CHAPTER 8

Summary and Suggestions for Further Work

On the basis of the experiments performed, results obtained and evaluation done, following significant conclusions can be drawn:

- TiO_2 nanoparticles are successfully synthesized from a novel green source of *Syzygium cumini* (Jamun) leaf extract, which acted as a capping/stabilizing agent.

- Crystalline nature and anatase phase of the synthesized TiO_2 particles is confirmed from the XRD analysis. Also, the crystalline size of green synthesized TiO_2 NPs is calculated by Debye Scherrer's equation and found to be in the range 11-13nm.

- Other characterization techniques like HR-SEM, HRTEM and BET are adopted to know the size, shape and surface area of the green synthesized TiO_2 nanoparticles. Results obtained from the characterization techniques confirmed that spherical shape of particles with size in the range 10 nm to 13 nm. Also, the synthesized particle surface area is found to be $105 m^2 g^{-1}$ with 2:1 ratio of leaves extract to metal precursor.

- Particle suspension and stability is confirmed by Zeta potential analysis.

- TiO_2 NPs are also studied for their antibacterial performance against gram negative (*E. coli*) and gram positive (*B.cereus*).

- Synthesized nanoparticles are successfully used as a photo-catalyst for removal of lead from explosive industry waste water in a cost-effective way with 75.5 %

removal of chemical oxygen demand (COD) and 82.53 % removal of lead (Pb^{2+}).

- Kinetic study reveals that 1st order kinetics is followed for photo-catalytic removal of lead as well as the COD removal by the TiO_2 NPs

- Green synthesized TiO_2 NPs are successfully immobilized into the PDMS polymer to study the photo catalytic degradation of methylene blue dye solution and degradation efficiency of dye up to 88.9% is achieved using immobilized particle to overcome the drawbacks of using particles in suspended form without much compromising the efficacy of the particles.

- Silica nanoparticles are synthesized from a green source, i.e., *Bambusa bambos* (bamboo) leaf through thermal combustion and precipitation technique and are appplied to enhance the photocatalytic efficiency of TiO_2NPs.

- Dye degradation studies reveal that, addition of SiO_2 nanoparticles along with TiO_2 nanoparticles in the ratio1:4 have improved the degradation from 88.9 % to 94.66 %.

- SiO_2 NPs are also succesfully used as inorganic filler material to improve the pervaporation performance of polydimethylsiloxane (PDMS) membrane.

- Polymeric membrane with varying dosage of nano-silica, 2 to 6 %, is synthesized from PDMS polymer solution by solution casting method.

- Pervaporation performance evaluation study reveals a significant improvement in membrane pervaporation flux in presence of SiO_2 NPs compared to membranes without nanoparticles.

- Cost analysis of synthesized and commercial TiO_2 and SiO_2 NPs

Cost Analysis of Synthesized Nanoparticles

Cost Analysis - synthesis of TiO_2 NPs (1gm)		
Item	**Quantity**	**Approx. Cost (INR)**
Raw Materials cost		
TTIP (Titanium isopropoxide)	1gm	45
Leaf Extract	500ml	0
Process cost		
Electricity	12 units	60
Filtration	-	12
Total Cost	**=**	**Rs. 117**
Cost of commercially procured (from Sigma Aldrich) TiO_2 NPs (1gm)		**Rs. 220**

Cost Analysis - synthesis of SiO_2 NPs (1gm)		
Item	**Quantity**	**Approx. Cost (INR)**
Raw Materials cost		
Bamboo Leaves	250 gm	0
HCl	10 ml	10
NaOH	1 gm	10
H_2SO_4	0.5 ml	10
Process cost		
Electricity	12 units	60
Filtration	-	12
Total Cost	**=**	**Rs. 102**
Cost of commercially procured (from Sigma Aldrich) SiO_2 NPs (1gm)		**Rs. 150**

Thus, green approach for nano particle synthesis not only benefited the process by making it more environmental friendly but also stands economical.

Suggestions for Further Work

Even though detailed studies on the synthesis, characterization and application of nanoparticle is elaborated in current work, due to various constraints and time limitation several aspects related to synthesis of nano-particles, their use as photo catalyst in

wastewater treatment, their applicability as filler for separation process are left unexplored. Hence, it would be interesting to carry out further investigations as mentioned below:

- Various other techniques to address the problem of nanoparticle agglomeration can be explored.
- Development of environment friendly materials with excellent properties can be investigated.
- New leaf extract or different parts of plant can be tested for the synthesis of nanomaterial.
- Scale up studies from lab to bench to pilot could be done.
- Usage of various waste water sources for the treatment can be explored.
- Membrane synthesis using different solvents can be done.
- Alternate green sources for SiO_2 NPs can be investigated.
- Comparative studies with commercially available nanoparticle can be explored.

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