



**SRI VENKATESWARA INTERNSHIP PROGRAM  
FOR RESEARCH IN ACADEMICS  
(SRI-VIPRA)**



**SRI-VIPRA**



**Project Report of 2025: SVP-2511**

**“Fabrication of Biopolymer-Integrated Nanocomposites for Targeted Environmental Remediation and Sensing Technologies”**


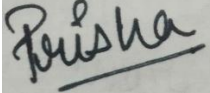
**IQAC  
Sri Venkateswara College  
University of Delhi  
Benito Juarez Road, Dhaula Kuan, New Delhi  
New Delhi -110021**


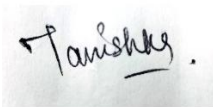
## SRIVIPRA PROJECT 2025

**Title : “Fabrication of Biopolymer-Integrated Nanocomposites for Targeted Environmental Remediation and Sensing Technologies”**

<b>1. Name of Mentor: Dr. Laishram Saya Devi</b> <b>Name of Department: Chemistry</b> <b>Designation: Assistant Professor</b>	<b>Photo</b> 
<b>2. Name of Mentor: Dr. Shikha Gulati</b> <b>Name of Department: Chemistry</b> <b>Designation: Assistant Professor</b>	

### *List of students under the SRIVIPRA Project*

S. No	Photo	Name of the student	Roll number	Course	Signature
1.		Prisha Ganeriwala	1224042	B.Sc. (H) Biochemistry	

2.		Tanishka Yadav	124045	B.Sc. (H) Biochemistry	
----	---	----------------	--------	---------------------------	---



Signature of Mentors

### **Certificate of Originality**

This is to certify that the aforementioned students from Sri Venkateswara College have participated in the summer project SVP-2511 titled “**Fabrication of Biopolymer-Integrated Nanocomposites for Targeted Environmental Remediation and Sensing Technologies**”. The participants have carried out the research project work under my guidance and supervision from 1<sup>st</sup> July, 2025 to 30<sup>th</sup> September 2025. The work carried out is original and carried out in an online/offline/hybrid mode.



Signature of Mentors

### **Acknowledgements**

We are grateful to the Principal, Sri Venkateswara College, University of Delhi, for his continuous encouragement and support in the field of research. We also would like to thank the SRI VIPRA team for giving us the opportunity and a platform to guide undergraduate students for research in the college as a mentor through the internship programme.

## TABLE OF CONTENTS

<b>Sl. No</b>	<b>Topic</b>	<b>Page No.</b>
<b>1.</b>	<b>Objectives</b>	<b>5</b>
<b>2.</b>	<b>Abstract</b>	<b>5</b>
<b>3.</b>	<b>Introduction</b>	<b>5-6</b>
<b>4.</b>	<b>Literature Survey</b>	<b>6-7</b>
<b>5.</b>	<b>Characterisation Techniques</b>	<b>7-9</b>
<b>6.</b>	<b>Types of Using Biopolymer-Integrated Nanocomposites</b>	<b>9-10</b>
<b>7.</b>	<b>Research Gaps</b>	<b>10</b>
<b>8.</b>	<b>Conclusions</b>	<b>11</b>
<b>9.</b>	<b>REFERENCES</b>	<b>11</b>

**Objectives:**

- To explore the potential of biopolymer–nanocomposites in non-invasive sensing applications, including electrochemical, optical, and colorimetric detection of pollutants at trace levels.
- To give a hands-on practice of various tools and softwares which are required in doing research subsequently making its way to its publication.
- To evaluate the long-term stability, regeneration capability, and environmental safety of the fabricated nanocomposites to ensure sustainable application potential.
- To critically analyze literature findings, identify limitations in current biopolymer–nanocomposite systems, and propose potential improvements for industrial and environmental implementation.

**Abstract**

Ecosystems and human health are seriously threatened by environmental contamination caused by heavy metals, synthetic colors, pesticides, and pharmaceutical residues. The need for sustainable alternatives is highlighted by the drawbacks of conventional treatment techniques, which frequently include high costs, poor selectivity, and secondary waste creation. The creation of biopolymer-integrated nanocomposites, which combine the high surface activity and functional characteristics of nanomaterials with the renewable and biodegradable nature of biopolymers, is the main goal of this project. While nanomaterials like metal oxides and graphene derivatives bring adsorption, catalysis, and sensing capabilities, biopolymers like chitosan, alginate, and cellulose offer stability and reactive sites. Advanced techniques (FTIR, SEM, TEM, XRD, and BET) will be used to characterize the synthesized composites, and their suitability for pollutant removal and real-time sensing applications were assessed. This review-based project aims to compile and analyze recent findings on fabrication techniques, pollutant interactions, and sensing applications of biopolymer–nanocomposites. The study identifies research gaps, highlights future possibilities, and underscores their significance as next-generation green technologies for sustainable environmental management.

