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Biodetoxification of Azo Dye Containing Textile Effluent Through Adapted Fungal Strains

R. Rajendran, S. Karthik Sundaram, B.V. Sridevi, P. Prabhavathi and V. Gopi
PG and Research Department of Microbiology, PSG College of Arts and Science, Coimbatore-14, India

Corresponding Author: R. Rajendran, PG and Research Department of Microbiology, PSG College of Arts and Science, Coimbatore-14, India

ABSTRACT

This study investigated the potential of adapted fungi isolated from textile effluent containing a mixture of azo which were used in the bioremediation analysis. Around 4 organisms with a potential for color removal was selected and were found to be *Aspergillus* sp., *Penicillium* sp., Fusarium sp. and *Mucor* sp. These organisms were compatible with each other hence they could both be used in bioremediation as individual pure cultures as well as a consortium. On analyzing the treatment trials with the individual cultures and consortium it was found out that the consortium was found to be effective in bioremediation when compared to individual fungal strains. The fungal consortium was able to reduce color upto 75%, organic load to 50% and total solids upto 54%. This study also presents the standardization of organic load concentration, pH, retention time, inoculum concentration and incubation temperature required to decolorize the azo textile effluent. Langmuir and Freundlich adsorption isotherms have been used to investigate with adapted fungal consortium on removal of toxic pollutants (dye), the best fitting was observed in both monolayer model (R^2 about 0.98) as well as Freundlich model in an experimental data with used dye (R^2 about 0.92). GCMS analysis performed for the treated effluent under optimized condition (Retention time -5 days; pH-6; Organic loading rate-100%; Incubation temperature -27°C; and Inoculum concentration-5%) confirmed that the sample treated was devoid of any toxic end products.

Key words: Adapted fungi, fungal consortium, bioremediation, GC-MS, detoxification, azo reduction

INTRODUCTION

Coimbatore which is also known as the Manchester of South India flourishes mostly on the wealth generated by the textile industry. Though, it could be ascertained that textile industry brings more wealth but the environmental hazards that it brings in is equally inevitable. Textile effluents are in general tough to treat because of their high organic content, tough pH conditions and due to the presence of a variety of classes of dyes. The most commonly used dyes in the textile arena for dyeing are the azo dyes owing to its cheaper cost, contributes to about 50-65% of the total colors used for dyeing purpose (Chung and Stevens, 1993; Melgoza *et al*., 2004). Due to their poor exhaustion properties more than 30% of the dye components end up in the effluent (Omar, 2008). The major drawback of the usage of azo dye is that they are recalcitrant in nature and when ingested could prove fatal to the living forms (Levine, 1991). Till now these effluents were treated through physical and chemical means but they have many disadvantages like their lack of implementation which has been largely due to high cost, low efficiency and generation of toxic by-products (Quezada *et al*., 2000).

Bio treatment offers a cheaper and an environmental friendly alternative for remediation of textile effluents. These azo dyes could be reduced under anaerobic conditions by the usage of bacterial systems but with the liberation of toxic intermediates (aromatic amines). These aromatic amines should be treated under aerobic conditions in order to be neutralized (Olukanni *et al.*, 2009). The use of microbes for the treatment of textile effluent ensures that the technique is both cost effective and the treated effluent is devoid of any toxicity due to its wide range of enzymatic systems present it its system (Ahmedna *et al.*, 2004). Although, a wide variety of microbes are capable of treating the textile effluent, fungi are considered the best alternative to bacterium in the treatment of effluent (Banat *et al.*, 1996).

An example for the most primitive form of eukaryotic system is the fungal cell. They could adjust themselves well to the harsh environment of the textile effluent because of two reasons (1) they are capable of synthesizing the heat shock proteins (2) their ability to synthesize a wide variety of enzymes. There are certain groups of lignin degrading fungi which are capable of synthesizing non-specific enzymes like laccase, lignin peroxidase and manganese peroxidase (Khammuang and Sarnthima, 2009). These enzymes act on any substrate having the aromatic ring reducing them to non-toxic forms (Fu and Viraraghavan, 2001). But this group of fungi could not be involved directly in the treatment of textile effluent as the organic load used present in the effluent could not be efficiently utilized by the fungus used. The usage of adapted fungal strains that have evolved in the reactor of the wastewater treatment plant could be suggested as an effective alternative to the lignin degrading fungi. When the concentrations of these adapted fungal strains were increased during the treatment process, there is a greater opportunity for an effective bioremediation. Also, the use of a fungal consortium could prove more effective than the use of a single fungus, due to the capability of a wide spectrum of enzymes produced by the consortium which could be used in bioremediation (Robinson *et al.*, 2001). With the presence of a wide variety of enzymes it is sure that both the organic load and dyes present in the effluent could be completely mineralized by the fungal consortium under normal aeration in a biological tank.

