Research Journal of Environmental Toxicology

ISSN 1819-3420

Academic Journals Inc.

www.academicjournals.com

Research Journal of Environmental Toxicology 5 (2): 97-107, 2011
ISSN 1819-3420 / DOI: 10.3923/rjet.2011.97.107

Biodegradation of Mixed Textile Dyes by Bacterial Strains Isolated from Dyewaste Effluent

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ABSTRACT

In recent years bacteria have been drawing a tremendous attention due to their ability to treat waste water and thereby improve water quality. Hence, a study was undertaken to explore the nature of bacteria in order to exploit them as a tool in the bioremediation of dyehouse wastes. Effluent samples were collected from textile dyeing units and a Common Effluent-Treatment Plant (CETP) located in Tiruppur and Telungupalayam, Tamil Nadu. Totally 112 bacterial strains were obtained from Textile dyeing units and the CETP, based on their growth on nutrient agar medium supplemented with mixed azo dyes and their ability to decolorize mixed reactive azo dyes was studied. The effect of nutrient on decolorization revealed 0.5% of yeast extract was the best nitrogen source for up to 98% decolorization of mixed dye. Out of 112 strains 5 most effective strains were selected based on their decolorization of the dye up to 2700 mg L^{-1} through an acclimatization study. Optimum decolorization took place strictly under static conditions and pH and temperature were maintained constant at 7.0 and 30°C, respectively. The degradation product after decolorization was examined by TLC and FTIR.

Key words: Reactive dyes, decolorization, bioremediation, dyewaste effluent, bacteria

INTRODUCTION

Water pollution control is at present one of the major thrust areas of scientific research. Colour removal in particular, has recently become an area of major scientific interest as indicated by Moosvi *et al.* (2005). Dyes are released into the environment through industrial effluents from three major sources such as textile, dyestuff manufacturing and paper industries. One of the most pressing environmental problems related to dye effluents is the improper disposal of waste water from dyeing industry. With regard to their color removal by conventional treatment methods lead to severe water pollution, thus developing cost effective clean-up operations. Microbial degradation seems to be promising compared to other organisms and the method of application are simpler compared to other available methods (Jayarajan *et al.*, 2011). The majority of synthetic dyes currently used are the highly water soluble azo-reactive dyes. Azo dyes are characterized by the existence of nitrogen-nitrogen double bonds (-N = N-) and the bright color of their aqueous solutions. The azo-reactive dyes are used extensively in textile industries to their favourable characteristics of bright color, water-fast and simple application techniques with low energy consumption (Othman *et al.*, 2011). Commonly used conventional treatments (biological, chemical oxidation and adsorption) often fail to generate final effluents with the required discharge quality at affordable costs (El-Shora and Metwally, 2008).

The removal of the polluting dyes is a serious problem, particularly for small scale textile industries where working conditions and low economic status do not allow them to treat their wastewater before disposal and they have no choice other than to dump all effluents into the main stream of water sources. Microbial decolourization and degradation is an environmental- friendly and cost-competitive alternative to chemical decomposition processes (Verma and Madamwar, 2003). At present, bioremediation relies on the pollutant-degrading capacities of naturally occurring microbial consortia in which bacteria play a central role (O'Neill *et al*., 2000). The ability of microorganisms to carry out dye decolorization has recently received much attention as microbial decolorization of dyes is a cost-effective method for removing them from the environment (Kalyani *et al*., 2008).

Approximately 10,000 commercial dyes and dyestuffs are used in the coloring industries (Robinson *et al*., 2001). As more than 10% of the dyestuff used during these dyeing processes does not bind to the fibers, large amount of dyes are released into the environment, therefore resulting in serious environmental pollution (Pearce *et al*., 2003) .The physical and chemical methods have disadvantages of being highly expensive, coupled with the formation of large amounts of sludge and the emission of toxic substances. In addition, the accumulation of concentrated sludge creates an additional disposal problem. The general approach of bioremediation is to improve the natural degradation capacity of the native organism. Several microorganisms have been reported by a number of investigators which have the capacity to decolorize various textile azo dyes (An *et al*., 2002; Sarnaik and Kanekar, 1999). The degradation of azo dyes produces aromatic amines which are carcinogenic and mutagenic. Recently, several reports appeared showing that the microorganism has the ability not only to decolorize dyes but also to detoxify it (Adedayo *et al*., 2004; Kumar *et al*., 2007; Rajaguru *et al*., 2000). The process of biodegradation is a well-established and powerful technique for treating domestic and industrial effluents. Microbial populations has an amazing and extensive capacity to degrade a variety of organic compounds (Manogari *et al*., 2008).

