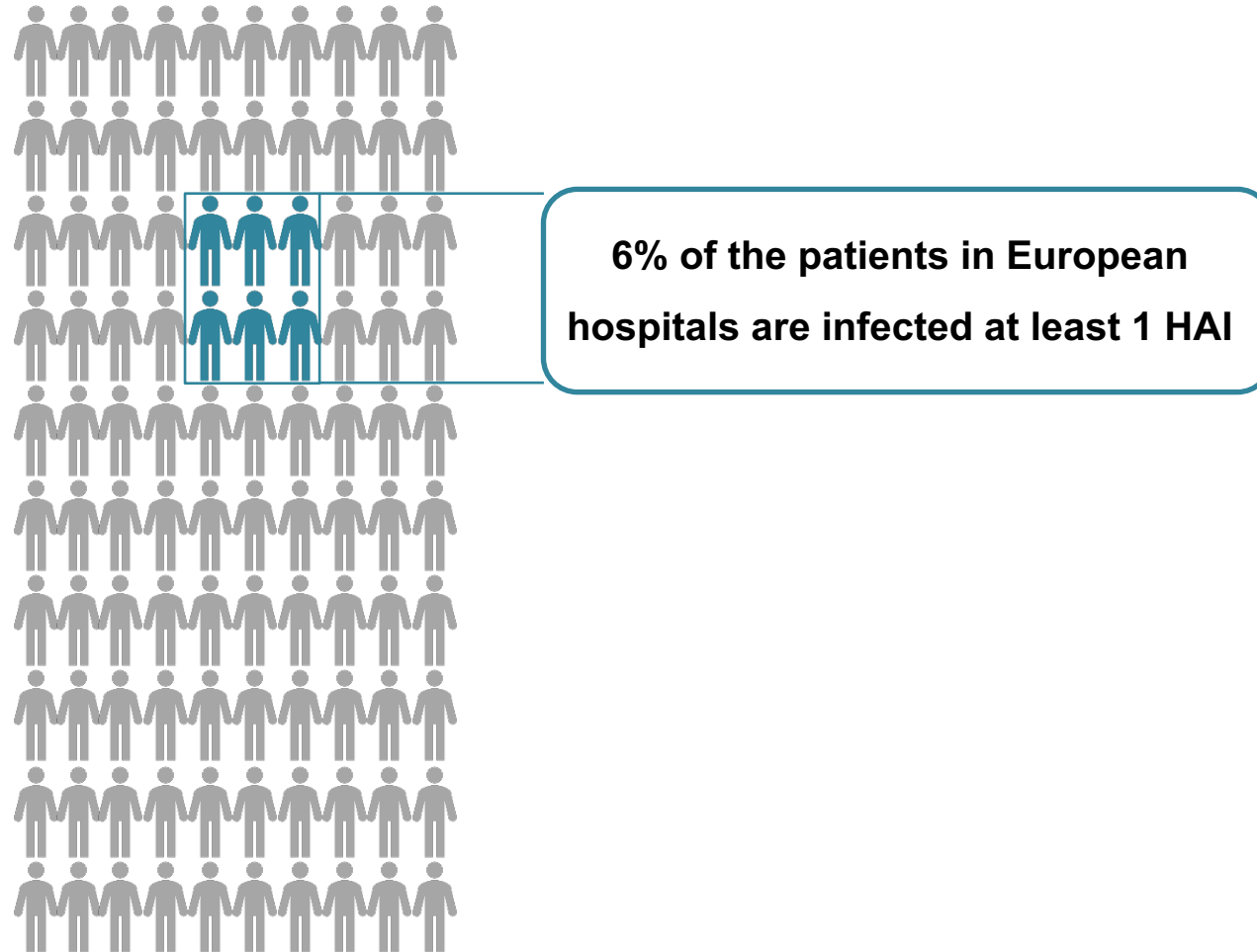


Plasma-assisted Deposition of Antimicrobial Silver Nanoparticles on Medical Textiles

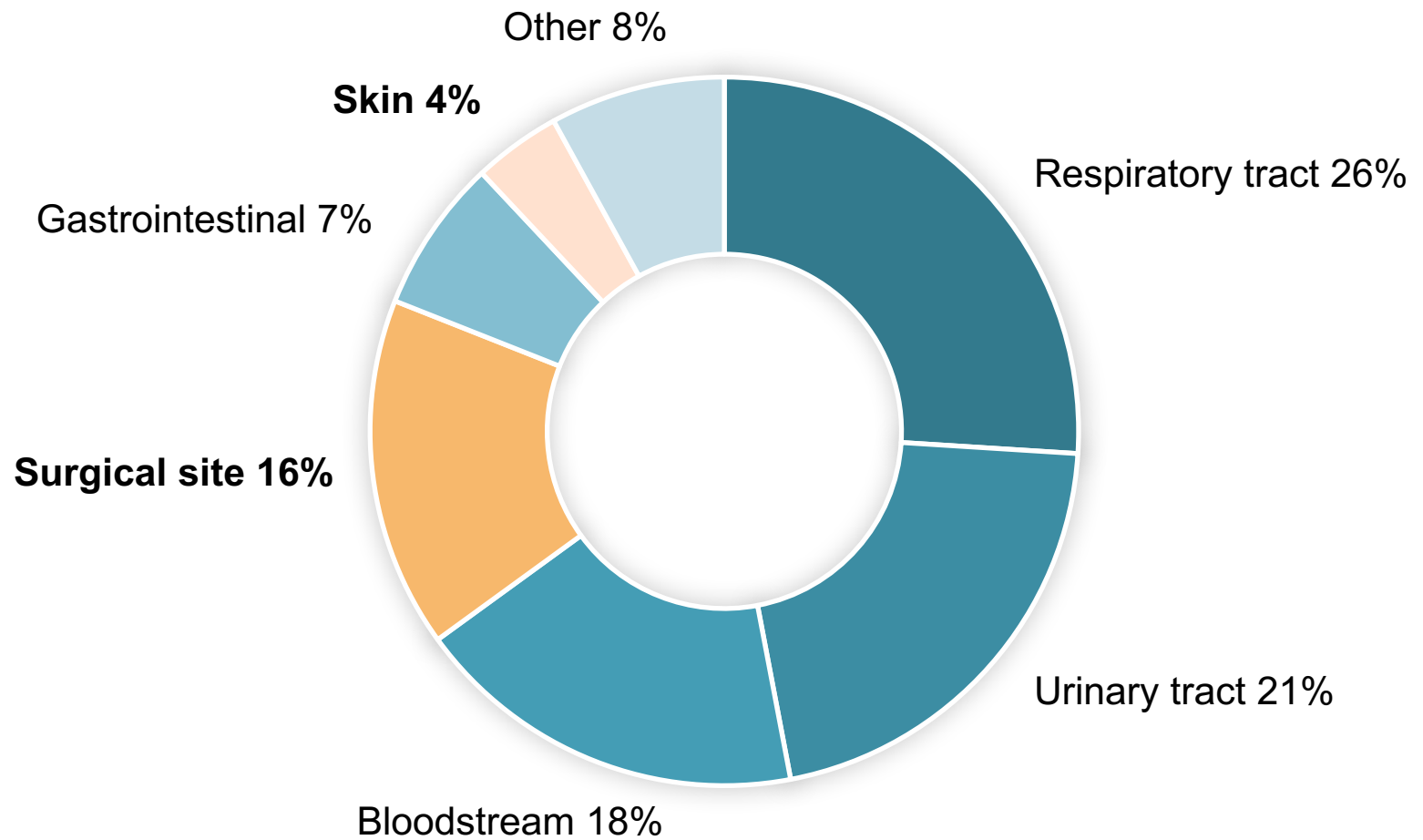
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Healthcare-associated infections (HAIs) - statistics