In the present study, adapted fungal strains with a potent decolorizing ability were isolated from the textile effluent. These strains were identified and were then used in the bioremediation of the textile effluent as both individual pure cultures and as a consortium. The efficient strain was optimized under different cultural conditions. The treated effluent was then characterized using GC-MS to analyze the presence of any toxic end products.

MATERIALS AND METHODS

Sample collection: Textile effluent sample was collected from a common effluent treatment plant in Coimbatore. This sample was used for isolating adapted fungal strains and in analyzing the treatment efficiency of the isolated fungal strains. The sample was stored in refrigerator at 4°C and used without any pretreatment.

Isolation and screening of fungi for decolorization: Fungal strains from the textile effluent sample were isolated through serial dilution and plating on Potato Dextrose Agar (PDA) amended with 0.01 g of mixture of six different dyes (primary screening). Reactive red 120, Remazol brilliant violet, Reactive black 5, Re Yellow merl, Orange merl and Red M5B were the six different synthetic dyes used in screening. The plates were incubated at 27°C for 48 h. The colonies which exhibited zone of clearance were selected. These selected colonies in pure form were further screened in potato dextrose broth amended with 0.01% of six different dyes individually (secondary screening) and incubated. After 48 h the supernatant was collected and percentage of decolourization was

measured spectrophotometrically (Phetsom *et al*., 2009). Decolorization efficiency can be expressed in terms of percentage:

$$\% \text{ of Decolorization} = \frac{\text{Initial absorbance-Final absorbance}}{\text{Initial absorbance}} \times 100$$

Identification of screened isolates: The screened fungi which showed maximum decolorization were selected and identified using lactophenol cotton blue staining.

Compatibility analysis: About four distinct fungal strains which were found to be efficient in decolorization of azo dyes were analyzed for its compatibility nature with one another. Four PDA agar plates were taken and each plate was bored with three wells. The first plate was swabbed with the isolate 1 and was added with 10 µL of culture supernatants of the selected screened isolates 2, 3 and 4, respectively in the three wells. This was to study the antagonistic effect of the 3 adapted organisms on the growth of the swabbed organism. The test was repeated by changing the swabbed organism and the supernatants were added to the bored wells to check the antagonistic effect of each organism screened. The plates were then kept for incubation at 27°C for 48 h. The culture said to be compatible with each other if no zone of clearance appeared around the bored well (Rajendran *et al*., 2011).

Physiochemical analysis of untreated effluent: The untreated effluent was characterized by measuring 11 different parameters-pH, color, tubidity, Total Solid (TS) Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD) and hardness, electrical conductivity, resistivity, alkalinity. Color and turbidity were measured by using UV spectrophotometer at 435 nm and 620 nm, respectively (Telke *et al*., 2010). The remaining parameters were analyzed using standard protocols (APHA, 1992).

Treatment trials of textile effluents using the selected fungal strains: The four selected fungal strains were studied for their bioremediation efficiency both as individual cultures and as a consortium. About 5 mL of the inoculum was inoculated in 95 mL of the textile effluent individually in four different flasks. Combination of 4 adapted fungal strains (in equal concentration making a volume of 5 mL) was inoculated in 95 mL of the textile effluent. These flasks were incubated at 27°C in a metabolic shaker at 120 rpm for 7 days. Samples were retrieved from the flasks at the end of 7 days of incubation and analyzed for the bioremediation efficiency of the fungal cultures involved. The bioremediation efficiency of the treatment trials were analyzed statistically through ANOVA.

Optimization of cultural conditions for maximum bioremediation ability: The adapted fungal consortium which was efficient in bioremediation of the textile effluent compared with that of the non-adapted fungal strains was optimized under different cultural conditions such as retention time, initial pH, incubation temperature, initial inoculum concentration and initial organic loading rate.

Effect of retention time: Seven flasks with raw effluent were taken and each flask was inoculated with 5% inoculum and incubated at 27°C over a period of 1-7 days. Physico-chemical parameters were analyzed on daily basis. Based on the bioremediation efficiency the optimal retention time was selected and used as single cycle for optimization of other parameters.

