Chapter 7

Conclusions
In this thesis the effect of cavitation on different physical and chemical processes and its comparison with the conventional methods have been reported. The use of ultrasound plays an important role in emulsion polymerization, synthesis of nanoparticles and also in the extraction of compounds from plants due to extreme environment generated because of cavitation effects of ultrasound. In this work, four systems viz. Hydrogel synthesis, TiO$_2$ synthesis, calcium carbonate synthesis and extraction of curcumin were taken for the comparison purpose. The following are the conclusions drawn based on the use of ultrasound for different systems:

- Ultrasound assisted in situ emulsion polymerization improves the dispersion of bentonite-FeCo into PAA matrix because of physical effects and enhances the rate of polymerization due to chemical effects. The crosslinked polymer hydrogel network formed in presence of ultrasound showed a good swelling behaviour due to the presence of bentonite. Poly(acrylic acid) and bentonite clay were able to form network structures without any organic cross-linker. The addition of B-FeCo served the dual purpose of providing the mechanical strength to the hydrogel as well as increased the adsorption capacity due to improvement in the electrostatic interaction. Further, the adsorption of dye was also successfully carried out and the equilibrium data for adsorption showed good agreement with both Langmuir and Freundlich isotherms. The positive value of $\Delta H^o$ suggested the endothermic nature of the adsorption and the negative value of $\Delta G^o$ indicated the feasibility and spontaneity of the adsorption process.

- Nanosized doped TiO$_2$ catalysts were successfully prepared by using ultrasound at room temperature with efficient distribution of the incorporated metals. The cavitation effect of ultrasound could contribute to grain refinement and uniform dispersion of doping materials. Anatase TiO$_2$ particles were formed with a fairly narrow size distribution and uniform shape. The rapid micromixing and implosive collapse of bubbles in a liquid solution resulted in extremely high temperatures during ultrasound induced hydrolysis accelerating the hydrolysis reaction. The doped TiO$_2$ powders showed a strong absorption in the UV-visible light region and a
red shift in the band gap transition. The method of preparation played a major role in deciding the photocatalytic activity and catalysts prepared by sonochemical method exhibited higher photocatalytic activity as compared to the catalysts prepared by conventional method. The Cerium doped TiO$_2$ exhibited maximum photocatalytic activity and the photocatalytic degradation followed first-order kinetics.

- Calcium carbonate synthesis was carried out in a CSTR in continuous mode in the presence and absence of ultrasound. The smaller nanoparticles of calcium carbonate were synthesized with the assistance of ultrasonication as against conventional stirring. The experimental analysis of the obtained data suggests that the Ca(OH)$_2$ slurry concentration, CO$_2$ flow rate and Ca(OH)$_2$ slurry flow rate significantly influence the particle size and the morphology to some extent. The particle size is found to be decreased with an increase in the concentrations of Ca(OH)$_2$ slurry, increased with increasing CO$_2$ flow rate and decreased with slurry flow rate. Characterization techniques such as FTIR and XRD confirmed the formation of only calcite form of calcium carbonate. During most of the experiments formation of rhombohedral calcite particles was observed.

- The extraction of *Curcuma amada* powder was performed under direct sonication and the results were compared with the conventional methods of Soxhlet and batch extraction. Comparison of the results of conventional Soxhlet extraction and batch extraction with ultrasound assisted extraction indicated that ultrasound significantly improved the curcumin extraction yield. These improvements may be attributed to the mechanical and thermal effects of ultrasound. The maximum of 72% curcumin extraction was achieved in 1 h by using ultrasound assisted extraction at 35°C temperature as compared to Soxhlet extraction for 8 h at 78°C. During the extraction the cavitation helps in reduction of the extraction time and the operation can be carried out at lower temperature thus saving the energy during extraction process. Scanning electron microscopy images of ultrasound irradiated samples showed the particle breakage leading to increased contact surface area favourable for higher extraction. The Peleg’s model was employed to describe the kinetics of the ultrasound assisted extraction process and the mathematical model showed a good agreement with the experimental results.