Healthcare-associated infections (HAIs) - statistics



Healthcare-associated infections (HAIs) - main concerns



Health risk



Health costs



Antibacterial resistance



New antibacterial materials are needed

Metal Nanoparticles

Ag

Cu

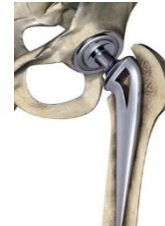
ZnO

Unique Chemical and Physical Properties

Antimicrobial

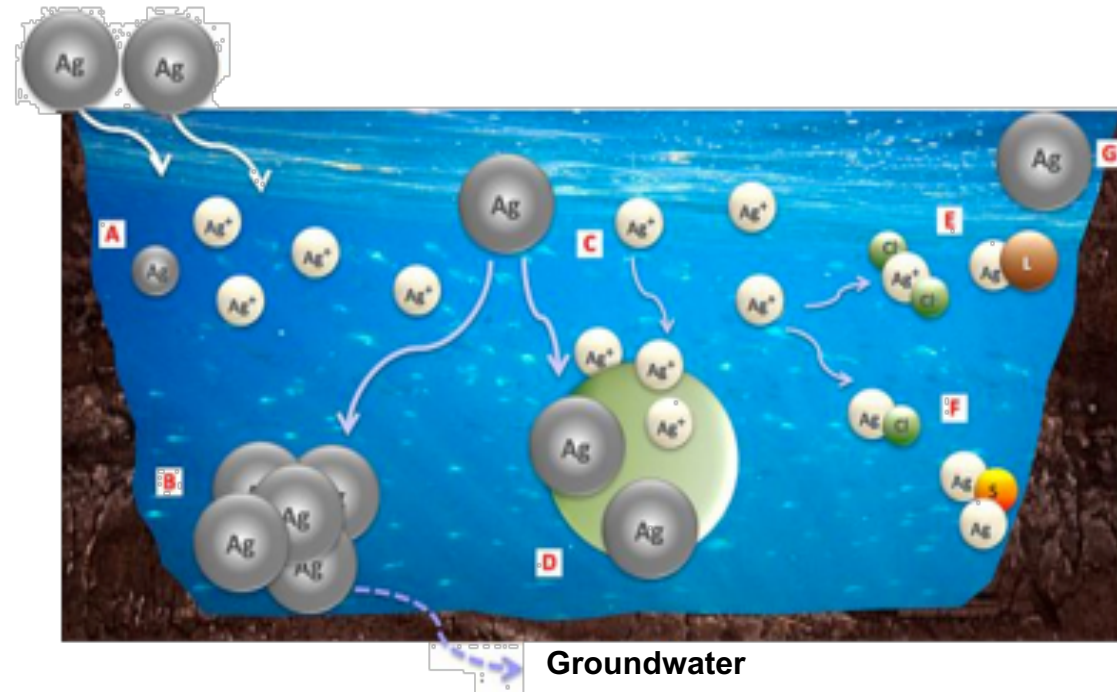
Antiviral

Anti-inflammatory



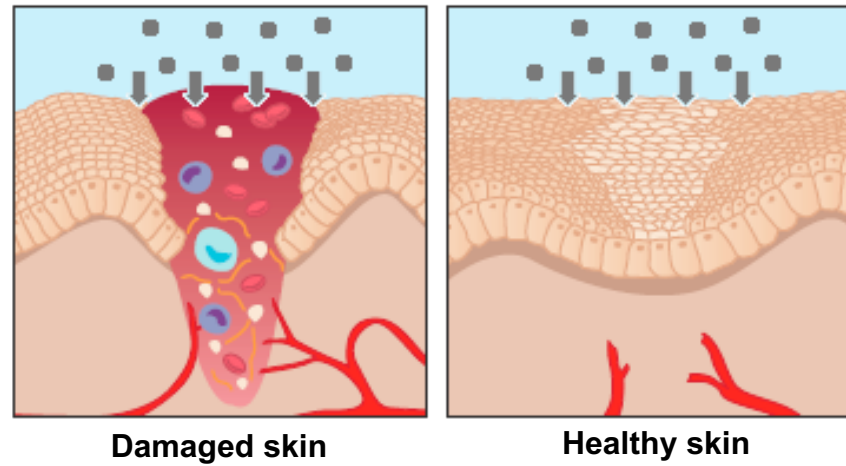
AgNPs employment - main disadvantages

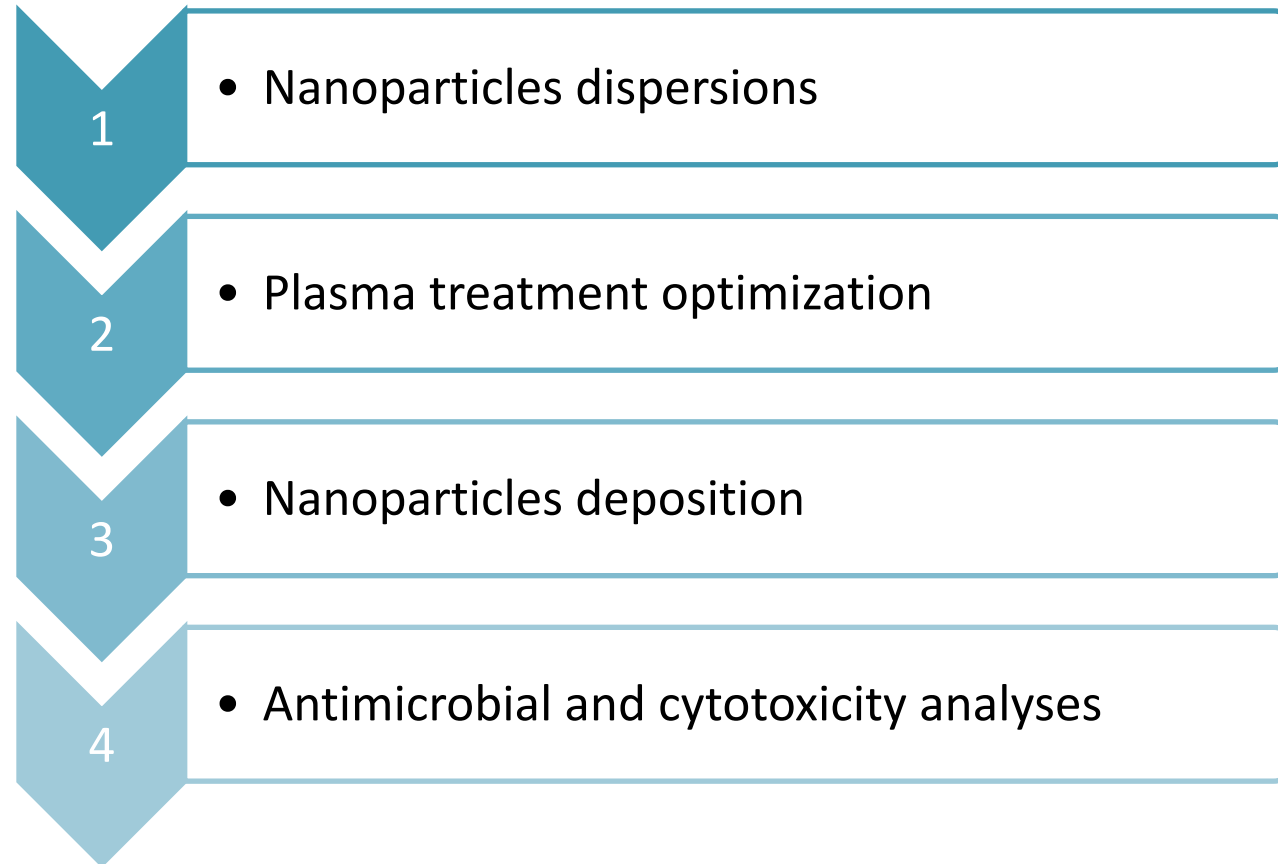
- The release and fate of silver nanoparticles into the environment



AgNPs employment - main disadvantages

- AgNPs can display cytotoxicity and genotoxicity in human body





Nanoparticles
dispersion

Plasma treatment
optimization

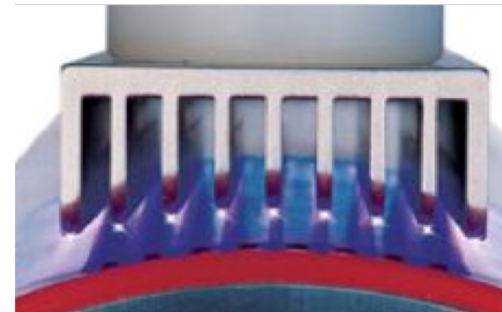
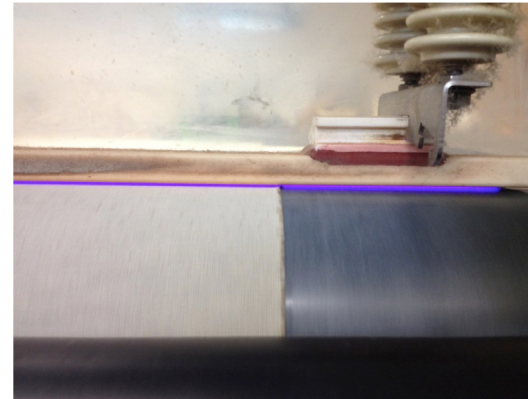
Nanoparticles
deposition

Antimicrobial and
cytotoxicity analysis

PA66 Woven

PES Woven

PES Non woven



PVP-AgNPs Dispersions

- ✓ Ethanol 70%
- ✓ Water
- ✓ Water + Alginate (0.25%)
- ✓ Water + Chitosan (0.25%)

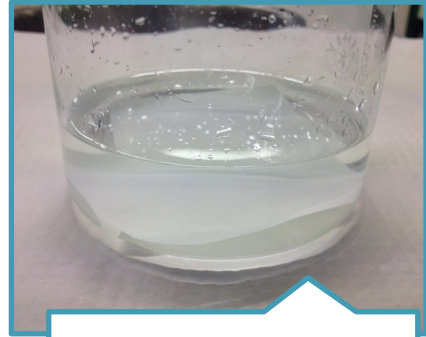
DBD plasma optimized parameters

- ✓ 1 kW, 4 m min⁻¹
- ✓ 2.5 - 5 kW min m⁻² of dosage
- ✓ 5 - 10 Plasma passages

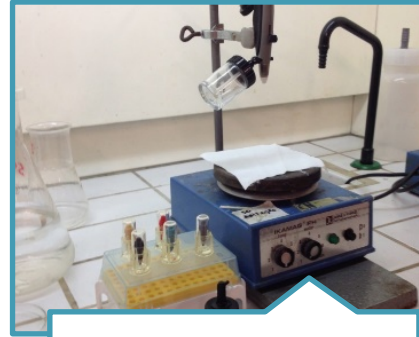
Deposition Methods



Ultrasound Tip
Irregular distribution despite its local good deposition



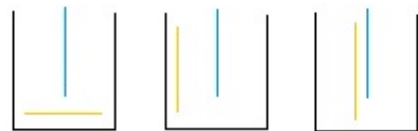
Dip Coating
Low amount of AgNPs and agglomeration



Spray
Low amount of AgNPs abut low agglomeration



Exhaustion at 30°C
The best results for both NPs distribution and reduced agglomeration.