Effect of initial pH: Raw effluent was taken in 5 different flask was pre adjusted to different pH ranges (5, 6, 7, 8 and 9), inoculated with 5% inoculum of the consortium and incubated at 27°C for a period of 5 days. After incubation the treated effluent sample was characterized using the different physico-chemical parameters.

Effect of initial incubation temperature: The dependence of bioremediation of effluent on incubation temperature can be found by incubating the raw effluent inoculated with 5% inoculum under different temperatures (7, 17, 27 and 37°C). After a period of 5 days the physico-chemical parameters were analyzed and the efficient incubation temperature was determined.

Effect of initial Organic Loading Rate (OLR): Five different organic load concentrations (20, 40, 60, 80 and 100%) of the raw effluent were taken. To this 5% inoculum was added and incubated at 27°C for a period of 5 days. The efficiency of bioremediation was analyzed after 5 days of incubation using the different physic-chemical parameters.

Effect of initial inoculum concentration: Five flasks with raw effluent were taken and to it inoculum was added at various concentrations (1, 3, 5, 7 and 9%) and incubated at 27°C for 5 days. The efficiency of bioremediation was analyzed after 5 days of incubation using the different physico-chemical parameters.

Adsorption isotherm kinetics on Bioremediation of azo textile effluent by adapted fungal consortium: This test was required to evaluate Langmuir and Freundlich adsorption isotherm kinetics to determine the adsorption equilibrium in azo dye containing textile effluent for the approximation of obtained results. The constant in the Langmuir isotherm can be determined by plotting Ce/(x/m) versus Ce and making use of Eq. 1:

$$Ce/(x/m) = 1/ab+1/a\ (Ce) \quad (1)$$

Where:
x/m = Inoculum concentration
a,b = Empirical constants
Ce = Equilibrium concentration of adsorbate in solution after adsorption (mg L^{-1})

In Freundlich isotherm can be determined by plotting Ce/(x/m) versus Ce and making use of Eq. 2:

$$Log(x/m) = Log\ Kf+(1/n)\ log\ Ce \quad (2)$$

Where:
Kf and 1/n = Freundlich constants

Physico-chemical characterization of the treated effluent under optimized condition: GC-MS has been widely used to identify products of dyes degraded by fungi. The major limitation of this technique is that the sample must be volatile and thermally stable at the temperature of analysis. The effluent treated under optimized condition was taken and mixed with equal volume of diethyl ether and allowed to evaporate. The remaining residue was collected and mixed with

methanol. Sample was dissolved in methanol and GC-MS analysis of untreated and treated effluents was carried out using a THERMO GC-TRACE ULTRA VER: 5.0, THERMO MS DSQ II. The ionization voltage was 70 ev. Gas chromatography was conducted in temperature programming mode with a 100-250°C, RATE: 8/min, HOLDING TIME: 10 min at 250°C. The initial column temperature was 40°C for 4 min, then increased linearly at 10°C per min to 270°C and held at 4 min. The temperature of injection port was 275°C and GC/MS interface was maintained at 300°C. The helium was carrier gas; flow rate was 1.0 mL min^{-1} and 30 min run time. The compounds were identified on the basis of mass spectra and using the NIST library stored in the computer software (version 1.10 beta Shimadzu).

RESULTS

Isolation and screening of fungal isolates: Around 9 fungal isolates which showed zone of clearance were able to reduce the chromophore of the synthetic azo dyes in the medium (primary screening). Among the 9 fungal isolates, 4 fungal isolates (isolate 1, 5, 8 and 9) (Table 1) were able to reduce the azo dyes by more than 50% (secondary screening). The organism 1 was able to reduce the color of orange merl by upto 62% whereas the organism 5 reduced the color of yellow merl by upto 76%. Organism 8 was able to reduce remazol brilliant violet upto 87% and about 75% reduction in red 5MB was observed for the organism 9. These four organisms were able to reduce the color all the dyes used in the study whereas the other organisms analyzed were not able exert a reduction in all the dyes used. These four fungal isolates were chosen for further identification and treatment trials.

Identification of screened isolates: The screened adapted fungal strains (1, 5, 8 and 9) were found to be *Aspergillus* sp., Penicillium sp., *Fusarium* sp. and *Mucor* sp., respectively based on the microscopical appearance of fungi through lactophenol cotton blue staining. The *Aspergillus* sp., showed single celled spore (conidiospores) arranged in chains developing at the end of sterigma arising from the terminal bulb of the conidiophores. Long conidiophores arise from a septate mycehum. The *Penicillium* sp. showed single celled spores arranged in chains developed at the end of sterigma arising from the medulla of the conidiophores. Branching conidiophores arise from the septate mycelium. The *Fusarium* sp. multi celled spores are sickle shaped and attached to conidiophores arise from a septate mycelium. The *Mucor* sp. showed oval, colorless spores with black sporangium containing a columella. It has a non septate mycelium and does not contain rhizoids.

