

Adsorption of anionic dyes using functionalized cellulose as adsorbent.

Jessica Tsakani Mhlongo, Anita Etale, Yannick Nuapia
School of chemistry, Witwatersrand



Water pollution by synthetic dyes

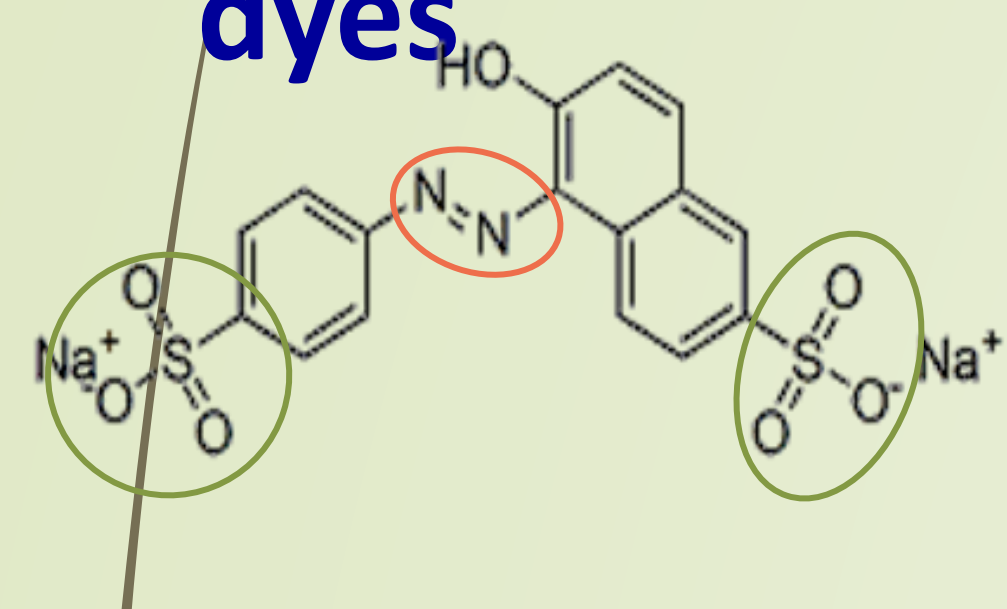


Fig 1: Sunset Yellow

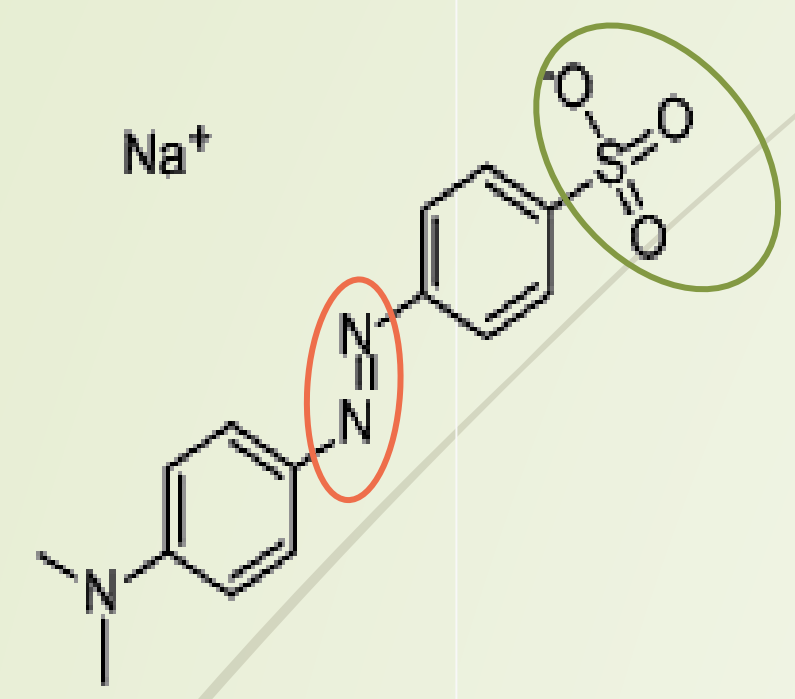
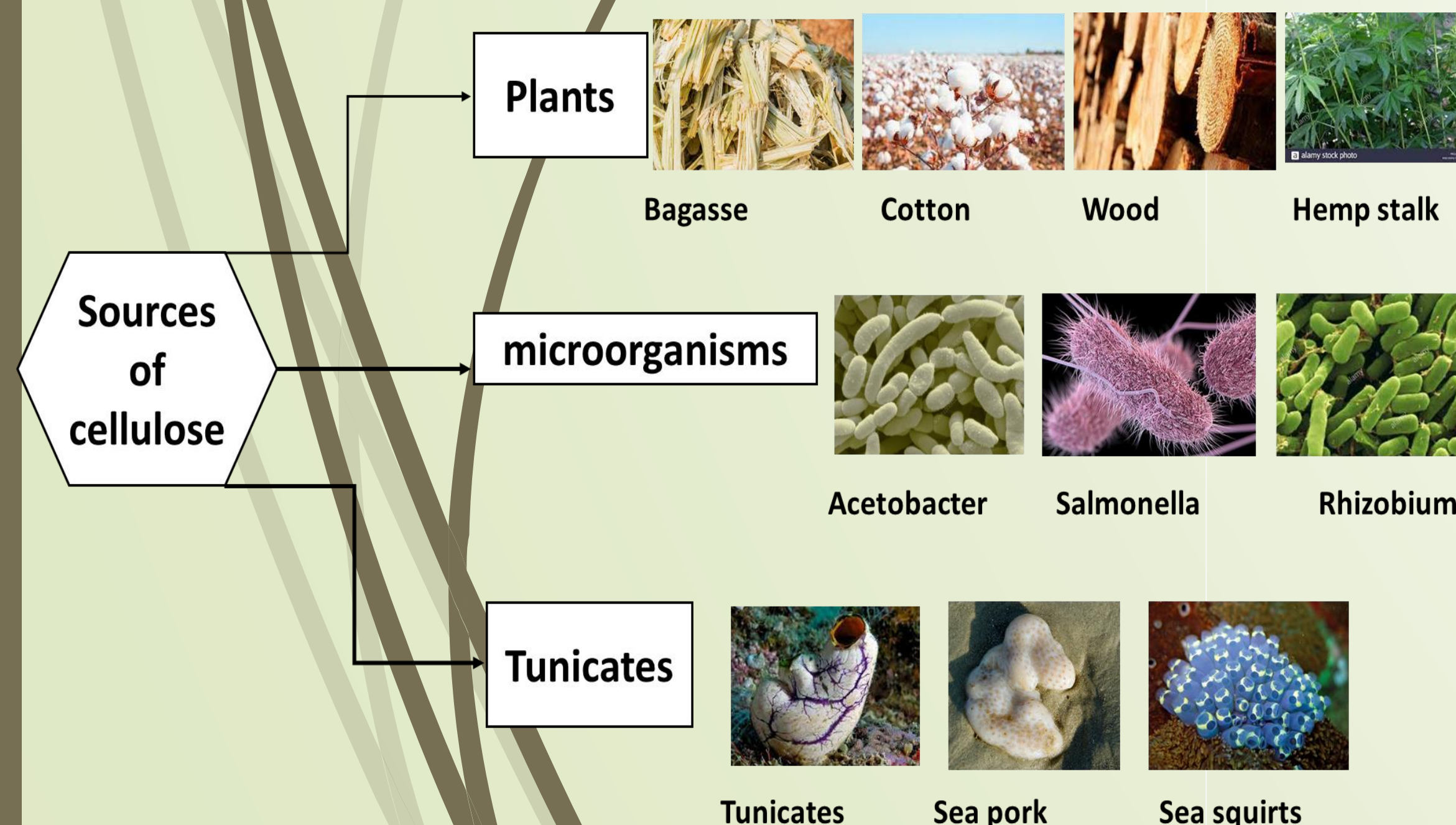


