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Retraction

Retracted: Adsorption Potential of *Schizophyllum commune* White Rot Fungus for Degradation of Reactive Dye and Condition Optimization: A Thermodynamic and Kinetic Study

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] A. Raees, H. N. Bhatti, S. Alshehri et al., "Adsorption Potential of *Schizophyllum commune* White Rot Fungus for Degradation of Reactive Dye and Condition Optimization: A Thermodynamic and Kinetic Study," *Adsorption Science & Technology*, vol. 2023, Article ID 4725710, 12 pages, 2023.

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Research Article

Adsorption Potential of *Schizophyllum commune* White Rot Fungus for Degradation of Reactive Dye and Condition Optimization: A Thermodynamic and Kinetic Study

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The pollution due to dyes from textile sector is one of the major issues faced worldwide. This study was focused on the removal of the reactive dye, Drimaren Turquoise CL-B using *Schizophyllum commune,* a white rot fungus (WRF) keeping in mind the current environmental conditions. Different parameters like pH, sources of carbon & nitrogen, temperature, concentration of dye and C/N ratio were used to investigate their effect on the process. Maximum dye removal of 95.45% was obtained at pH 4.5, temperature 35°C, inoculum size 3 mL, veratryl alcohol (mediator), glucose (carbon source) and ammonium nitrate (nitrogen source). The enzyme activity was determined by employing enzyme assay. Laccase and Lignin peroxidase (LiP) activity was low while Manganese peroxidase (MnP) activity was highest. Maximum bio-sorption was achieved at pH 1 and 313 K. The pseudo-2nd-order kinetic model & Freundlich isotherm was best suited for the process of removal of dye. From these data, it is concluded that white rot fungus could possibly be the excellent biomaterial for elimination of synthetic dyes from wastewater.

1. Introduction

Many industries including paper, plastic, tannery, and textile broadly use dyes. Reactive dyes, being extensively used in textile, pose the greatest problem due to nonbiodegradable nature and needs an extensive treatment for complete removal of color from the effluents [1–6]. Nowadays, the industrial usage of dyes and other chemicals has become a great challenge with reference to environment [7, 8].

Dyes are difficult to degrade in aquatic environment, since these are resilient to light and oxidizing agents [9–14]. The dyes are characterized as cationic, nonionic and anionic type depending on the structural features. The heavy metals in industrial effluents also pose environmental problems along with the dyes. Discarding industrial effluents without treatment into the environment makes the water bodies colored. This will limit the oxygenation capacity of the water body at receiving end and ultimately interrupts the photosynthetic process in the marine environment and responsible for severe toxicity. Prior to discharging the effluents in water bodies, it is highly appreciated to treat for removal of impurities [7, 15–18].

Conventional methods of wastewater treatment are not efficient for the treatment of dye wastewater, since the dyes

Table 1: Time course study for the removal of reactive dyes using *S. commune*.

Dyes	Removal (%) Days									
	1	2	3	4	5	6	7	8	9	10
Drimaren Red CL-58	39.4	44.55	54.35	58.8	59.85	61.75	62.73	63.01	**63.95**	63.19
Drimaren Orange CL-3R	18.95	30.55	42.35	55.80	56.35	58.15	59.85	59.91	**59.95**	59.83
Drimaren Black CL-CX	28.7	30.20	48.25	53.65	59.05	60.45	62.05	62.45	**63.35**	63.25
Drimaren Navy CL-B 110	59.32	61.30	85.8	**89.50**	86.40	87.25	87.53	88.23	88.91	88.75
Drimaren Yellow CL-2R	25.3	36.55	38.83	42.77	42.89	44.12	44.43	54.95	67.37	**91.94**
Drimaren Turquoise CL-B	44.07	50.6	66.35	72.60	80.51	94.60	95.95	96.65	**97.17**	96.20

