International Research Journal of Biological Sciences ISSN 2278-3202
Vol. 2(6), 77-82, June (2013) Int. Res. J. Biological Sci.

Review Paper

Recent Biological Technologies for Textile Effluent Treatment

Butani Naresh*, Jobanputra Jaydip, Bhatiya Prabhat, Patel Rajkumar
Department of Microbiology, Bhagwan Mahavir College of Biotechnology, Surat-394220, Gujarat, INDIA

Available online at: www.isca.in
Received 13th April 2013, revised 1st May 2013, accepted 25th May 2013

Abstract

Development and industrialization are two parallel wheels for any country because industrialization plays very important role in the economy of the nation. Textile industries plays important role in human civilization by providing cloths. Many environmental issues are associated with effluent of textile industries. Various biological technologies are available for treatment of effluent of textile industries; here we have reviewed various biological technologies available including aerobic treatment, anaerobic treatment and combined technologies.

Keywords: Decolorization, dye, textile effluent, aerobic treatment, anaerobic treatment, Bactria, fungi.

Introduction

Industrialization is vital to a nation's financial system because it serves as a vehicle for progress. First an agricultural industry is established to feed the people[1]. Next to the food, the 'cloth' is second basic need of man which is supplied by processing of natural and synthetic fibers in the industries called "Textile". Textiles are among the basic needs of human being. The textile industry is one of the most complicated industries among manufacturing industry. Increased population and modernized civilization trend gave rise to blooming of textile sector. Textile industry is one of the many industries that discharge large quantities of wastewater rich in different types of pollutants[2]. Wastewater generated from the textile industries may contain a variety of polluting substances, such as acids, heavy metals, bases, toxic organic and inorganic dissolved solids, and colors. Colors are considered the most undesirable substance and are mainly due to the various dyes[3,4]. Dyes are released in nature from textile industries and dye manufacturing plants[5]. The conventional textile finishing industry requires nearly about 100 l of water to process about 1 kg of textile materials[6]. Dyeing and printing process consume relatively largest amount of water during textile processes [7]. Wastewater from printing and dyeing units is often rich in organic compounds, colors and heavy metal[8,9], containing residues of various dyes and chemicals, and toxic to microorganism and fishes hence requires proper treatment before being released into the environment[10]. Environmental pollution is one of the major and most important problems of the modern world[11]. The biological treatment has many advantages over physical or chemical methods. There is a possibility of biological degradation of dye molecules to CO_2 and H_2O and significantly less amount of sludge formation take place[12]. The capability of biological treatment process for decolorization of industrial effluents is ambiguous, different and divergent. The application of microorganisms for the biodegradation of synthetic dyes is an attractive and simple method by operation. The treatment based on using microorganisms are cable to decolorizing/degrading these recalcitrant compound are environmental friendly and can lead to mineralization of the target compounds[13]. For removal of the bulk of toxic pollutants from complex and high-strength organic wastewater, biological treatment (aerobic or anaerobic) is usually believed to be the most effective mean[14]. Also, microorganisms are known to play an important role in the mineralization of biopolymers and recalcitrant xenobiotic compounds. Biological process of removal of the dyes from textile and dyestuff manufacturing industry can be broadly classified into three categories: aerobic treatment, anaerobic treatment, and combined anaerobic–aerobic treatment[15].

Aerobic Treatment

Biological treatment using activated sludge in aerobic condition is one of regularly used treatment methods for textile dyeing effluent[16]. Stabilization ponds, aerated lagoons, or percolating filters are widely applied in aerobic treatment. In aerobic treatment, dissolved oxygen is utilized by microorganism and finally, wastes are converted into more biomass and carbon dioxide. Organic matter is partially oxidized and some of the energy produced is used for generating new living cells under the formation of flocs. After the flocs has been settled down, are removed as sludge[17].

The results of various researcher showed that the dyestuffs were not showing any considerable biodegradation under aerobic conditions. However, research is still continued to isolate aerobic microorganisms capable of degrading dyes and dye related compounds. Bacteria and fungi are the two microorganism groups that have been most widely studied for their capability to remediate textile and dye wastewaters[15].