Fig 2: Methyl orange

- Synthetic dyes found in paper, printing, textile and food industries
- ~ 8^{10} tons of dye are produced every year worldwide
- 10-15% of dyes end up in industrial wastewater effluents
- Dye WWT methods include coagulation, flocculation, adsorption, ultrafiltration, biodegradation, and electrocoagulation ^{2,3,4}

Cellulose sources, uses and properties

- Most abundant natural polymer on earth, with an annual production of up to 10^{12} tones
- Unique properties: wide availability, low cost, high strength, biodegradability, renewability
- Raw hemp stalks contain ~72% cellulose and most under-utilized agricultural residue sources of cellulose



Aims and objectives

Aims

- Extraction and synthesis of functionalized cellulose for use as low-cost adsorbent.

Objectives

- Extract cellulose from hemp stalk
- Prepare cationic cellulose from cellulose fibers using glycidyl trimethylammonium chloride (GTMAC)
- Characterize using SEM, and NMR
- Adsorption studies : pH studies, adsorbent dosage studies, concentration studies, temperature studies and time studies

Experimental procedure

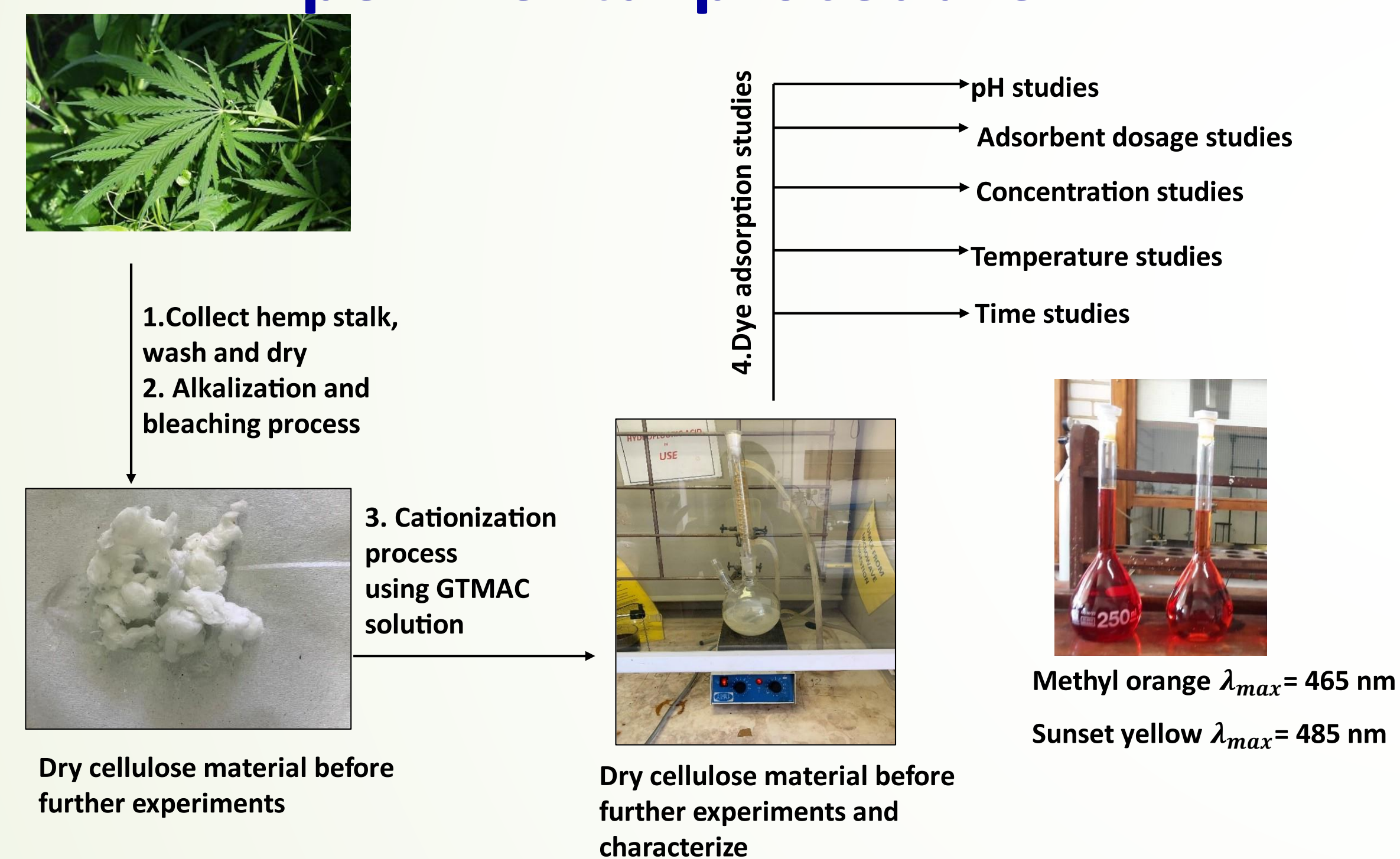


Fig 3: Schematic for experimental protocol

Characterization results and discussion

- Using SEM imagery, bleached cellulose has long rod-like features whereas after cationization it displayed shorter rod-like features.
- Carbon NMR spectra confirmed the incorporation of GTMAC carbons at ~52 ppm due to the quaternary amines' salts
- With regards to crystallinity of the celluloses, the C-4 and C-6 region signal that the broad peak represents the amorphous region while the sharp peak represents the crystalline region

