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Production and Characterization of Chitosan-Based Magnetic Field-Sensitive Beads: A Comprehensive Study on Synthesis, Structural Properties, and Environmental Applications

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Abstract: The primary objective of this study was to synthesize chitosan-based magnetic bead sorbents (MCS) and evaluate their effectiveness in the sorption of both organic solvents and distilled water. In the initial phase, chitosan-based polymeric beads were synthesized using the precipitation-aggregation method, followed by comprehensive characterization using appropriate instrumental and analytical techniques to determine their physical and chemical properties. An interesting observation in this study was that the MCS without any cross-linking agents displayed a significantly higher capacity for distilled water sorption compared to those cross-linked with glutaraldehyde or epichlorohydrin. The study revealed that non-crosslinked chitosan beads exhibited the highest sorption capacity for distilled water (35%), while cross-linked beads showed a reduced capacity of (24%). On the other hand, cross-linking benefited the sorption of organic solvents, particularly toluene. The beads cross-linked with glutaraldehyde exhibited slightly better toluene sorption capacity than those cross-linked with epichlorohydrin, which might be attributed to differences in the molecular interactions between the cross-linkers and the solvent molecules. For organic solvents, glutaraldehyde-cross-linked beads achieved the highest toluene sorption (27%), slightly outperforming epichlorohydrin-cross-linked beads (25%). Furthermore, the study found that temperature played a crucial role in influencing the sorption capacity of the MCS. The sorption capacity decreased by approximately 15% as the temperature increased from 25 °C to 45 °C, highlighting the temperaturedependent nature of the process. This inverse relationship between temperature and sorption capacity could be due to the reduced interaction between the solvent molecules and the surface of the MCS at higher temperatures, potentially caused by increased molecular motion that hinders effective adsorption. These findings provide valuable insights into the design of chitosan-based magnetic sorbents for different applications, particularly in removing organic solvents and water purification processes. Future studies could further explore the optimization of cross-linking agents and investigate these sorbents' long-term reusability and stability in various environmental conditions.

Keywords: Chitosan, magnetic bead, characterization, sorption properties.

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1. INTRODUCTION

Chitosan is a renewable, hydrophilic, biodegradable, and non-toxic biopolymer that has garnered significant attention due to its environmentally friendly properties (Du et al., 2014). Structurally, it contains three reactive functional groups—amino and hydroxyl groups—located at the C-2, C-3, and C-6 positions, which contribute to its versatility in various applications. The presence of weakly basic amino groups gives chitosan a positive charge in acidic environments, enabling strong interactions with polyanions and enhancing its functionality in diverse fields (Youssef et al., 2015; El-Aidie, 2018).

Despite its promising characteristics, chitosan has notable limitations. It is highly soluble in acidic environments and exhibits poor mechanical strength, which restrict its application in more demanding conditions (Ngah and Fatinathan, 2010; Liu et al., 2021). These challenges have spurred significant research into the physical and chemical modification of chitosan to enhance its properties and expand its applicability.

Physical modification processes have been widely employed to improve chitosan's porosity and functional characteristics. By incorporating inorganic substances into its matrix, chitosan can be transformed into a variety of porous structures, such as beads, fibers, microspheres, membranes, and gel beads, without compromising its intrinsic properties (Solisio et al., 2006; Liu et al., 2021; Boominathan et al., 2021). On the other hand, chemical modification methods, such as cross-linking, involve the reaction of chitosan's amino (-NH₂), hydroxyl (-OH), and Nacetamido groups, resulting in a three-dimensional network structure. This structural transformation enhances the material's resistance to water dissolution and improves its mechanical properties, making it more stable in acidic environments and broadening its scope for use in challenging applications (Ajitha et al., 2017; Piekarska et al., 2023).

Among these modification techniques, cross-linking technology is particularly noteworthy. It preserves chitosan's sorption capabilities while significantly enhancing its durability and usability in harsh conditions. However, chitosan's low specific gravity remains a drawback, complicating its recovery after sorption. Traditional recovery methods such as centrifugation and filtration are often timeconsuming and expensive, which limits their practicality in large-scale applications (Liu et al., 2022).