Treatment by Fungi

In nature, most efficient class of microorganisms in degrading synthetic dyes is the white-rot fungi (WRF). WRF are a class of microorganisms that produce efficient enzymes capable of decomposing dyes under aerobic conditions[11].

Lignin modifying enzymes (LME) from WRF, including Manganese Peroxisade (MnP), Lignin Peroxidase (LiP) and laccases, are directly involved in the degradation of not only lignin in their natural lignocellulosic substrates but also various recalcitrant xenobiotic compounds including dyes[12]. Peroxidases and laccases of WRF are oxidative enzymes, which do not need any other cellular components to work.

Phanerochaete chrysosporium, lignin-degrading white rot fungus, was studied widely during the last decade due to its capability to degrade many recalcitrant pollutants including chlorophenols, nitrotoluenes, and polycyclic aromatic hydrocarbons. Additionally, it is also established that it is able to decolorize a wide range of dyes. *Phanerochaete chrysosporium* was reported to be able to decolorize various azo dyes, orange II, Congo red, and tropaeolin O, under aerobic conditions[5,15,18-27].

It has been assumed that in the decolorization process of dye, various extracellular peroxidases (lignin peroxidase and Mn-dependent peroxidase)[28-30] or laccases are involved. The data further indicated that the high decomposition rate of dyes can be achieved only by careful selection of the fungi and cultural conditions[31].

The detailed record of fungi known to degrade the various types of dyes is long: amongst others, various *Trametes* sp.[32], *Trametes versicolor*[33-40], *Irpex lacteus*[41,42], *Pleurotus ostreatus*[43,44], *Pycnoporus sanguineus*[45-47], *Pycnoporus cinnabarinus*, *Phlebia tremellosa, Ischnoderma resinosum*[48], *Funalia trogii*[49], *Aspergillus flavus*[50, 51], *Aspergillus fumigatus*[51], *Aspergillus sulphureus*[52], *Alternaria solani*[53], *Aspergillus niger*[54,55], *Geotrichum candidum*, or *Neurospora crassa*, and *Phanerochaete chrysosporium* seem to be the most extensively investigated fungi for dye decolorization working on dyes of all classes. The genus of *Penicillium* has been shown to degrade various polymeric dyes[56,57,58]. *Trametes versicolor, Pleurotus ostreatus, Phanerochaete chrysosporium, Piptoporus betulinus, Laetiporus sulphureus* and several *Cyathus* species have been described in literature to degrade triphenylmethane dyes[17].

Treatment by Bacteria

Bacterial decolorization is usually faster as compare to fungal decolorization[11,59]. Numerous bacteria capable to degrade dyes have been reported. Efforts to isolate bacterial cultures capable of degrading azo dyes started in the 1970s with reports of a *Bacillus subtilis*, then *Aeromonas hydrophila*, followed by a *Bacillus cereus*[60]. Recent reports have demonstrated that some bacterial strains can mineralize various dyes under aerobic conditions[15]. Some researcher have been also applied Sulphate reducing bacteria for degradation of dyes[61,62]. Ganesh Parshetti *et al. 2009* had applied *Rhizobium radiobacter* for the biodegradation of triphenylmethane dye.

During the past few years, many bacterial strains have been isolated that can aerobically decolorize azo dyes. Many of these strains require organic carbon sources, as they cannot utilize dye as the growth substrate[63,64]. Many bacterial strains are reported as dye decolorizer or dye degrader like *Bacillus megaterium*[65], *Alcaligenes faecalis* 6132 and *Rhodococcus erythropolis* 24[66], *Bacillus licheniformis* LS04[67], *Rahnella aquatilis*[68], *Acinetobacter guillouiae*[68], *Microvirgula aerodenitrificans*[68], *Pseudomonas desmolyticum* NCIM 2112[29],

