8 Conclusion and Future Aspects

This thesis focused on the process dynamics, toxicity evaluation, and cost optimization of the biological and ozonation methods for treating azo dyes in simulated wastewater. The bacterial species (*Bacillus subtilis MN372379.1*) isolated from the textile effluent discharge site showed their ability to break down azo bonds, validating the biological route's significance in the degradation of azo dyes. In prior investigations, a computational technique was developed to account for 'metabolite' inhibition, which was never accounted for before to predict bacterial growth kinetics during the biodegradation of dyeing wastewater. The impact of metabolite inhibition was incorporated into the growth kinetic by computing the specific bacterial growth rate based on the entire sigmoidal log phase profile (including the decelerating phase). This study showed that the negligence of the inhibition caused by metabolite byproducts could immensely overestimate (by 30-60%) the prediction of bacterial growth in a bioreactor. Therefore, the inhibition caused by the metabolites/secondary by-products must be considered in predicting bacterial growth where dyes are used as substrates by the bacterial cells.

In the investigation of the effect of external mass transfer on biodegradation of Congo Red dye in a recirculating packed bed bioreactor (RPBB) with packing material made of low-density polyethylene (LDPE) foam, the overall rate of removal of Congo red dye was found to be increasing with the feed flow rate or recycle rate. Next, an empirical correlation to predict the non-dimensional Colburn factor for determination of mass transfer coefficient of Congo red dye in the RPBB was also obtained as $J_D = 1.34\ Re^{-0.3}$.

The ozonation of azo dye in a bubble column reactor at various process conditions was utilized in the Response Surface Method (RSM) statistical tool to develop an empirical correlation for determining the *specific electricity consumption, SEC*, (defined as the electricity consumed per unit mass of dye removed from a unit volume of dyeing wastewater). It was found that the *SEC* during ozonation can be lowered if the dyeing water was treated at high initial dye concentrations. Under the optimized conditions at an initial dye concentration of ~4.4g/L, the cost of electricity consumption was found to be reduced significantly (by ~25-30 %). Therefore, this study recommended having a dye-enriching step for the regular textile effluent to achieve the desired dye loading before performing the ozonation.

Finally, when the ozonation was integrated with anaerobic/ aerobic biological treatment to improve the overall dye removal efficiency, processing time, and toxicity, it was noted that the anaerobic biodegradation and ozonation processes, both, resulted in high (>95%) color removal. The ozonation process offered faster color removal than the anaerobic process; however, the latter offered a higher COD and toxicity reduction. Therefore, the proposed strategy for textile wastewater treatment comprises ozonation as the first step primarily for rapid color removal, with a subsequent biodegradation step for meeting the mineralization and detoxification targets. A combined phyto- and geno-toxicity assays as suggested in this work should be used to evaluate the toxicity of the treated dyeing water.

Future work may focus on the scale-up study of the proposed ozonated-bioremediation approach to degrade azo dyes of the textile wastewater at high volume. To enrich the dye concentration before ozonation, a pretreatment step (maybe a physical method) should be explored. A consortium of potent microbes identified from the actual textile effluent discharge site may be used to accelerate the biodegradation further. Other avenues, apart from irrigation, gardening, or washing, where the treated dyeing water may be used as a raw material may be explored.