Currently, extensive research is being focused on finding an optimal microbial biomass that would be as cheap as possible for the removal of contaminating dyes from large volume of polluted water (Youssef *et al*., 2008). In this study, the screening of bacteria from dye effluent was done for adapting them for maximum removal of textile dye.

Azo dyes are widely used in textile finishing and have become of concern in wastewater treatment because of their color, bio-recalcitrance and potential toxicity to animals and humans. Thus, wastewater with azo dyes must be decolorized and furthermore mineralized in appropriate systems (Chang *et al*., 2000; Uddin *et al*., 2007). An attempt was made to isolate bacterial strains from dyewaste effluent and their decolorization efficiency was studied.

MATERIALS AND METHODS

Isolation of microorganisms from dyewaste effluent: Samples were collected from a Textile dyeing unit and three different Common Effluent Treatment Plants (CETPs) located in Tirupur and Telungupalayam, Tamil Nadu, India in the year 2009. Initially serial dilution plating technique was followed for the isolation of bacteria and then were cultivated on nutrient Agar medium with a composition of (g L^{-1}): peptone (5.0), yeast extract (2.0), Beef extract (3.0), NaCl (5.0), agar (16.0). The plates were incubated at 30°C for 24 h. Colonies of different morphology were isolated and utilized for decolorization study.

Dyes and media: The common name of the reactive azo dyes viz., Blue RR, Red ME4B, Black B, Yellow MR, Yellow ME4G, Turquise prine, Red RR, Yellow MER, Yellow M4G, Blue MR, Red M5B, Yellow RR and Navy Blue used for the biodecolorization studies were a generous gift from the Tirupur textile unit. All other chemicals were analytical grade. The Mineral Salts Medium (MSM) of pH 7.0 contained (g L^{-1}) the following composition NaCl (1.0), $CaCl_2 \cdot 2H_2O$ (0.1), $MgSO_4 \cdot 7H_2O$ (0.5), KH_2PO_4 (1.0) and Na_2HPO_4 (1.0).

Screening of microorganisms based on decolorization activity: Isolates were individually tested for their growth and decolorization ability on nutrient agar medium containing 100 ppm of each dye. All the dyes were prepared separately and each of the cultures was tested against a single dye. The plates were incubated at 30°C till zone formation. Based on the growth on the nutrient agar medium, secondary screening was performed with the same procedure on solid MSM medium incorporated with 10 ppm of different dyes.

Acclimatization study: The acclimatization was done by gradually exposing the isolates to increasing concentrations of four different mixed azo dyes viz., Blue RR, Black B, Red RR and Yellow RR. The stock mixture contained 250 mg^{-1} of each dye. Cultures which were obtained from secondary screening were utilized for the study. The set-up contained liquid MSM composed of 100 ppm of mixed dye amended with optimized concentration of 0.5% yeast extract. When decolorization occurred, an additional 200 ppm of dye was added to the same flask. Likewise the dye was added in increasing concentrations to the decolorized medium. Consecutive cycles of dye decolorization were studied by the repeated additions of mixed dye to the medium.

Influences of additional sources of carbon and nitrogen on decolorization efficiency of mixed azo dyes: Five Efficient Strains (ES) were selected from the acclimatization study and their efficiency of decolorization was studied in three separate C and N source media, namely Liquid MSM containing 0.5% of yeast extract, a second containing MSM with 1% glucose and a third with MSM alone. The media were inoculated with the respective bacterial strains by adding inocula of uniform cell density (λ_{600} =1 OD). The medium to inoculum ratio (v/v) was 50:1. All the cultures were incubated at 30°C. The absorbance was measured at its maximum of 598 nm against a blank. Decolorization of the medium was observed on a daily basis using spectrophotometric readings at 598 nm. The percentage of decolorization was calculated as follows:

$$\% \text{ Decolorization} = \text{Initial absorbance} - \text{Observed absorbance/Initial absorbance} \times 100$$

A total of 112 strains were isolated from various places in and around Tirupur city including dyeing unit and CETP plant .During primary screening, the percentage of 48.21 isolates were obtained from Textile dyeing unit and CETP resolves 51.78% . Upon secondary screening about 10.71% of isolates represent dyeing unit and 33.92% represent CETP were obtained when cultured on MSM containing the dye as only source of C and N.. From acclimatization study, out of 50 isolates checked only 10% of isolate represent CETP had effective decolorization ability was obtained. The isolates from dyeing unit resolved only 2% of total isolates. Finally out of 112 isolates the 5 most effective isolates were included for further analysis.