Anaerobic treatment

There are many reports are available in recent past that under aerobic condition dye decolorization is achieved successfully but the general observation of non-biodegradability of most azo dyes in conventional aerobic condition still persists. On the other hand, the potential of anaerobic microorganisms to decolorize dyes is well documented and established[15]. By using sludge, anaerobic reduction of azo dyes can be an effective and economic treatment process for removing color from textile wastewater[12]. The efficacy of various anaerobic treatment applications for the degradation of a wide variety of synthetic dyes has been many times demonstrated[31]. The investigations on anaerobic decolorization of azo dyes were started way back in the early 1970s. Several laboratories reported decolorization of azo dyes using intestinal anaerobic bacteria. The potential of intestinal anaerobes to decolorize azo dyes was further established by many other researchers[15]. Anaerobic bioremediation allows azo and other water-soluble dyes to be decolorized. This decolorization involves an oxidation-reduction reaction with hydrogen rather than free molecular oxygen aerobic system[60]. Anaerobic bioremediation of azo and other soluble dyes to undergo decolorization by breaking them into corresponding amines has been widely researched. Primary degradation and decolorization of dyes with azo-based chromophores can be achieved by the reduction of the azo bond. This can be done by using strong reducing agents such as sodium hydrosulphite, thiourea dioxide, sodium formaldehyde sulphoxylate and sodium borohydride. Reduction of the azo bond can also be achieved under the reducing conditions prevailing in anaerobic bioreactors. The amines produced by the reduction of the azo dyes are colorless but they are very resistant to further degradation under anaerobic conditions[69].

Many anaerobic (e.g. *Bacteroides* sp., *Eubacterium* sp., and *Clostridium* sp.) and facultative anaerobic (e.g. *Proteus vulgaris* and *Streptococcus faecalis*) bacteria can decolorize various azo dyes under anaerobic conditions via reduction of the azo bond[17]. The exact mechanism of azo dye reduction is not clearly understood yet. The different mechanisms may be involved like enzymatic, non-enzymatic, mediated, intracellular, extracellular and various combinations of these mechanisms[70]. Many authors have been reported that anaerobic condition using following organisms seems to be effective: *Shewanella oneidensis* MR-1[71], *Bacteroides* sp., *Eubacterium* sp., and *Clostridium* sp.

Under anaerobic condition azo dyes are degraded and converted into aromatic amines, which may be toxic, mutagenic, and possibly carcinogenic to mammalians. Therefore, to achieve complete degradation of azo dyes, another stage that involves aerobic biodegradation of the produced aromatic amines is necessary[72,73]. This anaerobic reduction implies decolorization as the azo dyes are converted to usually colorless but potentially harmful aromatic amines. Aromatic amines are normally not further degraded under anaerobic conditions. Anaerobic treatment must therefore be considered merely as the first stage of the complete degradation of azo dyes. The second stage involves conversion of the produced aromatic amines under aerobic condition. For several aromatic amines, this can be achieved by biodegradation under aerobic conditions. Combined anaerobic and aerobic bacterial biodegradation of azo dyes, as well as its applications in wastewater treatment processes[74].

Combined Anaerobic / Aerobic Reactions

The common observation that has emerged over the years is that most dyes are generally recalcitrant to aerobic degradation but can be reductively decolorized under anaerobic conditions[15,75]. The azo dyes are toxic, and also become harmful to the environment by the formation of aromatic amines, which are carcinogenic and/or mutagenic, when degraded in anaerobic condition[18]. Azo dyes are usually degraded under anaerobic conditions by bacteria to colorless toxic aromatic amines, of which some are readily metabolized under aerobic conditions[11].

Usually, bacterial biodegradation of azo dye is carried out in two separate stages. The first stage involves reductive cleavage of the dyes' azo linkages, resulting in the formation of generally colorless aromatic amines. The second stage involves aerobic degradation of the aromatic amines. Reduction of azo dye usually proceeds under anaerobic conditions, whereas bacterial biodegradation of aromatic amines is an almost exclusively aerobic process[76]. A wastewater treatment process in which anaerobic and aerobic conditions are combined is therefore the most logical concept for removing azo dyes from wastewater[75]. The mineralization of azo dyes requires integrated or sequential anaerobic and aerobic step[77]. Sequential microaerophilic/ aerobic reactors using *Staphylococcus arlettae* was also applied for biodegradation of various dyes[78,79].

