- XPS analysis suggested the oxidation state and chemical bonding associated with the elements present in the samples. It also inferred about the existence of the multiple phases (viz. oxide and carbide) based on their binding energies and satellite features.
- Mössbauer spectroscopy validated the presence of only carbide phase in pure and Zn substituted Fe_3C samples. However, it indicated a coexistence of Fe_3C and Fe_3O_4 phases in Ni or Mn substituted (Fe_3C/Fe_3O_4) nanocomposites. In addition, the relative areas for the two phases described their quantification which was well matched with the estimation carried out by X'pert high score software. It also indicated that Ni or Mn concentration promoted the formation of the oxide phase in the composites. The presence of superparamagnetic component in all the nanocomposites was also indicated by this spectroscopy.
- From the magnetic measurements, it can be concluded that M_S values were decreasing on enhanced substituent concentration. But the reduction in the M_S values was exclusively depending on the nature as well as amount of the dopants. It was observed that on Zn substitution in the Fe_3C, the M_S values did not reduce significantly due its diamagnetic nature. In contrast, for Ni or Mn substituted samples, the M_S values reduced drastically due to the formation of the antiferromagnetic coupling amongst Fe-Ni or Fe-Mn.
- Magnetic hyperthermia experiment was performed at various fields for all the nanocomposite samples. The optimum heating efficacy was displayed for the pure Fe_3C/C at a field of 23 mT due to its higher M_S value (~78 Am^2/kg). The inferior heating performance for the other nanocomposite based ferrofluids could be assigned to their lower M_S values.

- The *in-vitro* studies with A549 cells for various nanocomposites suggested that pure and Zn substituted Fe_3C samples had compatibility up to 1 mg/mL after 48 h of treatment. In contrast, Mn or Ni substituted composites (M2FOC or N3FOC) were compatible up to 0.1 and 0.5 mg/mL with the same cell lines after 48 h of treatment. Nevertheless, at a concentration of 0.1 mg/mL of MNPs, all types of composites allowed usual growth of the cells which was confirmed from fluorescence microscopy.
- Amongst nanocomposites of FC, FOC and Ni substituted (N1FOC, N3FOC, and N5FOC), the best degradation performance with methyl orange and p-nitrophenol was observed for FOC. This happened for both Fenton as well as photo Fenton conditions. Further, it was noticed that on increasing Ni substitution in the nanocomposite, the degradation performance under photo Fenton condition with both the dyes improved.
- The electrochemical performance of the FC and Mn substituted (M2FOC and M7FOC) samples suggested that the sample M7FOC gives optimum irreversible capacity ~1206 mAh g^{-1} for the first cycle and the reversible capacity of ~826 mAh g^{-1} after 25 cycles. Therefore, it is worth to say that Mn enhanced the electrochemical performance of nanocomposites.

7.2 Future scope

Based on the present results, the following suggestions could be made for future work:

- Other elements can be substituted in the Fe_3C to observe the effect on magnetic behavior.
- Either other forms of iron carbide or carbides of other elements may be prepared using the present synthesis protocol.
- *In-vivo* studies for these magnetic carbides may be performed to find their suitability for bioapplications.
- These carbide nanocomposites or similar materials may be explored for battery or photocatalysis applications.