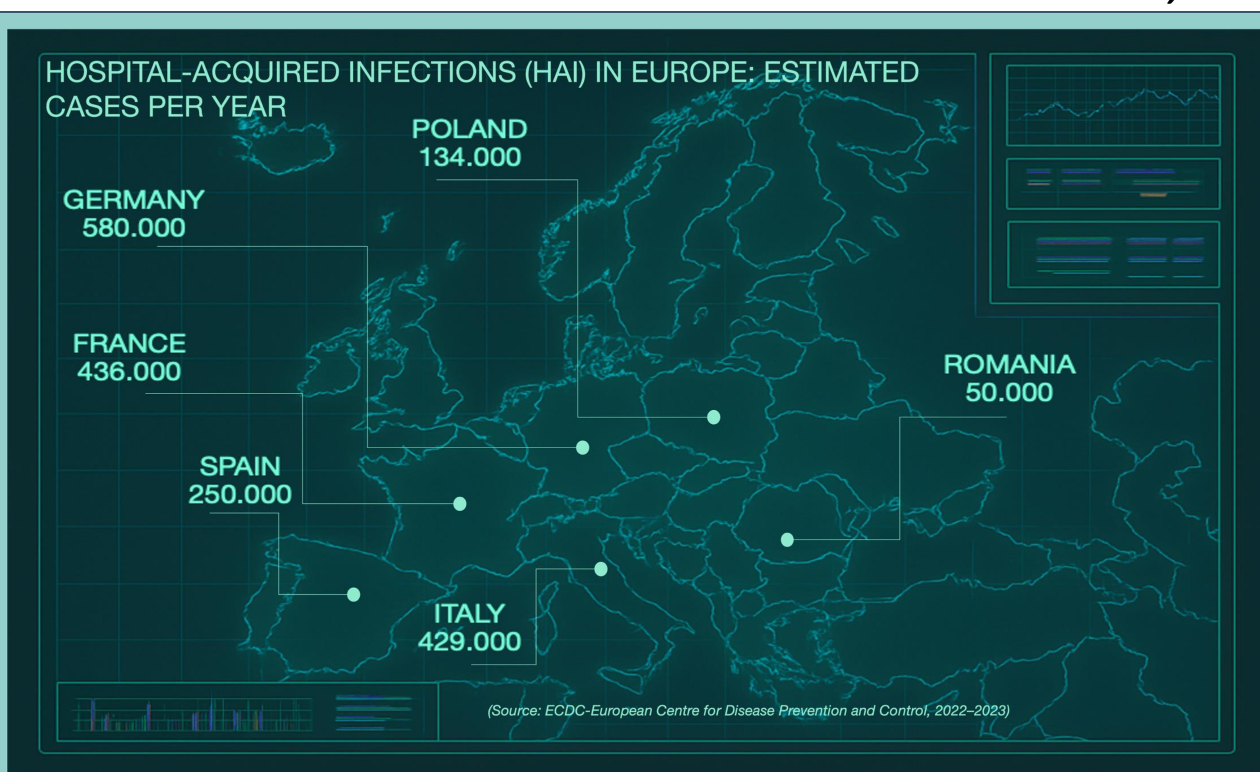
Nonwovens functionalized with poly(N,N-dimethylaminoethyl methacrylate) – divalent metal ion complex systems

Maria Czajka[1], Dawid Stawski[1], Lucyna Herczyńska[1]

[1]**Textile Institute**, *Lodz University of Technology, Poland*



Introduction

- ❑ Awareness of **hospital-acquired infections (HAIs)** remains low in many countries.
- ❑ Healthcare facilities are often seen primarily as places of healing rather than **potential sources of infection.**
- ❑ The **COVID-19 pandemic** significantly increased public awareness of **pathogen transmission** via surfaces, air, and person-to-person contact.
- ❑ **Textile products** in hospitals (e.g. uniforms, bedding, curtains) are **critical but overlooked vectors** in the spread of HAIs.
- ❑ According to the **European Centre for Disease Prevention and Control (ECDC),** ~4.3 million HAIs occur in EU/EEA hospitals annually, contributing to **over 90,000 deaths** each year.
- ❑ **Surface modification of textiles** to reduce microbial colonization and **biofilm formation** is a growing research focus in improving hygiene and safety in healthcare settings.

