Chapter 5

Summary & Conclusions
Dyes are responsible for addition of beautiful colors to life and important class of chemicals widely used in many industrial processes, like in leather, textile and printing, food, and cosmetics industries. More than 10,000 different synthetic dyes are widely used in textile processing industry for dyeing and printing purposes. Now days, it become an integral part of industrial wastewater due to extensive use of these dyes in industries. The fixation rate of synthetic dyes is not 100%, thus they enter into the environment as wastewater. Inefficiency of the dyeing processes, poor handling of spent effluent and insufficient treatment of wastes of the dyestuff industries lead to dye contamination of the environment such as soil and natural water bodies. Many synthetic azo dyes and their metabolites are toxic, carcinogenic, mutagenic, leading to potential health hazard to humankind.

Solid state fermentation (SSF), the fermentation of solids in absence of free water has an advantage of supporting the growth and metabolism of microorganisms under moisture conditions. The most of the studies on the dye decolorization have been carried out using submerged culture conditions. The problem arises for the development and maintenance of such huge volume systems. Very few reports are available on dye decolorization under solid state fermentation. Agro-industrial residues such as wheat bran, rice bran, maize bran, gram bran, wood shavings etc. are generally considered to be the best substrates for solid state fermentation processes and have ability to adsorb various types of textile dyes. These compounds are environment friendly. Therefore, the use of solid-state fermentation using agro-industrial residues as a substrate for the removal of textile dyestuff from wastewater could offer some apparent economic and engineering advantages over the classical submerged fermentation. Exploring capacity of microorganism for adsorbed textile dye decolorization in SSF will be useful tool to reduce the effluent volume and treatment like composting process. Therefore, implementation of solid state fermentation for textile wastewater treatment solves the environmental pollution problem as well as utilizes agricultural waste which is generated in huge amount. Released waste/biomass can be used as fertilizer after evaluation of its nutritive value and toxicity.

Chapter 4.1 concludes that Pseudomonas sp. SUK1 and A. ochraceus were able to degrade dye adsorbed on rice bran under solid state fermentation; however consortium-PA was more efficient than individual microorganisms. Consortium-PA had potential to decolorize CPTDE (chemical precipitate of textile dye effluent) when added with rice bran for their growth. Degradation of adsorbed dyes on rice bran could be strongly attribute to the
synergistic effect of excreted extracellular enzymes such as, azoreductase, laccase, tyrosinase and NADH-DCIP reductase secreted by the fungi and bacteria. This approach will be effective to reduce effluent volume by adsorbing textile dye on agricultural waste residues available at low cost and its bioremediation/disposal to nontoxic form by solid state fermentation. In this chapter, we describe the mechanism for azo dye degradation by intracellular blue laccase of *A. ochraceus*, which has potential for environmental applications. *A. ochraceus* laccase decolorized textile dyes in the absence of redox mediators with a decolorization efficiency from 56 to 90%.

Chapter, 4.2 did explore potential of *B. cereus* to decolorize adsorbed textile dyestuff on DIW-YB (Distillery Industrial Waste – Yeast Biomass) under SSF. This developed system showed consistent adsorption and decolorization of textile effluent up to seven cycles. The extracellular oxidoreductase enzymes suggest their role in decolorization of Red M5B. *B. cereus* along with DIW-YB also showed improved decolorization in tray bioreactors that gave an additional insight to treat textile wastewater under SSF, which offers an economically feasible and eco-friendly approach. The reuse of DIW-YB medium for adsorption and decolorization has given clues to develop large scale treatment protocols. SSF using DIW-YB gives a dual solution for solid waste management of distillery industry as well as for the treatment of textile wastewaters.

Chapter, 4.3 explains enhancement in the adsorption of dyes due to CaCl₂ pretreatment of SCB. In the earlier reports, the decolorization of adsorbed dyes was carried out without improving the adsorption performance of the substrate. However, enhanced adsorption capacity of the substrate and subsequent decolorization under SSF conditions was observed in this study. Adsorbed dyestuff on pretreated SCB were decolorized under SSF by *P. stuartii*. Metabolites analysis by FTIR, HPLC and HPTLC confirmed biodegradation of SR5B by *P. stuartii*. Phytotoxicity studies revealed significant reduction in the toxicity due to biodegradation of adsorbed dye SR5B under SSF. Textile dyes even adsorbed on adsorbents has toxic effect on the plant as they remain persistent in the environment but biodegradation of adsorbed dyes under SSF removes the toxicity of dyes significantly. Decolorization of dyes from RTE adsorbed on CaCl₂ pretreated SCB in tray bioreactor can also be used to develop large scale treatment protocol.

Chapter, 4.4 concludes enhanced efficiency of consortium-RARB (PGPRs) of (*Rhodobacter erythropholis* MTCC 4688, *Azotobacter vinelandii* MTCC 1241, *Rhizobium*
Chapter 5

Summary and conclusions

*meliloti* NCIM 2757 and *Bacillus megaterium* NCIM 2054) compared to an individual microorganism in case of decolorization of SCB adsorbed DR73 under SSF conditions. Being rhizospheric microorganism they are known to be efficient plant growth promoters and hence generated biomass after decolorization of textile dye may be successfully implemented as rhizobial inoculants. Phytotoxicity studies revealed that only adsorption process does not detoxify the dye contaminant, but SSF of adsorbed dyes completely removes dye toxicity. FTIR, HPLC and HPTLC analysis confirms biodegradation of DR73 by individual cultures as well as by developed consortium-RARB.

Chapter, 4.5 suggests the coagulation process by using novel coagulant ZnCl$_2$. Coagulation is the most widely used technology for textile wastewater treatment. Hence, coagulation of various textile dyes, mixture of textile dye and real textile wastewater using novel coagulant put new option for the coagulation technique. Similarly even the coagulation was used worldwide as most efficient technique its major drawback is to generation of dye sludge which is called as secondary pollutant. Therefore, this problem was solved by decolorizing the dye sludge under the solid state fermentation conditions. The scale of coagulation process in coagulation reactor was carried out. Dye sludge collected from 500 L textile effluent treated in composting bioreactor. Hence, here combination of most efficient physical process coagulation and biological process SSF gives good alternative to textile industries and similarly its scale up studies suggests it can probably apply at industry scale for further studies.