Table 1: Secondary screening of the selected fungal strains (Broth decolorization assay)

	Decolorization of synthetic textile dyes (%)					
Fungal isolates	Reactive red 120	Remazol brilliant violet	Reactive black 5	Re yellow merl	Orange merl	Red M5B
1	59.25	49.31	50.98	57.21	62.98	74.23
2	21.69	44.81	54.22	20.37	33.26	19.87
3	27.32	33.87	44.26	39.11	25.59	33.29
4	40.32	22.02	31.34	44.02	36.61	22.36
5	62.52	67.98	56.87	76.10	66.32	49.90
6	11.34	34.98	34.99	45.60	52.55	22.89
7	22.76	44.90	25.54	11.45	32.76	45.86
8	65.67	87.54	55.67	47.67	69.45	53.33
9	50.48	54.34	63.56	58.25	68.85	75.77

Compatibility analysis: The 4 adapted fungal strains selected were found to be compatible with each other. There was no zone of inhibition around their colonies in any of the plates incubated. The main reason for the compatible nature of the selected fungal strains was mainly due to their co-existence in the effluent over a considerable period of time (Aslim *et al*., 2002).

Physico-chemical characterization of untreated effluent: The raw effluent as such cannot be depleted to the environment since it has a huge load of organic content and dyes in them than the prescribed limits of Tamil Nadu Pollution Control Board (TNPCB) (Table 2). A high organic load in the effluent was higher than the limit which was evident high TS, TSS, TDS and COD of the untreated effluent. The high organic load depletes the dissolved oxygen level in the natural water system which affects aquatic life. The color of the effluent also aids a problem due the presence of the dyes which are toxic to the environment.

Treatment trials of textile effluents using adapted fungal strains: On observing the reduction in the various physico-chemical parameters of the treated effluent sample, it could be concluded that the fungal consortium consisting of all the four selected adapted fungal strains was efficient than the individual fungal strains after 7 days of incubation (Table 3). Among the individual strains the *Aspergillus* sp. was found to be efficient in reducing the colour upto 27.61% whereas the *Penicillium* sp. reduced the organic load by upto 23% and the *Fusarium* sp. was

Table 2: Physico-chemical characterization of pooled untreated effluent

Physico-chemical parameters	TNPCB limits	Levels
Chemical Oxygen Demand (COD)	400 (mg L^{-1})	1120 (mg L^{-1})
Color (at 490 nm)	25 HU	0.9
Total Solids (TS)	2500 (mg L^{-1})	13600 (mg L^{-1})
Total Suspended Solids (TSS)	50 (mg L^{-1})	3330 (mg L^{-1})
Total Dissolved Solids (TDS)	1500 (mg L^{-1})	10270 (mg L^{-1})
Turbidity (at 620 nm)	Not objectionable	0.5713
Hardness	600 (mg L^{-1})	260 (mg L^{-1})
pH	6.5-9	6.9

Table 3: Bioremediation potential of individual fungal strains and consortinm

		Aspergillus sp.		*Penicillium* sp.		*Fusarium* sp.		*Mucor* sp.		Consortinm	
Physico-chemical parameters	Untreated	Treated effluent	% Redn	Treated effluent	% Redn	Treated effluent	% Redn	Treated effluent	% Redn	Treated effluent	% Redn
Colour (435 nm)	0.86	0.62	27.61	0.78	9.07	0.72	15.95	0.73	14.67	0.21	75.5
Turbidity (620 nm)	0.57	0.5	12.48	0.54	5.48	0.47	17.73	0.49	14.23	0.45	21.23
TS (mg L^{-1})	13600	9000	34	10080	26	9800	28	8987	34	6217	54
TSS (mg L^{-1})	3330	2600	22	2480	26	2960	11	2777	17	2217	33
TDS (mg L^{-1})	10270	6400	38	7600	26	6840	33	6210	40	5099	50
COD (mg L^{-1})	1120	956	15	857	23	897	20	921	18	560	79
Conductivity (mS)	13.74	13.11	4.59	12.95	5.75	12.98	5.53	11.11	19.14	12.48	9.17
pH	6.9	5.2	24.64	5.23	24.20	5.43	21.30	4.9	28.99	5.27	23.62
Alkalinity (ppt)	7.96	7.93	0.35	7.50	5.76	7.91	0.60	7.92	0.48	6.98	12.29
Resistivity (Ω)	33.90	32.15	5.16	33	2.65	31.66	6.61	32.21	4.99	31.11	8.23
Hardness (mg L^{-1})	260	198	24	194	25	173	33	189	27	155	40