To address these limitations, recent advancements have focused on the development of magnetic chitosan beads (MCS). By incorporating magnetic materials like Fe₃O₄, γ -Fe₂O₃, FeO, and CoFe₂O₄ into the chitosan matrix, MCS sorbents achieve rapid and efficient recovery using magnetic separators (Buhani et al., 2023; Elgarahy et al., 2023; Khan et al., 2024). This innovative approach not only simplifies the recovery process but also reduces operational costs, making chitosan-based adsorbents more practical for industrial and environmental applications.

In this study, magnetic gel beads were synthesized using chitosan samples with varying degrees of deacetylation (minimum 75% DD) and molecular weights, obtained from commercial sources. The primary objective was to evaluate the sorption efficiency of these gel beads under diverse environmental conditions, including distilled water and organic solvents. Comprehensive characterization of the synthesized beads was conducted to assess their morphological, structural, and physicochemical properties. Additionally, the study examined the sorption and desorption efficiencies of the beads across different media, providing insights into their performance and applicability.

This research aims to advance the utility of chitosan-based adsorbents by integrating magnetic properties, thereby overcoming traditional limitations and enhancing recovery efficiency. These developments pave the way for the broader application of MCS sorbents in tackling environmental and industrial challenges, with the potential for future studies to address a wider range of pollutants and operational scenarios.

2. EXPERIMENTAL SECTION

Chemicals and Reagents: Various chemicals were employed during the experimental stages of this study. The key chemicals used for producing chitosan-based magnetic beads, sourced from commercial suppliers, can be summarized as follows: Acetic acid (CH₃CO₂H; ≥99.85%), chitosan with varving degrees of deacetvlation (75% DD and 85% DD) and molecular weights (low, medium, and high), and cross-linkers such as epichlorohydrin (E) (C₃H₅ClO, synthesis grade) and glutaraldehyde (G) (OHC(CH₂)₃CHO; 25%). Other reagents included ammonium persulfate, ethanol (absolute), hydrochloric acid (37%), sodium hydroxide (pellet form), and Fe₃O₄ to impart magnetic properties to the chitosan beads.

Characterization of Chitosan (CS): The chitosan samples were characterized using a combination of analytical and instrumental methods. Surface functional groups in the chitosan structure were analyzed using a Shimadzu IR Spirit Spectrometer, which provided detailed insights into the chemical composition. Moisture content was determined using a Mettler LJ16 moisture analyzer, ensuring accurate measurement of water content within the samples.

Synthesis of CS and MCS Beads: To synthesize the chitosan beads, 1 gram of chitosan was weighed and dissolved in 25 mL of 2% acetic acid solution. The dissolution process was carried out using an ultrasonic homogenizer set to 50% amplitude, with a 5-second spray time, and 1-second dwell time, ensuring complete dissolution of the chitosan. The resulting gel solution was then combined with a calculated amount of magnetic agent (Fe₃O₄), and the mixture was carefully dropped into an alkaline solution (20 g/L NaOH concentration) containing 1 mL of 5% ammonium persulfate and 1% cross-linker, either glutaraldehyde or epichlorohydrin. Dropping was performed at a controlled rate of three beads per minute to ensure uniform bead formation. The mixture was stirred gently to avoid breaking up the beads, and the chitosan beads were allowed to solidify in the alkaline solution for 24 hours. After the 24-hour period, the beads were filtered and washed with pure water until the pH of the wash reached neutrality (İpek 2023). water The production method has also been used in our previous studies (Demirtas et al., 2023; Demirtas et al., 2022; İpek et al., 2025). To investigate the effect of the degree of deacetylation, chitosan samples with 75% and 85% DD were used. Additionally, to evaluate the influence of molecular weight, low,

medium, and high molecular weight chitosan samples were employed. The effect of cross-linking was assessed by using both glutaraldehyde (G) and epichlorohydrin (E) as cross-linking agents. After initial characterization, Fe₃O₄ was incorporated into the chitosan structure at a weight ratio of 1:100 relative to the chitosan monomer, to impart magnetic properties. This magnetic feature was essential for the development of magnetic chitosan beads (MCS), enhancing the ease of bead recovery post-sorption. A systematic coding system was used to label the chitosan beads, with the first term indicating the alkaline concentration, the second term representing the molecular weight or degree of deacetylation, the third term signifying the crosslinker type, and the fourth term denoting magnetic properties. For example, the code 20/85DD/E/FM indicates beads synthesized with a 20 g/L NaOH concentration. 85% deacetvlated chitosan. epichlorohydrin as the cross-linker, and magnetic properties.