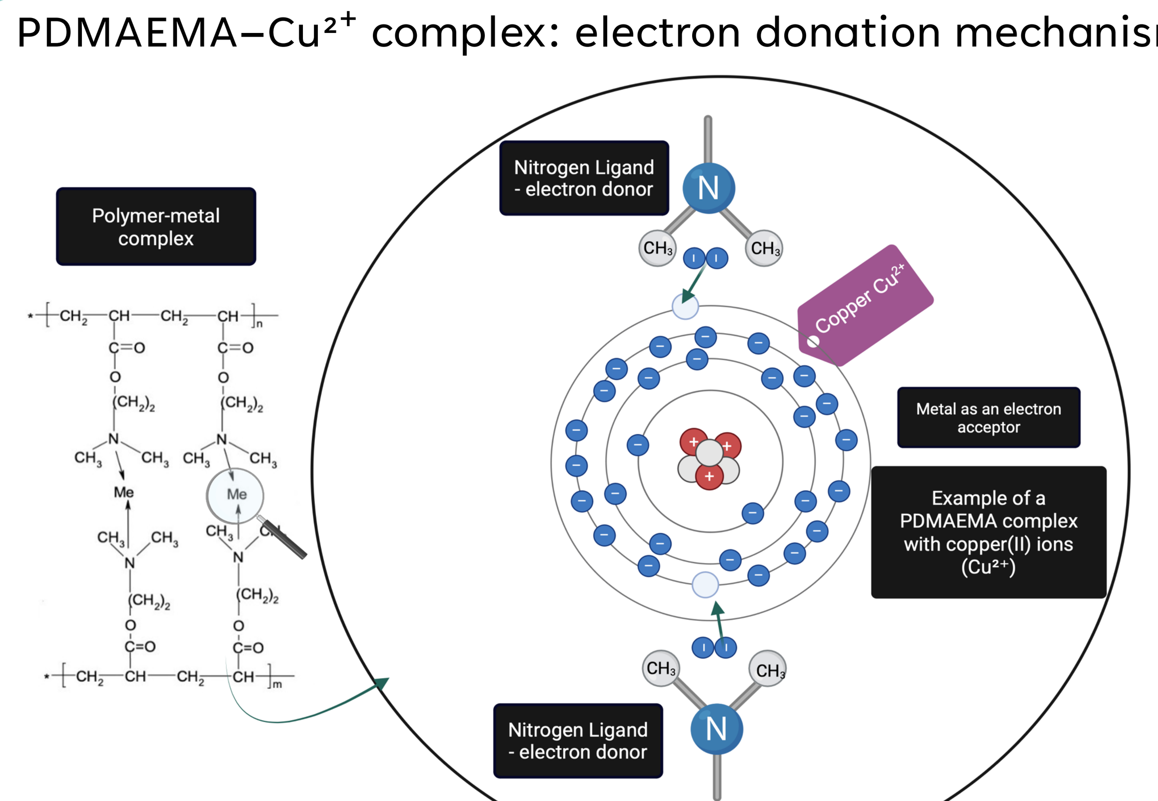
Materials

Nonwovens: polylactide (PLA) nonwovens 40 $\frac{g}{m^2}$, polylactide nonwovens 120 $\frac{g}{m^2}$.

Polymer : poly(N,N-dimethylaminoethyl methacrylate) (PDMAEMA)
Application of 1.5% by weight relative to the sample.

