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Eco-Friendly Chitosan (CTS) Films for Indigo Carmine Removal and Wastewater Treatment

Sepideh Dadashi [1,*], Gabriele Giancane [2] and Giuseppe Mele[1]

[1] Department of Engineering for Innovation, University of Salento,73100, Lecce, Italy

[2] Department of Cultural Heritage, University of Salento, I-73100, Lecce, Italy

INTRODUCTION & AIM

The continuous release of synthetic dyes such as potassium indigotrisulfonate (ITS), into industrial effluents poses a significant environmental threat because of their persistence, toxicity, and resistance to conventional treatment methods .These dyes contribute to water pollution, disrupt aquatic ecosystems, and can present potential health risks to humans. Developing efficient and sustainable removal methods is therefore essential to minimize their environmental impact [1,3].

In this study, chitosan (CTS), a naturally derived, biodegradable, and non-toxic polysaccharide, was investigated as an eco-friendly material for dye removal. CTS is known for its high adsorption capacity, biocompatibility, and ability to form stable films through its amino and hydroxyl functional groups . These functional groups facilitate electrostatic interactions and hydrogen bonding with dye molecules, making CTS an effective adsorbent for pollutant removal [4-6]. Here, CTS-based films were designed and optimized for the adsorption and photodegradation of potassium indigotrisulfonate (ITS) from both ultrapure and real wastewater samples.

The work focuses on preparing CTS hydrogels using different concentrations of acetic acid (AA) solutions (0.05%, 1.5%, and 3%) to identify the most effective film composition and drying conditions. The main objectives were to produce homogeneous, transparent, and detachable films, test their adsorption efficiency toward ITS, and assess their behavior under UV irradiation to explore a dual adsorption–photodegradation mechanism.

METHOD

Chitosan (CTS) was dissolved in acetic acid (AA) solutions of 0.05%, 1.5%, and 3%, and stirred for 3 hours in sealed vials at room temperature to obtain homogeneous hydrogels. The hydrogels were then cast on different substrates—glass slides, watch glasses, and polyethylene (PE) sheets—to identify suitable drying conditions.

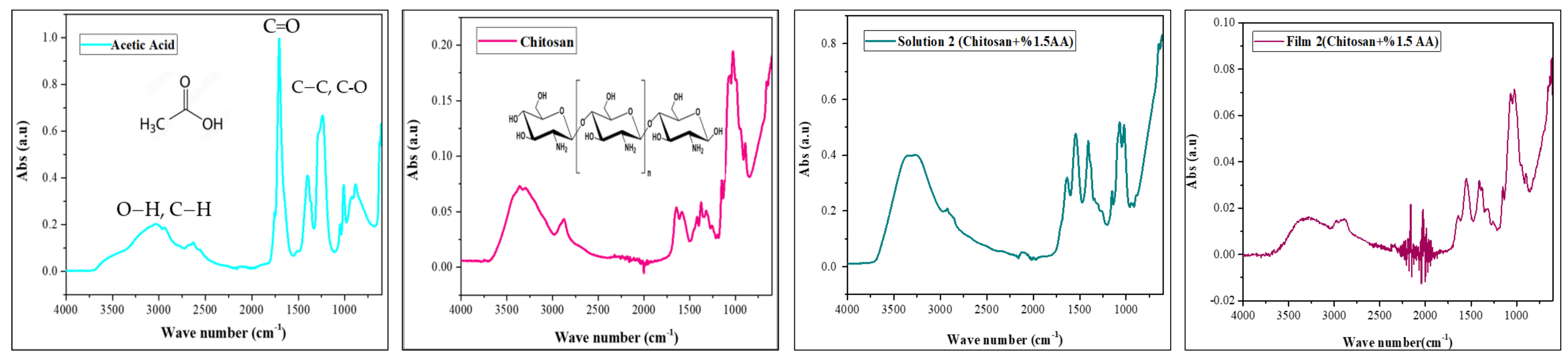
- Films dried on glass and watch glass at 73°C for 35 minutes adhered irreversibly, while those cast on PE sheets and dried at ambient temperature formed uniform, transparent, and detachable layers. The optimized composition, 1% CTS in 1.5% AA, was used for subsequent experiments.
- Fourier-transform infrared (FTIR) spectroscopy (400–4000 cm^{-1}) was employed to study the functional groups and structural interactions among CTS, AA, the hydrogel, and the dried CTS–1.5%AA/PE film.
- For adsorption testing, ITS solutions (16 mg/mL) were prepared in ultrapure water and secondary-treated wastewater supplied by Aquasoil Company (Italy). The CTS films were immersed in both solutions under ambient conditions, and dye removal was monitored visually and spectroscopically.
- After adsorption, the dye-loaded films were exposed to UV-A light (365 nm) for two hours to evaluate photodegradation efficiency and structural stability.