Characterization of CS and MCS Beads: The diameter of the chitosan beads was measured using a digital micrometer (Digital Caliper). Measurements were repeated on at least five beads to ensure accuracy, and the average diameters were recorded. To investigate the surface morphology of the chitosan beads, SEM (scanning electron microscopy) analysis was conducted using a JEOL JSM 7001F microscope. The surface morphology provided insights into bead formation, porosity, and any structural changes due to cross-linking. FTIR (Fourier-transform infrared spectroscopy) analysis was carried out using a Shimadzu IRSipirit FTIR spectrometer to identify the functional groups present in the chitosan beads. This analysis also helped determine the functional groups blocked or modified due to cross-linking. The FTIR scans were performed in the range of 400-4000 cm⁻¹, with 45 scans conducted to obtain detailed spectra. Sorption measurements for distilled water and organic solvents were performed using a gravimetric method, allowing for precise assessment of the sorption capacity of the beads under varying conditions.

3. RESULTS AND DISCUSSION

Figure 1 illustrates the loss on ignition and moisture contents of chitosan samples obtained from various commercial suppliers, each differing in their degrees of deacetylation and molecular weights. The low moisture content across all samples, remaining below 1%, reflects minimal water retention. Additionally, with the exception of the 85% DD sample, the loss on ignition values fall below approximately 1.75%, consistent with findings by Fawzya et al. (2018), which reported similar moisture and ignition loss trends in chitosan samples. The Figure 1 also presents viscosity measurements of solutions prepared by dissolving chitosan samples in a 2% acetic acid solution. The viscosity values range from 202 to 640 mPa, indicating a clear trend: viscosity decreases as the degree of deacetylation increases and molecular weiaht decreases. As the degree of deacetylation rises, polymer chains become more rigid, while a decrease in molecular weight shortens the polymer chains. Both factors contribute to lower viscosity, demonstrating an inverse relationship between deacetylation degree, molecular weight, and viscosity, consistent with previous studies and theoretical expectations.

Overall, molecular weight and degree of deacetylation significantly impact moisture retention, thermal stability, bulk density, and viscosity in chitosan samples, directly influencing their applications and functionality. High molecular weight and 75% DD chitosan samples exhibit the highest moisture content, while low molecular weight chitosan shows notably low moisture retention, suggesting a correlation between molecular weight and moisture-holding capacity. The 85% DD sample displays a remarkably high ignition loss value of 4.4%, in contrast with the lower values observed in other samples, indicating that a higher deacetylation degree may reduce thermal stability. In terms of bulk density, the 75% DD chitosan exhibits the lowest value, while the 85% DD sample shows the highest, suggesting a positive relationship between deacetylation degree and bulk density. Finally, the 75% DD chitosan has the highest viscosity (640 mPa), while the 85% DD chitosan has the lowest (202 mPa), supporting the idea that a higher degree of deacetylation can lead to reduced viscosity.



Figure 1. Physicochemical properties of chitosan(C) samples: HMW (High Molecular Weight), MMW (Medium Molecular Weight), LMW (Low Molecular Weight), and 85DD (85% Degree of Deacetylation)

Figure 2 presents the FTIR spectra of the chitosan samples, highlighting characteristic peaks that are in agreement with both our previous research and relevant findings in the literature (Demirtaş et al., 2023; Demirtaş et al., 2022). These FTIR peaks not only confirm the structural integrity of the chitosan samples but also validate the presence of functional groups, thus reinforcing their chemical composition.

In addition to confirming these aspects, the FTIR analysis was conducted to identify any blocked bonds resulting from cross-linking during the production of cross-linked and magnetic field-sensitive chitosan beads, using epichlorohydrin as the cross-linking agent. This was specifically aimed at preparing the beads for sorption studies. The analysis successfully detected the expected modifications in the molecular structure, demonstrating the impact of cross-linking on the chemical bonds. The resulting spectrum, which reflects these changes, is displayed in Figure 2.

This characterization provides further evidence of the suitability of these chitosan samples for their intended application, offering insights into how the structural changes influence their performance in sorption processes. The data captured by FTIR supports the efficacy of the cross-linking process, confirming that the structural adjustments were achieved as intended. The spectrum in Figure 2 serves as a visual confirmation of these findings.