Conclusion

Over the last three decades, much research has been focused on dye decolorization and degradation. These approaches show that global communities are much aware about the environmental pollution created by dyes. Over a long period of time it is clear that dye are not easy to degrade. Many biological technologies are available which can degrade the dye. But, due to complex nature of textile effluent, these technologies are failed to be implemented. So, research should be focused on dye degradation in complex condition. Out of many biological technologies investigated combined biological technologies show good results. Future technologies involving enzymatic reaction should be investigated. Potential of different group of microbes for degrading dyes can be investigated deeply and science of bioremediation should be applied in textile wastewater treatment.

References

1. Smith C., The textile coloration industry in the European Union, *Reviews in Progress in Coloration,* **29**, 37-42 **(1999)**
2. Abu-Ghunmi L.N. and Jamrah A.T., Biological treatment of textile wastewater using sequencing batch reactor technology, *Environmental Modeling and Assessment,* **11**, 333-343 **(2006)**
3. Daneshvar N., Ayazloo M., Khataee A.R. and Pourhassan M., Biological decolorization of dye solution containing Malachite Green by microalgae *Cosmarium* sp., *Bioresource Technology,* **98**, 1176-1182 **(2007)**
4. Wafaa M.A. E.-R., Assessment of textile dye remediation using biotic and abiotic agents, *Journal of Basic Microbiology,* **46(4)**, 318-328 **(2006)**
5. Cripps C., Bumpus J.A. and Aust S.D., Biodegradation of azo and heterocyclic dyes by *Phanerochaete chrysosporium, Applied and Environmental Microbiology,* **56(4)**, 1114-1118 **(1990)**
6. Selvam K., Swaminathan K. and Keon-Sang C., Microbial decolorization of azo dyes and dye industry effluent by *Fomes lividus, World Journal of Microbiology & Biotechnology,* **19**, 591-593 **(2003)**
7. Defrawya N.M.H.El., Water management in textile industry: technical and economic aspects, *International Journal of Environmental Studies,* **59(5)**, 573-587 **(2002)**
8. Chandra Sekhar K., Chary N.S., Kamala C.T., Vairamani M., Anjaneyulu Y., Balaram V., et al., Environmental risk assessment studies of heavy metal contamination in the industrial area of kattedan, India-A case study, *Human and Ecological Risk Assessment: An International Journal,* **12(2)**, 408-422 **(2006)**
9. Soares G.M.B., Amorium M.T.P., Lageiro M. and Maria C.F., Pilot-scale enzymatic decolorization of industrial dyeing process wastewater, *Textile Research Journal,* **76(4)**, 4-11 **(2006)**
10. Ramesh Babu B., Parande A.K., Raghu S. and Prem Kumar T., Cotton Textile Processing: Waste Generation and Effluent Treatment, *The Journal of Cotton Science,* **11**, 141-153 **(2007)**
11. Ali H., Biodegradation of synthetic dyes—a review, *Water Air Soil Pollution*, **(2010)**
12. Erkurt H.A. Biodegradation of azo dyes, New York: Springer Heidelberg Dordrecht; **(2010)**
13. Sharma D.K., Saini H.S., Singh M., Chimni S.S. and Chadha B.S., Isolation and characterization of microorganisms capable of decolorizing various

triphenylmethane dyes, *Journal of Basic Microbiology,* **44(1)**, 59-65 **(2004)**

14. Hardin I.R., Zhao X. and Akin D.E. Biotreatment approach to decolorizing textile waste effluents, In: Kathryn J. Hatcher, editor. Georgia Water Resources Conference; 2003; University of Georgia; **(2003)**

