Hybrid Silica Xerogel Coatings Reinforcing Hydrophilicity and Antimicrobial Action of Gauzes and Medical Leathers

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ABSTRACT

This study aims to combat microbial resistance and overuse of antibiotics in hospitals by developing novel antimicrobial agents from diverse sources. Nanotechnology has significantly impacted various aspects of daily life, including medicine, by improving intracellular drug delivery. The study focuses on using dendritic polymers, such as polyethyleneimine (PEI), as sustainable antibiotic delivery technology for coating medicinal leathers and gauzes. Four distinct antibiotics were studied, leading to the creation of four different coatings: PEI/ampicillin, PEI/tetracycline, PEI/gentamycin, and PEI/neomycin. Experiments were conducted on leather and gauze samples to evaluate their capacity to maintain biological activity. The initiative aims to make it easier to govern the use of antibiotics through controlled release and may lead to the creation of xerogels containing different antibiotic components that remain effective against resistant strains for future use.

INTRODUCTION

Figure 1

PEI DENDRIMER

The monomer and the polymer that it builds

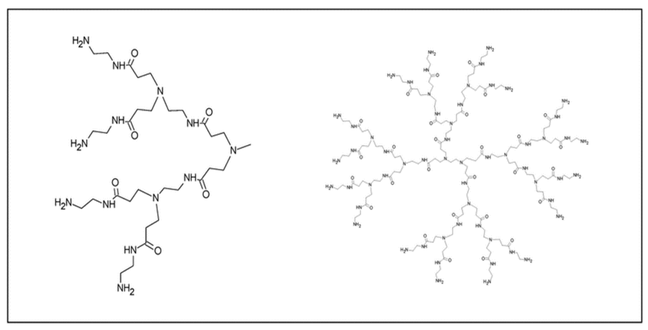
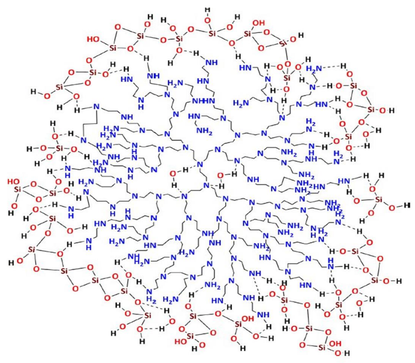


Figure 2

PEI DENDIMER IN XEROGEL FORMATION

The poymer with silica in xerogel formation



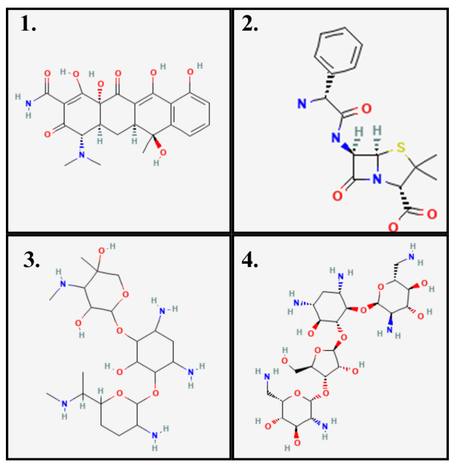
Polyethyleneimine (PEI), a cationic polymer, is used in the creation of nanoparticles[5]. Dendrimers, a type of nanostructured carrier, have a unique structure with a central core containing monomeric units and branching interiors with distinct groups[1]. These carriers are commonly used in nanomedicine for transporting medicines and DNA due to their structural diversity and versatility[4] (Figure 1).

The sol-gel process is utilized to create silicon hybrid xerogels, allowing for the fabrication of materials with varying properties based on synthesis conditions, while the co-condensation technique ensures uniform organic moiety dispersion[3] (Figure 2).

Figure 3

Antibiotics

Antibiotic structures used in this study



Tetracycline (**1**), is a broad-spectrum antibiotic, isolated from *Streptomyces aureofaciens* and it is effective against gram-positive and gram-negative bacteria.

Ampicillin (**2**) belongs to the penicillin class of medications, it is produced by *Penicillium chrysogenum* and *Penicillium nalgiovense* and it is effective against both gram-positive and gram-negative bacteria.