RESEARCH ARTICLE



Figure 2. FTIR spectra of CS samples and 20/85DD/E/FM beads used in the sorption study.

Figure 3 presents detailed data on the average bead diameter, bead volume, and bead density for the chitosan samples. The data reveals interesting trends regarding the influence of alkali concentration on the physical characteristics of the beads. As depicted, a non-linear relationship exists between the alkali concentration and bead diameter, where increasing the concentration of alkali results in larger bead sizes. This suggests that the swelling of the chitosan matrix becomes more pronounced at higher alkali levels, leading to increased bead dimensions.

However, an inverse trend is observed with regard to bead mass. As alkaline concentration rises, the mass of the beads tends to decrease. This indicates that higher alkali concentrations may contribute to the formation of more porous or less dense bead structures. Such porous structures are likely due to increased interaction between the chitosan and the alkali, leading to expanded bead matrices with reduced material density. The formation of such structures can be advantageous in certain applications, such as drug delivery systems or adsorbents, where higher porosity might enhance the material's performance.

A particularly notable observation is the behavior of beads synthesized using a NaOH solution at a concentration of 20 g/L. These beads exhibited a relatively smaller diameter and lower mass compared to those produced at higher alkali concentrations. Despite their smaller size and reduced mass, these beads showed greater physical strength, making them more resistant to mechanical stress during handling and experimental procedures.



Figure 3. Physical characterization results of chitosan beads.

This suggests that a moderate alkali concentration such as 20 g/L NaOH—yields beads with a denser, more compact structure, which enhances their mechanical stability. Such beads may be more suitable for applications where structural integrity is critical, such as in sorption studies or mechanically demanding processes.

Moreover, this data highlights the critical role that alkali concentration plays in tuning the properties of chitosan beads. The ability to control bead size, mass, and mechanical properties by adjusting alkali levels opens up a range of possibilities for customizing the beads for specific applications. For example, in scenarios where large surface areas and high porosity are required, higher alkali concentrations might be preferable. Conversely, for applications demanding robust, mechanically stable beads, lower alkali concentrations may be more suitable.

Additionally, the relationship between bead density and alkaline concentration provides further insight into the structural changes occurring at the molecular level. As alkaline concentration increases, the decrease in bead density suggests that the internal structure of the beads becomes more open and expanded, likely due to the alkali's ability to disrupt the intermolecular bonds within the chitosan. This trend aligns with the observed decrease in bead mass, confirming the hypothesis that higher levels of alkali lead to a more porous and expanded material.

In conclusion, Figure 3 effectively illustrates how concentration alkaline influences the physical characteristics of chitosan beads. Understanding these relationships is crucial for tailoring chitosan beads for specific industrial, biomedical, or environmental applications. The ability to optimize bead size, density, and mechanical strength through alkaline concentration adjustments provides a powerful tool for enhancing the functional properties of chitosan-based materials.

The SEM analysis results of the beads are shown in Figure 4. The images reveal a highly irregular surface morphology, featuring prominent pores and ridges. This rough texture indicates a large surface area, which is advantageous for applications such as adsorption and catalysis. The presence of welldistributed pores suggests good porosity, enhancing the material's ability to interact with or capture target molecules, including dyes and pollutants. At 1000× magnification, microstructural details such as cracks and voids become evident, further underscoring the material's potential for enhanced adsorption performance. However, slight variations in pore distribution may introduce some inconsistencies in functionality. Despite this, the observed surface characteristics align well with the material's intended application, confirming its suitability for adsorptionbased studies.



Figure 4. The SEM analysis results of the chitosan beads: (a) chitosan (b)20/85DD (c) 20/LMW (d) 20MMW (e)20HMW (f) 20/85/DD/G (g)20/85/DD/E.

Distilled water and organic solvent sorption capacities of chitosan beads: Figure 5 presents the effects of various factors, such as alkaline concentration, crosslinker type, cross-linking density, deacetylation degree, and molecular weight of chitosan, on the sorption capacity of chitosan beads for distilled water and toluene. Upon examining the data, it becomes clear that chitosan beads without cross-linkers exhibit significantly higher sorption capacities for distilled those cross-linked water compared to with glutaraldehyde and epichlorohydrin. This can be attributed to the fact that cross-linking, while enhancing the structural integrity of the beads, reduces the overall water sorption capacity by limiting the availability of hydrophilic sites and hindering the swelling capacity of the beads. Cross-linking forms a denser network within the chitosan matrix, which restricts water absorption by preventing the polymer from fully expanding. Among the cross-linked beads, produced with epichlorohydrin displayed those marginally higher water sorption capacity than those cross-linked with glutaraldehyde, indicating that the choice of cross-linker can fine-tune the sorption properties of chitosan.

