

Hydrogels: Next-Generation Smart Materials for Multifunctional Applications

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Hydrogels, comprising three-dimensional crosslinked hydrophilic polymer networks capable of holding a significant volume of water, have emerged as promising next-generation smart materials owing to their tunable physicochemical properties, biocompatibility, and responsiveness to external stimuli. These materials can be prepared through chemical and/or physical crosslinking of hydrophilic polymers. In recent years, natural polysaccharide-based gums have gained substantial attention as sustainable precursors for hydrogel development because of their biodegradability, environmental compatibility, and cost-effectiveness compared with synthetic counterparts. Our group has explored a range of plant-derived gums, including gum ghatti, neem gum, hing gum, amla, guggul gum, and fenugreek gum, for the fabrication of functional hydrogels. The developed hydrogels exhibit multifunctional properties with potential application across various sectors. In biomedical applications, their swelling behaviour and pH-responsiveness make them ideal candidates for controlled drug delivery. In agriculture, they can function as controlled fertilizer release systems and soil moisture-retaining agents, improving water-holding capacity and supporting crop growth under water-stress conditions. For environmental remediation, their porous structure, high surface areas, and strong affinity toward pollutants enable efficient removal of dyes from wastewater and effective oil-spill cleanup. Furthermore, Moreover, the incorporation of natural gums into hydrogel-based materials offers opportunities for sustainable food-packaging applications, with antimicrobial, biodegradable, and moisture-regulating functionalities. The talk will highlight natural polysaccharide-based hydrogels as a sustainable and versatile platform for developing next-generation smart materials. Their multifunctional performance across biomedical, agricultural, environmental, and industrial applications demonstrates their potential to address emerging societal challenges related health, food security, resources conservation, Environmental Protection.

Keywords: Hydrogels, Smart Materials, Natural Polysaccharides, Environmental Remediation, and industrial applications

Short biography of the presenting author

Dr. Vijay Kumar is currently an Assistant Professor in the Department of Physics at the National Institute of Technology (NIT) Srinagar, Jammu & Kashmir, India. His research focuses on solid-state luminescent materials, photonic functional materials, soft and ceramic materials, biopolymers, drug delivery systems, and wastewater treatment materials. Dr. Kumar has published more than 120 research papers in reputed international journals, 12 peer-reviewed conference proceedings, and 34 book chapters. He has also edited 17 international books published by leading publishers. His research has received over 8335 citations, with an h-index of 48 and an i10-index of 130 (Google Scholar). He is the inventor of two granted patents and has established active research collaborations with several leading international research groups. He serves on the Editorial Boards of Vacuum (Elsevier), Journal of Electronic Materials (Springer), Results in Surfaces and Interfaces (Elsevier), Frontiers in Energy Research (Nano Energy section), and Materials (MDPI). He has also served as Guest Editor for several special issues in reputed journals, including Vacuum, Discover Polymers, Results in Surfaces and Interfaces, Crystals, and Materials Today: Proceedings. In recognition of his sustained research excellence, he has been included in the Stanford–Elsevier World's Top 2% Scientists list for three consecutive years (2023–2025). He is also a Member of the DST Subject Expert Committee under the WISE-KIRAN Programme (2024–2027), an Elected Member of the Indian National Young Academy of Science (INYNAS) (2023–2027), and Joint Secretary of the Electron Microscope Society of India (EMSI), North Zone.