- The spray and exhaustion at 30°C was used to continue the work.

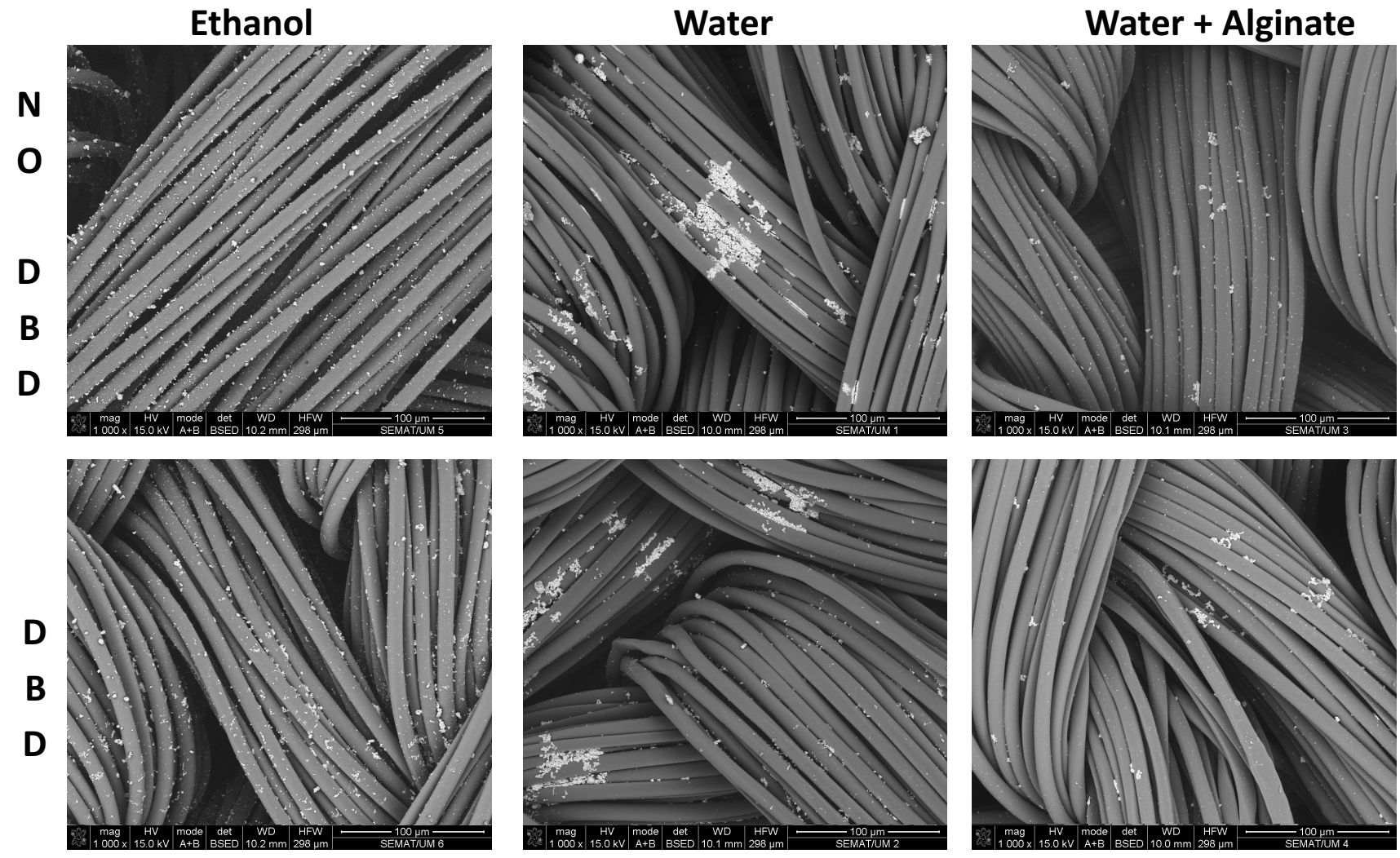
1. Different approaches for preparation of the 1 mg mL⁻¹ PVP-AgNPS dispersions and its effect in deposition step

2. pH effect in PVP-AgNPs deposition onto PES

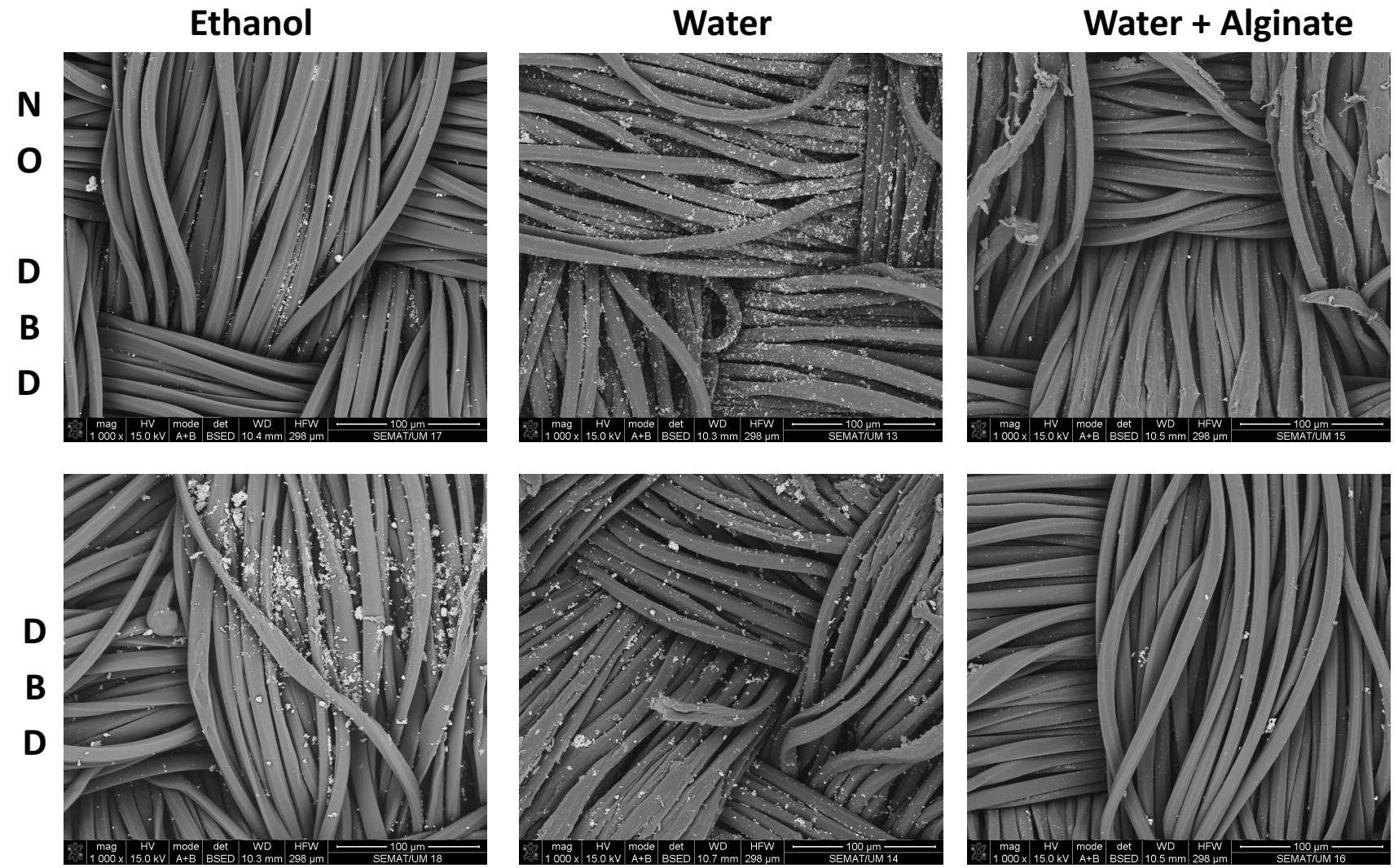
3. Development of sandwich configurations using HMDSO and chitosan

