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1,4-Bis(2-hydroxyethyl)piperazine-derived water-dispersible and antibacterial polyurethane coatings for medical catheters

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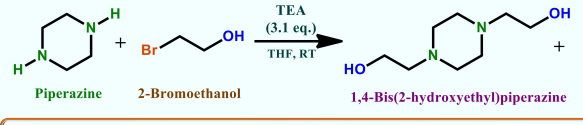
Objective of the study

To develop 1,4-bis(2-hydroxyethyl)piperazine-derived water-dispersible polyurethane coatings enriched with antibacterial properties for medical devices.

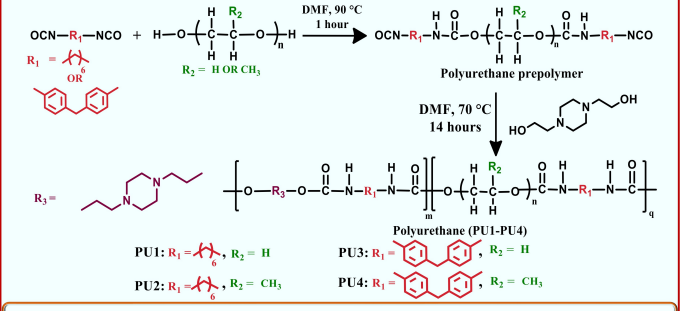
Work Plan/Experimental

Synthesis of polyurethanes using aliphatic or aromatic diisocyanates, polyether polyols, and piperazine-based chain extender → Generation of quaternized polyurethanes with water dispersibility and antibacterial properties through an alkylation approach → Formulation of the water-dispersible PU coatings and application to catheters through brush coating technique

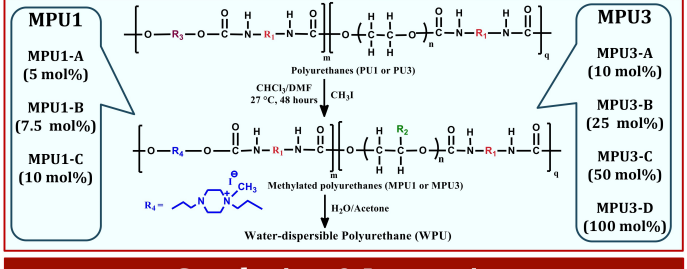
❑ Synthesis of 1,4-bis(2-hydroxyethyl)piperazine (HEP) as a chain extender



❑ Preparation of HEP-derived polyurethanes (PU1-PU4)



❑ Synthesis of water-dispersible PU1 & PU3 using an alkylation approach

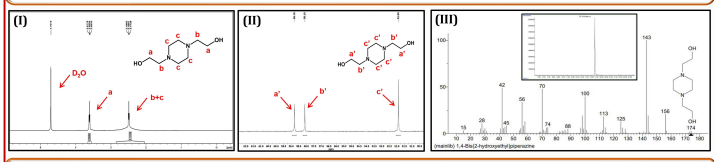


Conclusion & Innovation

- Piperazine-based water-dispersible polyurethanes (WPUs) with antibacterial activity were prepared and formulated into coatings for catheters
- MDI-PEG-HEP-based water dispersion with *72.5 %* methylation was found to be the most stable with a particle size of *~190.8 nm* and a surface charge of *+ 49.0 mV*
- Cytocompatibility studies demonstrated excellent cell viability of MDI-based WPUs (80-90%); however, HDI-based WPUs showed marginal compatibility (30-40%) with the cells
- Antibacterial analysis revealed 7 mm and *8 mm* zones of inhibition against *E. Coli* and *S. Aureus* bacteria, respectively, which suggests its suitability for coatings on medical catheters

Results & Discussion

✓ Structural confirmation of HEP by Fig. (I) ^{1}H NMR, (II) ^{13}C NMR, and (III) GCMS (m/z : 174.24 g/mol)



✓ Structural, thermal, and mechanical analysis of PU1-PU4

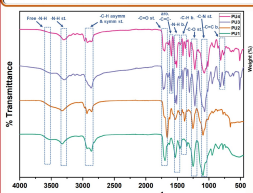


Fig. 1: FTIR spectra of PU1-PU4.

