Redox-Active Hydrogel Scaffolds for Nanoparticle Encapsulation and Controlled Manganese Release in Postoperative Anticancer Applications

Hydrogel-based biomaterials are increasingly explored as localized platforms for improving postoperative cancer treatment by enabling the encapsulation and sustained release of therapeutic nanomaterials. In this context, manganese dioxide (MnO_2) nanoparticles offer redox-responsive properties and the ability to release manganese ions, which can induce oxidative stress and contribute to cancer cell cytotoxicity. This thesis proposes the development of MnO_2 nanoparticle–embedded photocrosslinkable hydrogels as systems for nanoparticle encapsulation and controlled, sustained manganese release for in vitro anticancer evaluation.

Two hydrogel matrices, Gelatin Methacryloyl (GelMA) and Carboxymethyl Cellulose Methacrylate (CMCMA), will be investigated in a comparative study. GelMA provides a biomimetic and biocompatible environment, while CMCMA offers enhanced mechanical stability and potential printability. The study will focus on the fabrication and mechanical characterization of MnO_2-loaded hydrogels, evaluating key properties including rheological behavior, compressive strength, swelling ratio, degradation rate, gel fraction, and porosity. These parameters will be correlated with the hydrogel's ability to encapsulate nanoparticles and regulate their sustained release.

The cumulative release of manganese species will be monitored using UV–Vis spectrophotometry and colorimetric manganese detection assays, enabling analysis of MnO_2 degradation and Mn^{2+} ion release kinetics. The biological effects of released manganese species will be assessed using in vitro cancer cell models, with cell viability evaluated via the CellTiter-Glo® 3D assay (Promega) and Live/Dead staining to visualize cell survival and membrane integrity.

By correlating hydrogel structure, nanoparticle encapsulation, release behavior, and cellular response, this work aims to establish MnO_2-loaded hydrogels as effective platforms for localized and controlled nanomaterial delivery in postoperative anticancer applications.