Figure 1: Hydrogel solution vials following 3 hours of stirring

Table 1 : Composition and Parameters of Chitosan-Based Film Solutions.

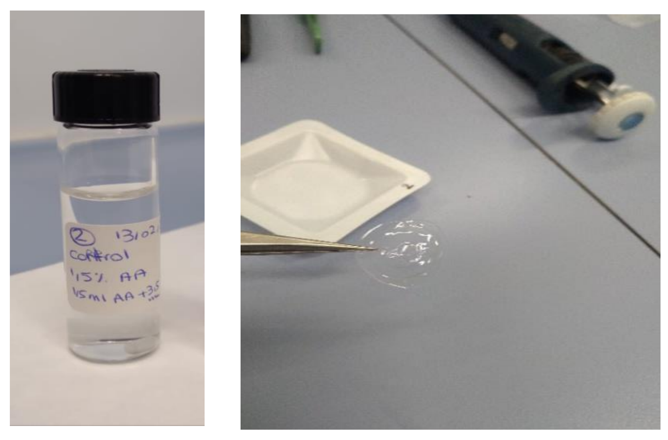
Sample	Final volume 5mL	AA 5%	Water
1	3% AA	3ml	2mL
1A	3% AA+C-CDs	3ml	-
2	1.5 % AA	1.5 ml	3.5 mL
2A	1.5 % AA+C-CDs	1.5 ml	1.5 mL
3	0.05% AA	0.5 ml	4.5 ml
3A	0.05% AA+C-CDs	0.5 ml	2.5 ml

RESULTS & DISCUSSION



(a) (b) (c) (d)

Figure 2: FTIR spectra of the base materials: a) Acetic Acid, b) Chitosan (CTS), c) CTS solution 1.5% AA and d) CTS film 1.5% AA.



(a) (b)

Figure 3: a) CTS hydrogel 1.5% AA, b) CTS film on PE plate in ambient temperature.