Analysis of biodegraded product: The degraded product was extracted from the efficient strains. Cells were centrifuged and supernatant was extracted with equal volume of ethyl acetate and then

dried over anhydrous sodium sulphate. The residue was dissolved in a small amount of methanol and this was utilized for a TLC test. The developing solvent systems used were ethyl acetate: hexane (2:3, v/v) for biotransformed intermediates/products and ethyl acetate: methanol (7:3, v/v) for residual dye. The bands of aromatic components were observed under UV light (365 nm) and other bands were observed by exposing the plates to iodine vapor in an iodine chamber. Dry pellets were utilized for FTIR spectral analysis.

RESULTS AND DISCUSSION

Throughout India, there is grave concern and constant attention given to the treatment of industrial effluents from textile and dye manufacturing units. Several researchers have demonstrated the possibility of utilizing microorganisms for biotreatment of textile wastewater. In India, most textile units are scattered and/or operated from private homes. Therefore, it is necessary to collect and treat the waste in common effluent treatment plants. Biological methods are simple to use and the cost of operation is low (Padmavathy *et al.*, 2003).

Screening of microorganism: The present investigation describes the isolation of native bacterial strains from different dye units with the ability to decolorize azo dyes. Totally 112 isolates were obtained from dyewaste effluents of Tirupur and Telungupalayam dye units. A significant growth was observed on Nutrient agar medium incorporated with 100 ppm of different dyes. All the 112 isolates were tested for their decolorization ability on MSM supplemented with 10 ppm dye concentration. We isolated 50 strains from secondary screening using which decolorization was done in MSM. These 50 strains were adapted to high dye concentrations as they were collected from sites near textile industries. The effectiveness of microbial decolorization depends on the adaptability and the activity of selected microorganisms (Abd El-Rahim and Moawad, 2003).

Acclimatization study: The acclimatization was done by gradually exposing the selected 50 isolates (obtained from secondary screening) in increasing concentrations of dye. Decolorization occurred only when nitrogen source was available in the growth medium. Most of the Dyeing unit in and around Tirupur region utilizing reactive dyes for dyeing fabrics. Thus our microbe have significant potential for decolorization of reactive textile dyes and are an important and promising material for the removal of reactive dyes from textile effluents. Consecutive cycles of dye decolorization were studied by the repeated additions of mixed dye to the medium. Since waste of textile industries consist of a mixture of various dyes, the ability of the different isolates to decolorize the mixed textile dyes was studied. The set up contained 0.5% of yeast extract.

Yeast extract was found to be the most effective supplement for promoting higher decolorization efficiency. Such organic nitrogen sources are considered essential media supplements for the regeneration of NADH that act as electron donors for the reduction of azo dyes by microorganisms (Khehra *et al.*, 2005).

All the decolorization experiments were done under static conditions. Of the total isolates, the five most efficient stains (3.57%) were obtained through acclimatization capable of decolorizing 2700 ppm of mixed dye within 13 days of incubation. Our isolate KP 23 took 24 h for 98% decolorization of initial 100 ppm dye. The dye was added additionally as soon as in the decolorized medium. Like wise the dye was added in increasing concentration in the decolorized medium. The results are summarized in Table 1. Upon the addition of final dye (total concentration 2700 ppm) the decolorization efficiency was only 76%. Since the isolate KP 23 represent CETP can be

Table 1: Effect of continuous addition of mixed azo dye in the ongoing study of superior strain KP 23 (obtained from CETP)

Step	Total dye added in medium (ppm)	Time (h)	Decolorization (%)
1	100	24	98
2	200	24	96
3	300	24	90
4	400	48	90
5	500	48	86
6	600	72	84
7	600	72	76

effectively utilized for the treatment of real textile effluent .Azoreductase-driven bacterial decolorization of azo dyes is inhibited by the presence of oxygen primarily owing to the competition in the oxidation of reduced electron carriers (e.g., NADH) with either oxygen or azo groups as the electron acceptor. In static incubation, only a trace amount of oxygen was transferred, probably onto the broth surface and thus, the cells mostly sedimented to the bottom of the flasks were likely to undertake decolorization under anaerobic conditions (Mathew and Madamwar, 2004).

However, the isolates proved very effective in their decolorization capability and therefore it can be utilized for real dyewaste water treatment. The acclimatization was done by gradually exposing *Pseudomonas* sp. SUK1 to increasing concentrations of dye. *Pseudomonas* sp. SUK1 was consecutively transferred into the nutrient medium with increasing concentration of Red BLI dye up to 600 mg L^{-1} at 30°C and static conditions. (Kalyani *et al*., 2008). The decolorization potential of Reactive Yellow 42 (RY 42), Reactive Blue 13 (RB 13) and Reactive Red 58 (RR 58) by the bacterium Micrococcus sp was investigated by Olukanni *et al*. (2009).