Table 4: Two way ANOVA analyses of adapted fungal strains and consortium

Source of variance	Degrees of freedom	Sum of squares	Mean sum of squares	Variance ratio or F	Table value
Between percentage of decolorization	4	3184.602	796.1506	7.273771	2.606
Between the different physicochemical characters	10	7177.153	717.7153	6.557172	2.0772
Residual error	40	4378.2	109.455		

found to be efficient in reducing the hardness upto 33% and *Mucor* sp. was found to be efficient in reducing the TDS (mg L^{-1}) upto 40%. Color of the effluent sample treated by the consortium reduced upto 75% and COD upto 79%.

On analyzing the results through ANOVA it was found that there exists a significant difference between the bioremediation percentage of different isolates upon the effluent sample treated (ANOVA, $p>0.05$). However, there was no significant difference between the bioremediation percentages of the textile effluent used by adapted fungal strains and consortium (ANOVA, $p>0.05$) (Table 4).

Optimization of cultural conditions for maximum bioremediation ability

Effect of retention time: Reduction was observed in consortium from the first day onwards till the fifth day of incubation. Maximum reduction in all the parameters was observed on the fifth day with the color removal upto 74.9% and the COD reduction upto 79% and there was not much reduction after 5 days of incubation (Fig. 1). Reduction in parameters increased steadily in the first 5 days since the organism takes time in utilizing the organic load for its growth and enzyme producing which is necessary for bioremediation. The percentage of decolorization remained stagnant after 5 days of incubation which is due to depletion of nutrients in the system. The maintenance of reduction in the decolorization and organic load of the sample after 5 days of incubation was as a result of the enzymes present in the media during growth and multiplication. After 5 days the nutrient supply decreases which results in competition between the fungi for the available nutrients which is why there is no significant reduction after 5 days. As per the work of Kilic *et al.* (2007), the retention time in bioremediation was one of the major conditions which play a vital role and according to the work of Ryu and Weon (1992) the percentage of color removal increased with increase in incubation period.

Effect of initial pH: Maximum bioremediation was observed at pH 6 with reduction in color by upto 69.1% and reduction in organic load to upto 65% (Fig. 2). At other pH there was not much reduction observed in the physico-chemical parameters. pH has an effect on the activity of the fungal enzymes which is used in the decolorization of different dyes present in the effluent. Above or below the optimal pH range the activity of the fungal enzymes reduces which reduced the bioremediation activity of the organisms involved. According to Levin *et al.* (2004) there is an inverse relation that exists between increase in pH of the textile effluent and biomass production.

Effect of initial incubation temperature: A reduction was observed with consortium from the first day onwards till the fifth day of incubation. Efficient reduction in the physico-chemical parameters was observed at 27°C with reduction in color to upto 65% and reduction in organic load by upto 59.7% (Fig. 3). At other incubation temperature though there was a considerable reduction in the parameters there was no significant reduction. The effect of different temperatures on growth rate could be predicted in terms of activation energy required for growth. Below the

