Computational Analysis of the Release Kinetics of Natural Compounds from PEG/PVA Blended Hydrogels for Wound Healing Applications

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Introduction

- Drug delivery to wounds is a long-standing clinical challenge due to the presence of biofilm, emergence of drug resistant microbes and heterogeneity of wound environment
- Study of the release kinetics aids in the optimization of the design parameters of drug delivery systems for wound healing applications
- Blended hydrogels are preferred for controlled release due to their enhanced mechanical stability and biocompatibility

Methodology

Components of the Mathematical Model

- **Hydrogels : PEG, PVA and PEG/PVA blend**
- **Therapeutic agents : Plant metabolites, Proteins and Synthetic drugs**

Prediction of the Structural Parameters

- **Molecular weight between crosslinks:**

$$\frac{1}{\bar{M}_c} = \frac{2}{\bar{M}_n} - \frac{(\bar{v}/V_1)\left[ln\left(1-v_{2,s}\right)+v_{2,s}+\chi_1 v_{2,s}^2\right]}{v_{2,s}^{1/3}-\frac{v_{2,s}}{2}}$$

- **Correlation length or Mesh size:**

$$\xi = v_{2,s}^{-\frac{1}{3}}\left(\bar{r}_o^2\right)^{\frac{1}{2}}$$

Estimation of the Diffusion Characteristics

- **Diffusion coefficient in water:**

$$D_o = \frac{kT}{6\pi\eta r_s}$$

- **Diffusion coefficient in hydrogel:**

$$\frac{D}{D_o} = \left(1-\frac{r_s}{\xi}\right)\exp\left(-Y\left(\frac{v_{2,s}}{1-v_{2,s}}\right)\right)$$

Simulation of the Drug Diffusion

- **Cumulative drug release fraction in a pure hydrogel:**

$$\frac{M_t}{M_\infty} = 1-\sum_{n=0}^{\infty}\frac{8}{(2n+1)^2\pi^2}\exp\left(\frac{-D(2n+1)^2\pi^2 t}{L^2}\right)$$

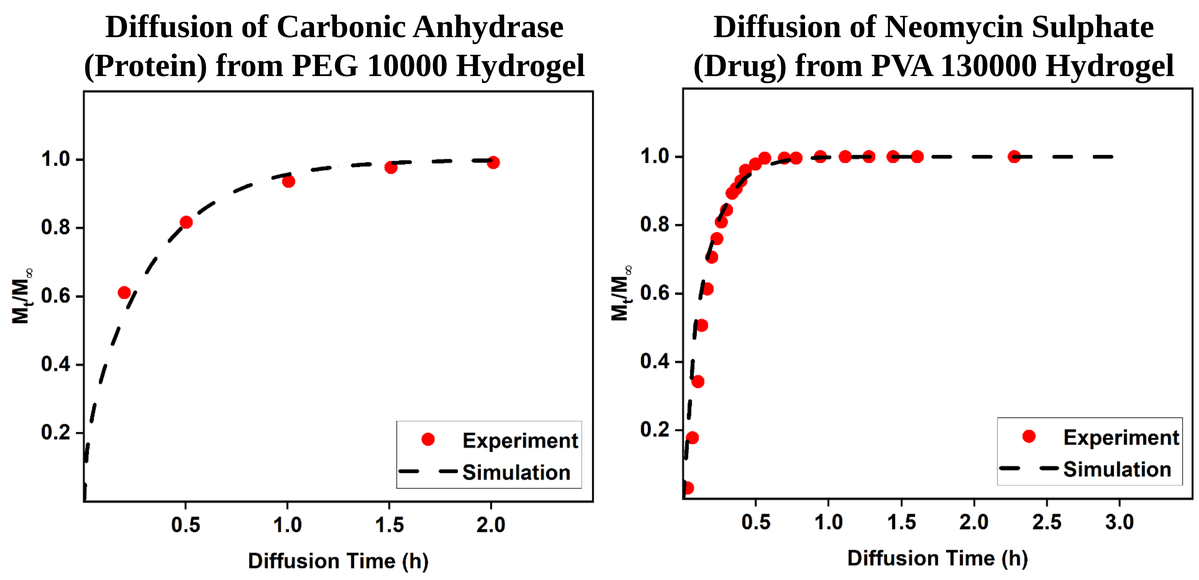
- **Cumulative drug release fraction in a blended hydrogel:**

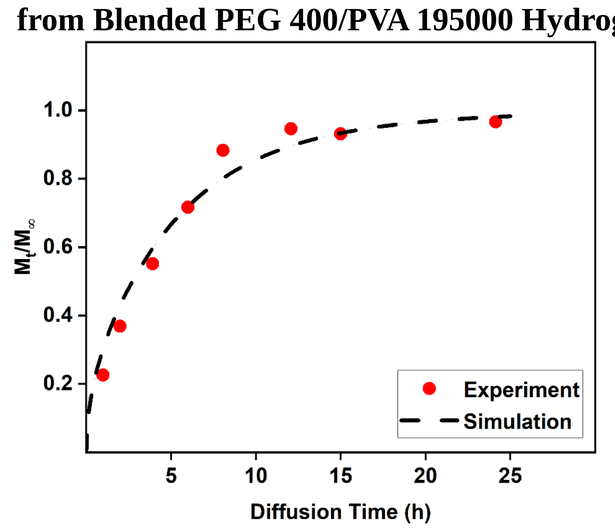
$$\left\{\frac{M_t}{M_\infty}\right\}_{Blend} = f_{PEG}\left\{\frac{M_t}{M_\infty}\right\}_{PEG} + f_{PVA}\left\{\frac{M_t}{M_\infty}\right\}_{PVA}$$

Validation of the Computational Model

Comparison of the simulated release profiles with the experimental data obtained from the literature

Results





- The free volume theory based modelling framework is capable of simulating the diffusion of therapeutic agents encapsulated within the pure and blended hydrogels
- Experimental and simulated release profiles are observed to be in fair agreement with the R^2 value of more than 0.9 for all the hydrogel samples

Conclusion

- The proposed model predicts the release kinetics of the therapeutic agents from the pure and blended hydrogels
- This study will be clinically useful for designing the drug-loaded hydrogel dressings for enhanced wound healing
- The theoretical framework can be further extended to develop a smart system for fabricating commercial drug delivery devices

References

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