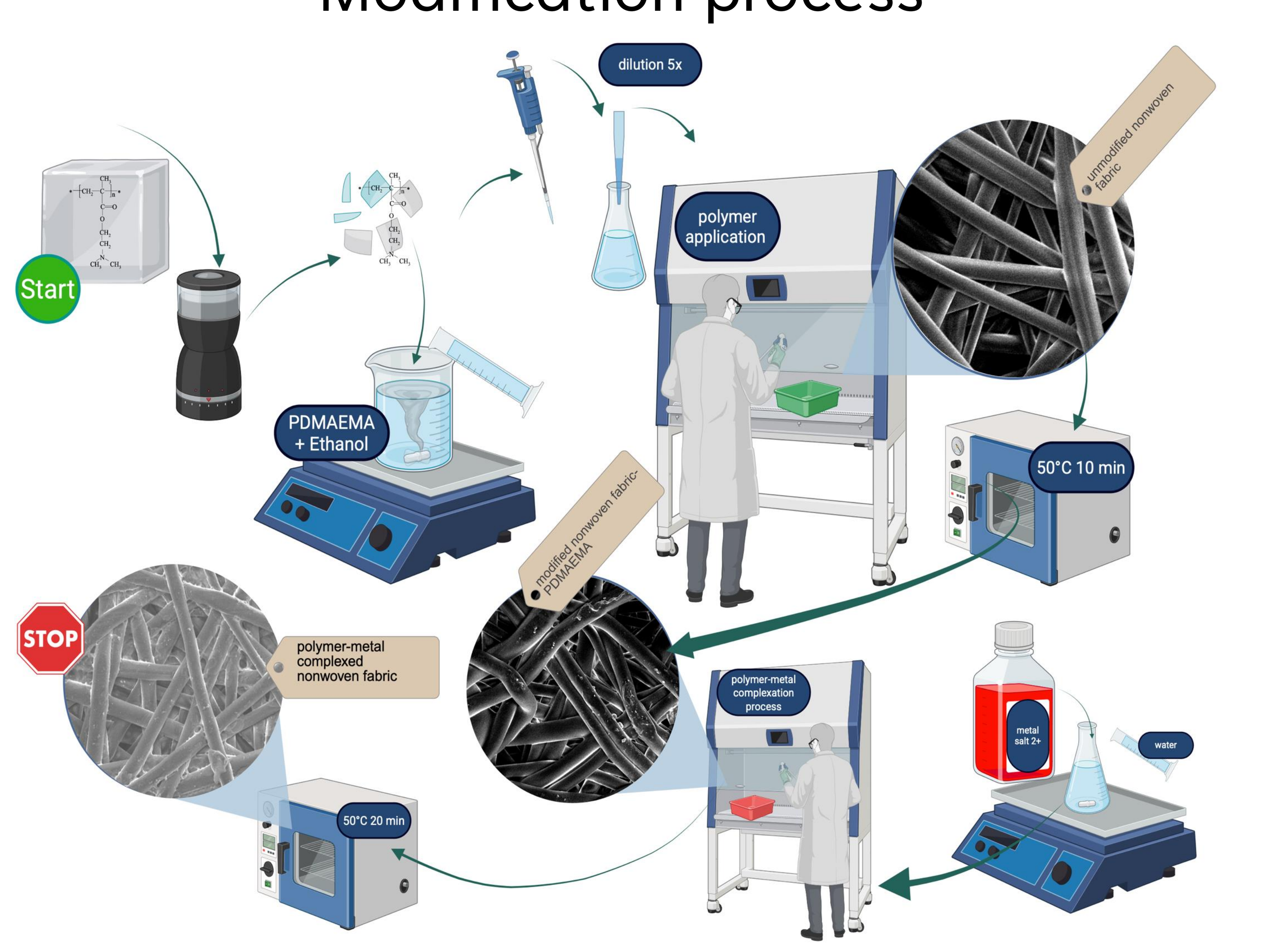
Metallic salts: Copper(II) nitrate trihydrate, Cobalt(II) acetate hydrate, Zinc sulfate heptahydrate, Zinc chloride, Iron(II) sulfate. Metal salts were applied in an equimolar ratio relative to the polymer.

PDMAEMA–Cu^{2+} complex: electron donation mechanism



In complexes with divalent metals, the nitrogen atom in the PDMAEMA group can act as an electron donor, transferring its lone pair of electrons to the vacant orbitals of the metal. The metal then acts as an electron acceptor, allowing the formation of a coordination bond between the metal and the amine group.