4. Synthesis of citrate-capped 20 nm AgNPs and its deposition

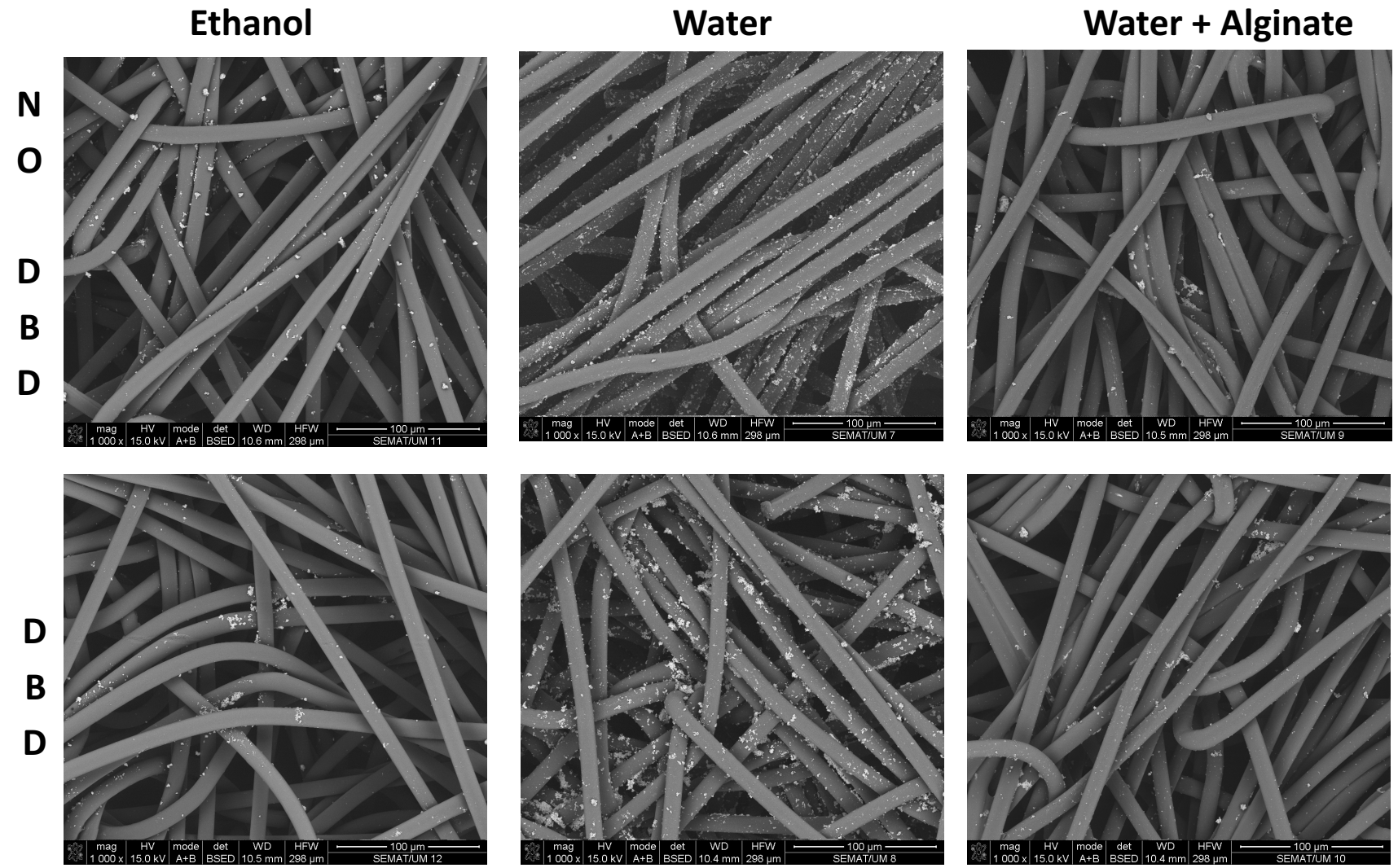
PA66 knitted - 1 mg mL⁻¹ PVP-AgNPS



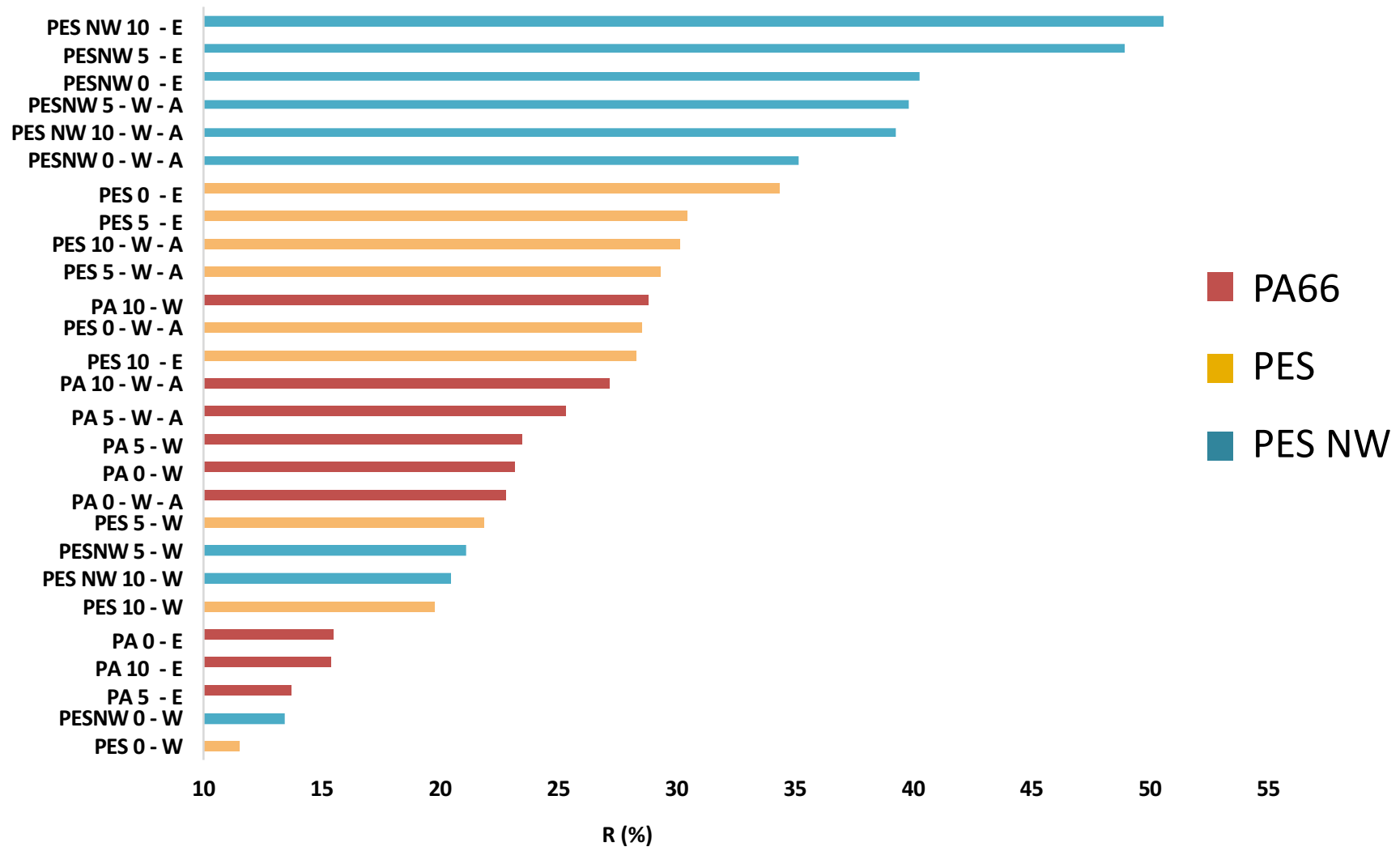
PES woven - 1 mg mL⁻¹ PVP-AgNPS



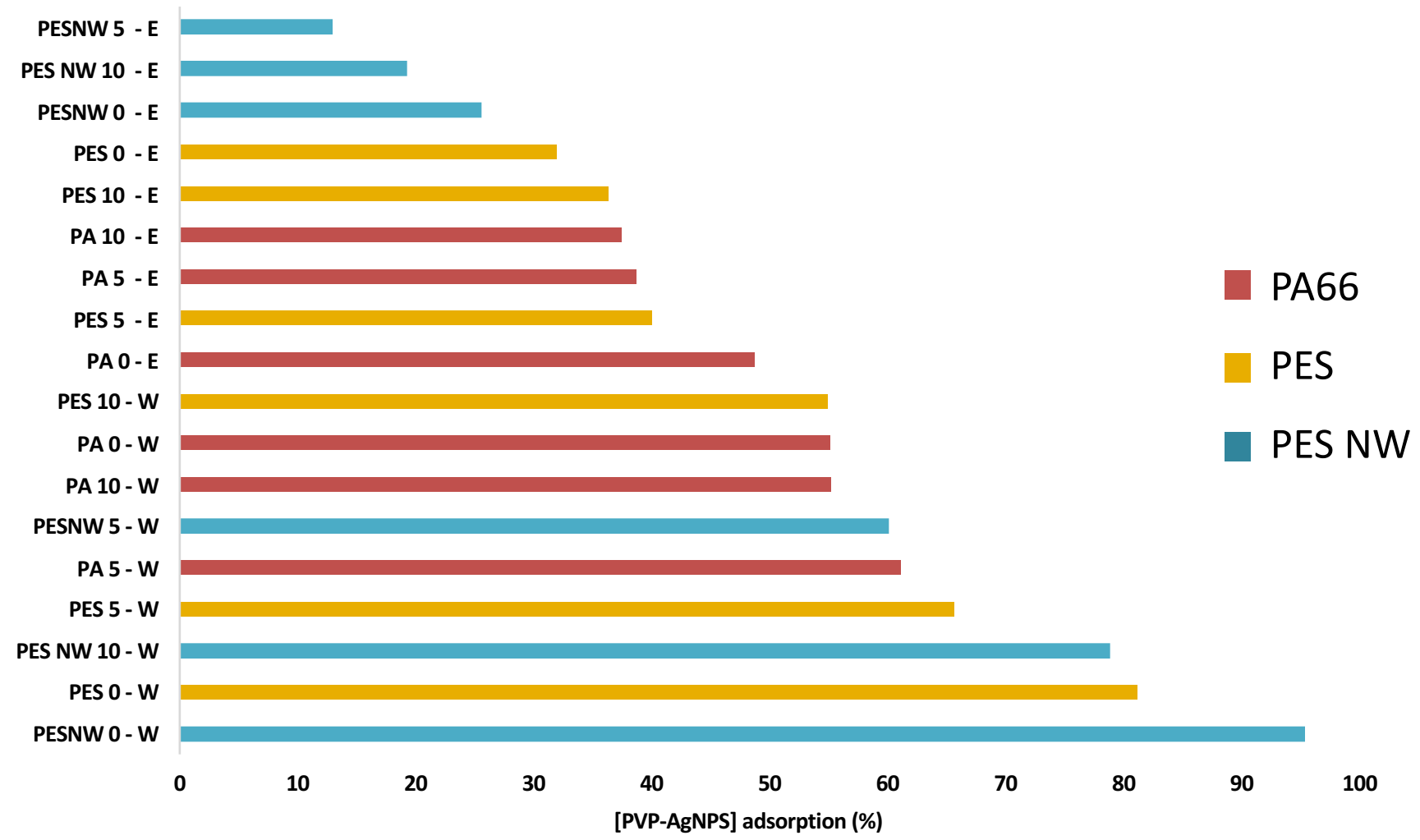
PES nonwoven- 1 mg mL⁻¹ PVP-AgNPS



Specular reflectance



Atomic Absorption Spectroscopy



pH effect, PVP-AgNPs onto PES

PVP-AgNPs Dispersions	
1 mg mL ⁻¹ PVP-AgNPs dispersions	pH 4 – Acetate buffer pH 5 – Acetate buffer pH 7 – Phosphate buffer pH 9 – Tris buffer
Textile Substrates	
	PES Woven
Area density	100 g m ⁻²
