Chapter 5

Summary and Future scope

5.1. Summary

❖ The **first chapter** depicts the brief introduction and highlighting the objective of the thesis. Based on the introduction identifying the objectives are as follows:

- The objective is to prepare single and multicomponent composite material for the removal of toxic dyes and antibiotic from wastewater simultaneously.
- Sugarcane bagasse and Polyaniline/Ganga Sand composite are used to determine their efficiency in eliminating pollutants such as MB, MO, NR and DXN.
- To synthesized and optimized different characterizations (mesh size, SEM, EDAX, optical image, XRD, CHN analysis, TGA and FTIR) of the prepared adsorbents.
- To optimize the operational parameters (e.g., pH, temperature, contact time, and adsorbent dosage, initial concentration) for maximum removal of dyes and antibiotic using Sugarcane bagasse and Polyaniline/Ganga Sand composite adsorbent.
- To analyze the adsorption kinetics and isotherms involved in the interaction between adsorbents and the contaminants for a deeper understanding of the adsorption mechanisms.
- To assess the economic feasibility of using bagasse-based adsorbent in large-scale wastewater treatment applications.

❖ The **second chapter** contains the literature reviews of adsorbent, sugarcane bagasse, polyaniline, and applications for removal of dyes and antibiotics (emerging pollutants). By the following literature review we are figure out some research gap.

- ***Limited Understanding of Interaction Mechanisms***: There is a lack of comprehensive studies investigating the underlying mechanisms of dye adsorption and antibiotic degradation on polyaniline-bagasse composites, necessitating a detailed mechanistic understanding.

- ***Optimization of Synthesis Conditions***: Current research often overlooks the optimization of synthesis parameters for polyaniline-bagasse composites, which can significantly affect their structural properties and adsorption efficiency.
- ***Diversity of Dyes and Antibiotics Tested***: Most studies focus on a narrow range of dyes and antibiotics; broader investigations are needed to evaluate the effectiveness of Sugarcane bagasse and Polyaniline/Ganga Sand composite against various contaminants with differing physicochemical properties.
- ***Long-term Stability and Reusability:*** Research is limited on the long-term stability and reusability of Sugarcane bagasse and Polyaniline/Ganga Sand composite adsorbents, which are critical for practical applications in wastewater treatment.
- ***Environmental Impact Assessments:*** There is a need for more studies assessing the environmental impacts of using Sugarcane bagasse and Polyaniline/Ganga Sand composite, particularly concerning the degradation products of antibiotics and dyes.
- ***Batch vs. Continuous Flow Systems:*** Current research primarily focuses on batch adsorption studies; further investigation into the performance of Sugarcane bagasse and Polyaniline/Ganga Sand composite in continuous flow systems is essential for practical wastewater treatment applications.
- ***Comprehensive Kinetic and Isotherm Studies:*** Existing studies often provide limited kinetic and isotherm analyses; thorough characterization of these dynamics is necessary to enhance predictive models for real-world applications.
- ***Cost-Effectiveness and Scalability:*** There is insufficient exploration of the cost-effectiveness and scalability of producing polyaniline-bagasse-based adsorbents, which is crucial for their commercial viability.
- ***Synergistic Effects:*** Limited research has explored the potential synergistic effects of combining polyaniline-sand composite.

❖ ***Field-Scale Applications:*** Most research is conducted in laboratory settings; there is a significant gap in studies evaluating the performance of Sugarcane bagasse and Polyaniline/Ganga Sand in real-world field applications and their effectiveness in treating industrial effluents.

❖ The **third chapter** is consisting of the Novel Ganga-sand-encapsulated polyaniline granules for effective remediation of textile and pharmaceutical wastewater. The following inferences are drawn from above investigation.

- Ganga-sand encapsulated polyaniline granules synthesized via in-situ polymerization method for textile and pharmaceutical wastewater remediation.
- The granules were characterized via scanning electron microscopy and Fourier transform infrared techniques.
- Key factors such as adsorbent dose, contact time, pH, and concentration were optimized for maximum dye removal, achieving 98.2% efficacy for methylene blue and 85.1% for doxycycline.
- Kinetic studies indicated a pseudo-second-order model, while isotherm studies showed better adherence to the Langmuir model.
- The results suggest that these granules are effective adsorbents for treating textile and pharmaceutical wastewater.