15. Rai H.S., Bhattacharyya M.S., Singh J., Bansal T.K., Purva V. and Banerjee U.C., Removal of dyes from the effluent of textile and dyestuff manufacturing industry: A review of emerging techniques with reference to biological treatment, *Critical eviews in Environmental Science and Technology,* **35**, 219-238 **(2005)**

16. Joshi M. and Purwar R., Developments in new processes for colour removal from effluent, *Reviews in Progress in Coloration,* **34**, 58-71 **(2004)**

17. Chrisie R.M. Environmental aspects of textile dyeing: CRC Press; **(2005)**

18. Martins A.M., Ferreira I.C., Santos I.M., Joao Q.M. and Lima N., Biodegradation of bioaccessible textile azo dyes by *Phanerochaete chrysosporium, Journal of Biotechnology,* **89**, 91-98 **(2001)**

19. Paszcznski A. and Crawford R.L., Potential for Bioremediation of Xenobiotic Compounds by the White-Rot Fungus *Phanerochaete chrysosporium, Biotechnology Progress,* **11**, 368-379 **(1995)**

20. Asamudo N.U., Daba A.S. and Ezeronye O.U., Bioremediation of textile effluent using *Phanerochaete chrysosporium, African Journal of Biotechnology,* **4(13)**, 1548-1553 **(2005)**

21. Arora D.S. and Chander M., Decolourisation of diverse industrial dyes by some *Phlebia* spp. and their comparison with *Phanerochaete chrysosporium, Journal of Basic Microbiology,* **44(5)**, 331-338 **(2004)**

22. Bakshi D.K., Gupta K.G. and Sharma P., Enhanced biodecolorization of synthetic textile dye effluent by *Phanerochaete chrysosporium* under improved culture conditions, *World Journal of Microbiology & Biotechnology,* **15**, 507-509 **(1999)**

23. Ghasemi F., Tabandeh F., Bambai B. and Sambasiva Rao K.R.S., Decolorization of different azo dyes by *Phanerochaete chrysosporium* RP78 under optimal condition, *International Journal of Environmental Science and Technology,* **7(3)**, 457-464 **(2010)**

24. Assadi M.M., Rostami K., Shahvali M. and Azin M., Decolorization of textile wastewater by *Phanerochaete chrysosporium, Desalination,* **141**, 331-336 **(2001)**

25. Gomaa O.M., Linz J.E. and Reddy C.A., Decolorization of Victoria blue by the white rot fungus, *Phanerochaete chrysosporium, World Journal of Microbiology & Biotechnology*, **(2008)**

26. Radha K.V., Regupathi I., Arunagiri A. and Murugesan T., Decolorization studies of synthetic dyes using *Phanerochaete chrysosporium* and their kinetics, *Process Biochemistry,* **40**, 3337-3345 **(2005)**

27. Zahmatkesh M., Tabandeh F. and Ebrahimi S., Biodegradation of reactive orange 16 by *Phanerochaete chrysosporium* fungus: Application in a fluidized bed bioreactor, *Iranian Journal of Environmental Health Science and engineering,* **7(5)**, 385-390 **(2010)**

28. Ghodake G.S., Kalme S.D., Jadhav J. and Govindwar S.P., Purification and Partial Characterization of Lignin Peroxidase from *Acinetobacter calcoaceticus* NCIM 2890 and Its Application in Decolorization of Textile Dyes, *Applied Biochemistry and Biotechnology*, **(2008)**

29. Kalme S.D., Parshetti G.K., Jadhav S.U. and Govindwar S.P., Biodegradation of benzidine based dye Direct Blue-6 by *Pseudomonas desmolyticum* NCIM 2112, *Bioresource Technology,* **98**, 1405-1410 **(2007)**

30. Khandare R.V., Kabra A.N., Tamboli D.P. and Govindwar S.P., The role of *Aster amellus* Linn. in the degradation of a sulfonated azo dye Remazol Red: A phytoremediation strategy, *Chemosphere,* **82**, 1147-1154 **(2011)**

31. Forgacs E., Cserhati T. and Oros G., Removal of synthetic dyes from wastewaters: A review, *Environment International,* **30**, 953-971 **(2004)**