Warp density	30 threads cm ⁻¹
Weft density	30 threads cm ⁻¹
DBD plasma optimized parameters:	
1 kW, 4 m min ⁻¹	
2.5 - 5 kW min m ⁻² of dosage	
5 - 10 Plasma passages	
Deposition method	
Exhaustion at 30°C	

pH effect, PVP-AgNPs onto PES

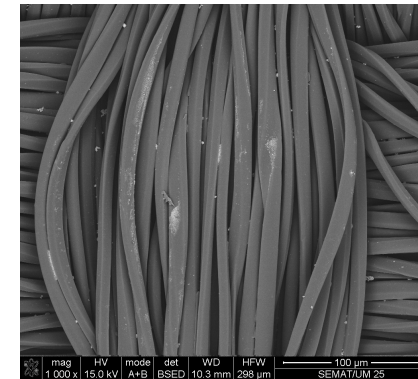
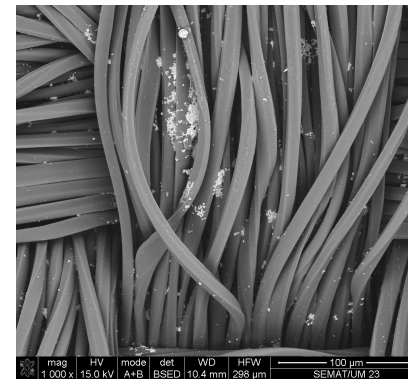
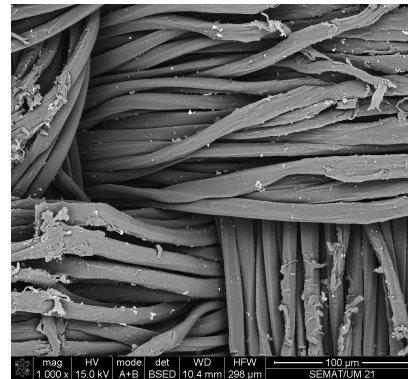
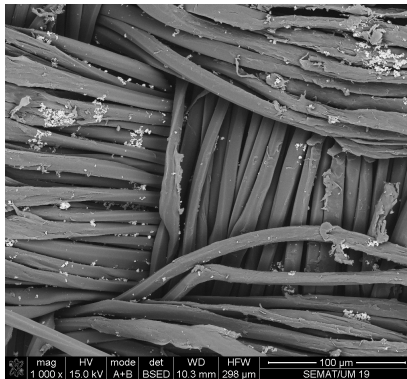
pH 4

pH 5

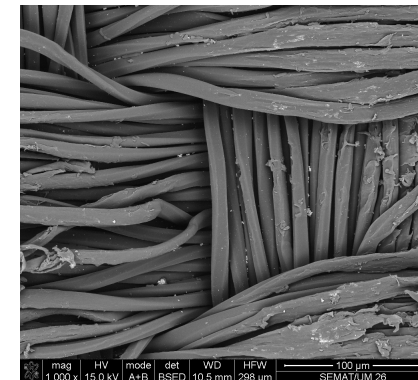
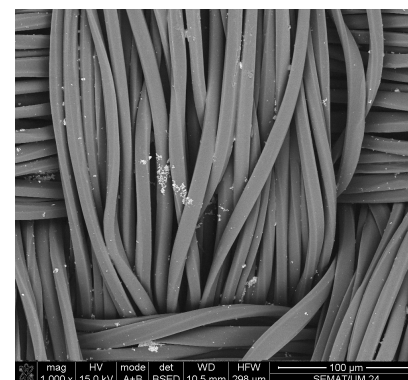
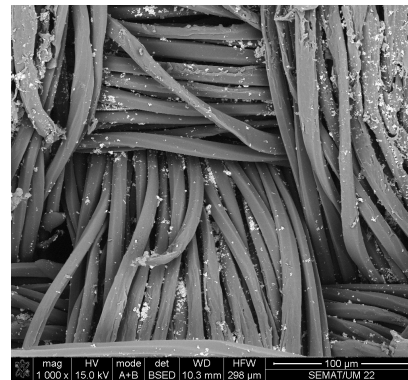
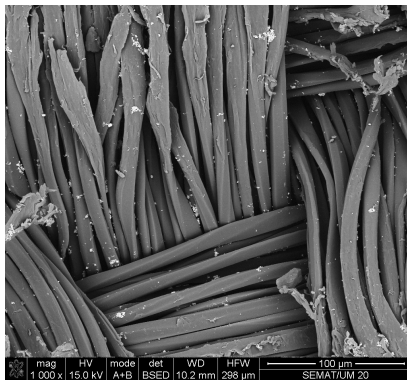
pH 7

