Chapter 6

Conclusions and Recommendations

6.1 General

The aim of the present study was to reduce the MB dye by photocatalytic degradation. This could be accomplished by using undoped, La doped, I doped and La-I co-doped TiO_2 photocatalysts prepared by citric acid assisted solution-combustion technique.

6.1.1 The dye degradation with La doped TiO_2 photocatalysts

- La-doped TiO_2 photocatalysts, $Ti_{1-x}La_xO_2$ (x = 0.00, 0.005, 0.01, 0.015, 0.02 and 0.025) were synthesized successfully by the solution-combustion method.
- The synthesized La-doped TiO_2 photocatalysts were utilized for photodegradation of dye in simulated dye solutions in a photochemical reactor with quartz tube.
- In UV-PCR reactor the 1.5% La-doped TiO_2 photocatalyst showed the best photocatalytic activity among all the synthesized undoped and La-doped TiO_2 photocatalysts.
- The photocatalytic activity of the synthesized photocatalyst was enhanced with La doping in TiO_2 up to a particular concentration (0.5-1.5%). After that, the activity declined (2-2.5% La doping in TiO_2).
- The rate of dye degradation follows the pseudo-first-order kinetics in a UV-PCR reactor with a simulated dye solution.
- The photodegradation of the dye with the regenerated 1.5% La-doped photocatalyst shows that the activity of photocatalyst decreases with the number of regenerations of the photocatalysts. After the fifth cycle, a loss of 7.85% of activity.
- The result of a comparative study among the synthesized undoped TiO_2, 1.5% La-doped, and commercial Aeroxide P-25 shows that the 1.5% La-doped photocatalyst has

better photocatalytic activity than both undoped TiO_2 and Aeroxide P-25 photocatalysts.

6.1.2 The dye degradation with I-doped TiO_2 photocatalysts

- I-doped TiO_2 photocatalysts with compositions $Ti_{1-x}I_xO_2$ (x = 0.01, 0.02, 0.03, 0.04, and 0.05) were prepared by a solution-combustion route, and their photocatalytic activities were determined by photodegradation of dye in simulated dye solution in UV-PCR.
- The results of dye degradation showed that the 3% of I-doped TiO_2 photocatalyst exhibited the best photocatalytic activity among all the synthesized undoped and I-doped TiO_2 photocatalysts UV-PCR.
- The photocatalytic activity of the synthesized photocatalyst was enhanced with I doping in TiO_2 up to a particular concentration (1-3%). After that, the activity declined (4-5% I doping in TiO_2).
- The rate of dye degradation follows the pseudo-first-order kinetics.
- The photodegradation results of regenerated $Ti_{0.97}I_{0.03}O_2$ photocatalyst revealed that the activity of the photocatalyst decreased with the increasing number of regenerations. After the fifth cycle, a loss of 10.13% of activity.
- A comparison among the synthesized undoped TiO_2, $Ti_{0.97}I_{0.03}O_2$, and commercial Aeroxide P-25 revealed that the synthesized $Ti_{0.97}I_{0.03}O_2$ photocatalyst exhibited the highest photocatalytic activity.
- A phytotoxicity study was conducted to assess the benefit of photocatalytic treatment of MB dye solution by examining the toxicity effect of MB dye on mung beans.
- The germination was found to be low in phytotoxicity test in *Vigna radiata* (59.09%) seeds irrigated with MB (untreated water), whereas 93.18% with treated water and 100% with control (distilled water), showing potential use of treated water in irrigation.

6.1.3 The dye degradation with La-I co-doped TiO_2 photocatalysts

- La-I co-doped TiO_2 photocatalysts with compositions $Ti_{1-x-y}La_xI_yO_2$, where x = 0.00 – 0.05, y = 0.00 – 0.005) were prepared by a solution-combustion route and their photocatalytic activities were determined by photodegradation of dye in simulated dye solution in UV-PCR.
- The results of dye degradation showed that the 2% La & 3% of I co-doped TiO_2 photocatalyst exhibited the best photocatalytic activity among all the synthesized undoped and La-I co-doped TiO_2 photocatalysts in UV-PCR.
- The rate of dye degradation follows the pseudo-first-order kinetics.
- The photodegradation results of regenerated 2% La & 3% of I co-doped photocatalyst revealed that the activity of the photocatalyst decreased with increasing number of regenerations. After the fifth cycle, a loss of 11.67 % of activity.
- A comparison among the synthesized undoped TiO_2, 2% La & 3% of I co-doped, and commercial Aeroxide P-25 revealed that the synthesized 2% La & 3% of I co-doped photocatalyst exhibited the highest photocatalytic activity among the three.
- A phytotoxicity study was conducted to examine the harmful effects of MB dye on mung beans.
- The germination was found to be low in phytotoxicity test in *Vigna radiata* (70%) seeds irrigated with MB (untreated water), whereas 90% with treated water and 100% with control (distilled water), showing potential use of treated water in irrigation.

6.1.4 Recommendations for future studies

- The degradation of similar dye should also be studied with the synthesized photocatalysts.
- To handle large amount of dye-contaminated wastewater for dye degradation, the design and fabrication of photochemical reactor is required.

- A scale-up study should be undertaken, and the catalyst's performance should be studied using different reactor configurations.

LIST OF PUBLICATIONS

1. **Veeresh Verma**, Satya Vir Singh, La-doped TiO_2 Nanoparticles for Photocatalysis: Synthesis, Activity in Terms of Degradation of Methylene Blue Dye and Regeneration of Used Nanoparticles, Arabian Journal for Science and Engineering, 2023, DOI: https://doi.org/10.1007/s13369-023-08325-3 **SCI, IF-2.6**
2. **Veeresh Verma**, Satya Vir Singh, Augmentation of photocatalytic degradation of methylene blue dye using lanthanum and iodine Co-doped TiO_2 nanoparticles, their regeneration and reuse; and preliminary phytotoxicity studies for potential use of treated water, Journal of Environmental Chemical Engineering, 2023, DOI: https://doi.org/10.1016/j.jece.2023.111339 **SCI, IF-7.4**
3. **Veeresh Verma**, Sudhakar Saroj, Vivek Kumar Jaiswal, Satya Vir Singh, Remediation of methylene blue water solution with iodine doped TiO_2 nanoparticles and their regeneration: For reuse and check phytotoxicity level of treated water, Optical Materials, 2024, DOI: https://doi.org/10.1016/j.optmat.2024.115521 **SCI, IF-3.8**