**1. Introduction**

Uncontrolled release of hazardous chemicals from home, industrial, and agricultural operations has made environmental pollution a global concern. Heavy metals, artificial colors, pesticides, and pharmaceutical residues are a few examples of pollutants that are frequently persistent, bioaccumulative, and harmful to

human health and ecosystems. Despite their widespread use, conventional treatment techniques such as chemical precipitation, membrane filtration, ion exchange, and activated carbon adsorption have drawbacks such as high cost, poor selectivity, energy intensity, and secondary waste production. Furthermore, real-time pollutant detection—which is equally important for guaranteeing environmental safety—cannot be accomplished with these technologies. One effective technique for overcoming these obstacles is nanotechnology. Metal oxides ( $\text{TiO}_2$ ,  $\text{ZnO}$ ,  $\text{Fe}_3\text{O}_4$ ) and carbon-based materials (graphene oxide, carbon nanotubes) are examples of nanomaterials that have a large surface area, adjustable characteristics, and potent interactions with contaminants. However, aggregation, poor recovery, and possible toxicity are common problems with free nanoparticles that limit their direct use. A sustainable substitute is provided by biopolymers such as chitosan, alginate, cellulose, and starch. They have many functional groups that can bind contaminants via adsorption, ion exchange, or chelation, and they are biodegradable and renewable. Biopolymers serve as stabilizing and supporting matrices when paired with nanomaterials, resulting in biopolymer-integrated nanocomposites that are more stable, reusable, and multifunctional.

These nanocomposites have shown exceptional efficacy in pollutant removal—for instance, chitosan–graphene oxide hybrids for heavy metal adsorption and alginate– $\text{Fe}_3\text{O}_4$  composites for magnetic separation. Additionally, they can be designed for sensing uses, such as the optical and electrochemical detection of contaminants at trace levels.

## **2. Literature Survey**

Biopolymers such as chitosan, alginate, cellulose, and starch have gained significant attention in environmental remediation due to their biodegradability, abundance, and presence of reactive functional groups including hydroxyl ( $-\text{OH}$ ), amino ( $-\text{NH}_2$ ), and carboxyl ( $-\text{COOH}$ ) groups. These functional moieties allow biopolymers to interact effectively with various pollutants through mechanisms such as adsorption, chelation, and ion exchange. When combined with nanomaterials—including metal and metal oxide nanoparticles such as  $\text{Fe}_3\text{O}_4$ ,  $\text{TiO}_2$ ,  $\text{ZnO}$ , and  $\text{Ag}$ , as well as carbon-based nanostructures like graphene oxide and carbon nanotubes—the resulting composites exhibit enhanced surface area, reactivity, and electronic properties. The integration of biopolymers with nanomaterials creates biopolymer–nanocomposites that synergistically combine the advantages of both components, offering high adsorption capacity, catalytic activity, and biocompatibility. For example, chitosan–graphene oxide composites have been shown to efficiently remove dyes and heavy metals from aqueous solutions, while alginate–metal

oxide hybrids are widely applied in electrochemical sensing for pollutant detection. These studies highlight the multifunctional potential of biopolymer-integrated nanocomposites in addressing environmental challenges.

### **3. Characterization techniques**

**3.1. UV-Visible Spectrophotometry:** UV-Visible spectrophotometer is a simple, sensitive, reliable, low-cost technique that allows the determination of very less concentrations of compounds and the use of very small amounts of samples. This technique is based on attenuation of electromagnetic radiation measurement by an absorbing substance. Using Beer-Lambert's law, it can determine the concentration of the analyte quantitatively. We intend to employ a double beam Cary-100 UV-Visible spectrophotometer in this study.