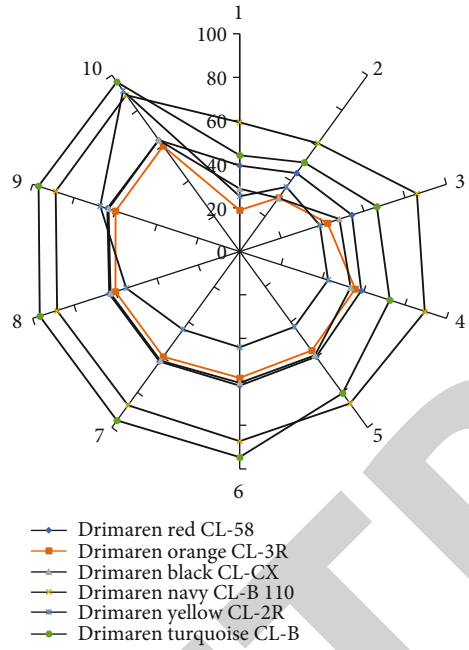

Figure 1: Removal of reactive dyes using *Schizophyllum commune* culture.

are nonbiodegradable and chemically stable. Some of the already employed methods including oxidation, adsorption, filtration, coagulation, and ionization are effective. These physical and chemical methods have limitations, e.g., excess chemical usage, concentrated sludge, operational costs, and ineffective color reduction. So, the researchers are thinking about some cost effective, ecofriendly methods that produce less sludge. In this view, the microbial biodegradation of dyes is considered one of the better alternatives.

Previous studies suggested that the microbes can reduce dyes comprehensively. These microbes have the ability to degrade very complex natured pollutants [19–25]. White rot fungi are considered the best tool for biodegradation of lignin in nature. The fungi have an advantage over bacterial organisms that they can solubilize substrates using extracellular enzymes [26–31].

Biosorption is sequestration of complex natured pollutants using biomass or their derivatives. The dead biomass is preferred over the live one because the sorption process is unaffected by toxicity of pollutants. Through the process of biodegradation, the dyes are broken down using enzymes; e.g., white rot fungi secrete ligninolytic enzymes to degrade variety of pollutants [32]. The working of white-rot fungi is primarily dependent on nutrient limitation. This is not actually affected by the concentration of pollutants [33–39].

The key aim and objective of this research are to explore the ability of locally sequestered white rot fungus, *S. commune*, for the process of removal of dyes and, furthermore, to study the enzyme profile, to examine the influence of biodegradable carbon source, and to evaluate the sorption capability of *S. commune* biomass for the elimination of reactive dye under numerous experimental circumstances.

2. Material and Methods

Reactive textile dyes including Drimaren Orange CL-3R, Drimaren Red CL-58, Drimaren Yellow CL-2R, Drimaren Black CL-CX, Drimaren Navy CL-B110, and Drimaren Turquoise CL-B were collected from Clariant (Pvt.) Limited, Faisalabad, Pakistan. WRF *S. commune* was sequestered from decomposing wood located in Murree Hills and nearby vicinity. The strain was isolated and identified from the Department of Microbiology, UAF. Decaying wood samples were aseptically positioned onto potato dextrose agar (PDA) plates for the isolation of fungal mycelia, which were subcultured until pure mycelia were obtained and kept at 4°C [40]. The isolate was identified based on the morphology, hypha, and spores [41].

2.1. Sporulation Media and Inoculum Preparation. The potato dextrose agar (PDA) is a general-purpose medium used for the culture of fungi, and to avoid contamination from bacterial growth, some antibiotics were also added in PDA medium. In the current study, for the preparation of WRF slant, PDA medium is used. For slant preparation, 100 mL distilled water was taken to dissolve 3.9 g PDA and autoclaved at 121°C for 15 min. After autoclave, the warm 10 mL medium was aseptically transferred into a sterilized culture tube, put on a slanting position on a slanting rack, and allowed to cool. In the culture medium, due to the presence of agar-agar, it is solidified on cooling. Using aseptic loop, few spores of *S. commune* were transferred into slant using all possible sterilized conditions in laminar air flow [42].

Table 2: Removal (%) of Drimaren Turquoise CL-B at different pH, temperature, carbon sources, nitrogen sources, inoculum size, and mediator effect.