The repeated use of microorganisms is important from the commercial point of view. This study was carried out to examine the ability of a pure culture to decolorize repeated additions of mixed azo dyes in static condition. The decolorization of the dye solution could be selectively supported by the media composition. The yeast extract medium was the most suitable for the decolorization of dye. However, we were not successful in isolating bacteria capable of decolourizing and utilizing only dyes as the sole source of carbon and energy.

Decolourization occurred only when additional nitrogen energy source was available in the growth medium. The culture exhibited the ability to decolourize repeated additions which is significant for its commercial application. Normally the dye concentration in the effluent varies within a narrow range of 0.1-0.2 g L^{-1} (O'Neill *et al*., 2000). Isolates could decolourize dyes far above the reported dye concentration in wastewaters and thus could be successfully employed for treatment of dye-bearing industrial wastewaters. Moreover, it exhibited efficient decolourizing ability even for mixed dye tests.

Effect of carbon and nitrogen source: All the 5 ES namely TU57, TR26, VP9, KP27, KP23 were tested for their decolorization activity in liquid MSM medium supplemented separately with 1% glucose, 0.5%yeastextract and MSM alone. Other inorganic sources were also tried for the effective decolorization of dyes but isolates could not able to utilize as growth factor also we found no growth in those medium (data not shown) Spectrophotometric analysis revealed that the strains could utilize the mixed dye (100 ppm) and decolorize it up to 83.8-91.8% when 0.5% of yeast extract was supplemented in the medium (Fig. 1). However, Glucose (Fig. 2) resolved only 5.8-11.1% of

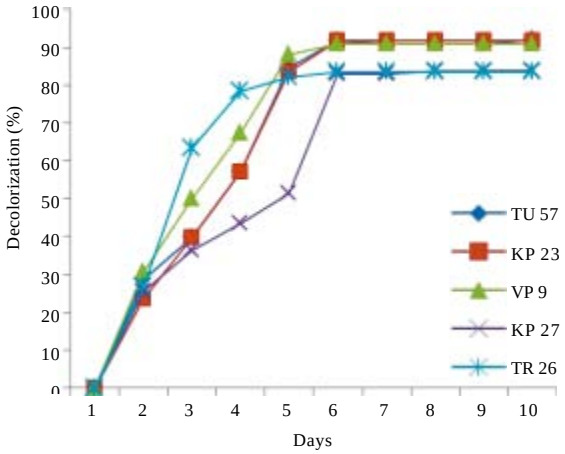

Fig. 1: Effect of yeast extract (0.5%) on decolorization of 100 ppm of mixed dye

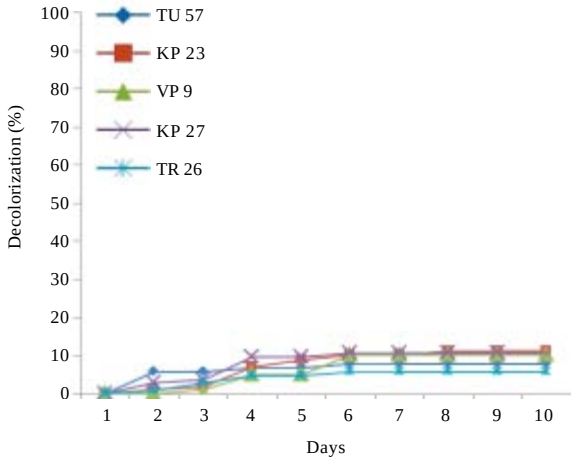

Fig. 2: Effect of glucose (1%) on decolorization of 100 ppm of mixed dye

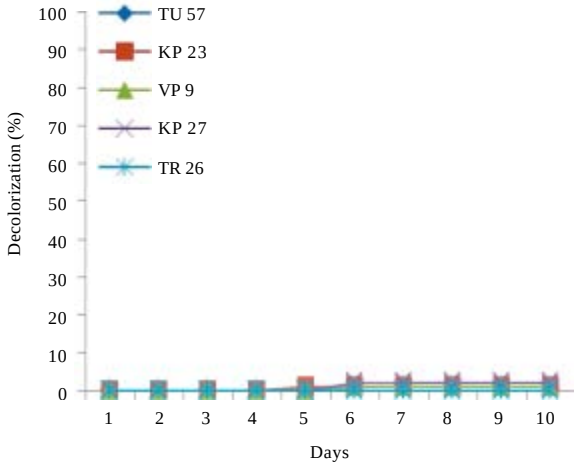

Fig. 3: Effect of dye alone for the decolorization of 100 ppm of mixed dye

decolorization, while we could achieve only 1.04-2.08% of decolorization (Fig. 3) when dye alone was used. The ES could not utilize dye as the sole source of C and N. It was observed that the decolorization was due to degradation since the centrifuged pellet of the isolates after decolorization showed a white pellet instead of dye colour.