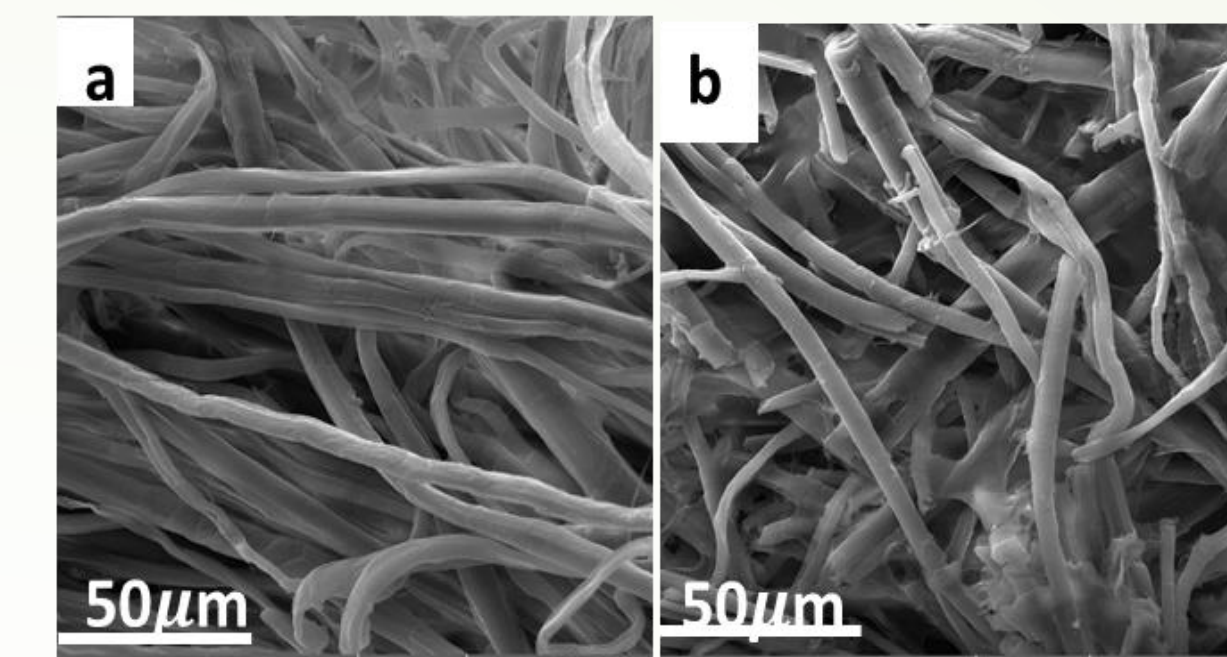


Figure 4: SEM images of a) bleached cellulose b) cationised cellulose

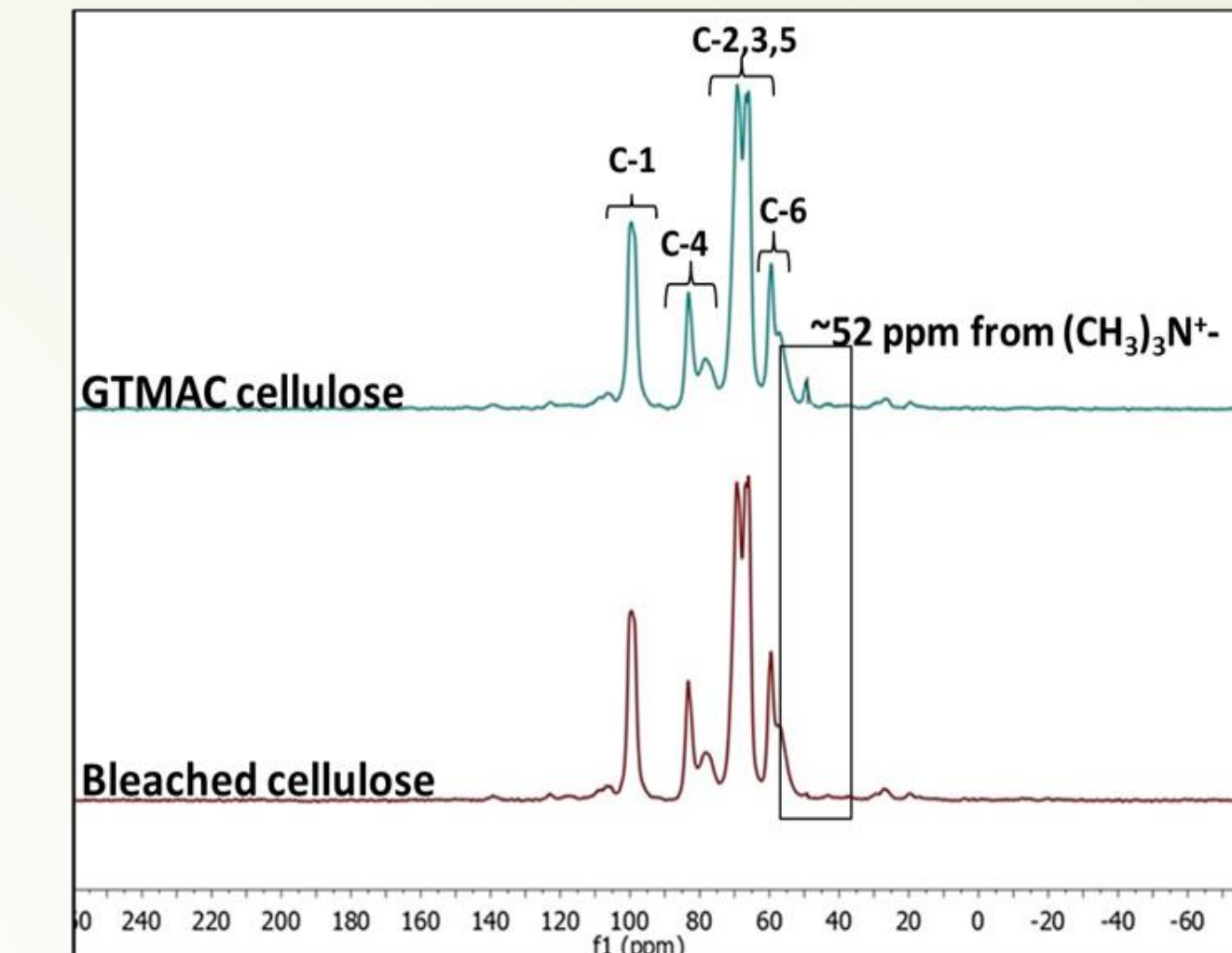


Figure 5: NMR spectra of bleached cellulose and Cationised cellulose

Adsorption studies results and discussion

- Removal of dye contaminants from the wastewater largely depends on the pH of the solution, which affects surface charge of the adsorbent.
- The zero-point potential of the adsorbent was at pH_{pzc} 4.01.
- Interaction can be attributed to not only electrostatic but also hydrogen bonding and/or Van der Waals interactions