	Days							Mean
	1	2	3	4	5	6	7	
pH								
3	64.5	78.1	79.05	79.35	79.75	80.8	81.8	77.62
3.5	71	84.15	84.85	86.15	87.31	88.65	89.25	86.6
4	71.5	85.31	85.95	87.4	87.55	89.65	90	85.34
4.5	74.5	86.9	87.35	86.45	89.15	91.2	**95.45**	88.44
5	73	84.6	85.4	86.1	86.9	89.05	89.85	84.98
5.5	72.3	82.15	82.3	84.65	84.8	86.55	87.3	82.86
Temperature (°C)								
30	48	82.8	84.4	87.35	88.8	91.35	91.8	82.07
35	49	82.5	90.1	90.3	90.6	93.05	93.65	84.17
40	36.5	79.5	85.9	88.9	89.95	92	92.65	80.77
45	29	78.5	83.3	85.85	87.8	90.65	90.35	77.92
Carbon sources								
Glucose	84.3	87.45	90.95	91.95	93.1	93.35	94.7	90.83
Fructose	79.25	83.25	88.95	89.75	87	87.55	91.65	86.77
Maltose	78.65	81.5	87.10	87.15	87.55	88.15	88.75	85.55
Sucrose	78.45	81.45	86.05	87.05	89.3	87.53	87.85	85.38
Rice bran	41.34	51.25	55.9	56.65	56.71	57.85	57.90	53.94
Wheat bran	69.15	72.4	73.95	72.85	75.25	74.1	78.95	73.81
Nitrogen sources								
Am. tartrate	69.6	81.6	83.65	83.57	—	—	—	79.6
Am. nitrate	68.2	91.55	93.75	95.15	—	—	—	87.16
Urea	35.15	40.9	59.2	64.5	—	—	—	49.94
Am. sulphate	57.8	79.65	85.3	90.45	—	—	—	78.3
Peptone	33.55	43.45	40.8	42.5	—	—	—	40.07
Inoculum size (mL)								
2	59.35	71.7	85.4	88.45	89.6	90.55	91.64	82.38
3	51.35	76.35	88.7	91.5	93.9	94.3	94.4	84.35
4	52.3	77.6	89.7	91.3	92.05	92.9	94.1	84.27
5	54.15	75.55	87.9	91.4	90.5	92.9	93.1	83.64
6	52.55	78.1	80	90.8	92.55	93.15	93.5	82.95
Mediator								
ABTS	84.98	91.1	93.17	—	—	—	—	89.75
$MnSO_4$	87.03	90.78	87.7	—	—	—	—	88.5
Ver. alcohol	89.07	95.2	91.5	—	—	—	—	91.9
Guaicol	87.7	94.19	92.15	—	—	—	—	91.3

For the preparation of fresh culture of WRF, 2.4 g potato dextrose broth was dissolved into water and later on was sterilized. After sterilization, the flask was maintained on room temperature, the sterile tartaric acid (10%) was used to lower the pH of the medium up to 4.5 to inhibit the bacterial growth. Using sterilized condition in laminar air flow, few spores of white rot fungi from slant culture were inoculated into a medium flask and placed at 120 rpm; 30°C; 72 h for the required number of spore's inoculum (1×10^8 spores/mL) at 100 μL sample. This was transferred to a UV spectrophotometer, and optical density of sample was measured at 600 nm.

2.2. Decolorization Procedure and Time Course Study. Six duplicate containers were placed for the reactive dyes. Each flask contained 0.01% of the respective dye along with 95 mL sterilized Kirk's basal nutrient medium [43]. The pH of the media used for removal of dyes was kept at 4.5. Each flask was inoculated with 2 mL suspension of the strain of WRF after being autoclaved and cooled. These dyestuff sets were kept in aseptic laminar air flow. The incubation parameters for the flasks in shaking incubator were optimum temperature (30°C) and centrifugation speed (120 rpm) for 10 days. The dye with most removal affect was picked up to optimize the removal process [44]. After 24 h, the removed sample (1 mL) from flask was centrifuged for 10 min. The absorbance was taken at λ max to determine the removal (%) by *S. commune*. Maximum removal was perceived for the dye Drimaren Turquoise CL-B by the culture of *S. commune*. This dye was subjected to optimization of different parameters [45].

2.3. Process of Optimization. The pH of 0.01% Drimaren Turquoise CL-B was adjusted using different initial pH values starting from 3 and up to 5.5 before inoculation. 2 mL of the spore suspension of the fungal strain was inoculated after being autoclaved followed by incubation in orbital shaker (120 rpm) at 30°C. Samples were centrifuged using a Sigma centrifuge machine (Germany) at 7379 × g for 10 min at 25°C. The effect of temperature on dye removal was studied using 25, 30, 35, 40, and 45°C. Nutrients with dye solution was autoclaved and then 2 mL of inoculum was added. Samples were removed after 24 h from each flask, centrifuged at 7379 × g for 10 min, and absorbance was read on a spectrophotometer [46].