Study revealed that the isolates were able to decolorize the dye up to 91% when 0.5% of yeast extract was supplemented in the medium (Joshi *et al*., 2008). Yeast Extract (YE) alone resulted in much higher decolorization of AO7 as compared to glucose alone, peptone or starch when novel microbial consortia were used. The yeast extract medium was most appropriate for the decolorization of dye Navy blue 2GL as compared to the beef extract and nutrient broth medium (Dawkar *et al*., 2009). An earlier report showed that maximum decolorization of Acid Black 210 by Vibrio harveyi TEMS1 was observed when the yeast extract concentration was 5 g L^{-1} (Ozdemir *et al*., 2008). The decolorization efflciency is strongly affected by the medium compositions. Organic nitrogen sources such as peptone or yeast extract incorporation shows higher decolourization when compared with inorganic sources nitrate and ammonium chloride (Ramya *et al*., 2008). Yeast extract, a powder supplement consisting of protein, free amino nitrogen, B vitamins, minerals, nucleotides and other yeast cell components, has been the most commonly used nitrogen source for dye decolourization processes. A number of studies reported that yeast extract was the best nitrogen source for efficient decolorization of various textile dyes.

This may be owing to the metabolism of yeast extract which is considered essential for the regeneration of NADH. Many pure cultures like *Pseudomonas luteola, Klebsiella pneumoniae* and *Aeromonas hydrophila* have exhibited effective decolourization of different dyes in the presence of yeast extract (Elisangela *et al*., 2009) With glucose as the only carbon source, the culture showed negligible decolourization (5.57%), while with yeast extract as the sole carbon source, 23% decolourization of RV 5 was observed (Moosvi *et al*., 2005) The growth of *Pseudomonas luteola* was directly related to the concentration of yeast extract and when the concentration of yeast extract was reduced growth and colour removal decreased (Hu, 1998). The ability of *Staphylococcus aureus, Bacteroides fragilis, Bacillus subtilis, Bacillus cereus, Clostridium perfringens, Escherichia coli* and *Peptostreptococcus* spp. to reduce and stabilize textile effluents containing predominantly indigo blue was carried out by Ajibola *et al*. (2005).

TLC and FTIR result of biodegraded product: The dye decolorization study of bacterial isolate was further supported by TLC analysis. When the dye chromatogram was observed in UV light, the brown spot (Table 2) with Rf value 0.24, 0.3, 0.3, 0.25 and 0.3 were observed, while no such bands were observed for spots of dye and uninoculated medium, indicating that decolorization was due to dye degradation.

Fourier Transform Infrared Spectroscopy (FTIR) analyses were done for the control and the decolorised sample (Fig. 4 and 5) the results of which showed various peaks. The FTIR spectrum

Table 2: Result of TLC

Strain	Rf Value and UV observation
TU57	0.24, Brown spot
TR26	0.30, Brown spot
VP9	0.30, Brown spot
KP27	0.25, Brown spot
KP23	0.25, Brown spot