Gentamicin (**3**) is an aminoglycoside antibiotic produced by *Micromonospora purpurea* or *M. echinospora* and is effective against both gram-positive and gram-negative bacteria.

Neomycin (**4**) is also an antibiotic derived from Streptomyces fradiae and it is effective against gram-positive and gram-negative bacteria.

METHODOLOGY

Four different molecular weights of PEI were used to synthesize xerogels, which were then combined with orthosilicic acid to form gel-forming solutions[2]. These hydrogels were applied to leather and gauze substrates and incubated overnight to dry. All four antibiotics were applied to the xerogel samples for both gauze and leather materials and their controlled release was evaluated using UV/Vis spectroscopy.

Three bacteria (*Escherichia Coli, Pseudomonas Aeruginosa, and Staphylococcus Aureus*) were used as model organisms in a study. They were grown in solid media and inoculated under aerobic conditions. Two different methodologies were used. To assess the gauze samples antibacterial activities, the final bacterial densities were plated on Luria-Bertani agar plates. For leather samples assessment, overnight bacterial cultures were diluted to the desired concentration in Luria-Bertani solid media and layered on petri dishes, with the tested samples embedded.

RESULTS

Figure 4

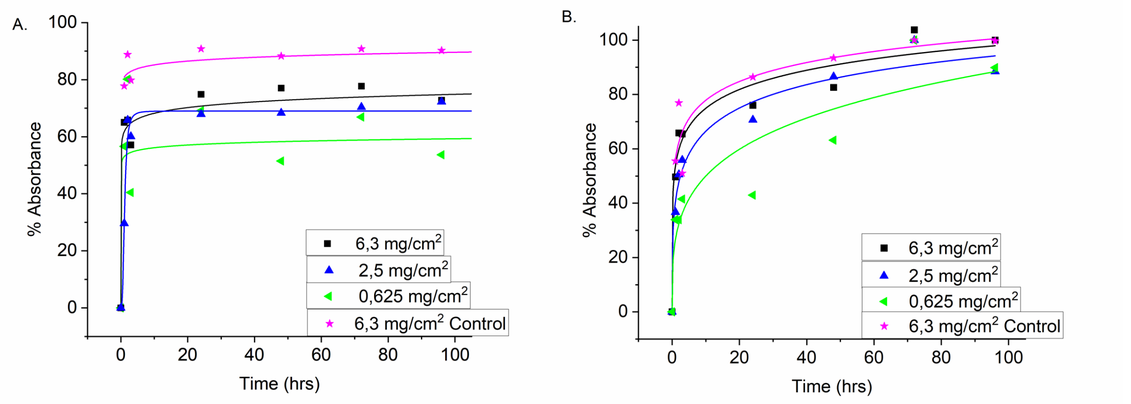
GAUZE SAMPLES – AMPICILLIN XEROGELS

Controlled release measurements using UV/VIS spectroscopy

Figure 5

LEATHER SAMPLES – AMPICILLIN XEROGELS

Controlled release measurements using UV/VIS spectroscopy



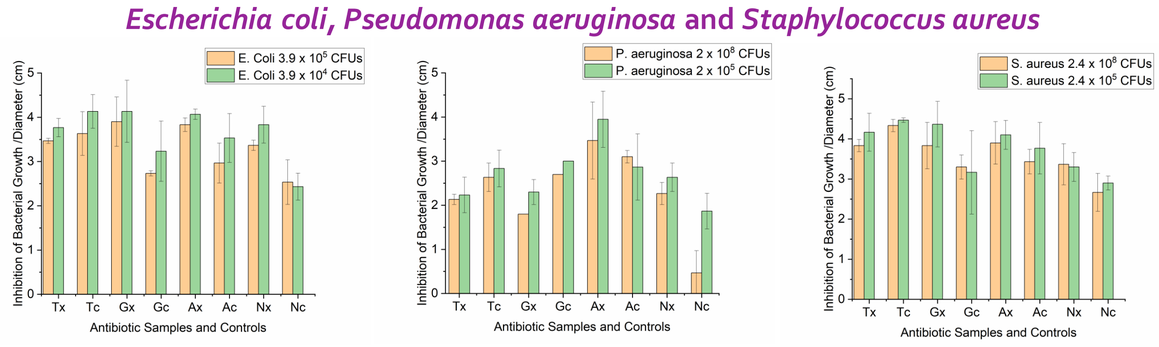
Controlled release measurements indicate that the different concentrations (Figure 4) have the same rapid antibiotic release rate in the highest molecular weight, and the maximum release occurs at 24 hours for all concentrations. No desirable effect was observed for all four antibiotics, so the study continued with the largest molecular weight and leather samples