Different materials including wheat bran, fructose, rice bran, sucrose, glucose, and maltose were used for the removal of the Drimaren Turquoise CL-B dye by the culture of *S. commune* in a shake flask experiment. The experiment was directed at optimal pH and temperature for about 7 days. Glucose was evidenced to be the finest carbon source for Drimaren Turquoise CL-B removal by the culture of *S. commune*. The ammonium salts (tartrates and chlorides) are the most widely used nitrogen sources for removal of dyes using fungus biomass. These nitrogen sources are costly, so there was a need to find out relatively optimized source and ammonium nitrate which are considered optimum source. Five duplicate flasks were maintained for different inoculum size such as 2, 3, 4, 5, and 6 mL to study

Table 3: Enzyme assay for dye screening experiment along with the effect of pH, temperature and carbon source.

	Laccase		MnP		LiP	
	Abs	Enzyme activity (U/mL/min)	Abs	Enzyme activity (U/mL/min)	Abs	Enzyme activity (U/mL/min)
Dyes						
Drimaren Red CL-58	0.055	15.4	0.143	122.98	0.166	178.45
Drimaren Orange CL-3R	0.115	32.2	0.137	117.82	0.233	250.475
Drimaren Black CL-CX	0.082	22.96	0.142	122.12	0.137	147.275
Drimaren Navy CL-B 110	0.067	18.76	0.344	295.84	0.149	160.175
Drimaren Yellow CL-2R	0.091	25.48	0.134	115.24	0.056	60.2
Drimaren Turquoise CL-B	0.133	37.24	0.057	49.02	0.145	155.875
pH						
3	0.017	4.76	0.023	19.78	0.031	33.325
3.5	0.037	10.36	0.028	24.08	0.037	39.775
4	0.049	13.72	0.053	45.58	0.049	52.675
4.5	0.054	15.12	0.066	56.76	0.079	84.925
5	0.026	7.28	0.059	50.74	0.022	23.65
5.5	0.021	5.88	0.041	35.26	0.019	20.425
Temperature (°C)						
30	0.093	26.04	2.16	1857.6	0.061	65.575
35	0.146	40.88	2.05	1763	0.056	60.2
40	0.168	47.04	2.13	1831.8	0.055	59.125
45	0.134	37.52	2.01	1728.6	0.096	103.2
Carbon source						
Glucose	0.127	35.56	0.103	88.58	0.045	48.375
Fructose	0.109	30.52	0.276	237.36	0.046	49.45
Maltose	0.119	33.32	0.351	301.86	0.0235	25.2625
Sucrose	0.11	30.8	2.07	1780.2	0.0265	28.4875
Rice bran	0.201	56.28	0.118	101.48	0.011	11.825
Wheat bran	0.178	49.84	0.476	409.36	0.0535	57.5125

the effect on dye removal. Similarly, the mediator effect on the removal of dye was also monitored.

2.4. Ligninolytic Enzyme Profile. The fermented samples were removed, at the end of each experiment, from removal media and centrifuged. This was done to find out the patterns related to working of enzymes involved in removal process of different dyestuffs by different fungi. Supernatant was withdrawn, kept at -4°C, and studied for determination of enzyme effects. Laccase action was performed by 1 mL of ABTS added in 1 mL buffer and 100 μL enzyme solution. The absorbance of samples was observed at 420 nm. Controlled cuvette contained 100 μL of purified water. The MnP activity was estimated by adding 1 mL $MnSO_4$ in 1 mL malonate buffer with 0.5 μL H_2O_2 and 100 μL enzyme solution. Mn^{+3} forms a composite with malonate that is measured at the absorbance of 270 nm. Absorbance of sample will be taken after 10 min up to 30 min. Lignin peroxidase (LiP) test was done using 2.7 mL mixture along with 1 mL of buffer (pH 3) and veratryl alcohol (4 mM), 0.5 mL of H_2O_2, and 100 μL solution of enzyme and noted at 310 nm.