However, while non-cross-linked beads show higher water sorption, they are prone to structural instability. During and after the sorption process, these beads tend to fragment and disperse, losing their physical integrity.

This phenomenon underlines a critical trade-off in material design: non-cross-linked beads may offer superior sorption capacities but at the cost of mechanical stability. Cross-linked beads, on the other hand, maintain their integrity and physical resilience throughout the sorption process, even though their water absorption potential is somewhat reduced. This highlights the role of cross-linking in improving the mechanical durability of chitosan beads, which is vital in applications where mechanical stress is a concern.

relationship Additionally, an inverse between molecular weight and distilled water sorption capacity was observed. As the molecular weight of chitosan increases, the sorption capacity decreases. This trend can be explained by the fact that higher molecular weight polymers possess longer and more entangled chains, which may reduce the accessibility of hydrophilic groups responsible for water sorption. This relationship holds true across both cross-linked and non-cross-linked beads. Furthermore, increasing alkali concentration appears to enhance water sorption capacity for all beads, regardless of cross-linking. This is likely because higher alkali concentrations cause greater swelling and increase porosity within the bead matrix, allowing more water to be absorbed.

When considering the sorption of organic solvents such as toluene, the data reveals a contrasting trend. Chitosan beads without cross-linkers exhibit lower sorption capacities for toluene compared to their cross-linked counterparts. This suggests that crosslinking enhances the sorption capacity for hydrophobic solvents like toluene, potentially by creating a more rigid, stabilized network that can effectively interact with the solvent molecules. The presence of crosslinking may provide additional surface area or modify the internal structure in a way that improves the bead's affinity for non-polar molecules.

RESEARCH ARTICLE



Figure 5. Distilled water and toluene sorption capacity of CS beads.

Interestingly, beads cross-linked with glutaraldehyde exhibited slightly higher toluene sorption than those cross-linked with epichlorohydrin. This subtle difference in performance could be attributed to the nature of the chemical bonds formed by each crosslinker. Glutaraldehyde, a bifunctional aldehyde, may introduce more reactive sites or increase the crosslinking density, which in turn enhances interaction with toluene molecules. Epichlorohydrin, though effective, might result in a slightly less dense cross-linked network, leading to marginally lower toluene sorption.

Moreover, this pattern indicates that the choice of cross-linker not only influences the mechanical stability and water sorption capacity but also plays a significant role in dictating how the beads interact with organic solvents. This is particularly important when tailoring chitosan beads for specific applications, such as in organic solvent remediation or oil spill recovery, where organic solvent sorption is a key performance metric.

Overall, these findings underscore the complexity of optimizing chitosan-based sorbents. Adjusting factors such as cross-linking, molecular weight, and alkali concentration allows for precise control over both water and organic solvent sorption capacities. The data demonstrates that cross-linking is essential for enhancing mechanical stability and improving toluene sorption, whereas non-cross-linked beads excel in water sorption at the cost of structural durability. By balancing these factors, it is possible to design chitosan beads that are customized for specific sorption applications, ensuring optimal performance based on the desired properties of the final product.

To further investigate the influence of temperature on sorption sorption performance, capacities of 20/85DD/E chitosan beads were assessed across different temperatures using a variety of solvents, as depicted in Figure 6. The data reveal a clear inverse relationship between temperature and sorption capacity: as temperature increases, sorption capacity decreases consistently across all tested solvents. This trend suggests that higher temperatures may weaken the interaction between solvent molecules and chitosan beads. This reduced interaction may be attributed to several factors, including increased molecular motion at elevated temperatures, which disrupts the hydrogen bonds and van der Waals forces sorption. Additionally, responsible for higher temperatures might cause minor structural changes or loosening in the chitosan matrix, reducing the available binding sites and, consequently, the sorption efficiency. This observed temperature dependence underscores the importance of temperature control in practical applications involving chitosan beads, particularly in sorption-based processes. The data imply that chitosan's sorption performance may be optimized under lower temperatures, where solvent interactions with chitosan are more favorable, enhancing sorption efficiency. This characteristic is especially relevant in applications requiring solvent recovery, pollutant removal, or controlled-release systems, where maintaining low temperatures could maximize sorption capacity.