Modification process



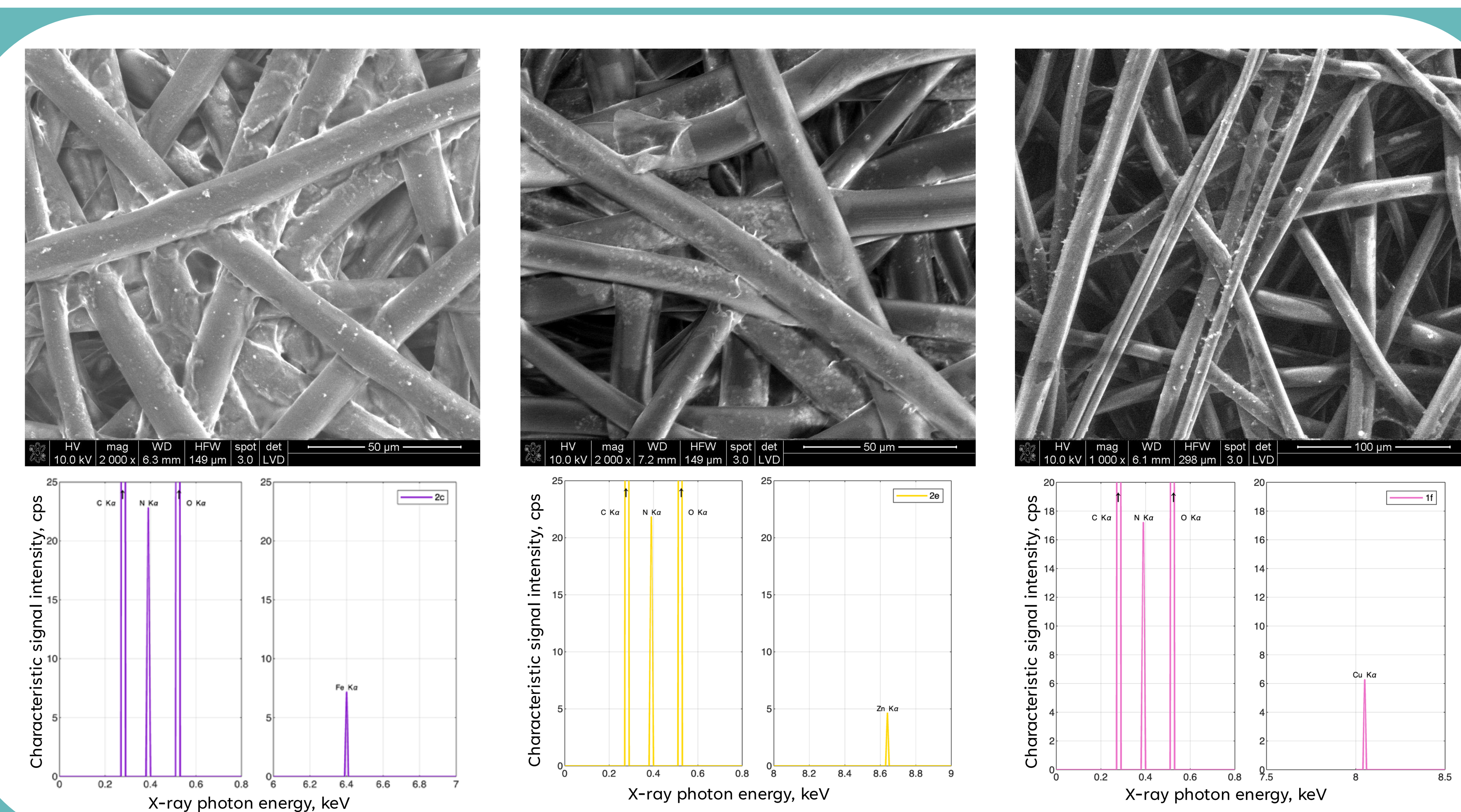
Research Objectives

Textiles are a significant factor in the transmission of bacteria and viruses in healthcare environments.
To address this problem, biologically active nonwoven materials were developed using a functional polymer and its metal complexes.
The aim of this study was to demonstrate that these textiles can effectively inhibit the growth of harmful bacteria and viruses.