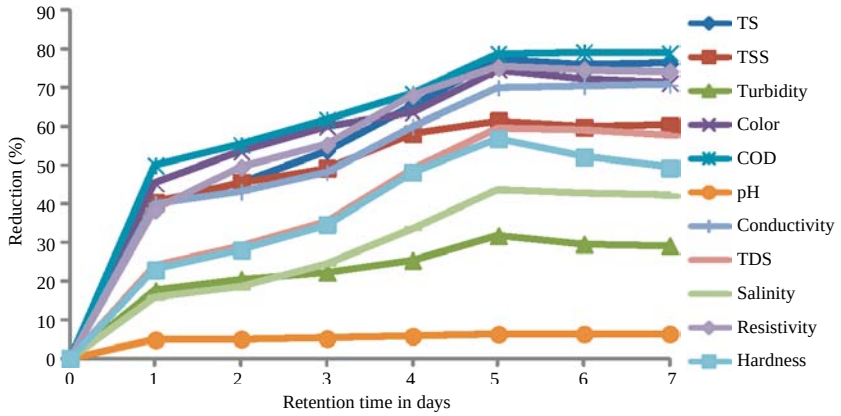

Fig. 1: Effect of retention time on bioremediation of textile effluent

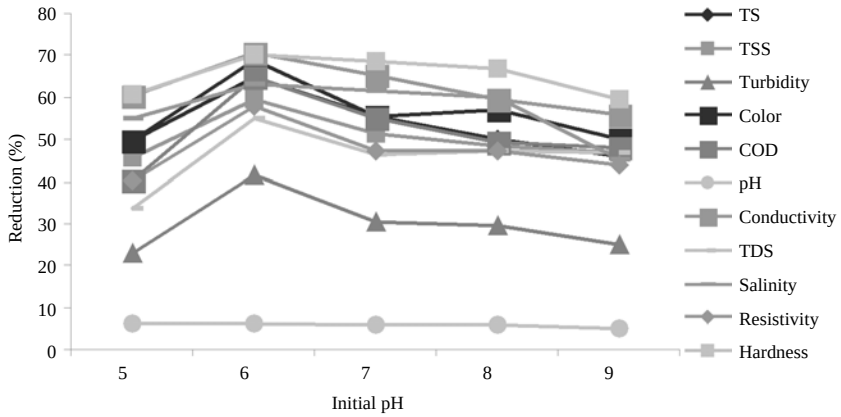

Fig. 2: Effect of initial pH on bioremediation of textile effluent

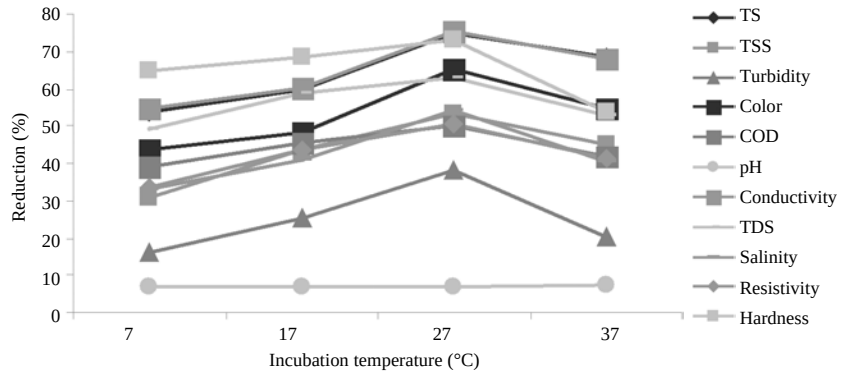

Fig. 3: Effect of incubation temperature on bioremediation of textile effluent

optimum temperature, cell growth is inhibited and the rate of metabolism decreases and so the bioremediation activity was not that efficient. Above the optimum temperature tampering of the cell and denaturation of the enzymes secreted dampens the bioremediation process. Hence, under optimum temperature, fungi can utilize the substrate better, with optimal nutritional and cultural conditions. As per the work of Yesilada *et al.* (1998) optimal temperature of 27°C was best suited for the efficient decolorization by fungi.

Effect of initial organic loading rate concentration: Increased amount of organic load has increased amount of nutrients which the organisms thrive and produce enzymes that participates in bioremediation. The efficient reduction in the physico-chemical parameters were observed at 100% OLR (color 77%, COD 79%). At other OLR there was not much reduction in the physico-chemical parameters (Fig. 4). From the graph we can conclude that the organic loading rate was directly proportional to decolorization. This was because as the organic load increases it increases the biomass of fungi which results in efficient bioremediation. Chen *et al.* (2003) reported that, increased amount of organic matter in the azo textile effluent increases the biomass content and hence the enzymes.

Effect of initial inoculum concentration: Efficient reduction in the physico-chemical parameters was observed at 5% initial inoculum concentration with 70% reduction in color and 56% reduction in the organic load (Fig. 5). Increase in inoculum concentration increases the biomass

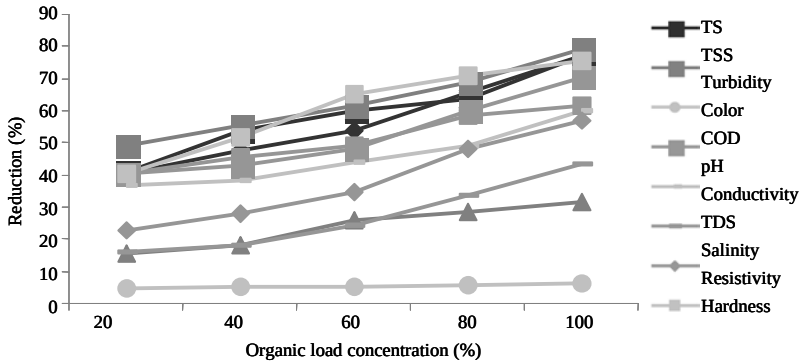

Fig. 4: Effect of organic load concentration on bioremediation of textile effluent