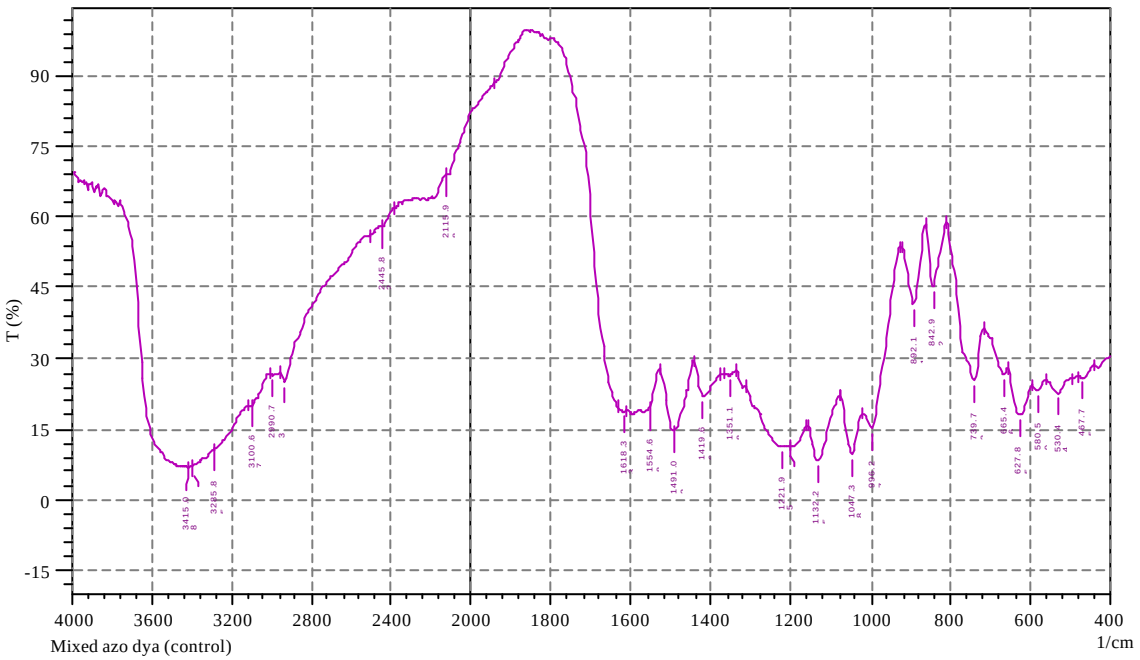

Fig. 4: FTIR spectrum of control mixed azo dye

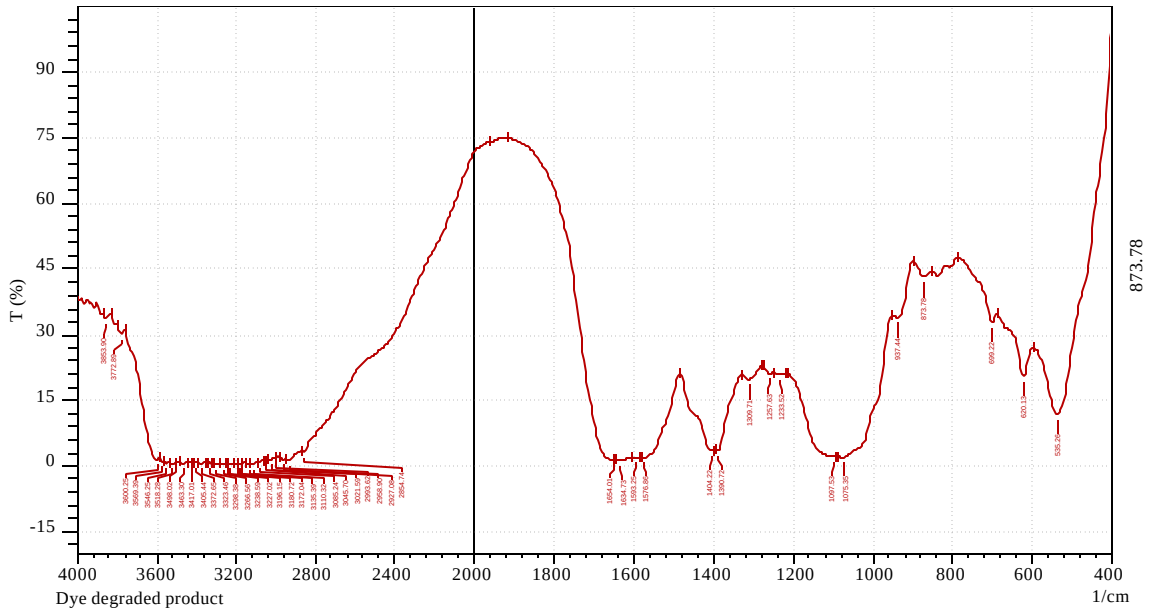

Fig. 5: FTIR Spectrum of degraded product

of control mixed dye displayed a peak at 3,415 cm^{-1} for the intramolecular hydrogen bonding aromatic -OH and O-H stretching;a peak at 2,929 cm^{-1} for C-H stretching of alkyl acetals and a peak at 2,445 cm^{-1} for N-H stretching of amines; a peak at 1,618 cm^{-1} for C = N stretching of azo group; a peak at 1,047 cm^{-1} for S = O stretching of sulfonic acid; a peak at 892 and 665 cm^{-1} for

aromatic nature and C-Cl stretching, respectively. The degradation metabolites of mixed dye showed a peak at 3,227 cm^{-1} for secondary amides, 1,654 cm^{-1} for C = C and C = N stretching and presence of amide bond, a peak at 1,404 cm^{-1} for O = H stretching and a peak at 620 cm^{-1} for C-Cl stretching indicating the presence of alkyl chloride. It indicated formation of nitrosamines, alkyl chloride, secondary and tertiary amides after decolorization. We had used a mixture of azo dyes, so it was not possible to compare the parent dye compound with the decolorized compound because we did not know which peak was from which compound. As we obtained different peaks for the parent compound and the decolorized compound it confirmed that it was degraded by the strain KP23.