pH 9

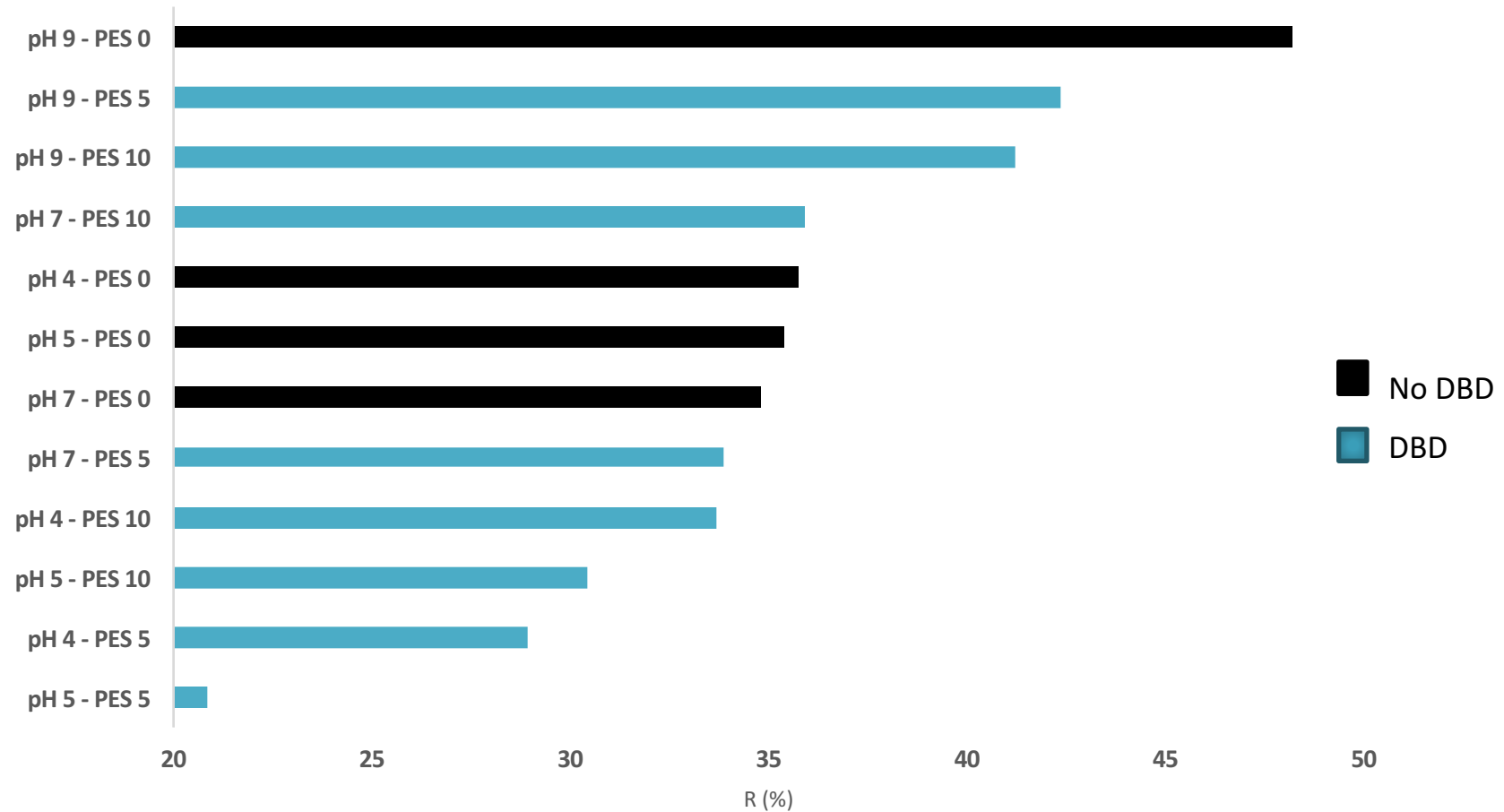
N
O
D
B
D



D
B
D



Specular reflectance pH effect, PVP-AgNPs onto PES



PVP-AgNPs Dispersions

1 mg mL⁻¹ PVP-AgNPs dispersions in Ethanol

Textile Substrates

PA66 Knitted PES Woven PES Non woven

DBD plasma optimized parameters:

