

Chapter-7

Conclusions

- An attempt was made to make several novel green and efficient catalysts as well as adsorbents to be applied for the removal and degradation of Rh-6G, RR-141 and RB-21 and their mixtures as well as degradation of nitrophenol.
- Capped silver catalysts were prepared by using palm shell extract and guar gum as reducing and stabilizing agents. Furthermore nano composites were prepared using palm shell capped Ag and chitosan (CAGPS) and Chitosan Guar gum blend (CGAGPS)
- The prepared catalysts were effective in degradation of Rh-6G, RR-141 and RB-21 as well as their mixtures including reduction of TOC. They were also found to be effective as SERS substrates especially for Rh6G where enhancement was of the order of 10^4 . The presence of Guar gum led to no SERS enhancement for RB-21. RR-141 did not show a significant SERS enhancement for any of the substrates under study.
- To the best of our knowledge there are no reports on the use of plant extract capped silver nano particles as SERS substrates and as catalysts for degradation of dyes
- GAg and CGAGPS could degrade the dyes (100 ppm) in 2 minutes while for mixture of dyes it took 24 hr. Maximum TOC reduction was with CGAGPS for RB (80%), 60% for RR while GAg and AgPS were effective in reducing 75 % TOC for Rh6G. CGAGPS and CAGPS were effective in reducing 55% TOC for binary mixtures of the dyes under study.
- The degradation of the dyes was by the Reactive oxygen species like superoxide ($O_2^{\cdot-}$), hydroxyl radical ($\cdot OH$), hydrogen peroxide and singlet oxygen (1O_2) produced during the decomposition of H_2O_2 by the silver nanoparticles and their composites under study.
- The advantage of the catalytic process adopted is that textile effluents contain H_2O_2 which could be used effectively for the degradation of dyes.
- Furthermore the nanoparticles and their composites under study were also effective in reducing nitrophenol to aminophenol. AgPS and CAGPS took 5min and 8 min respectively for the reduction.

- An attempt was also made to make capped iron oxide nano particles (IO) as well as their composite with chitosan (CIO) to study their potential in the catalytic Fenton degradation of dyes. IO and CIO were found to be composed of mixtures of Fe_3O_4 , $\gamma\text{-Fe}_2\text{O}_3$ and $\alpha\text{-Fe}_2\text{O}_3$. We were able to obtain unique superparamagnetic Iron oxide nanoparticles (SPIONS). CIO showed large negative isomer shift in its Mossbauer spectra. To the best of our knowledge there are no reports till date for plant base extract capped SPIONS.
- IO and CIO were effective in degrading the three individual dyes in 2 min and took on average 35 min for degradation of dyes in mixtures except that IO was not able to degrade completely RB+ RH mixture even after 24h.
- The clay chitosan bionano composites under study (C, NC, CC, HT, CHT, H-0.2) were effective as adsorbents for the removal of Rh6G, RR141 and RB21 as well as their binary mixtures. The adsorption capacity was found to reduce on an average to an extent of 20%. The adsorption capacity of the adsorbents under study was comparable and in many cases much better to the adsorbents reported in literature. Langmuir model could not give a clear picture about competitive adsorption in binary mixtures while JS model could predict the extent of competitive adsorption.
- Zirconium phosphate(ZrP) nanoparticles were effectively prepared by the autoclave technique which were also incorporated into chitosan to form a bionanocomposite(CZrP).
- ZrP and CZrP could be used both as an adsorbent and as a catalyst for the removal/degradation of dyes as well as their binary mixtures.
- There are no reports till date where catalytic degradation of binary mixture of dyes was investigated more so involving cationic and anionic dyes. Though recently there are adsorption studies involving mixture of dyes, no studies have been done that involves both cationic and anionic dyes. It was observed that competitive adsorption existed to different extents on different adsorbents.
- ZrP functioned as a catalyst for the disproportionation of H_2O_2 , as a support for H_2O_2 through peroxo complex formation, as well as a support for the substrate to be degraded by adsorption.

- Nano particles of zirconium tungstate (ZrW) could be prepared effectively by autoclave technique. ZrW and its bionanocomposite with chitosan (CZrW) were effectively used as catalysts for the degradation of dyes. As discussed in chapter 6 there are multiple mechanisms which could be playing a role in the functioning of ZrW and CZrW as catalysts. They were also effective as photocatalysts, in the presence of H₂O₂.
- There have been no reports on the use of ZrW as catalysts for the degradation of dyes till date.

Scope of future work

- The effectiveness of the nanoparticles under study as SERS substrates needs to be affirmed by taking the SERS spectra for different concentration of dyes as well as after deposition of nanoparticles on thin substrate
- Though the effectiveness of the prepared nanoparticles as SERS substrates for dyes has been investigated, their effectiveness for 4-Nnitrophenol has not been studied. The effectiveness of the nanoparticles under study as SERS substrates can be investigated for nitrophenol and other pollutants as well.
- Efforts could be made to prepare more uniform sized nanoparticles to obtain still better SERS enhancement.
- Further investigations need to be done for characterization of ROS generated during degradation of H₂O₂ by the catalysts under study.
- The formation of rod shaped ZrP in chitosan matrix is surprising as well as interesting. Further investigations in this direction would be of interest
- Further investigations are warranted regarding interaction between chitosan and palm shell extract as the SPIONS formed CIO and their unique Mossbauer spectra are interesting. Further experiments need to be done with reference to Mossbauer spectroscopy (spectra at different temperatures need to be taken) to understand the nature of SPIONS formed.

- Furthermore since SPIONS are known to be T2-type contrast agents in MRI imaging and IO and CIO are biocompatible they could have magnetic resonance (MR) signal-enhanced property and could have potential to function as T2 type contrast agents. Efforts in this direction would be useful
- Thus future development of novel green bionanocomposites with improved properties and multi functionality can be envisaged as an emerging, field of research, with plenty of possibilities because of the great abundance and diversity of biopolymers in nature, as well as the advantage of their synergistic combination with inorganic nanosized solids.