Figure 6. Sorption capacities of 20/85DD/E beads in different temperatures and solvent environments.

Moreover, the results confirm that factors such as cross-linking, molecular weight, alkaline concentration, and temperature collectively influence the sorption behavior of chitosan beads. Cross-linking, for example, strengthens the bead matrix and improves stability but may limit water sorption due to restricted swelling and reduced hydrophilic sites. This is contrasted with noncross-linked beads, which, while offering higher water sorption, tend to be structurally less stable and are more prone to degradation during the sorption process.

Additionally, cross-linked chitosan beads are shown to perform better in sorbing organic solvents like toluene, likely due to a more stable matrix structure that provides a higher affinity for organic molecules. This insight suggests that the choice of cross-linking agents, degree of cross-linking, and selection of chitosan type (based on molecular weight and deacetylation) must be carefully balanced depending on whether the goal is to maximize sorption capacity for water or organic solvents.

In summary, these findings emphasize the need to tailor chitosan bead properties to meet specific application requirements. Lower temperatures and non-cross-linked configurations are favorable for maximizing water sorption, while cross-linked chitosan beads are better suited for organic solvent sorption due to their enhanced mechanical stability. By adjusting chitosan bead characteristics such as crosslinking, molecular weight, and temperature, it is possible to optimize sorption behavior, making chitosan a versatile material for a wide range of applications in environmental cleanup, biomedicine, and industrial processing.

4. CONCLUSION

The chitosan beads synthesized in this study exhibited excellent physical stability under specified

sorption conditions, consistently retaining their structural integrity throughout the process. This stability was particularly pronounced in beads crosslinked with epichlorohydrin, which not only enhanced mechanical resilience but also enabled high sorption capacity for organic solvents. Such robustness underscores the suitability of epichlorohydrin-crosslinked chitosan beads as highly effective sorbents across a diverse range of applications. Specifically, the maximum sorption capacity for distilled water reached 35% for noncross-linked beads, while cross-linked beads showed a reduced capacity of 24% under the same conditions. Given their performance, these beads hold significant promise for the efficient sorption of dye molecules, sulfate ions, and other common pollutants found in wastewater, where mechanical durability and sorption efficiency are both essential.

Additionally, the temperature-dependent sorption characteristics revealed that sorption capacity tends rising temperatures. to decrease with This highlights relationship the importance of temperature control in applications requiring particularly optimal sorption efficiency, in environments where stability across temperature variations is critical. The distinct sorption trends observed with different solvents-where cross-linked beads showed superior affinity for organic solvents like toluene-further emphasize the influence of cross-linking on the selectivity and effectiveness of chitosan beads. toluene sorption, For glutaraldehyde-cross-linked beads exhibited а maximum capacity 27%, outperforming of epichlorohydrin-cross-linked beads, which reached 25%. Notably, temperature played a significant role in sorption performance. As the temperature increased from 25 °C to 45 °C, sorption capacities decreased by approximately 15% across all tested solvents, highlighting the temperature-dependent behavior of the synthesized beads.

These findings contribute to the growing knowledge of chitosan-based sorbents by providing a deeper understanding of how cross-linking, temperature, and molecular structure affect sorption performance. The study not only enhances the design of efficient and reusable sorbents but also establishes a foundation for further exploration into their industrial-scale applications in wastewater treatment, solvent recovery, and environmental remediation.

Future studies could focus on refining the synthesis parameters to optimize these beads for specific pollutants, as well as evaluating their sorption efficiency in complex real-world conditions, such as industrial wastewater and other environmentally challenging media. The exploration of their capacity to remove a broader range of contaminants, including heavy metals, pesticides, and organic pollutants, could provide valuable insights into their versatility as sustainable sorbents. Additionally, investigating the regeneration and reusability of these beads could further enhance their appeal as cost-effective, environmentally friendly solutions for lona-term environmental remediation. These findings collectively position cross-linked chitosan beads as a promising avenue for sustainable sorption technologies in both environmental and industrial applications.

5. CONFLICT OF INTEREST

There is no need to obtain ethics committee permission for the article prepared. There is no conflict of interest with any person/institution in the prepared article.

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148