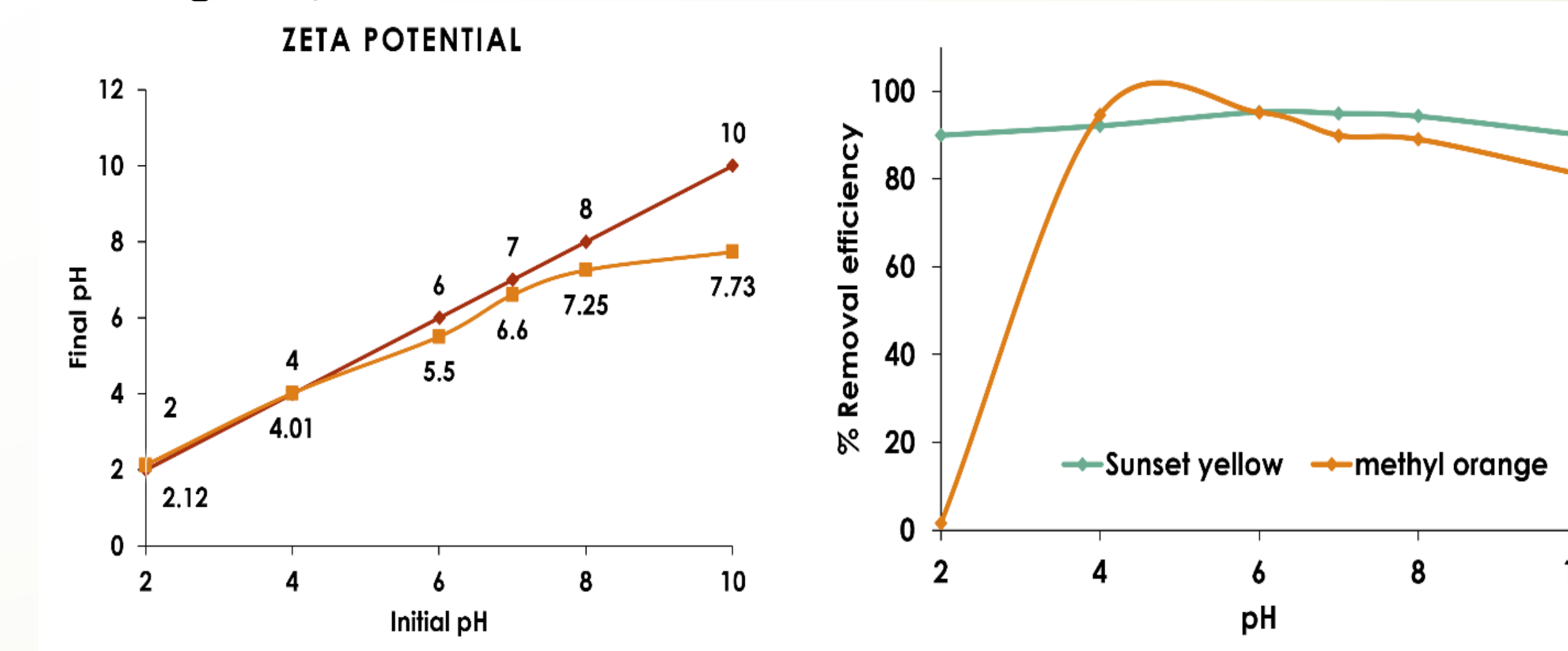


Fig 6: Effect of pH on methyl orange and sunset yellow uptake onto GT-cellulose.