The chemical structure of the dyes greatly influenced their decolourization rates and the decolourization efflciency is limited to several azo dye structures. Dyes with simple structures and low molecular weights usually exhibited higher rates of colour removal, whereas colour removal was more difficult with highly substituted, high molecular weight dyes. For this reason, RY107 and RR198 which are both monoazo, showed a short decolourization time (12 and 10 h, respectively), while the highly substituted diazo RB5 and the triazo DB71 showed longer decolourization times (24 and 48 h, respectively). It has been reported that the turnover rate of monoazo dyes increased with increasing dye concentration, whereas the turnover rate of the diazo and triazo dyes remained constant as the dye concentration increased. Moreover, the azo compounds with hydroxyl or amino groups were more likely to be degraded than those with methyl, methoxy, sulfo or nitro groups. Usually, the presence of sulfonates in reactive dye structures resulted in low levels of colour removal (Elisangela *et al*., 2009).

CONCLUSION

It was observed that the significant level of bioremediation indicated the ability of the isolate ES to withstand high concentrations of azo dyes during the bioremediation process. The ES could decolorize mixed azo dyes at much above the reported dye concentration in the wastewaters and thus can be used successfully in the commercial treatment of textile wastewaters. The toxicity analysis of degraded product is under process.

ACKNOWLEDGMENT

Authors acknowledge the Tamil Nadu State Council for Science and Technology for providing financial support for carrying out this work.

REFERENCES

Abd El-Rahim, W.M. and H. Moawad, 2003. Enhancing bioremoval of textile dyes by eight fungal strains from media supplemented with gelatine wastes and sucrose. J. Basic Microbiol., 43: 367-375.

Adedayo, O., S. Javadpour, C. Taylor, W.A. Anderson and M. Moo-Young, 2004. Decolourization and detoxification of methyl red by aerobic bacteria from a wastewater treatment plant. World. J. Biotecnol. Microbiol., 20: 545-550.

Ajibola, V.O., S.J. Oniye, C.E. Odeh, T. Olugbodi and U.G. Umeh, 2005. Biodegradation of indigo containing textile effluent using some strains of bacteria. J. Applied Sci., 5: 853-855.

An, S.Y., S.K. Min, I.H. Cha, Y.L. Choi, Y.S. Cho, C.H. Kim and Y.C. Lee, 2002. Decolorization of triphenylmethane and azo dyes by *Citrobacter* sp. Biotechnol. Lett., 24: 1037-1040.

Chang, J.S., T.S. Kuo, Y.P. Chao, J.Y. Ho and P.J. Lin, 2000. Azo dye decolorization with a mutant *Escherichia coli* strain. Biotechnol. Lett., 22: 807-812.

Dawkar, V.V., U.U. Jadhav, G.S. Ghodake and S.P. Govindwar, 2009. Effect of inducers on the decolorization and biodegradation of textile azo dye Navy blue 2GL by *Bacillus* sp. VUS. Biodegradation, 20: 777-787.

El-Shora, H.M. and M. Metwally, 2008. Use of tyrosinase enzyme from *Bacillus thuringiensis* for the decontamination of water polluted with phenols. Biotechnology, 7: 305-310.

Elisangela, F., Z. Andrea, D.G. Fabio, R.M. Cristiano and C.P. Artur, 2009. Biodegradation of textile azo dyes by a facultative *Staphylococcus arlettae* strain VN-11 using a sequential micro aerophilic/aerobic process. Int. Biodeterior. Biodegrad., 63: 280-288.

Hu, T.L., 1998. Degradation of azo dye RP_2B by *Pseudomonas luteola*. Water Sci. Technol., 38: 299-306.

Jayarajan, M., R. Arunachalam and G. Annadurai, 2011. Agricultural wastes of jackfruit peel nano-porous adsorbent for removal of rhodamine dye. Asian J. Applied Sci., 4: 263-270.