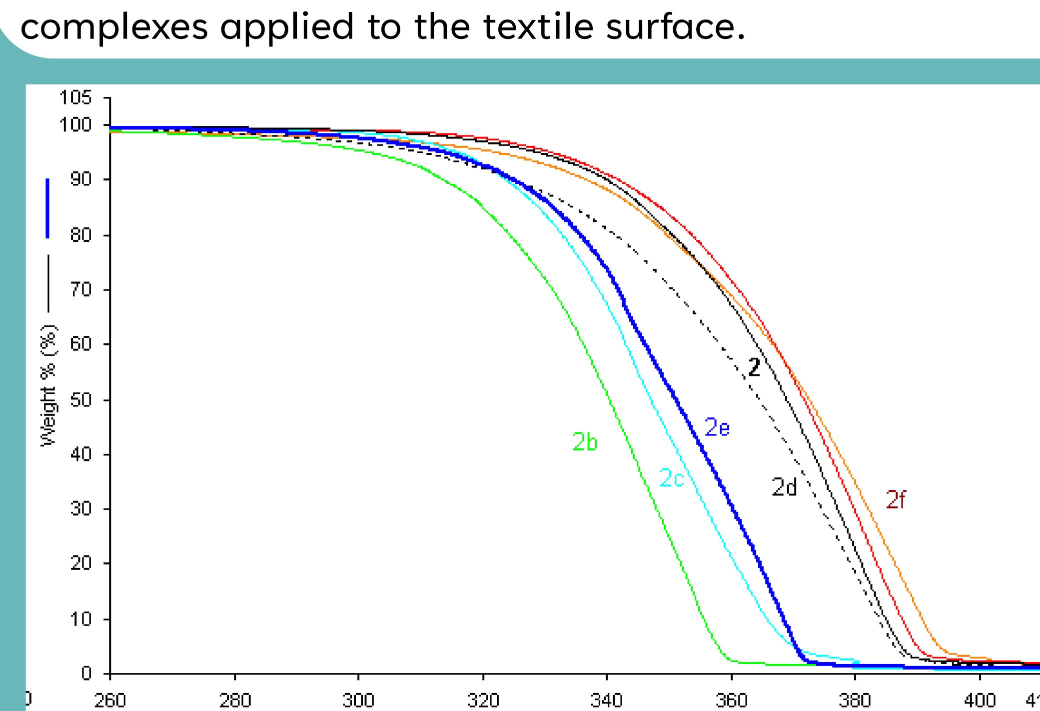
Results & Discussion

SAMPLE	CHARGE TYPE	STREAMING POTENTIAL (mV)	SURFACE CHARGE ($\times 10^{-6} eq/g$)
PLA 40 $\frac{g}{m^2}$	-	-9.5	0.8
PLA 40 $\frac{g}{m^2}$ + 1.5% polymer	+	158	29
PLA 120 $\frac{g}{m^2}$	-	-44	0.6
PLA 120 $\frac{g}{m^2}$ + 1.5% polymer	+	180	25

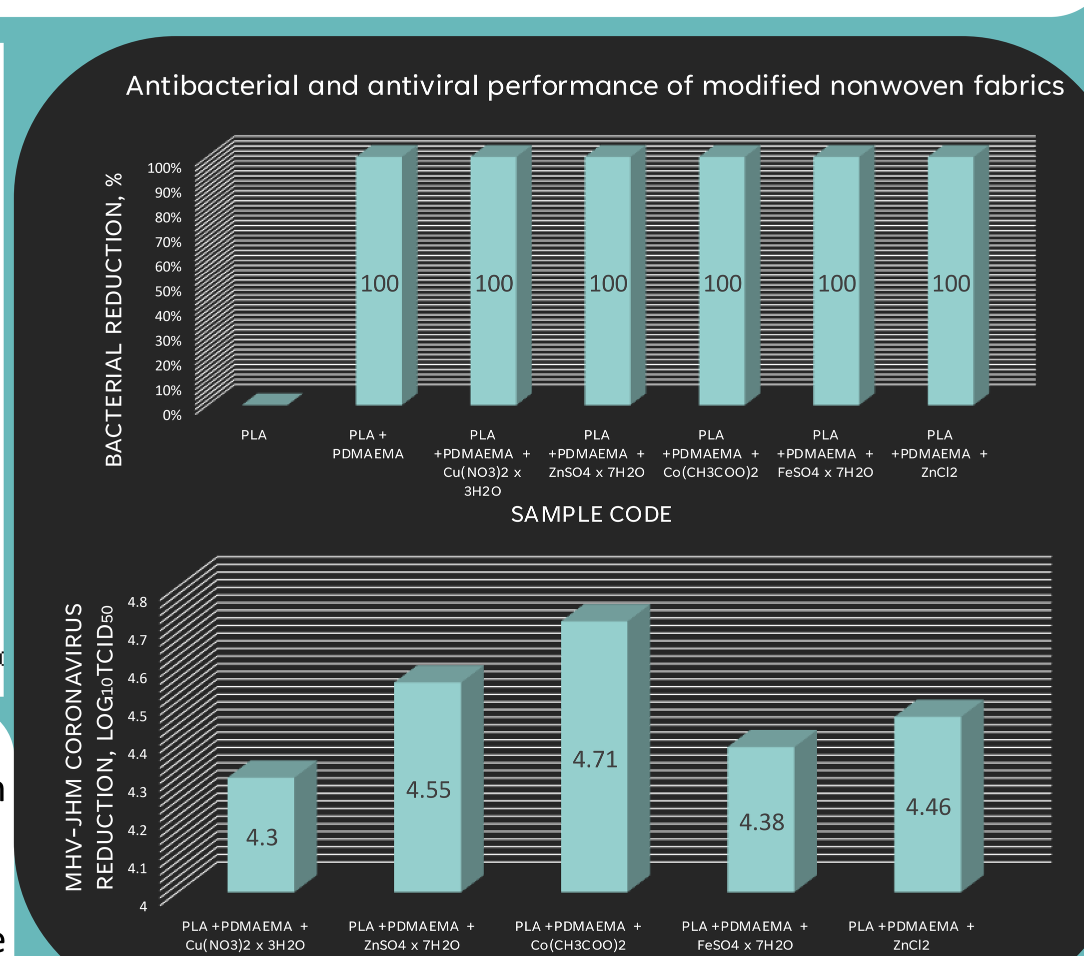
Electrokinetic analysis of the polymer layer using the Mütek PCD 03 charge analyzer revealed a positive surface charge of PDMAEMA-coated samples, which is consistent with the presence of protonated tertiary amine groups and confirms the successful deposition of the functional polymer layer.