A lower adsorbent dosage (10 mg) was more favorable for methyl orange and sunset yellow uptake due to increased adsorption capacity of the adsorbent material. High adsorption capacities were observed at room temperature for studies on the effect of temperature for dye adsorption. The adsorption capacity of methyl orange and sunset yellow dyes onto GT-cellulose reached equilibrium uptake at 120 mins for 20 ppm concentrations

Effect of adsorbent mass

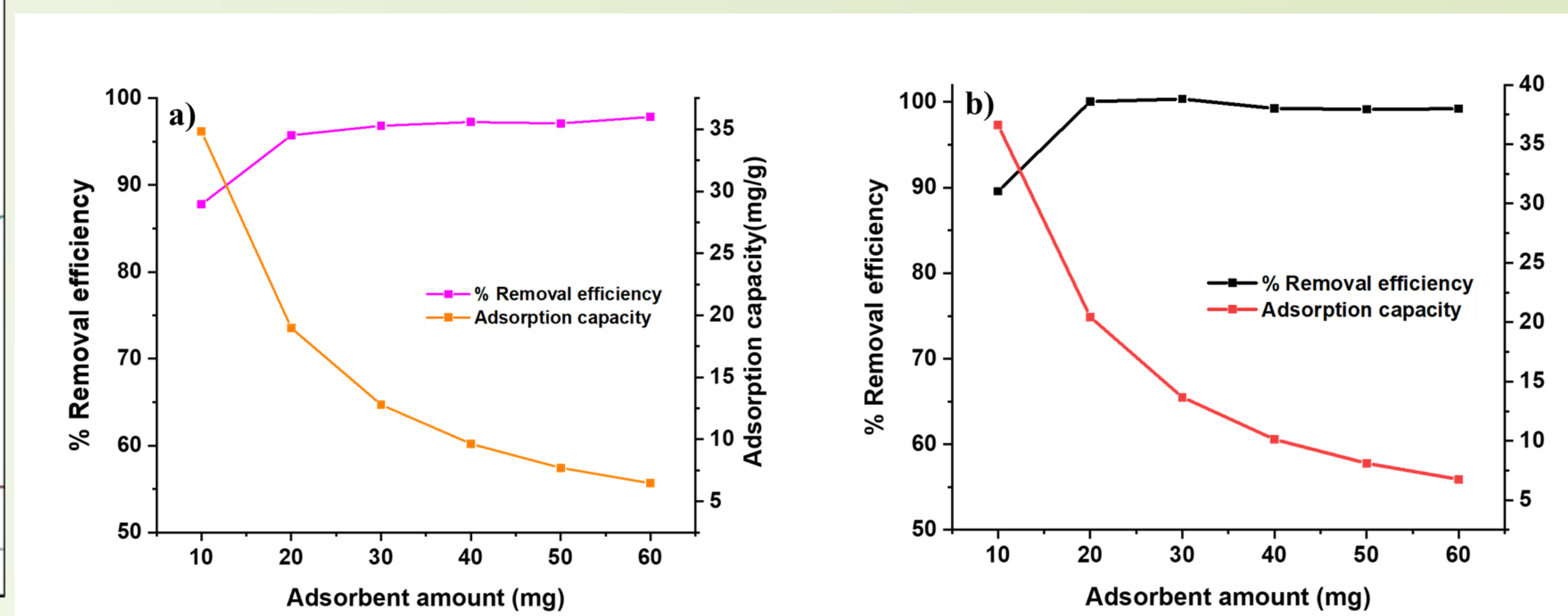


Fig 7: Effect of adsorbent mass on the uptake of a) Methyl orange and b) sunset yellow onto cationised GT-cellulose adsorbent.

