



Macroheterocycle–Bentonite Nanohybrids: A Multifunctional Platform for Antimicrobial Biomaterials

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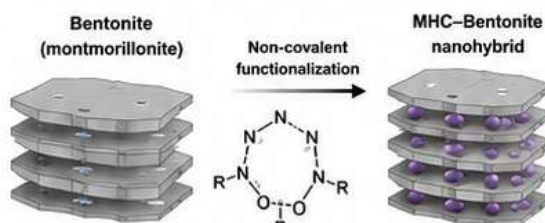
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INTRODUCTION

- Bentonite is an abundant montmorillonite clay with high surface area, cation-exchange capacity, and inherent antibacterial adsorption properties (Aliyev et al. 2025).
- Its layered structure enables intercalation of organic molecules, and chemical modification is routinely employed to tailor surface chemistry and functionality (Aliyev et al., 2026).
- In this study, we immobilize synthetic macroheterocycle (MHC) ligands onto bentonite to develop multifunctional antimicrobial nanohybrids.
- This approach extends our previous work on bentonite-based antibacterial nanocoatings by introducing purely organic MHC units as active agents.

OVERALL CONCEPT



Expected benefits:

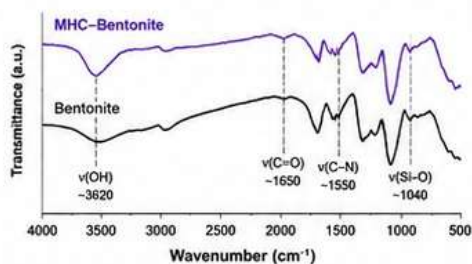
- ✓ Enhanced antimicrobial activity
- ✓ Sustained release of MHC ligands
- ✓ Synergistic effect of clay matrix and macroheterocycles
- ✓ Potential for infection-resistant biomaterials

METHODS

- Synthesis of MHC ligands**
Newly synthesized macroheterocycles (MHC) were prepared via solution-phase organic synthesis.
- Non-covalent functionalization**
Bentonite was dispersed in aqueous medium and MHC ligands were added to allow intercalation/adsorption.
- Purification**
The hybrids were separated by centrifugation, washed, and dried.
- Characterization & Evaluation**
Structure and morphology (FTIR, XRD, SEM, TEM); antimicrobial assays and ongoing bioactivity studies.

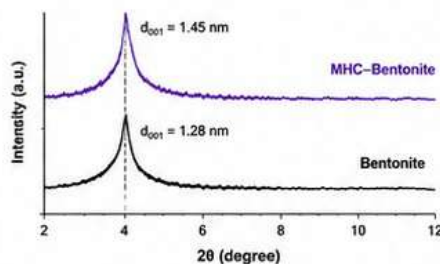
CHARACTERIZATION OF MHC-BENTONITE NANOHYBRIDS

FTIR Spectroscopy



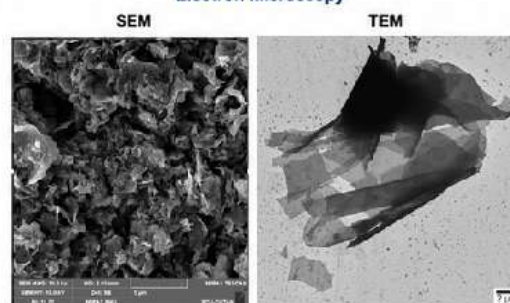
New bands corresponding to MHC functional groups confirm successful incorporation.

XRD Analysis



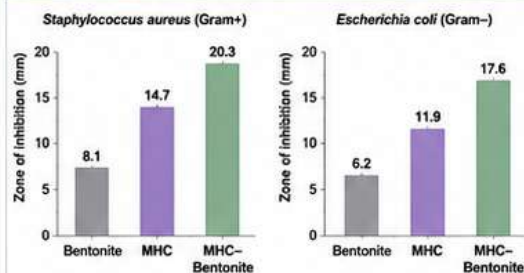
Slight shift of the (001) peak indicates interlayer expansion after MHC intercalation.

Electron Microscopy



Coated and partially exfoliated clay sheets confirm successful modification.

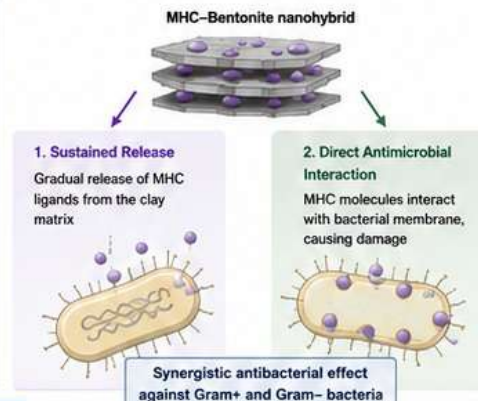
ANTIMICROBIAL ACTIVITY (Preliminary Results)



MHC-bentonite hybrids exhibit enhanced antimicrobial activity compared to unmodified clay.

(Assays performed by agar well diffusion method)

PROPOSED DUAL MECHANISM



FUTURE WORK

- Biofilm inhibition analysis
- ROS quantification
- Membrane integrity testing
- Cytocompatibility assessment
- Fabrication of polymer-clay composite coatings for biomaterial applications

CONCLUSIONS

- ✓ Synthetic macroheterocycle ligands were successfully immobilized onto bentonite via non-covalent functionalization.
- ✓ Structural and morphological analyses confirm MHC incorporation and interlayer expansion.
- ✓ MHC-bentonite nanohybrids demonstrate enhanced antimicrobial activity against *S. aureus* and *E. coli*.
- ✓ These hybrids act through dual mechanisms—sustained release and direct antimicrobial interaction—highlighting their potential for infection-resistant biomaterials.



ACKNOWLEDGEMENTS

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