CHAPTER 8
CONCLUSIONS AND FUTURE RESEARCH SCOPE

8.1 CONCLUSION

A novel approach was used in the presented work for generation of dataset by investigating water quality parameters on artificially simulated lake systems to model eutrophication indicators. From the results and discussions on experimental investigation carried out and performance evaluation of developed models presented through chapter 5 and chapter 7 respectively, the following major conclusions can be drawn.

i. Lake eutrophication scenario was successfully replicated by continuous addition of wastewater into artificially constructed prototype lakes in two trials. Significant changes have been observed in water quality of the studied lakes during the process of eutrophication. Increase in pH, EC, TDS, TN, TP, BOD, Chl-a, and turbidity was observed whereas DO and SD reduced considerably.

ii. Trophic status index (TSI) was estimated for the studied lakes that indicated transition of the lakes from initial clear water oligotrophic stage to hypereutrophic stage due to nutrient enrichment.

iii. The linear correlation among investigated water quality parameters were found to be generally poor as reflected by smaller correlation coefficient values between parameters. This facilitates the necessity of sophisticated non-linear machine learning methods for development of eutrophication models.

iv. Input selection for the target parameters based on parameter trimming technique in ANN architecture proved to be a reliable method.

v. Water quality dataset gathered through this process were utilized for development of eutrophication models for indicators DO and SD using two ANN approaches (MLP and TDNN), SVR, and GPR algorithms in the 1^{st} trial. Performance of MLP, TDNN, and GPR models were found to be superior compared to SVR models for DO and SD prediction. During the 2^{nd} trial ANN, GPR and sophisticated machine learning algorithm ANFIS were utilized to check the prediction accuracy of eutrophication indicators DO, SD, and Chl-a. ANN, GPR, and ANFIS were found to produce better prediction accuracy of eutrophication indicators during both model training and testing phase. The results of model efficiency were found to be superior in case of 2nd trial compared to 1st trial as indicated by higher values of goodness-of-fit parameters R^2 and E and smaller values of error estimation parameters RMSE and E. Overall, performance of ANFIS models were found to be more accurate and robust.

vi. Effect of predictor variables on eutrophication indicators was identified with sensitivity analysis. The sensitivity values of inputs were comparatively small for DO, SD, and Chl-a prediction indicating robustness of model performance.

vii. Out of the two types of prototype lakes (i.e., concrete bedded and artificial pond), models based on artificial pond data were found to produce slightly better prediction accuracy in natural water bodies. But data gathered from concrete tanks were less time consuming and modelling results were very promising.

viii. This type of data-driven modelling approach based on laboratory investigated data on artificially simulated lake systems could be an alternate solution to rapid eutrophication management of waterbodies where prolonged water quality data is unavailable for the same.

8.2 FUTURE SCOPE

The present study was confined to development of eutrophication models based on laboratory investigation of artificially simulated prototype lake systems. As lake eutrophication is a very dynamic process related with different physio-chemical and biological factors, much more efforts can be made to enhance the present knowledge and successive mitigation measures. In order to carry forward the research of present investigation, following suggestions are listed below.

i. More detailed investigation can be carried out to understand eutrophication dynamics of lakes, incorporating more number of parametric studies and with varying influent properties. The present study only considers domestic waste water as nutrient enrichment pathway. The effect of agricultural run-off or industrial effluents on lake water can be investigated.

ii. Biological factors are closely related with the process of eutrophication. Study on algal and macrophyte composition, bacterial activity, zooplankton and benthic population and their effect on nutrient enrichment will enhance the understanding of eutrophication process. Incorporation of such biological interactions in lake modelling may produce rationale outcome.

iii. Application of more sophisticated machine learning methods like deep neural networks, hybrid approaches such as genetic algorithm optimized neural networks (GA-ANN), ensemble methods etc. may be explored to capture complex and non-linear data associated with eutrophication.

iv. Future modelling approaches may incorporate potential effect of climate change on lake eutrophication by considering factors such as change in weather conditions, precipitation trends and variations in temperature etc.