According to the study, at all concentrations, the highest molecular weight (Figure 5) exhibit the same fast rate of antibiotic release, with a maximum release seen after 50 hours. The similar pace is seen at low concentrations, with the maximal release happening after 50 hours. Under the same circumstances, leather samples had a more controlled release than gauze samples.

Figure 6

ANTIBACTERIAL ACTIVITY – GAUZE SAMPLES

Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus



In Figure 6, it can be observed that in the cases of Gx and Nx there are notable differences observed, for both concentrations of the three bacteria used, so there was controlled release of these antibiotics when compared to their controls. The results **showcased** that there are no other notable differences, so we concluded that the majority of the concentration of the antibiotics was released overnight. Therefore, the antibiotics retained their activity as expected.

Figure 7

ANTIBACTERIAL ACTIVITY – LEATHER SAMPLES

Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus

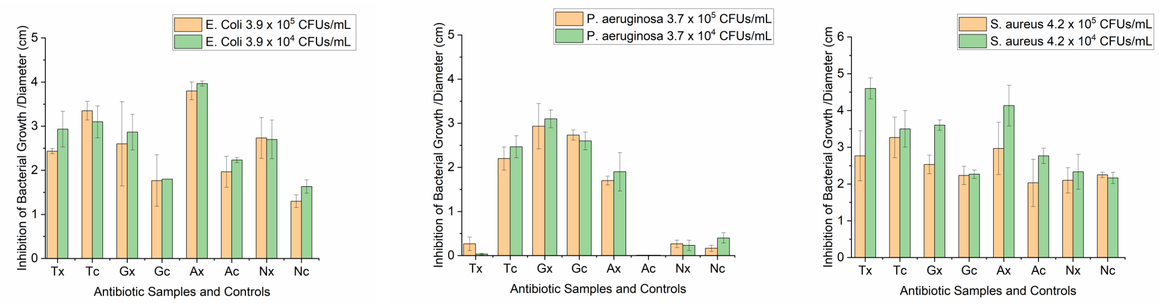


Figure 7 shows how the appropriate antibiotics and bacterial concentrations hinder the growth of E. Coli bacteria. When comparing the instances of Gx and Ax to their controls, notable variations are seen for both bacterial concentrations, indicating regulated release of these antibiotics. We came to the conclusion that most of the antibiotic concentration was discharged overnight because the data showed that there are no noticeable variations. As a result, the antibiotics retained their activity.

CONCLUSIONS

The World Health Organization has identified antibiotic resistance as a public health concern due to misuse. An experiment examined gauze and leather samples containing xerogel with four antibiotics and found that they inhibited bacterial growth in three strains without resistance. Samples treated with PEI/xerogels of different MW offered controlled release of the antibiotic. Although controlled release did not yield desirable effects, gentamicin showed a correlation between antibiotic action and controlled release. Future research should focus on different formulations for controlled release, study other known antibiotics, and study antibiotics against resistant bacterial strains.

REFERENCES

1. Arkas, M., et al., *Nano-Structures & Nano-Objects*, 2018, 14, 138-148.
2. Arkas, M., et al., *Nanomaterials*, 2022, 12(3), 445.
3. Jensen et al., Materialia, 2022, vol. 24
4. Vesoloski et al., Applied Biochemistry and Biotechnology, 2022, vol. 194(12) , 6270-6286
5. Tornesello et al., Cancers, 2020, vol. 12(4), 1049

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