**3.2. Fourier Transform Infrared (FTIR) spectroscopy:** Fourier transform Infrared Spectroscopy is one of the most important tools for surface characterisation of materials. Based on the molecular vibrations of the material, this particular spectroscopic technique results in a molecular fingerprint of these materials in the form of FTIR spectrum. It reveals the chemical composition of the nanoparticle surface as well as the reactive moieties/functional groups on the surface that are responsible for surface reactivity and chemical bonding. For obtaining the final FTIR spectrum, this method focuses on computing interferograms and applying Fourier transforms to them. FTIR is a time-saving approach which can analyse a wide range of samples including liquids, solids, gases and thin films for a variety of compounds in a short time span

**3.3. X-Ray Diffraction (XRD) Method:** X-ray diffraction technique, that work on the Bragg's Rule, is a very useful characterization tool to study, non-destructively, the crystallographic structure, chemical composition and physical properties of materials and thin films. It can also be used to measure various structural properties of these crystalline phases such as strain, grain size, phase composition, and defect structure. The intensities measured with XRD can provide quantitative, accurate information on the atomic arrangements at interfaces.

**3.4. Scanning Electron Microscopy (SEM):** pictures are crucial to many scientific fields because they offer insightful knowledge into the surface morphology, chemical makeup, and structural properties

of materials. Visualising and analysing the surface morphology of materials requires the use of SEM images. High-resolution SEM imaging enables close examinations of surface characteristics including topography, texture, and roughness. Understanding surface characteristics and behavior of materials, such as adhesion, friction, and contact interactions, requires the knowledge of this information. These surface features are visualized in SEM pictures, allowing researchers to assess and evaluate material performance.

**3.5. Energy-Dispersive X-Ray Analysis (EDAX):** The method of energy-dispersive X-ray analysis (EDAX) is utilized for the SEM assessment of nanoparticles. This method involves activating the nanoparticles using an EDS X-ray spectrophotometer, which is typically fitted together in current SEMs. The isolated individual nanoparticles are placed on a suitable substrate so that their characterization is unaffected. With regard to precise dimensions and elemental characterization, this technique has several drawbacks. EDAX works on the fundamental premise that an electron beam is used to generate X-rays from a specimen. The features and composition of the components present in the sample determine how the X-rays are produced.

**3.6. Transmission Electron Microscopy (TEM):** Images play a crucial role in various scientific disciplines, offering valuable insights into the microscopic structure, composition, and morphology of materials. TEM images provide high-resolution imaging which allows researchers to visualize materials at an extremely fine scale, revealing intricate details at the atomic and nanoscale levels. It is vital for understanding the arrangement of atoms, crystal defects, grain boundaries, and other structural features that govern the properties and behavior of materials.

**3.7. Brunauer–Emmett–Teller (BET) Surface Area Analysis:** BET analysis measures the specific surface area, pore size, and porosity of the nanocomposite. A higher surface area and appropriate pore distribution enhance adsorption capacity and catalytic efficiency. This technique is particularly useful for assessing the potential of biopolymer-integrated nanocomposites in environmental remediation applications, where pollutant capture is largely surface-driven.

**3.8. Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC):** TGA and DSC are employed to evaluate the thermal stability and decomposition behavior of

nanocomposites. TGA measures weight loss as a function of temperature, indicating the degradation profile of the biopolymer and embedded nanoparticles. DSC provides insights into phase transitions, melting points, and glass transition temperatures. These thermal analyses are crucial for determining the operational stability of nanocomposites under environmental conditions.

## **4. Types of Sensors Using Biopolymer-Integrated Nanocomposites**

### **4.1. Electrochemical Sensors**

Electrochemical sensors detect pollutants by measuring changes in current, potential, or impedance caused by interactions between analytes and the sensor surface. In these sensors, biopolymers such as chitosan, alginate, and cellulose serve as matrices to immobilize nanoparticles while providing functional groups like amino, hydroxyl, and carboxyl moieties for selective pollutant binding. Nanomaterials such as metal nanoparticles (Au, Ag), metal oxides ( $\text{Fe}_3\text{O}_4$ ,  $\text{TiO}_2$ ), or graphene derivatives enhance electron transfer and overall sensitivity. These sensors have been successfully applied to detect heavy metals like lead and cadmium, as well as pesticides and nitroaromatic compounds, offering high sensitivity, real-time monitoring, and minimal sample preparation.

### **4.2. Optical Sensors (Fluorescent/Photoluminescent Sensors)**

Optical sensors rely on changes in fluorescence, luminescence, or absorbance upon pollutant interaction with the sensor surface. Biopolymers play a crucial role by stabilizing fluorescent nanoparticles or quantum dots and providing selective binding sites for target contaminants. Nanomaterials such as quantum dots, carbon dots, and metal oxides ( $\text{ZnO}$ ,  $\text{TiO}_2$ ) enhance the optical response. These sensors are particularly effective for detecting dyes, heavy metal ions, and toxic organic compounds in water. Their non-invasive, rapid, and highly selective detection capabilities make them suitable for real-time environmental monitoring.