❖ **Chapter four** describes the Low-cost chemically treated sugarcane bagasse for removal of cationic, anionic, and neutral dyes from aqueous solution. The following conclusions are drawn from this chapter.

- This study explores the use of chemically treated sugarcane bagasse as a low-cost adsorbent for the removal of cationic (MB), anionic (MO), and neutral (NR) dyes from wastewater.

- Characterization via FTIR, TGA, SEM and EDAX revealed the presence of cellulose, pectin, and lignin in the bagasse.
- Optimal conditions achieved 98.2% removal for MB, 50.3% for MO, and 81.2% for NR. The adsorption process followed a pseudo-second-order kinetic model and the Langmuir isotherm model.
- The results highlight sugarcane bagasse as an effective adsorbent for textile wastewater treatment.

5.2. Future Scope

Future research should focus on several key areas to advance the use of Ganga-sand encapsulated polyaniline granules and chemically treated sugarcane bagasse for industrial wastewater treatment:

- Further studies could explore the scalability of using Ganga-sand encapsulated polyaniline granules for industrial wastewater treatment. Scaling up these materials for large-scale applications would help evaluate their potential for real-world use.

- Similarly, research should focus on the practical implementation of chemically treated sugarcane bagasse in treating industrial effluents to support large-scale commercialization.

- Expanding the scope of studies to include a wider variety of pollutants, such as heavy metals and emerging contaminants, would improve the versatility of Ganga-sand encapsulated polyaniline granules. By addressing these research areas, the use of Ganga-sand encapsulated polyaniline granules and treated sugarcane bagasse could be optimized and validated for sustainable industrial wastewater treatment solutions.

List of Publications and Conferences

Publications

1. **Umesh Kumar**, Vineeta Gautam, Sanjay D. Patil, Kesheo Prasad, Novel Ganga sand encapsulated polyaniline granules for effective remediation of textile and pharmaceutical wastewater, Indian Chemical Engineer, 19 march 2024, https://doi.org/10.1080/00194506.2024.2334468.

2. **Umesh Kumar**, Vineeta Gautam, Kesheo Prasad, Low-cost chemically treated sugarcane bagasse for removal of cationic, anionic, and neutral dyes from aqueous solution, Indian Chemical Engineer, 02 September 2024, https://doi.org/10.1080/00194506.2024.2389098.

Conferences

1. **Umesh Kumar**, Vineeta Gautam, Kesheo Prasad, "Low-cost adsorbents for single and multi- component system: remediation of textile and pharmaceutical wastewater treatment", Indian Institute of Chemical Engineers, Heritage Institute of Technology, Kolkata, IIChE - CHEMCON 2023, December 27-30, 2023.

2. **Umesh Kumar**, Gaurav Kumar, Kesheo Prasad, "New Generation Battery Binder for Cathode Active Materials Lithium and Sodium-ion Battery" in International Conference IIChE - CHEMCON 2023, at Indian Institute of Chemical Engineers, Heritage Institute of Technology, Kolkata, held on 27-30th Dec, 2023.

3. **Umesh Kumar**, Kesheo Prasad, "Treatment of textile and pharmaceutical wastewater using low-cost adsorbents for single and multicomponent systems", Sustainable Development in Chemical and Environmental Engineering, 2024, Thapar Institute of Engineering and Technology, Patiala -147004, Punjab, INDIA. 22-24th Feb 2024.

4. Vineeta Gautam,**Umesh Kumar,** Kesheo Prasad, "Synthesis and characterization of novel crystalline polyaniline/Kaolin composite", Sustainable Development in Chemical and Environmental Engineering, 2024, Thapar Institute of Engineering and Technology, Patiala -147004, Punjab, INDIA. 22-24th Feb 2024.

5. Vineeta Gautam**, Umesh Kumar,** "Synthesis of nano membranous composite material based on Polyaniline/MWCNTs/Cellulose acetate for selective electrochemical detection of Ascorbic Acid and Catechol" Sustainable Development in Chemical and Environmental Engineering, 2024, Thapar Institute of Engineering and Technology, Patiala -147004, Punjab, INDIA. 22-24th Feb 2024.