32. Zille A., Gornacka B., Rehorek A. and Artur C.-P., Degradation of azo dyes by *Trametes villosa* laccase over long periods of oxidative conditions, *Applied and Environmental Microbiology,* **71(11)**, 6711-6718 **(2005)**

33. Amaral P.F.F., Fernandes D.L.A., Tavares A.P.M., Xavier A.B.M.R., Cammarota M.C., COutinho J.A.P., et al., Decolorization of Dyes from textile wastewater by Trametes versicolor, *Environmental Technology,* **25(11)**, 1313-1320 **(2004)**

34. Xavier A.M.R.B., Tavares A.P.M., Ferreira R. and Amado F., *Trametes versicolor* growth and laccase induction with by-products of pulp and paper industry, *Electronic Journal of Biotechnology,* **10(3)(3)**, 444-451 **(2007)**

35. Binupriya A.R., Sathishkumar M., Kavitha D., Swaminathan K. and Yun S.E., Aerated and rotated mode decolorization of a textile dye solution by native and modified mycelial biomass of *Trametes versicolor, Journal of Chemical Technology and Biotechnology,* **82**, 350-359 **(2007)**

36. Emre E., Yasin K. and Nurdan K.P., Biosorption kinetics of a direct azo dye Sirius Blue K-CFN by *Trametes versicolor, Electronic Journal of Biotechnology,* **14(2)**, 1-10 **(2011)**

37. Heinfling A., Bergbauer M. and Szewzyk U., Biodegradation of azo and phthalocyanine dyes by

Trametes versicolor and *Bjerkandera adusta, Applied Microbiology & Biotechnolgy,* **48**, 261-266 **(1997)**

38. Ramsay J.A. and Goode C., Decoloration of a carpet dye effluent using *Trametes versicolor, Biotechnology Letters,* **26**, 197-201 **(2004)**

39. Ramsay J.A. and Nguyen T., Decoloration of textile dyes by *Trametes versicolor* and its effect on dye toxicity, *Biotechnology Letters,* **24**, 1757-1761 **(2002)**

40. Borchert M. and Libra J.A., Decolorization of Reactive Dyes by the White Rot Fungus *Trametes versicolor* in Sequencing Batch Reactors, *Biotechnology and Bioengineering,* **75(3)**, 313-321 **(2001)**

41. Jaromır P., Pavel H. and Cenek N., Decolorization of organic dyes by *Irpex lacteus* in a laboratory trickle-bed biofilter using variousmycelium supports, *Journal of Chemical Technology and Biotechnology,* **84**, 1031-1042 **(2009)**

42. Shin K.S., The role of enzymes produced by white-rot fungus *irpex lacteus* in the decolorization of the textile industry effluent, *The Journal of Microbiology,* **42(1)**, 37-41 **(2004)**

43. Casieri L., Varese G. C., Anastasi A., Prigione V., Svobodova K., Filippelo Marchisio V., et al., Decolorization and detoxification of reactive industrial dyes by immobilized fungi *Trametes pubescens* and *Pleurotus ostreatus, Folia Microbioogica,* **53(1)**, 44-52 **(2008)**

44. Hou H., Zhou J., Wang J., Du C. and Yan B., Enhancement of laccase production by Pleurotus ostreatus and its use for the decolorization of anthraquinone dye, *Process Biochemistry,* **39**, 1415-1419 **(2004)**

45. Lu L., Zhao M., Zhang B.-B., Yu S.-Y., Bian X.-J., Wang W., et al., Purification and characterization of laccase from *Pycnoporus sanguineus* and decolorization of an anthraquinone dye by the enzyme, *Applied Microbiology & Biotechnolgy,* **74**, 1232-1239 **(2007)**

46. Eugenio M.E., Carbajo J.M., Martín J.A., Gonzalez A.E. and Villar J.C., Laccase production by *Pycnoporus sanguineus* under different culture conditions, *Journal of Basic Microbiology,* **49**, 433-440 **(2009)**