### **4.3. Colorimetric Sensors**

Colorimetric sensors detect pollutants through visible color changes caused by chemical interactions between the analyte and the nanocomposite. Biopolymers stabilize metallic nanoparticles such as gold and silver, enhancing selectivity and sensor stability. Upon binding to pollutants like heavy metals, pesticides, or industrial dyes, these nanocomposites exhibit distinct color changes observable with the naked eye or simple optical devices. The simplicity, portability, and rapid

response of colorimetric sensors make them ideal for on-site monitoring in environmental applications, requiring no sophisticated instrumentation.

#### **4.4. Surface Plasmon Resonance (SPR) Sensors**

SPR sensors operate by measuring changes in the refractive index near the sensor surface when analytes bind to it. Biopolymers act as immobilization matrices for plasmonic nanoparticles, typically gold or silver, enhancing stability and sensitivity. These sensors allow label-free detection of trace pollutants in aqueous systems, such as heavy metals and organic contaminants, with high sensitivity and real-time monitoring capabilities. The combination of biopolymers and nanomaterials in SPR sensors provides a sustainable, efficient approach for precise environmental sensing.

#### **4.5. Piezoelectric / Mass-Sensitive Sensors**

Piezoelectric or mass-sensitive sensors detect pollutants based on changes in vibration frequency or surface mass upon analyte binding. Biopolymers serve as functional coatings that selectively capture pollutants, while nanoparticles increase surface area and sensitivity. These sensors have been applied for detecting heavy metals, organic compounds, and gaseous pollutants. They offer label-free operation, high sensitivity, and the ability to provide continuous monitoring, making them suitable for both laboratory and field environmental applications.

### **5. Research gaps**

Even though a lot of research has shown how effective biopolymer-integrated nanocomposites are in lab settings, there is still little evidence that these materials can be used in large-scale industrial settings. Assuring long-term stability, sustaining performance across several regeneration cycles, and evaluating these materials' environmental safety—especially when used in real-world scenarios—are important difficulties. Furthermore, the majority of sensing research published in the literature concentrates on detecting individual contaminants, yet real wastewater streams contain intricate contamination combinations that call for multiplexed sensing capabilities. Additionally, despite the development of a number of synthesis techniques, green, economical, and scalable manufacturing procedures that are appropriate for realistic and sustainable applications still need to be investigated. To properly utilize biopolymer–nanocomposites in environmental cleanup and monitoring technologies, these issues must be resolved.

## 6. Conclusion

Biopolymer-integrated nanocomposites have been shown in the literature to have great potential as multipurpose materials for environmental cleanup and sensing. The limitations of bare nanoparticles and conventional approaches are addressed by their combined benefits of high adsorption, biodegradability, catalytic efficiency, and sensing adaptability. However, further study is required to determine cost-effectiveness, environmental safety, and scalability. These hybrid systems have the potential to advance sustainable environmental management solutions, as this review highlights.

## REFERENCES

- [1] Lai, K. C., Lee, L. Y., Hiew, B. Y. Z., Thangalazhy-Gopakumar, S., & Gan, S. (2020). Facile synthesis of xanthan biopolymer integrated 3D hierarchical graphene oxide/titanium dioxide composite for adsorptive lead removal in wastewater. *Bioresource technology*, 309, 123296.
  - [2] Arora, D., & Kaur, D. (2025). Flexible Magnetolectric Composites and Devices for Wearables and Sensors-A Review. *IEEE Sensors Journal*.
  - [3] Chen, Z., Aziz, T., Sun, H., Ullah, A., Ali, A., Cheng, L., ... & Khan, F. U. (2023). Advances and applications of cellulose bio-composites in biodegradable materials. *Journal of Polymers and the Environment*, 31(6), 2273-2284.
  - [4] Bilal, M., Munir, H., Khan, M. I., Khurshid, M., Rasheed, T., Rizwan, K., ... & Iqbal, H. M. (2022). Gums-based engineered bio-nanostructures for greening the 21st-century biotechnological settings. *Critical Reviews in Food Science and Nutrition*, 62(14), 3913-3929.
  - [5] Ye, M., Guo, W., & Wen, X. (Eds.). (2025). *Natural Biopolymers for Wearable Devices*. Royal Society of Chemistry.
-