2.5. Biosorption Study. The spore suspension of *S. commune* was obtained after autoclaving using filtration of inoculum of fungi. The dried biomass of *S. commune* was obtained after drying spore suspensions in oven at 80°C for 24 h. The dried biomass was finally grinded (Molineux, France) and sieved through (OCT-DIGITAL 4527-01) sieve. The 0.25 mm size of sample was selected for further use. The sample was now placed in sealed vessels.

2.6. Immobilization of Biomass and Batch Studies. One gram of *S. commune* biomass was dissolved in 2% Na-alginate (100 mL). The mixture was reacted with 0.1 M $CaCl_2$ after being homogenized to get beads of uniform size. This immobilized mass was used for further experimentations. Different conditions of pH ranging from 1 to 9, temperature from 30 to 70°C, biosorbent dose in the range of 0.05, 0.1, 0.15, 0.20, and 0.30 g, concentration of dye (25, 50, 75, and 100 ppm) and contact time of 24 h were studied to evaluate the removal of Drimaren Turquoise CL-B [47–49].

The following equation was used to find out dye uptake q (mg/g);

$$q = \frac{(Ci - Ce)V}{1000\omega}, \quad (1)$$

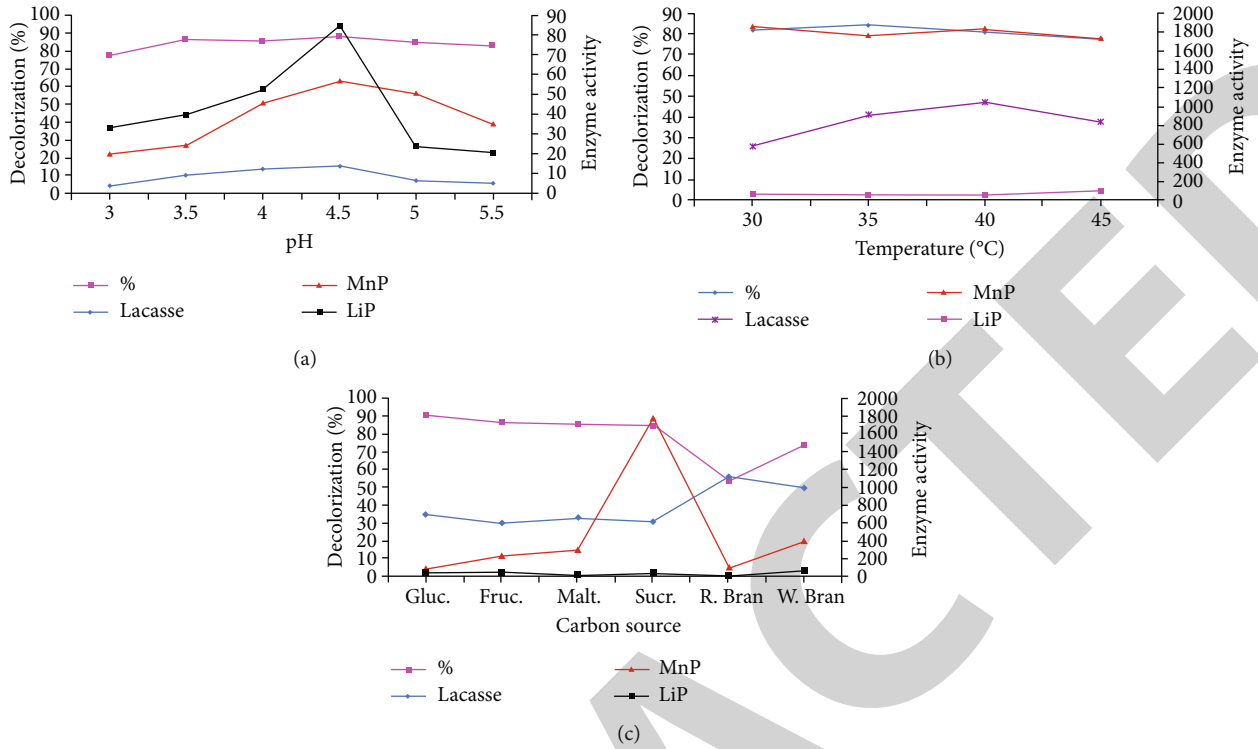

Figure 2: Removal of Drimaren Turquoise CL-B and enzyme activity of *Schizophyllum commune* at different (a) pH, (b) temperature, and (c) carbon source.