47. Pointing S.B. and Vrijmoed L.L.P., Decolorization of azo and triphenylmethane dyes by *Pycnoporus sanguineus* producing laccase as the sole phenoloxidase, *World Journal of Microbiology & Biotechnology,* **16**, 317-318 **(2000)**

48. Eichlerova I., Homolka L. and Nerud F., Evaluation of synthetic dye decolorization capacity in *Ischnoderma resinosum, Journal of Industrial Microbiology and Biotechnology,* **33**, 759-766 **(2006)**

49. Park C., Lee M., Lee B., Kim S.W., Chase H.A., Lee J., et al., Biodegradation and biosorption for decolorization of synthetic dyes by Funalia trogii, *Biochemical Engineering Journal,* **36**, 59-65 **(2007)**

50. Ali H., Ahmad W. and Haq T., Decolorization and degradation of malachite green by *Aspergillus flavus* and *Alternaria solani, African Journal of Biotechnology,* **8(8)**, 1574-1576 **(2009)**

51. Agnes M.D.C., Rajeshwari S. and Venckatesh R., Decolorization of Reactive Violet – 2RL Dye by *Aspergillus Flavus* and *Aspergillus Fumigatus* from Textile Sludge, *International Research Journal of Environment Sciences,* **1(2)**, 8-12 **(2012)**

52. Salar R.K., Rohilla S.K. and Rohilla J.K., Decolorization of Reactive Black HFGR by *Aspergillus sulphureus, ISCA Journal of Biological Sciences,* **1(1)**, 55-61 **(2012)**

53. Ali H. and Shah K.M., Biodecolorization of acid violet 19 by *Alternaria solani, African Journal of Biotechnology,* **7(6)**, 831-833 **(2008)**

54. Kumar Praveen G.N. and Sumangala K. Bhat., Fungal Degradation of Azo dye- Red 3BN and Optimization of Physico-Chemical Parameters, *ISCA Journal of Biological Sciences,* **1(2)**, 17-24 **(2012)**

55. Namdhari B.S., Rohilla S.K., Salar R.K., Gahlawat S.K., Bansal P. and Saran A.K., Decolorization of Reactive Blue MR, using *Aspergillus* species Isolated from Textile Waste Water, *ISCA Journal of Biological Sciences,* **1(2)**, 24-29 **(2012)**

56. Bergsten-Torralba L.R., Nishikawa M.M., Baptista D.F., Magalhaes D.P. and Da Silva M., Decolorization of different textile dyes by *Penicillium simplicissimum* and toxicity evaluation after fungal treatment, *Brazilian Journal of Miocrobiology,* **40**, 808-817 **(2009)**

57. Min G., Qu Y., Zhou J., Ma F. and Tan L., Azo dye decolorization by a new fungal isolate, *Penicillium* sp. QQ and fungal-bacterial cocultures, *Journal of Hazardous Materials,* **170**, 314-319 **(2009)**

58. Zhang S.J., Yang M., Yang Q.X., Zhang Y., Xin B.P. and Pan F., Biosorption of reactive dyes by the mycelium pellets of a new isolate of *Penicillium oxalicum, Biotechnology Letters,* **25**, 1479-1482 **(2003)**

59. Jirasripongpun K., Nasanit R., Niruntasook J. and Chotikasatian B., Decolorization and degradation of C.I. Reactive red 195 by *Enterobacter* sp, *Thammasat International Journal of Science Technology,* **12**, 6-11 **(2007)**

60. Anjaneyulu Y., Sreedhara Chary N. and Samuel Suman Raj D., Decolourization of industrial effluents – available methods and emerging technologies – a review, *Reviews in Environmental Science and Biotechnology,* **4**, 245-273 **(2005)**

61. Togo C.A., Mutambanengwe C.C.Z. and Whiteley C.G., Decolourisation and degradation of textile dyes using a sulphate reducing bacteria(SRB) – biodigester microflora co-culture, *African Journal of Biotechnology,* **7(2)**, 114-121 **(2008)**