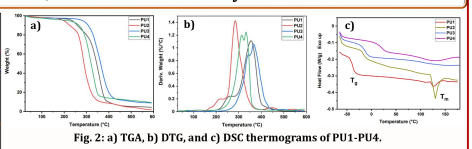


Fig. 2: a) TGA, b) DTG, and c) DSC thermograms of PU1-PU4.

Table 1: TGA and DSC data interpretation of PU1-PU4.

PUs	T_g (°C)	T_m (°C)	ΔH_m (J/g)	$T_{max\text{-}HS}$ (°C)	$T_{max\text{-}SS}$ (°C)
PU1	-39.5	127.5	1.8	279.3	397.2
PU2	-16.5	128.4	7.4	214.4	284.6
PU3	-11.5	130.9	0.9	343.3	366.9
PU4	23.8	134.6	3.4	313.6	332.4

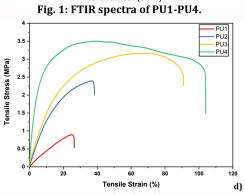


Fig. 3: Tensile plot of PU1-PU4.

Table 2: Tensile data of PU1-PU4.

PUs	Tensile stress (MPa)	Elongation at break (%)	Modulus of elasticity (MPa)
PU1	1.0	28.9	5.7
PU2	2.5	40.8	17.2
PU3	3.2	67.2	25.9
PU4	3.6	61.8	55.9

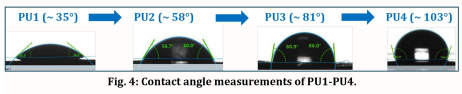


Fig. 4: Contact angle measurements of PU1-PU4.

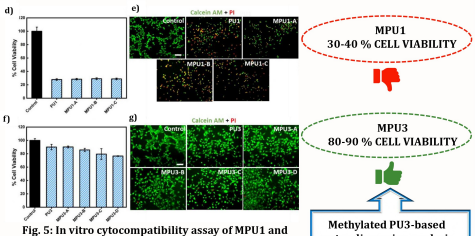


Fig. 5: In vitro cytocompatibility assay of MPU1 and MPU3 films via (d, f) MTT assay and (e, g) live-dead assay.

Structural analysis of methylated PU3

Methylated PU3-based water dispersion analysis

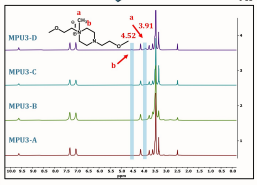


Fig. 6: ^{1}H NMR methylated PU3.

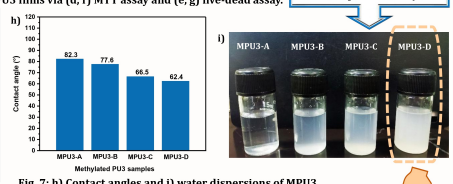


Fig. 7: h) Contact angles and i) water dispersions of MPU3.

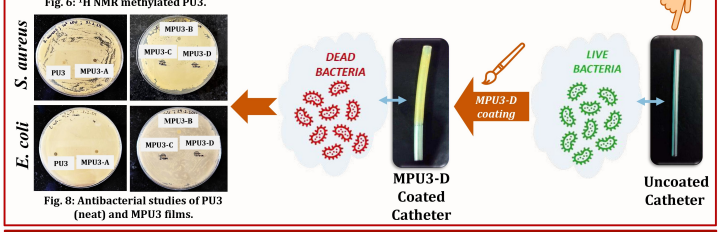


Fig. 8: Antibacterial studies of PU3 (neat) and MPU3 films.

References/Acknowledgement

1. Gupta, A., Rainu, S. K., Kaur, M., Meena, M., Singh, N., & Jacob, J. (2025). 1, 4-Bis (2-hydroxyethyl) piperazine-derived water-dispersible and antibacterial polyurethane coatings for medical catheters. Journal of Materials Chemistry B.

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