SUMMARY AND CONCLUSION

1. In situ incorporation of meso-Al₂O₃ into the MCM-41 to produce high surface area and chemically/thermally stable mesoporous support mesoporous alumina (AM) using starch as a template. The surface modification of mesoporous support AM through incorporation of copper generates a highly efficient adsorbent/catalyst (5 Cu/AM 10).

2. The 5 Cu/Al₂O₃-MCM-41 and Al₂O₃-MCM-41 showed intra-particle mesoporosity and high textural properties such as high surface area, narrow pore diameter and wide pore volume which gives platform to adsorb MB, MV, MG and Rd 6G.

3. The intra-particle mesoporosity, electron transfer and generation of •OH are the key properties of 5 Cu/Al₂O₃-MCM-41 aids to degrade high concentrated 500 mg/L dyes within 30 minutes.

4. 5 Cu/Al₂O₃-MCM-41 is not only an efficient catalyst for single dye degradation process but also treated as an excellent catalyst for mixed dyes degradation.

5. Thus, 5 Cu/Al₂O₃-MCM-41 act as an efficient photocatalyst/adsorbent for photocatalytic degradation and adsorption of dyes and will act as a futuristic material to control the industrial pollution.

6. The mesoporous 5 Cu/Al₂O₃-MCM-41 composites is found to be photo-Fenton like catalyst and showed excellent activity for degradation of phenolic compounds (phenol, 2-chloro-4-nitrophenol and 4-chloro-2-nitrophenol) in presence of sunlight.

7. The 5 Cu/Al₂O₃-MCM-41 and Al₂O₃-MCM-41 showed intra-particle mesoporosity and high textural properties such as high surface area, narrow pore diameter and wide pore volume which gives platform for degradation of phenolic compounds.

8. Small particle size, easy reducibility of copper metal, stabilization of Cu²⁺ in mesoporous support Al₂O₃–MCM-41, high textural property and active on visible light are the key factors for degradation of phenolic compounds over 5 Cu/Al₂O₃–MCM-41.
9. The generation of hydroxyl radical in presence of $\text{H}_2\text{O}_2$, sunlight and $5 \text{Cu/Al}_2\text{O}_3$–MCM-41 is responsible for degradation of phenolic compounds (100 mg/L) within 45 minutes at pH 4.

10. The photo-Fenton degradation of phenolic compounds followed first order kinetics.

11. Fabrication of meso-$\text{MnO}_2$-MCM-41 by incorporating meso-$\text{MnO}_2$ into the extra framework of MCM-41 using soft template (CTAB) yielded a high surface area and chemically/thermally stable, mesoporous, semiconducting nanocomposite material (meso-$\text{MnO}_2$-MCM-41).

12. The mesoporous semiconducting nanocomposite (meso-$\text{MnO}_2$-MCM-41) was prepared by varying Si/Mn ratio (10, 50, and 90) as meso-$\text{MnO}_2$-MCM-41(10), meso-$\text{MnO}_2$-MCM-41(50) and meso-$\text{MnO}_2$-MCM-41(90).

13. The coordination of Mn to a Si atom through oxygen atom in the extra framework region of MCM-41 is the most vital point for the increase of textural property of meso-$\text{MnO}_2$-MCM-41(10).

14. Among all the catalysts, meso-$\text{MnO}_2$-MCM-41(10) showed the highest surface area (1313 m$^2$ g$^{-1}$); narrow pore diameter (2.04 nm) and high pore volume (0.86 cm$^3$ g$^{-1}$).

15. The intra particle mesoporosity, high surface area, narrow pore diameter and high pore volume able to form a platform for effective adsorption of dyes such as Rd 6G, MB, MG, Rd B (100 mg L$^{-1}$).

16. The electron transfer and generation of $\text{HO}^-$ and photo response (band gap (1.9 eV) are the important properties of the meso-$\text{MnO}_2$-MCM-41(10) for the degradation of dyes in 60 min.

17. The meso-$\text{MnO}_2$-MCM-41(10) composite exhibited 100 % photo degradation and adsorption activity towards 100 ppm dye solution in 60 min and 90 min, respectively.

18. Mesoporous MnO$_2$ nanoparticles (meso-MnO$_2$ NPs) in situ incorporated into the extraframework of MCM-41, formed a mesoporous MnO$_2$NPs–MCM-41(MM). The synthesis of MM based on the incorporation mesoporous nanoparticles into the mesoporous architect.
19. Role of CTAB as a surfactant and ammonium hydroxide as a structure directing agent for fabrication of meso-MnO$_2$ NPs and mesoporous Fe@MM nanocomposite were highly significant.

20. Mesoporous Fe@MM nanocomposite treated as a dual catalyst such as photo-Fenton catalyst and photocatalyst for degradation of phenolic compounds, an exemplary move. Nearly 100% degradation took place within 45 minutes with high concentration of phenolic compounds (100 mg L$^{-1}$) by mesoporous 5 Fe@MM 10 nanocomposite under ambient conditions.

21. Mesoporosity, Small particle sizes of nanocomposite and quick reduction of Fe(III) are the key points for proficient degradation of phenolic compounds synthesis of high surface area mesoporous Cu/ZrO$_2$-MCM-41 by incorporating mesoporous ZrO$_2$ into MCM-41 framework (in situ) followed by impregnating different wt % of Cu (2, 4, 6 and 8) onto the surface of mesoporous ZrO$_2$-MCM-41 and utilized in photo-reduction of Cr (VI).

22. Photo-reduction of Cr (VI) takes place in acidic medium. The initial rate of photo-reduction of Cr (VI) increases with increasing the catalyst dose up to 0.8 g/L and there after it remains constant.

23. The photo-reduction of Cr (VI) was studied in the wide range of chromium concentration from 2 to 50 mg/L. It was observed that the initial rate of photo-reduction is high in case of 20 mg/L of Cr (VI), for higher concentration the rate decreases.

24. The photo-reduction of Cr (VI) over 2Cu/ZrO$_2$-MCM-41 follows pseudo first-order kinetics. The apparent rate constant values ($k$) were found to decrease with increase in the initial concentration of Cr (VI).

25. The intra particle mesoporosity, surface area and highly dispersed Cu$^{2+}$ are the key factors for the photo reduction Cr (VI) of nearly 100% under solar light irradiation within 30 min reaction time.

26. The mesoporous nanocomposite 2Cu/ZrO$_2$-MCM-41 can be reused for the further treatment.

27. The catalytic activity of the composite Cu/ZrO$_2$-MCM-41 was also evaluated towards benzene oxidation using H$_2$O$_2$ as the oxidant in acetic acid solvent at room temperature.
28. The effect of reaction parameters i.e. effect of solvent and effect of catalyst on the substrate was also investigated.

29. Among the catalysts studied 4 wt% copper loaded ZrO$_2$-MCM-41 showed maximum conversion (32%) and selectivity (96%) towards phenol.

**Future Scope of work**

The composite materials can further be used in various research works. Functionalized mesoporous silica materials are in the fore-front for the last two decades in research for practical applications as adsorbents, sensors and catalysts. The incorporation of transition metals into the framework of silica has enhanced the activity to many folds as adsorbent. The modification by metal-oxides and organic groups has tremendous effect on the increasing activity for remediation of environmental pollution as well as in various chemical conversions with practical applications. The composite materials can be used in water splitting and other organic transformations.