62. Parshetti G., Saratale G., Telke A. and Govindwar S., Biodegradation of hazardous triphenylmethane dye methyl violet by *Rhizobium radiobacter* (MTCC 8161), *Journal of Basic Microbiology,* **49**, S36-S42 **(2009)**

63. Stolz A., Basic and applied aspects in the microbial degradation of azo dyes, *Applied Microbiology & Biotechnolgy,* **56**, 69-80 **(2001)**

64. Pandey A., Singh P. and Iyengar L., Bacterial decolorization and degradation of azo dyes, *International Biodeterioration & Biodegradation,* **59**, 73-84 **(2007)**

65. Praveen Kumar G.N. and Bhat S.K., Decolorization of Azo dye Red 3BN by Bacteria, *International Research Journal of Biological Sciences,* **1(5)**, 46-52 **(2012)**

66. Angelova B., Avramova T., Stefanova L. and Mutafov S., Temperature effect on bacterial azo bond reduction kinetics: an Arrhenius plot analysis. *Biodegradation,* **19(3)**, 387-393 **(2008)**

67. Lu L., Zhao M., Wang T.N., Zhao L.Y., Du M.H., Li T.L., et al., Characterization and dye decolorization ability of an alkaline resistant and organic solvents tolerant laccase from Bacillus licheniformis LS04, *Bioresour Technol,* **115**, 35-40 **(2012)**

68. Han J.L., Ng I.S., Wang Y., Zheng X., Chen W.M., Hsueh C.C., et al., Exploring new strains of dye-decolorizing bacteria, *J Biosci Bioeng,* **113(4)**, 508-514 **(2012)**

69. Delee W., O'Neill C., Hawkes F.R. and Pinheiro H.M., Anaerobic treatment of textile effluents: A review, *Journal of Chemical Technology and Biotechnology,* **73**, 323-335 **(1998)**

70. Arnold R. Lang, Dyes and pigments: New research. New York: Nova Science Publishers, Inc; **(2009)**

71. Xiao X., Xu C.C., Wu Y.M., Cai P.J., Li W.W., Du D.L., et al., Biodecolorization of Naphthol Green B dye by Shewanella oneidensis MR-1 under anaerobic conditions, *Bioresour Technol,* **110**, 86-90 **(2012)**

72. Zille A. Laccase Reactions for Textile Applications. Portugal: University of Minho **(2005)**

73. Ganesh R., Boardman G. D. and Michelsen D., Fate of azo dyes in sludges, *Water Research,* **28(6)**, 1367-1376 **(1994)**

74. Frank P.V. D.Z. Anaerobic azo dye reduction. Wageningen, The Netherlands: Wageningen University, **(2002)**

75. Frank P.V.d.Z. and Santiago V., Combined anaerobic–aerobic treatment of azo dyes—A short review of bioreactor studies, *Water Research,* **39**, 1425-1440 **(2005)**

76. Goncalves I.M.C., Gomes A., Bras R., Ferra M.I.A., Amorim M.T.P. and Porter R.S., Biological treatment of effluent containing textile dyes, *Journal of the Society of Dyers and Colourist,* **116**, 393-397 **(2000)**

77. Nico C.G.T. Integrated and sequential anaerobic/aerobic biodegradation of azo dyes, Wageningen, The Netherlands: Wageningen University; **(2001)**

78. Franciscon E., Zille A., Dias G. F., Cristiano R. d. M., Regina D. L. and Artur C.-P., Biodegradation of textile azo dyes by a facultative *Staphylococcus arlettae* strain VN-11 using a sequential microaerophilic/aerobic process, *International Biodeterioration & Biodegradation,* **63**, 280-288 **(2009)**

79. Moutaouakkil A., Zeroual Y., Dzayri F. Z., Talbi M., Lee K. and Blaghen M., Decolorization of azo dyes with *Enterobacter agglomerans* immobilized in different supports by using fluidized bed bioreactor, *Current Microbiology,* **48**, 124-129 **(2004)**