Effect of temperature

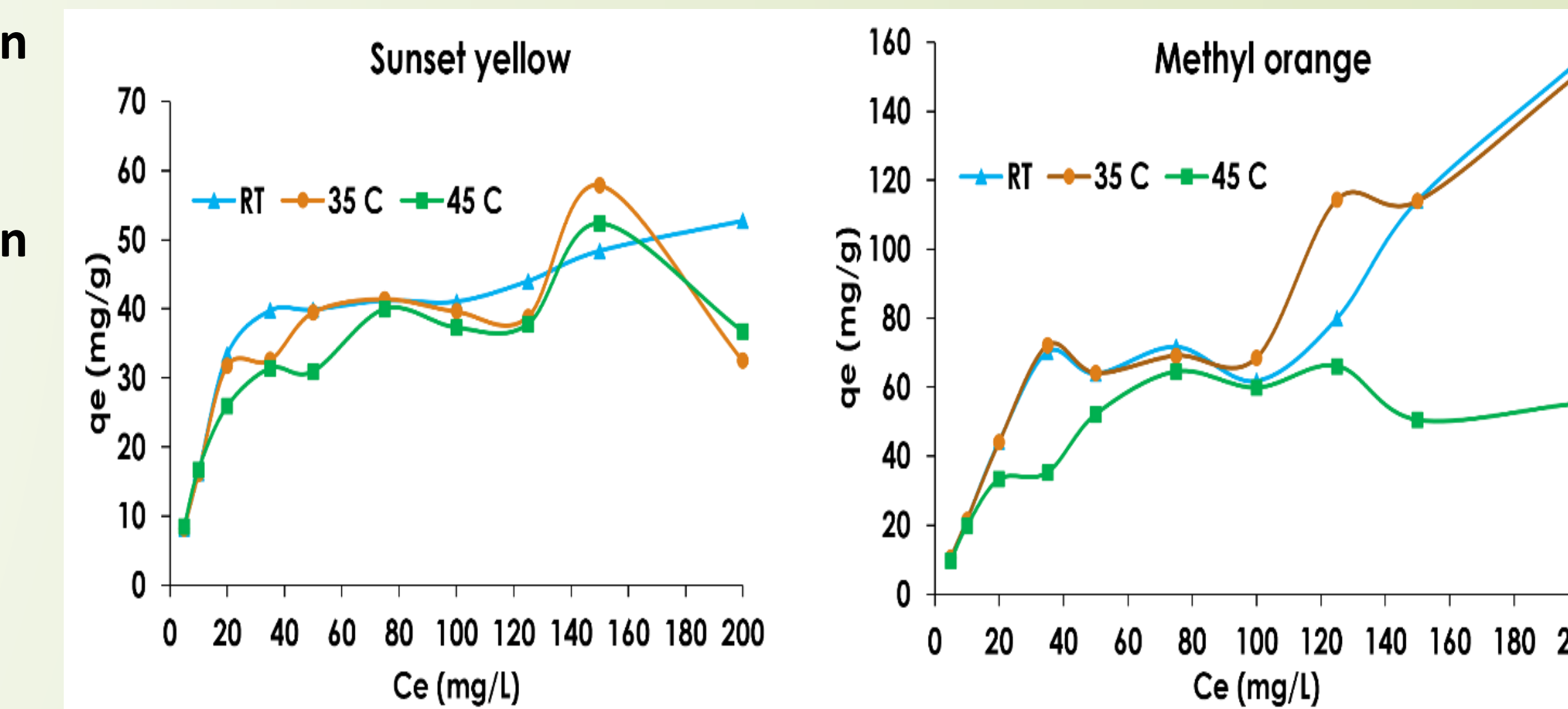


Fig 8: Effect on temperature on the uptake of a) sunset yellow and b) methyl orange onto GT-cellulose adsorbent.

Conclusion

- Cellulose fibers were successfully extracted from hemp stalk
- GTMAC can be used as an effective cationising agent provided there is no ethanol wash step
- GTMAC cellulose was successfully applied as an adsorbent for dye removal and showed excellent removal efficiencies

Acknowledgments

- Dr. Anita Etale and Dr. Yannick Nuapia
- Environmental analytical group
- NRF and Royal society for funding