CHAPTER 9

CONCLUSION

9.1 RESULTS OF THE STUDY

Energy efficiency in the dyeing of cotton, polyester and blend can be achieved by adopting non-conventional dyeing technologies using ultrasound, infrared, microwave and magnetic stirred hot plate dyeing. From the experimental results, it can be inferred that non-conventional technologies of dyeing are more energy efficient than conventional dyeing and also provide better quality dyeing of textile materials. The following inferences can be drawn from the experimental investigations.

The dyeing experiments were conducted using alternate equipments and the dye uptake values were estimated based on absorbance measurements of the dye solutions. It is observed that dye uptake showed an increased value for all materials and non-conventional technologies in comparison to conventional technologies.

The apparent diffusion coefficient for all textile materials was evaluated based on dye uptake for all technologies including conventional technology. The apparent diffusion coefficient was found to be highest in case of infrared followed by microwave, ultrasound and magnetic stirred hot plate dyeing. This is true for all materials and for all temperature, time and concentration ranges.
The time, temperature and concentration are varied from lowest possible values to highest values in each technology. It is found the dye uptake showed an increase with temperature for all processes. Dye uptake also increased with time and concentration. It is highest for infrared followed by microwave, ultrasound and magnetically stirred dyeing. It is found to be lowest in case of conventional dyeing technology.

Normalized specific energy consumption in kwh/kg of cloth/ g of dye uptake for cotton varies from a value of 11.58 to a value of 26.75 in ultrasonic process with increasing temperature. In case of microwave dyeing, the values are 16.43 and 47.57 with increasing temperature. In case of infrared dyeing, the values range from 14.40 to 26.13 for increasing temperature ranges. In case of magnetically stirred hot plate dyeing, the value range from 18.73 to 36.63. In case of conventional dyeing, the value ranges from 19.43 to 44.17 in the respective temperature ranges. Thus ultrasound is best suited to cotton. This is followed by infrared, microwave and magnetically stirred hot plate dyeing. Conventional dyeing shows the highest value.

The normalized specific energy consumption technologies values for cotton for different times in ultrasound ranges from 10.92 to 18.89. For microwave, it is 20.60 to 24.97. In infrared, the value range is from 18.20 to 20.60. For magnetic stirred hot plate dyeing, the value ranges from 23.21 to 32.85. In case of conventional dyeing, the value ranges from 23.30 to 38.45. Here ultrasound shows the lowest SEC\textsubscript{n} compared to other. This is followed by infrared, microwave and magnetically stirred hot plate dyeing. Conventional dyeing shows the highest.

For all concentrations, all the non-conventional technologies have shown lower specific energy consumption than conventional technologies in
cotton. Ultrasound shows the lowest followed by infrared, microwave and magnetically stirred hot plate dyeing.

In case of Polyester, normalized specific energy consumption in ultrasound ranges from 27.14 to 48.48 at different temperature ranges while it is from 34.41 to 44.94 for microwave and 34.86 to 43.13 for infrared, and it is 45.29 to 58.39 for magnetic stirred hot plate dyeing. In conventional dyeing, the value ranges from 45.74 to 64.73. Hence at lower temperature, ultrasound is more energy efficient but normally polyester requires a higher temperature due to its thermal fixation characteristics. At higher temperatures, infrared is more energy efficient.

In case of polyester, ultrasound process shows a normalized specific energy consumption range varying from 44.53 to 52.44 at increasing process timings and it is 36.24 to 44.91 for microwave, 40.40 to 46.48 for infrared, 48.03 to 61.25 for magnetic stirred hot plate dyeing. Thus, microwave is more energy efficient. This is followed by infrared, ultrasound and magnetically stirred hot plate dyeing.

In case of blend, the normalized specific energy consumption in ultrasound ranges from 26.75 to 56.08 for increasing temperature levels while it is from 45.83 to 61.74 for infrared, 47.57 to 65.09 for microwave, 55.54 to 82.11 for magnetic stirred hot plate dyeing. For conventional dyeing it is 58.44 to 86.61. Thus ultrasound is more energy efficient in blend for the temperature ranges. This is followed by infrared, microwave and magnetic stirred process.

The normalized specific energy consumption values in blend for different times show a range of value from 46.55 to 55.19 for ultrasound, 51.52 to 63.51 for microwave, 53.49 to 60.20 for infrared, 63.52 to 80.62 for magnetic stirred. In conventional dyeing, the value ranges from 66 to 82.
Ultrasound is more energy efficient with respect to concentration than others. This is followed by microwave, infrared and magnetically stirred hot plate dyeing.

For all concentrations, all new technologies show lower specific energy consumption than conventional dyeing process. Thus, in case of blend, ultrasound is more energy efficient followed by microwave, infrared respectively.

Based on the above values, it can be inferred that it is possible to save energy to an extent of 30 to 40% in all the non-conventional technologies except magnetic stirred hot plate dyeing. Magnetic hot plate stirred dyeing improves the energy efficiency only marginally and thus energy saving achieved will not be significant compared to other technologies.

Empirical relations are derived based on the experimental data for normalized specific energy consumption and this showed that SEC$_n$ is more affected by temperature first, and then by time dependent and then thirdly by concentration. These relations are applicable only on the value ranges of variables adopted in this experimental study.

Based on these effects of these technologies in energy savings, an attempt is made to apply these technologies in phased manner to Indian textile dyeing sector with the assumption that these technologies can replace conventional dyeing in about 20% of existing industries. The saving in total energy and emissions are projected and by this, it is possible to reduce energy consumption and save emissions to an extent of about 30%.
9.2 SCOPE FOR FUTURE WORK

Most of experimental studies have indicated that use of these non-conventional technologies in textile dyeing showed improvement in dyeing efficiency resulting in reduced energy consumption, process time, dyes and chemicals and water. But to obtain and realize the above during commercial application, efforts are needed to study the design factors required for equipment development. Hence, more analytical investigations to identify the design factors have to be studied for manufacturing at a production level. In this study, material to liquor ratio is kept high due to equipment size constraints. But this has to be analysed in order to reduce the effluent load.

All dyes with different physical and chemical properties have to be experimented before making any optimisation of the various parameters.

All materials need to be tested under wide operating conditions which will help in optimization of the design parameters of the equipments.

Upgrading from laboratory scale to pilot scale, experiments need to be done to evaluate the results and achieve the expected efficiency levels.

Additional factors like pH, amount of auxiliary chemicals need to be considered and a combination of these processes should also be experimented before commercializing these technologies.

However, already a pilot scale microwave dyeing machine has been developed in Japan and as per the data provided, it is indicated that above equipment has saved considerable dyes, chemicals, energy and effluent generation. The details are given in Appendix G.