1 kW, 4 m min⁻¹

5 kW min m⁻² of dosage

10 Plasma passages

Deposition method

Exhaustion at 30°C

Spray

A - Spray: HMDSO + AgNPs

B - Spray: HMDSO + AgNPs + HMDSO

C - Spray: Chitosan + AgNPs

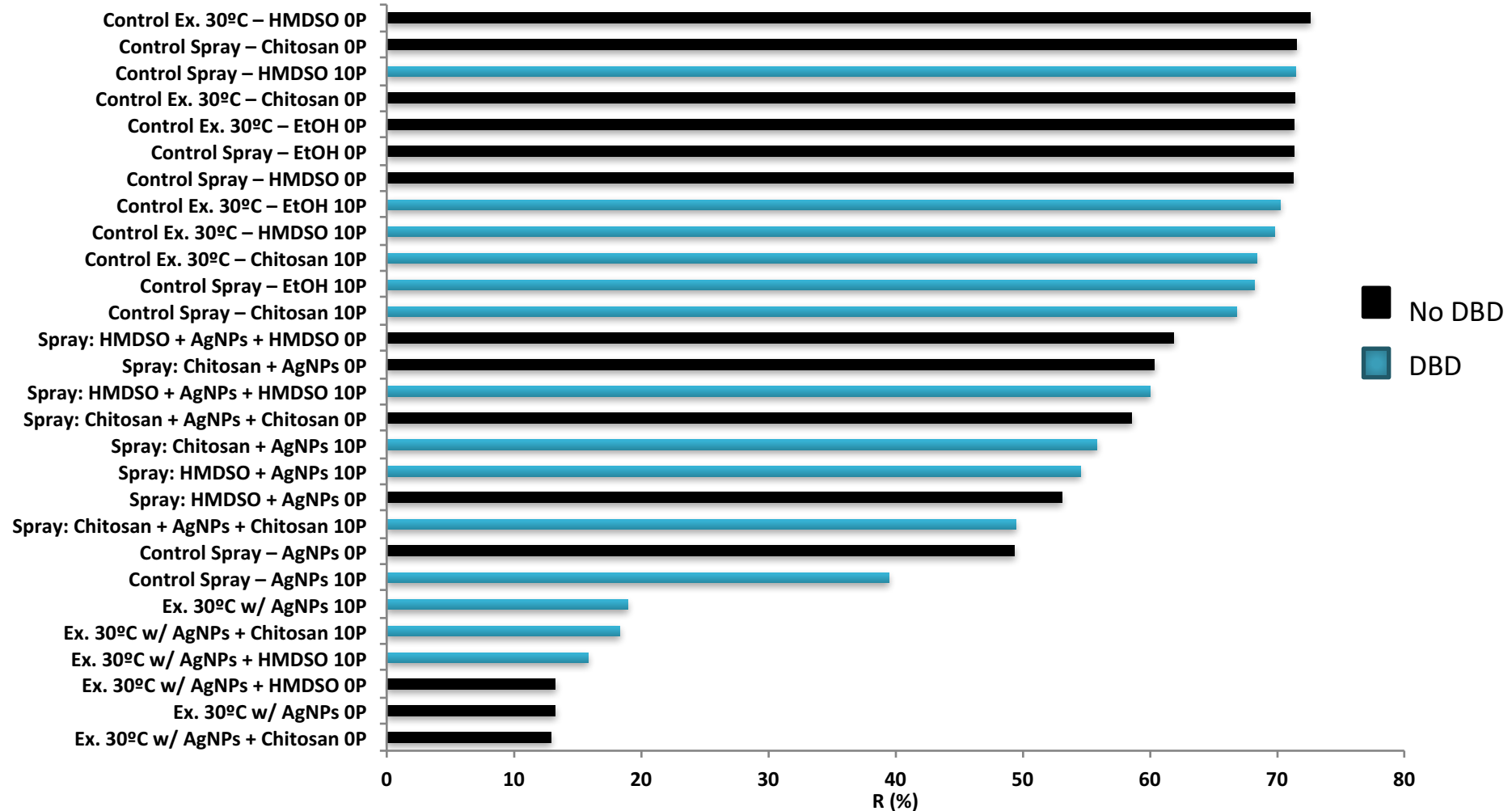
D - Spray: Chitosan + AgNPs + Chitosan

E - Exhaustion 30°C w/ AgNPs

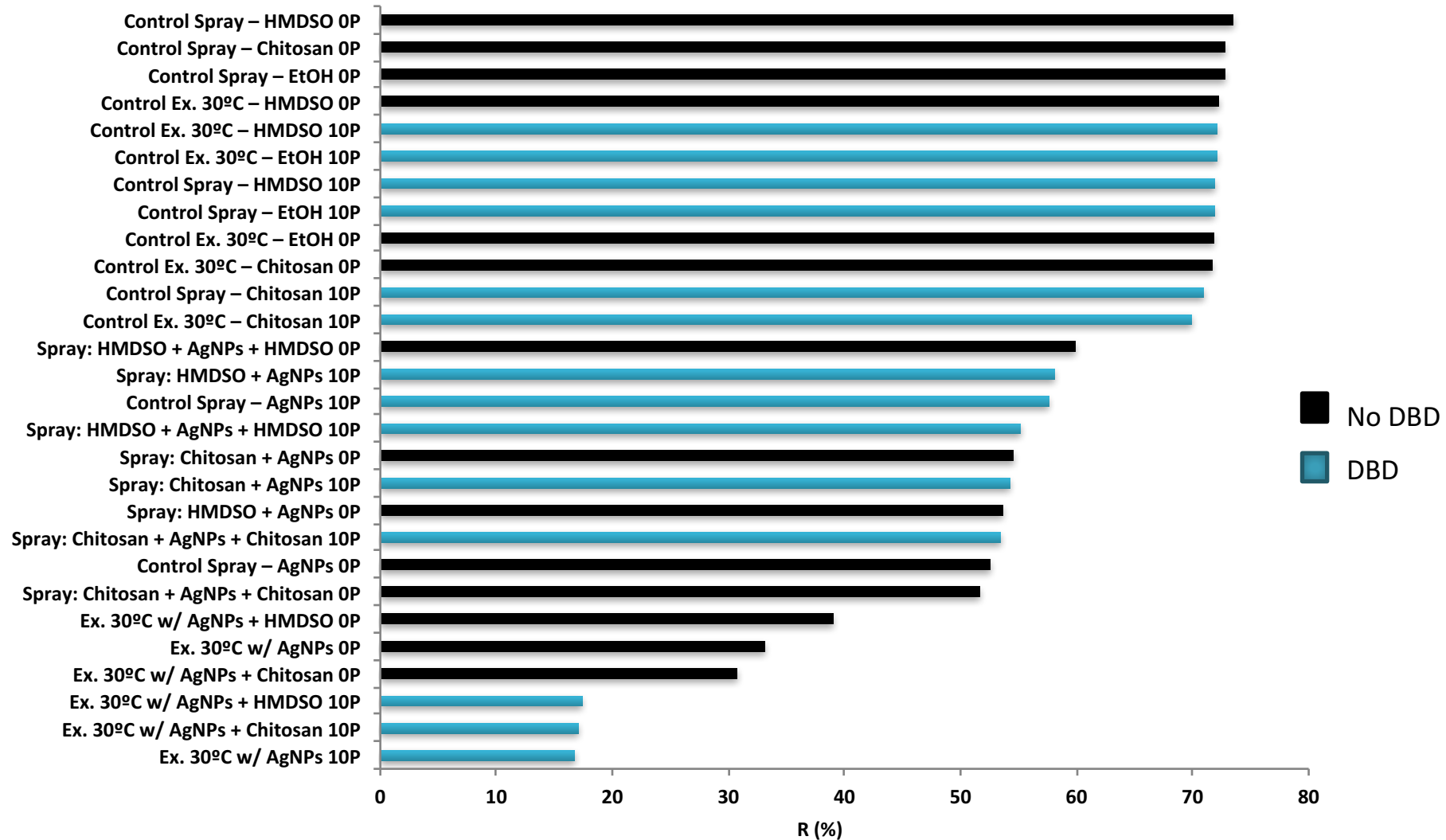
F - Exhaustion 30°C w/ AgNPs + HMDSO

G - Exhaustion 30°C w/ AgNPs + Chitosan

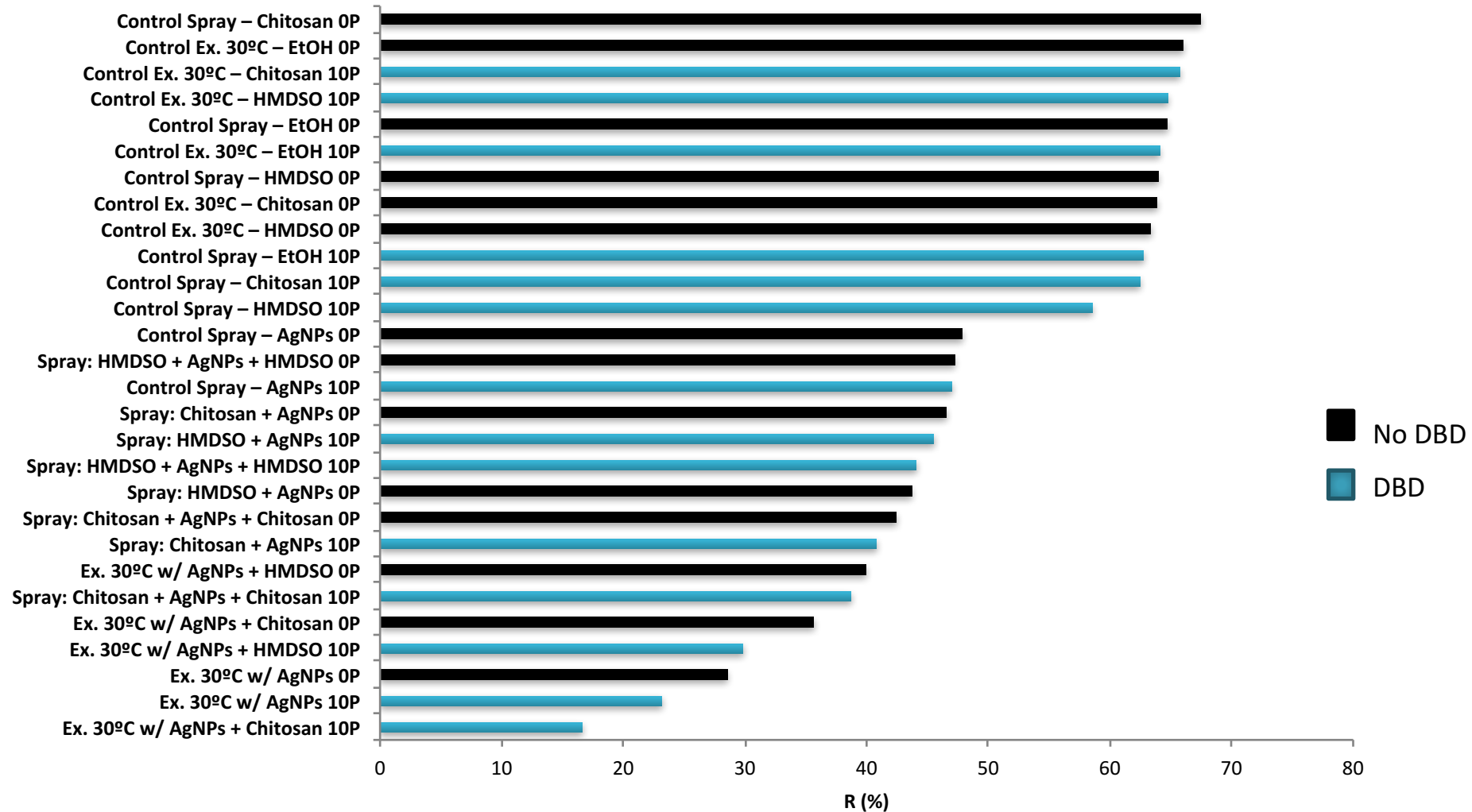
Specular reflectance – PA66- Layer by layer



Specular reflectance – PES W- Layer by layer



Specular reflectance – PES NW- Layer by layer



Cytotoxicity analyses PES W

Cytotoxicity analyses

Sample	No DBD	DBD
Control PESW	32.82 ± 16.80	104.31 ± 8.58
Control Spray-EtOH	0.53 ± 0.84	82,54 ± 7.69
Control Spray-AgNPs	5.70 ± 6.15	83.73 ± 9.53
Control Spray-HMDSO	0.41 ± 0.87	87.00 ± 7.59
Control Ex. 30°C - EtOH	95.80 ± 9.22	102.47 ± 10.60
Control Ex. 30°C - HMDSO	99.96 ± 9.22	101.42 ± 3.71
Spray HMDSO + AgNPs	5.25 ± 8.48	98.67 ± 7.64
Spray HMDSO + AgNPs + HMDSO	0.09 ± 0.44	97.13 ± 2.67
Ex. 30°C with AgNPs	83.71 ± 4.70	20.96 ± 4.60
Ex. 30°C with AgNPs + HMDSO	49.40 ± 7.71	32.31 ± 8.16