Scanning electron microscopy (SEM) revealed the presence of a thin layer covering the surface of the nonwoven fibers, presumed to be the deposited polymer. Embedded within this layer were microscale structures whose shape and morphology varied depending on the metal used, (2c) PDMAEMA + Fe^{2+}, (2e) PDMAEMA + Zn^{2+}, and (1f) PDMAEMA + Cu^{2+}.
Energy-dispersive X-ray spectroscopy (EDX), which detects element-specific X-ray emission, confirmed the presence of functionalizing agents, including nitrogen and selected metal ions, within the structure of the polymer–metal complexes applied to the textile surface.



Thermogravimetric analysis showed that the degradation remained a single-step process, with no distinct signals from the modifying layers. From a practical perspective, the choice of metal in the polymer–metal complex allows for control over the degradation kinetics and, consequently, the thermal behavior of the modified nonwoven system.



All tested samples showed 100% reduction of *Escherichia coli* (DSM 1576) after 6 hours of contact, as determined according to the ASTM E2149-10 standard, confirming strong antibacterial properties of the developed materials.

According to ISO 18184:2019, a reduction of ≥ 3 log units is considered effective antiviral performance. In this study, selected samples achieved a reduction of over 4 log units against the MHV-JHM murine coronavirus after 120 minutes of contact with the material, confirming high antiviral efficacy of the developed polymer–metal complexes. The tested systems exhibited moderate cytotoxicity.

Conclusions

- ❑ The method can be applied to a broad spectrum of textile materials, enabling the formation of polymer–metal complexes on different fiber types.
- ❑ The thermal degradation remained a single-step process, while the presence of the complexes reduced the degradation temperature.
- ❑ Solubility tests confirmed the formation of insoluble polymer–metal complexes on the fiber surface, acting as stable and durable modifiers.
- ❑ The structures developed in this study — biodegradable nonwoven – bioactive polymer – metal — exhibit biocidal activity against *Escherichia coli* and the MHV-JHM murine coronavirus. This activity results from the combined action of three factors: the tertiary amine group in the side chain of poly(N,N-dimethylaminoethyl methacrylate), the quaternary ammonium salt formed on this group, and the metal ion from the selected group.

The study was conducted as part of the doctoral research of Maria Czajka and was based on earlier research findings that formedthe basis of Patent No. 442838, granted in 2024. Scan to view the full doctoral dissertation (in Polish).

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contact: maria.czajka@dokt.p.lodz.pl

PL PATENT No. 442838