Table 4: Enzyme assay for different nitrogen sources, inoculum size, and mediator.

	Laccase		MnP		LiP	
	Abs	Enzyme activity (U/mL/min)	Abs	Enzyme activity (U/mL/min)	Abs	Enzyme activity (U/mL/min)
Nitrogen source						
Ammonium tartrate	0.126	35.28	0.175	150.5	0.08	86
Ammonium nitrate	0.181	50.68	0.312	268.32	0.118	126.85
Urea	0.22	61.6	0.173	148.78	0.173	185.975
Ammonium Sulphate	0.119	33.32	0.094	80.84	0.094	101.05
Peptone	0.219	61.32	0.076	65.36	0.076	81.7
Inoculum size (mL)						
2	0.173	48.44	2.076	1785.36	0.21	225.75
3	0.016	4.48	0.229	196.94	0.224	240.8
4	0.026	7.28	0.281	241.66	0.186	199.95
5	0.083	23.24	0.452	388.72	0.247	265.525
6	0.028	7.84	0.297	255.42	0.071	76.325
Mediator						
ABTS	0.104	29.12	2.0	1030.28	2.0	2144
$MnSO_4$	0.131	36.68	0.676	581.36	2.0	2144
Veratryl alcohol	0.066	18.48	2.0	1720	0.392	421.4
Guaiacol	0.121	33.88	0.161	138.46	2.0	2144

where C_i (mg/g) is the initial dye concentration, C_e (mg/g) is dye concentrations at any time, V (mL) represents volume of the solution, and w (g) is the mass of the sorbent. The collected data was analyzed statistically [39, 50].

3. Results and Discussion

White rot fungi have the ability to degrade very complexed nature polymers, e.g., lignin which is characteristics of