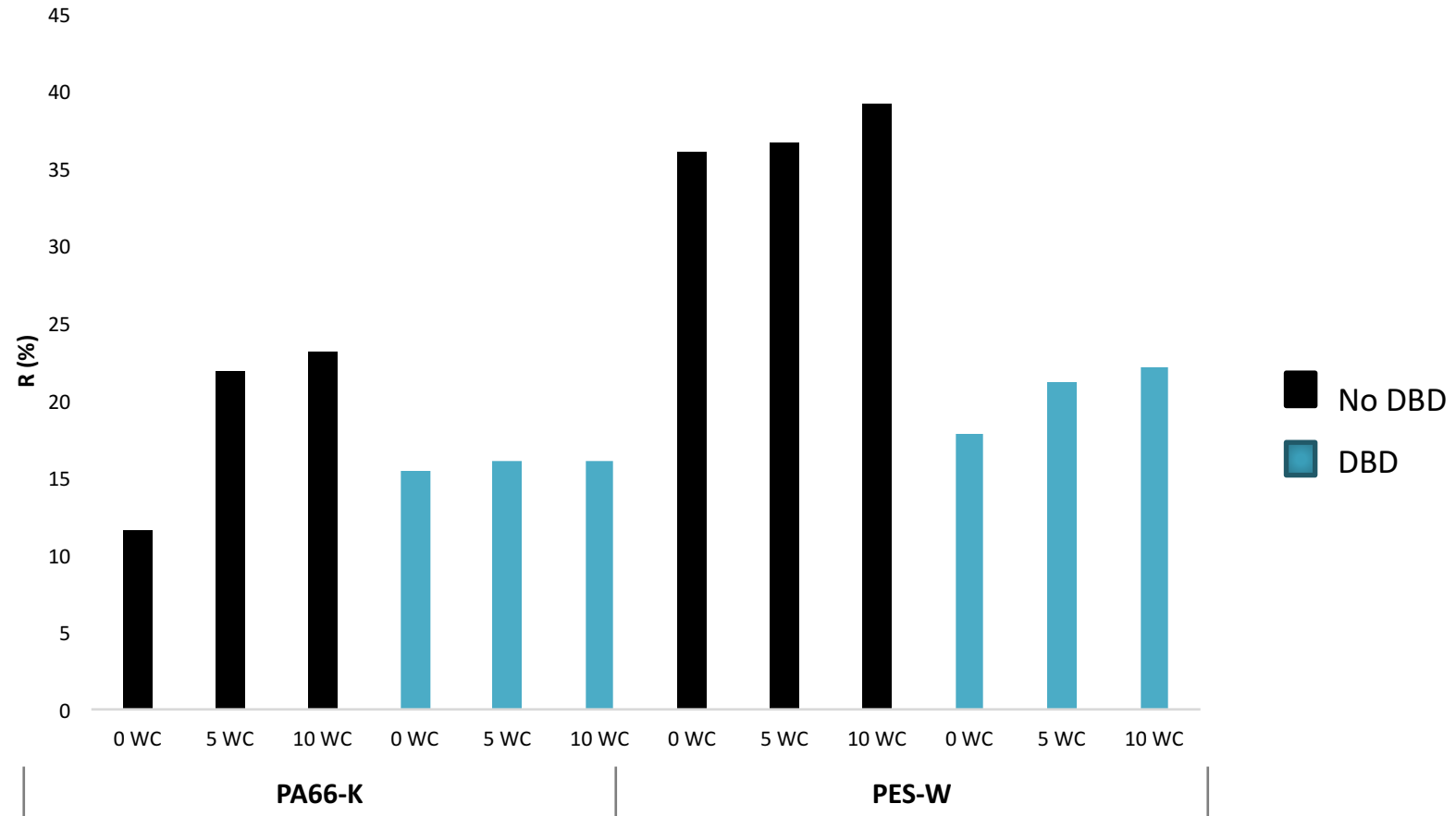
Cytotoxicity analyses PES NW

Cytotoxicity analyses

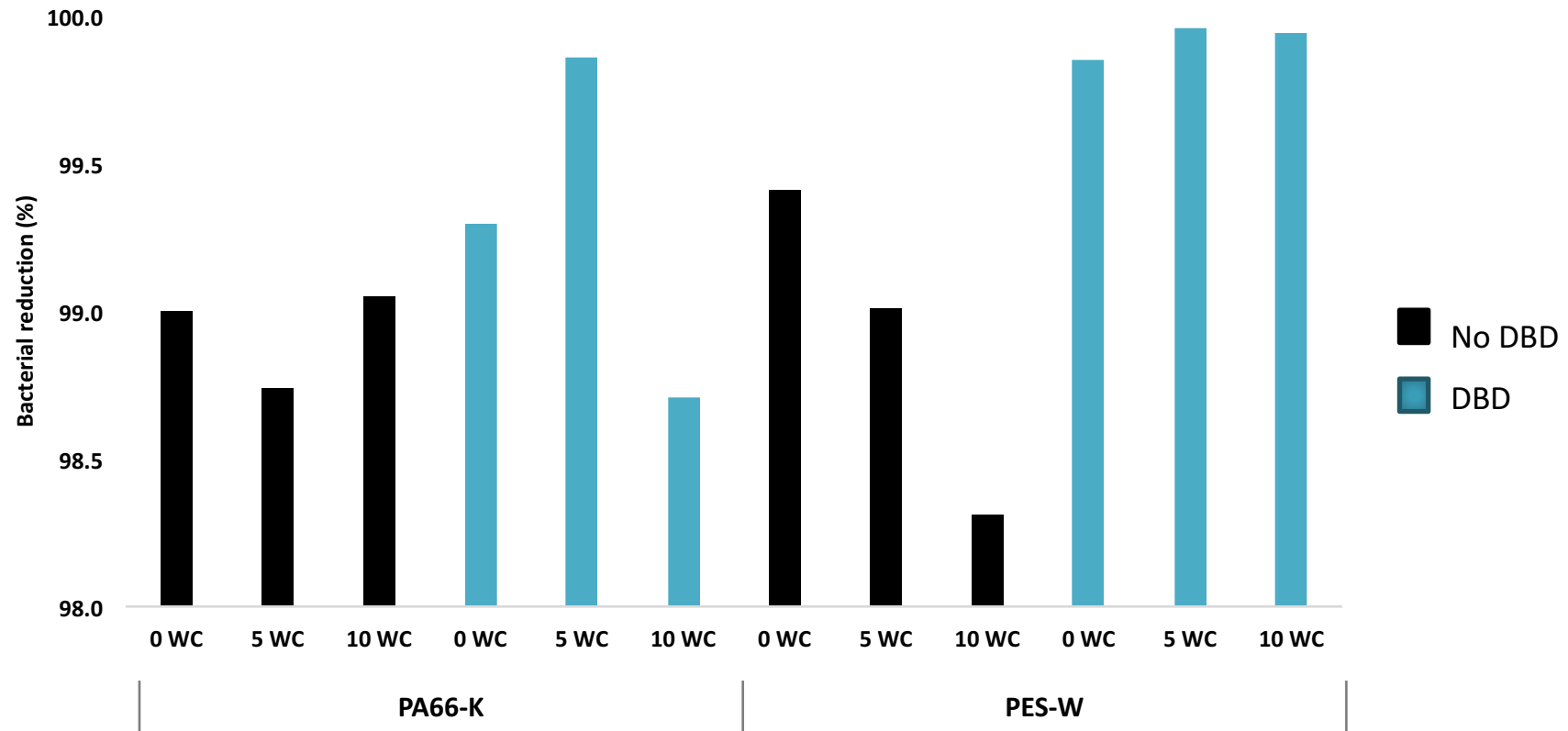
Sample	No DBD	DBD
Control PESNW	54.89 ± 5.87	98.99 ± 7.62
Control Spray-EtOH	20.01 ± 5.80	90.70 ± 6.24
Control Spray-AgNPs	62.44 ± 3.69	102.61 ± 1.91
Control Spray-HMDSO	84.47 ± 2.61	91.66 ± 6.18
Control Ex. 30°C - EtOH	93.51 ± 8.81	88.66 ± 4.18
Control Ex. 30°C - HMDSO	87.56 ± 6.30	83.49 ± 7.01
Spray HMDSO + AgNPs	70.32 ± 3.51	96.12 ± 8.64
Spray HMDSO + AgNPs + HMDSO	62.62 ± 3.94	98.28 ± 7.19
Ex. 30°C with AgNPs	92.49 ± 5.96	1.67 ± 1.77
Ex. 30°C with AgNPs + HMDSO	87.05 ± 6.28	0.39 ± 0.81

Specular reflectance – 0, 5 and 10 washing cycles

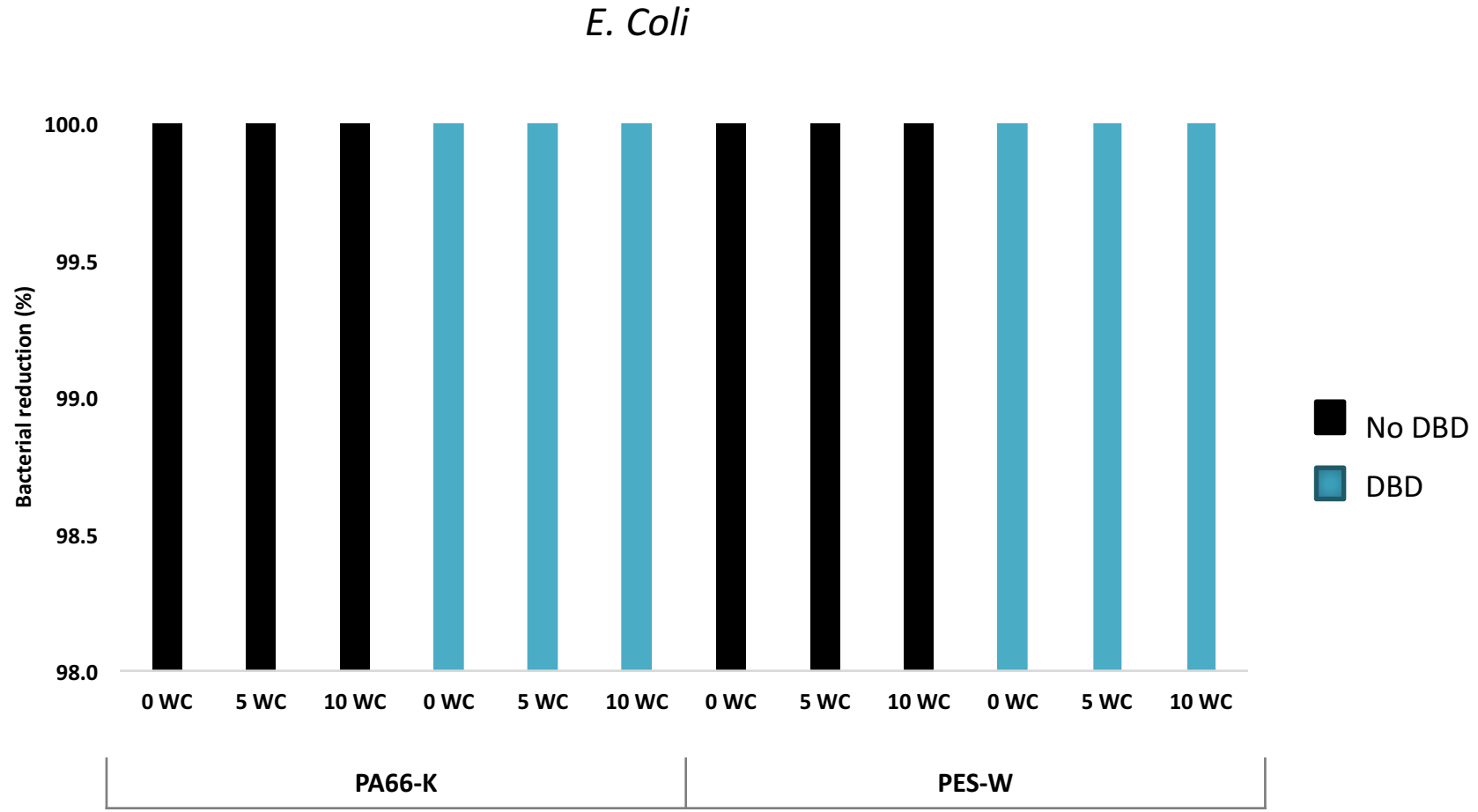
1 WC = 15 minutes at 75°C



S. aureus



Antimicrobial analyses – 0, 5 and 10 washing cycles



Acknowledgments

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Thank you for your attention



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