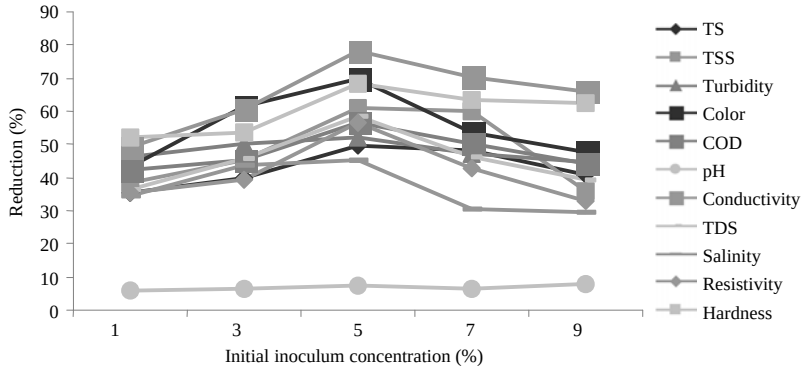

Fig. 5: Effect of initial inoculum concentration on bioremediation of textile effluent

added and the production of enzymes and hence results in efficient bioremediation. A higher load of inoculum concentration leads to decrease in bioremediation efficiency as an increase in biomass leads to competition between organisms for its survival and hence the rate of degradation decreases over a particular range. For a maximum rate of color removal was observed at 5% inoculum concentration with 80% decolorization efficiency. Biomass and dye removal are directly proportional which may be attributed to the fact that, the increase of biomass gave more surface area for sorption of dye molecules available (Muthezhilan *et al.*, 2008).

The effluent treated under optimized condition (retention time-5 days, pH-6, organic load-100%, incubation temperature -27°C and initial inoculum concentration-5%) showed an efficient degradation by reducing the color upto 86% and COD upto 73.21% (Lu *et al.*, 2009). The fungal consortium under optimized condition had an environment where the fungi could grow well and produce enzymes to maximum concentration and hence bioremediation was effective (Table 5).

Adsorption isotherm kinetics on Bioremediation of azo textile effluent by adapted fungal consortium: The linear plot of 'Ce/qe vs Ce' Langmuir isotherm model, the adapted fungal consortium value of correlation coefficient ($R^2 = 0.97$) obtained from the linear plot. This model was highly correlated with experimental data (Fig. 6a). In Freundlich isotherm, a plot of log C_e vs. log

Table 5: Percentage reduction of consortium treated effluent under optimized conditions

		Microbial consortium treated effluent	
Physicochemical chemical parameters	Untreated effluent	Values	% Reduction
Color (490 um)	0.86	0.12	86.00
Turbidity (620 um)	0.57	0.42	26.30
TS (mg L^{-1})	13600	5968	56.11
TSS (mg L^{-1})	3330	2028	39.00
TDS (mg L^{-1})	10270	4875	52.50
COD (mg L^{-1})	1120	300	73.21
Conductivity (mS)	13.74	11.32	17.61
pH	6.9	5.17	25.07
Alkalinity (ppt)	7.96	6.8	14.57
Resistivity (Ω)	33.90	31.11	8.23
Hardness (mg L^{-1})	260	150	42.30