Joshi, T., L. Iyengar, K. Singh and S. Garg, 2008. Isolation, identification and application of novel bacterial consortium TJ-1 for the decolourization of structurally different azo dyes. Bioresour. Technol., 99: 7115-7121.

Kalyani, D.C., P.S. Patil, J.P. Jadhav and S.P. Govindwar, 2008. Biodegradation of reactive textile dye Red BLI by an isolated bacterium *Pseudomonas* sp. SUK1. Bioresour. Technol., 99: 4635-4641.

Khehra, M.S., H.S. Saini, D.K. Sharma, B.S. Chadha and S.S. Chimni, 2005. Decolorization of various azo dyes by bacterial consortium. Dyes Pigments, 67: 55-61.

Kumar, K., S.S. Devi, K. Krishnamurthi, D. Dutta and T. Chakrabarti, 2007. Decolorization and detoxification of direct blue-15 by a bacterial consortium. Bioresour. Technol., 98: 3168-3171.

Manogari, R., D. Daniel and A. Krastanov, 2008. Biodegradation of rice mill effluent by immobilized *Pseudomonas* sp. cells. Ecol. Eng. Environ. Prot., 1: 30-35.

Mathew, S. and D. Madamwar, 2004. Decolorization of ranocid fast blue dye by bacterial consortium SV5. Applied Biochem. Biotechnol., 118: 371-381.

Moosvi, S., H. Keharia and D. Madamwar, 2005. Decolourization of textile dye reactive violet 5 by a newly isolated bacterial consortium RVM 11.1. World J. Microbiol. Biotechnol., 21: 667-672.

Olukanni, O.D., A.A. Osuntoki and G.O. Gbenle, 2009. Decolourization of azo dyes by a strain of *Micrococcus* isolated from a refuse dump soil. Biotechnology, 8: 442-448.

Othman, N., N. Mili and Y.M. Wong, 2011. Liquid-liquid extraction of black B dye from liquid waste solution using tridodecylamine. J. Environ. Sci. Technol., 4: 324-331.

Ozdemir, G., B. Pazarbasi, A. Kocyigit, E.E. Omeroglu, I. Yasa and I. Karaboz, 2008. Decolorization of acid black 210 by *Vibrio harveyi* TEMS1, a newly isolated bioluminescent bacterium from Izmir Bay, Turkey. World J. Microbiol. Biotechnol., 24: 1375-1381.

O'Neill, C., A. Lopez, S. Esteves, F. R. Hawkes, D. L. Hawkes and S. Wilcox, 2000. Azo-dye degradation in an anaerobic-aerobic treatment system operating on simulated textile effluent. Applied Microbiol. Biotechnol., 53: 249-254.

Padmavathy, S., S. Sandhya, K. Swaminathan, Y.V. Subrahmanyam, T. Chakrabarti and S.N. Kaul, 2003. Aerobic decolorization of reactive azo dyes in presence of various cosubstrates. Chem. Biochem. Eng. Q., 17: 147-151.

Pearce, C.I., J.R. Lloyd and J.T. Guthrie, 2003. The removal of color from textile wastewater using whole bacterial cells: A review. Dyes Pigments, 58: 179-196.

Rajaguru, P., K. Kalaiselvi, M. Palanivel and V. Subburam, 2000. Biodegradation of azo dyes in a sequential anaerobic-aerobic system. Applied Microbiol. Biotechnol., 54: 268-273.

Ramya, M., B. Anusha and S. Kalavathy, 2008. Decolorization and biodegradation of Indigo carmine by a textile soil isolate *Paenibacillus larvae*. Biodegradation, 19: 283-291.

Robinson, T., B. Chandran and P. Nigam, 2001. Studies on the decolorization of an artificial textile effluent by white-rot fungi in N-rich and N-limited media. Applied Microbiol. Biotechnol., 57: 810-813.

Sarnaik, S. and P. Kanekar, 1999. Biodegradation of methyl violet by *Pseudomonas mendocina* MCMB-402. Applied Microbiol. Biotechnol., 52: 251-254.

Uddin, M.S., J. Zhou, Y. Qu, J. Guo, P. Wang and L. Zhao, 2007. Biodecolorization of azo dye acid red B under high salinity condition. Bull. Environ. Contam. Toxicol., 79: 440-444.

Verma, P. and D. Madamwar, 2003. Decolourization of synthetic dyes by a newly isolated strain of *Serratia marcescens*. World J. Microbiol. Biotechnol., 19: 615-618.

Youssef, A.S., F.M. El-Sherif and A.S. El-Assar, 2008. Studies on the decolorization of malachite green by the local isolate *Acremonium kiliense*. Biotechnology, 7: 213-223.