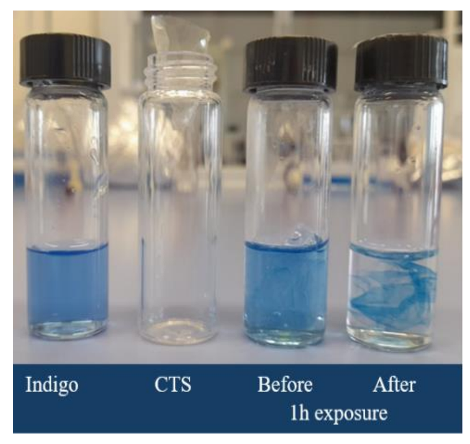
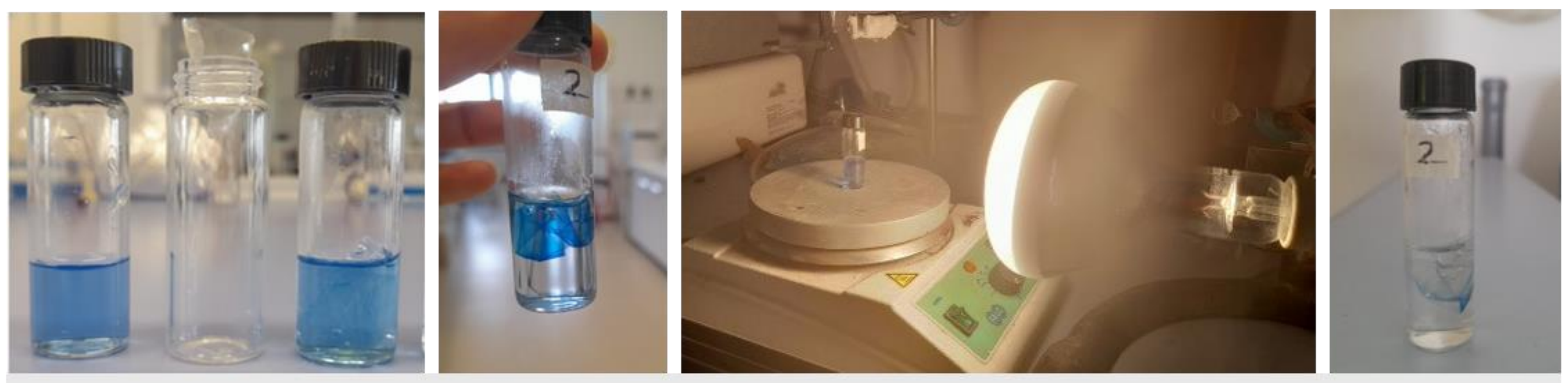


Figure 4: CTS film immersed in indigo water samples received from partner company.



ITS + CTS => ITS-CTS After 1 hour immersion 2h UV-vis exposure Complete Decolouration

CONCLUSION

Biodegradable chitosan (CTS) films were successfully developed for the efficient removal of indigo carmine (IC) from water and wastewater. The optimized 1% CTS–1.5% acetic acid film cast on polyethylene showed excellent stability, transparency, and rapid dye adsorption. Complete decolorization occurred within one hour, followed by UV-induced photodegradation of the adsorbed dye. These results confirm a dual adsorption–photodegradation mechanism and demonstrate the potential of CTS films as low-cost, eco-friendly materials for sustainable wastewater treatment.

FUTURE WORK / REFERENCES

Future work will focus on optimizing CTS film reusability, biodegradation, and large-scale application for sustainable wastewater treatment.

REF:

1. F. S. C. Dos Anjos, E. F. S. Vieira, and A. R. Cestari, "Interaction of indigo carmine dye with chitosan evaluated by adsorption and thermochemical data," *J. Colloid Interface Sci.*, vol. 253, no. 2, pp. 243–246, 2002, doi: 10.1006/jcis.2002.8537.
2. G. L. Dotto, J. M. Moura, T. R. S. Cadaval, and L. A. A. Pinto, "Application of chitosan films for the removal of food dyes from aqueous solutions by adsorption," *Chem. Eng. J.*, vol. 214, pp. 8–16, 2013, doi: 10.1016/j.cej.2012.10.027.
3. J. K. Fatombi *et al.*, "Adsorption of Indigo Carmine from Aqueous Solution by Chitosan and Chitosan/Activated Carbon Composite: Kinetics, Isotherms and Thermodynamics Studies," *Fibers Polym.*, vol. 20, no. 9, pp. 1820–1832, 2019, doi: 10.1007/s12221-019-1107-y.
4. G. Ali, M. Sharma, E. S. Salama, Z. Ling, and X. Li, "Applications of chitin and chitosan as natural biopolymer: potential sources, pretreatments, and degradation pathways," *Biomass Convers. Biorefinery*, vol. 14, no. 4, pp. 4567–4581, 2024, doi: 10.1007/s13399-022-02684-x.
5. J. Wang and S. Zhuang, "Removal of various pollutants from water and wastewater by modified chitosan adsorbents," *Crit. Rev. Environ. Sci. Technol.*, vol. 47, no. 23, pp. 2331–2386, 2017, doi: 10.1080/10643389.2017.1421845.