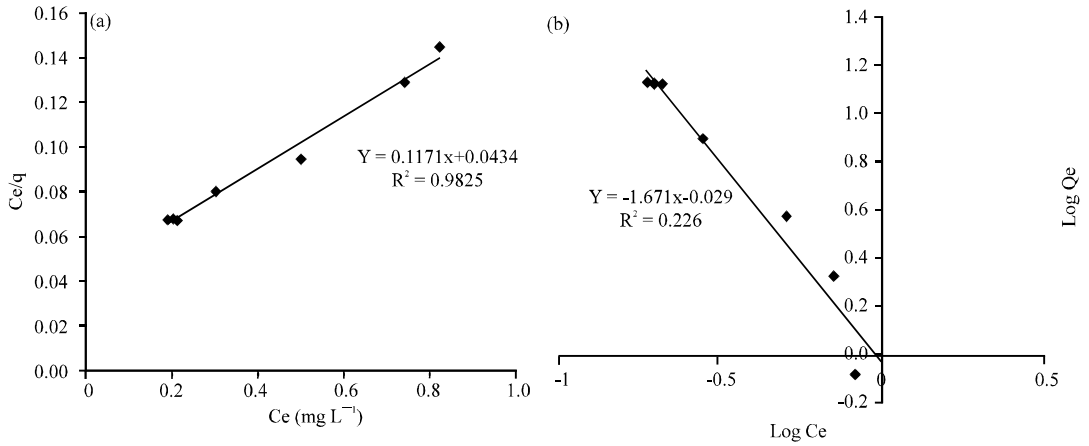

Fig. 6: Langmuir and Freundlich adsorption isotherms on bioremediation of Azo textile effluent by using Adapted fungal consortium (a) Langmuir isotherm and (b) Freundlich isotherm

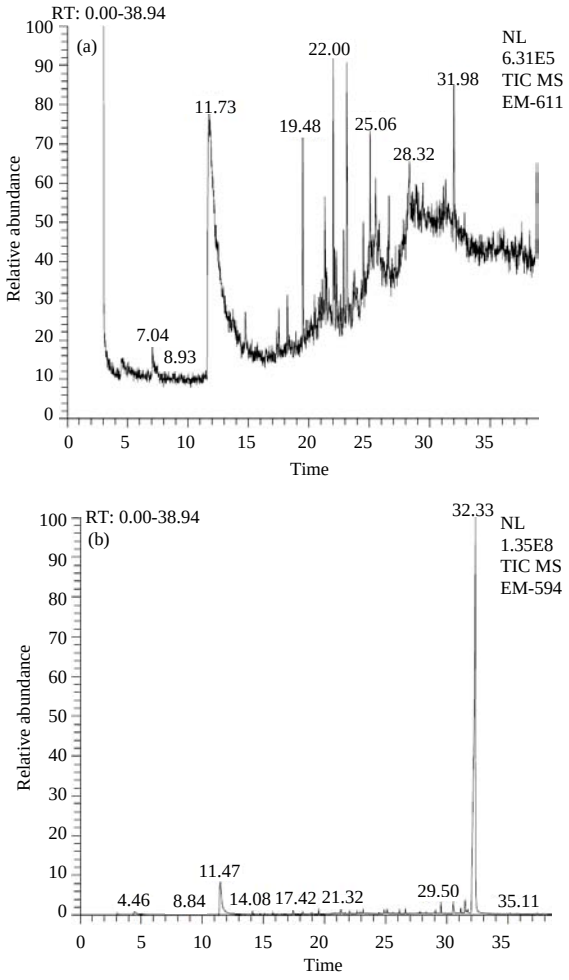

Fig. 7: GCMS analysis of untreated and treated effluent; (a) Untreated effluent and (b) Treated effluent

C_e/q_e made a energetic linear layer adapted fungal consortium, this model does not fit for adapted fungal consortium, the recreation coefficient data as follows $R^2 = 0.8$ (Fig. 6b). Adsorption model for Langmuir and Freundlich isotherm (using adapted fungal consortium) were determined under optimum condition and the equilibrium data fit well with the Langmuir monolayer model (Charry and Jamousy, 2011).

Physico-chemical characterization of the treated effluent under optimized condition: The untreated textile effluent showed a number of peaks in its chromatogram with a few peaks that were predominant and which were not found to be a contaminant of the column were studied. The compounds analyzed for these peaks were found to be Furan, 2-(methoxymethyl), n-cetyl thiocyanate and heptadecanoic acid-methyl ester which were the toxic product present in the untreated raw effluent sample. The treated (consortium) effluent showed a major reduction in all the organic contents and the number of peaks that were observed was reduced to significant extent when compared to untreated sample (Fig. 7). The fungal consortium has effectively degraded the

azo dyes and converted them to non toxic substances. About three peaks which were observed in the chromatogram of the treated effluent were analyzed and found to be 5-hexenal, iso-tanshinone and hexanedioic acid bis (2-ethylhexyl ether).Which were not found to be toxic.

CONCLUSION

The designed fungal consortium could very well degrade the azo textile effluent in an aerobic environment. The effluent sample treated under optimized conditions showed an effective reduction in the physico-chemical parameters which were found to be well within the permissible limits of TNPCB. GC-MS analysis done for the treated effluent reveals that it does not contain any toxic substances. The work has substantiated that the effluent sample treated using the fungal consortium was devoid of any toxicity and that it could be released to the environment which is not harmful to the aquatic life.

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