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PROCEEDINGS ABSTRACT

# Development and characterization of a novel nanocomposite hydrogel using polyvinyl alcohol, chitosan, and $SiO_2$: promising findings for its employment in biomedical applications

Karrar Najeh Chfat, Noor Hadi Aysa, and Shafq Al-Azzawi

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In the contemporary pharmaceutical sciences and nanotechnology, the development of smart drug delivery systems remains a pivotal challenge. Our study represents a comprehensive investigation into the fabrication and characterization of advanced nanocomposite hydrogels (NCHGs) that are specifically engineered so as to optimize structural integrity and morphological performance for drug-loading and various medical applications. The study focuses on a hybrid polymeric architecture primarily synthesized from polyvinyl alcohol (PVA) and chitosan (CS). These polymers were chosen for their inherent biocompatibility and their functional adaptability; properties further enhanced through the strategic incorporation of silica (silicon dioxide; $SiO_2$) nanoparticles. The objective of this formulation was to create a robust scaffold through a controlled blending and chemical crosslinking, ensuring a highly uniform dispersion of $SiO_2$ within the network so as to gain mechanical stability and to prevent a premature degradation at specific environments (such as tumor tissues). Hydrogels are widely recognised for their high-water absorption capacity, biocompatibility, and structural similarity to biological tissues, making them suitable for different biomedical applications (such as wound healing, tissue engineering, and drug delivery). The chemical architecture and the successful integration of the components were rigorously validated using Fourier transform infrared spectroscopy. The analysis revealed distinctive characteristic hydroxyl (-OH) and amine ($-NH_2$) groups originating from the PVA/CS matrix, which exhibited significant molecular interaction with the siloxane (Si-O-Si) networks of the $SiO_2$ nanoparticles. Specifically, the broad band at 3420 $cm^{-1}$ is linked to the overlapping O–H and N–H stretching vibrations of CS, thereby reflecting robust H-bonding in the hydrogel structure. These interactions enhance stability, providing a crosslinked environment that facilitates the loading and retention of therapeutic agents. Furthermore, the structural phase of the composite was examined through X-ray diffraction patterns. The results confirmed that the $SiO_2$ nanoparticles maintained a purely amorphous state, as evidenced by a broad angle. Conversely, the hydrogel matrix demonstrated a semi-crystalline nature, with distinct crystalline peaks corresponding to PVA regions. The coexistence of these two phases (amorphous $SiO_2$ and semi-crystalline polymer) proves that the nanoparticles were successfully intercalated into the scaffold without disrupting the

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overall structural continuity. Surface morphology and internal architecture were further elucidated using scanning electron microscopy; the latter revealed a rugged, highly porous polymeric framework, which acts as a sophisticated host for the nanoparticles. The $SiO_2$ nanoparticles were observed as bright, spherical entities distributed across the hydrogel surface. Other significant regions demonstrated a highly monodisperse and uniform distribution, while the hydrogel exhibited high mechanical strength (3.76 MPa) and remarkable elasticity (338% elongation). The observed swelling exhibited a controlled behaviour: it increased at acidic pH media and retained its stability in neutral environments with controlled swelling over 48 h, so as to ensure sustained drug release. By controlling the spatial arrangement of these particles, the system is capable of facilitating both a sustained and a regulated release of drugs, thereby improving therapeutic efficacy, ensuring that the drug concentration remains within the therapeutic window for an extended period of time (as in a tumour environment), and significantly reducing systemic toxicity. Overall, the produced NCHG displays significant potential to be applied in different biomedical applications.

**Keywords**

chitosan; hydrogel; nanocomposite; silicon dioxide; swelling capacity

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**Conflicts of interest statement**

None to declare.

**Affiliation(s)**

College of Pharmacy, University of Babylon, Hillah, Iraq *(KNC)* ▪ Department of Clinical and Laboratory Sciences, College of Pharmacy, University of Babylon, Hillah, Iraq *(NHA)* ▪ Department of Clinical Pharmacy, College of Pharmacy, University of Babylon, Hillah, Iraq *(SA)*

**Correspondence**

Karrar Najeh Chfat
College of Pharmacy
University of Babylon
Hillah, Iraq
pha482.karrar.najeh@student.uobabylon.edu.iq