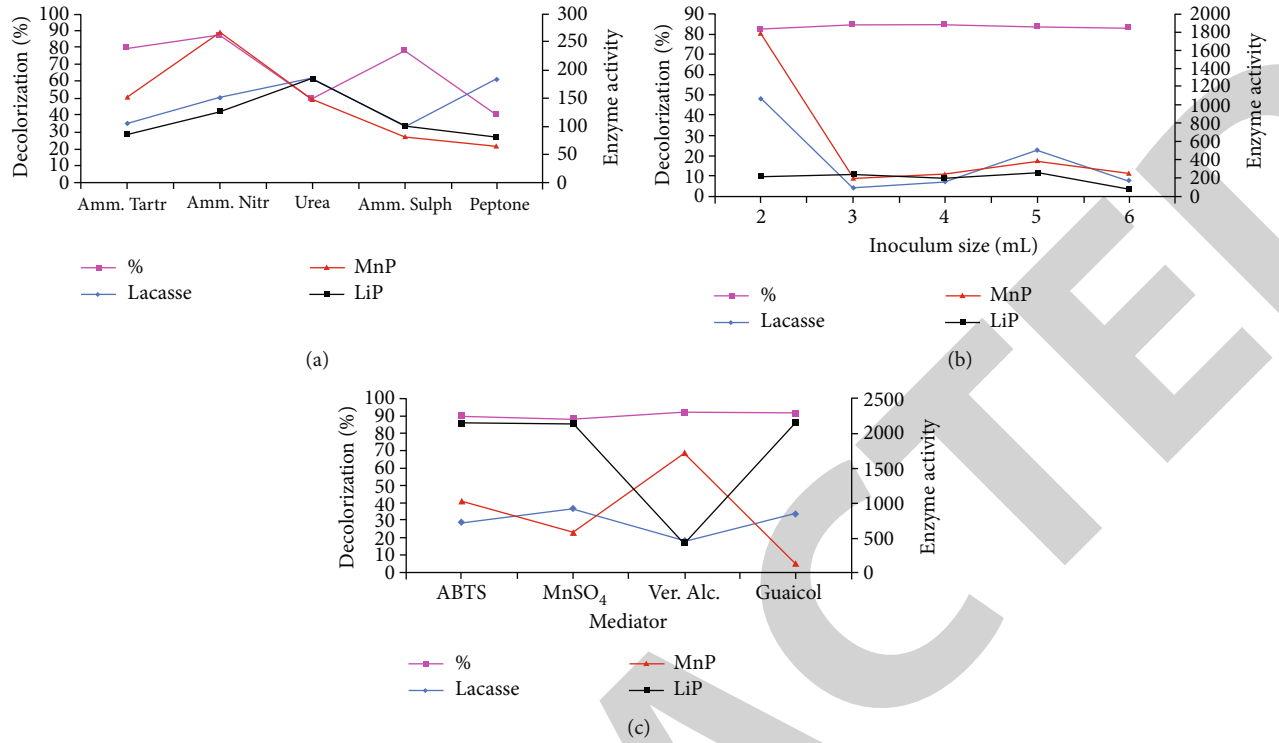

Figure 3: Removal of Drimaren Turquoise CL-B and enzyme activity of *Schizophyllum commune* at different (a) nitrogen source, (b) inoculum size, and (c) mediator.

woody plants. Furthermore, WRF can also degrade dyes with the help of enzymes including manganese peroxidase (MnP) and lignin peroxidase (LiP). They can make use of some other enzymes for removal of dyes especially the ones producing H_2O_2. For removal of the largest class of dyes (azo dyes), WRF are better customer than other microorganisms [51]. Culture of WRF showed variable removal potential for different dyes (Table 1). The culture of *S. commune* removed Drimaren orange CL-3R up to 59.95%, Drimaren red CL-58 up to 63.95%, Drimaren black CL-CX up to 63.35%, Drimaren Navy CL-B 110 up to 89.50%, Drimaren Yellow CL-2R up to 91.94%, and the culture of *S. commune* showed maximum removal on Drimaren turquoise CL-B (97.17%) (Figure 1). During the dye removal, the aromatic ring cleavage occurs. This cleavage is related with the uniqueness of the ring substituents. With the presence of easily biodegradable functional groups, the removal process moved up to larger extent [52]. Drimaren Turquoise CL-B dye was selected for subsequent optimization studies.

3.1. Optimization of Removal Parameters

3.1.1. Effect of Hydrogen Ion Concentration. Initial trial was run on pH 4.5. Different pH levels 3, 3.5, 4, 4.5, 5, and 5.5 were employed for the proper optimization of pH level for dye removal. The maximum dye removal after 7 days (95.45%) was observed at pH 4.5, followed by 90% at pH 4 and 89.85% at pH 3.5. 87.3% removal was observed at pH 5.5. At pH 3, the least dye removal (81.8%) was found. An inverse relationship between dye removal, and acidity level was observed. The minimum removal (81.8%) of dye was detected at pH 3. Enzymes of *S. commune* did not work actively on highly acidic and basic pH (Tables 2 and 3; Figure 2). It means that for proper functioning of enzymes, pH is a very vital parameter. Mostly, acidic conditions are favorable for WRF Lignolytic enzymes. Previous studies reported the effect of pH on removal of Solar golden orange R using *S. commune*. The maximum removal efficiency (73%) was detected at pH 4.5 [42]. On the other hand, some enzymatic species show their efficiency in basic conditions. The pH range for white rot fungi is 4-8 [53].

3.1.2. Temperature. The medium was incubated on 30, 35, 40, and 45°C estimation of optimized level of temperature for highest dye removal by WRF. The maximum removal was observed in the medium incubated at 35°C. Kumar et al. [54] reported the same results for the removal of reactive azo dye. The optimum temperature found for WRF growth is 35°C, but some species (*P. chrysosporium*) even grows at higher temperature, i.e., 37°C [53]. Optimum temperature was found to vary between 25 and 37°C among isolates. *Schizophyllum commune* shows maximum activity on 35°C. The culture of *S. commune* showed 93.65% removal of dye at 35°C followed by 92.65% removal of dye on 40°C. On the other hand, the culture of white rot fungi showed less removal, i.e., 91.8% and 90.35% at 30 and 45°C, respectively. Results showed that at temperature 30°C and 40°C there is nonsignificant difference but at 45°C there is significance difference in the removal of dye.

3.1.3. Carbon Sources. Different carbon sources were added to get the maximum removal of dye. The enzymes of WRF

Table 5: Effect of pH, temperature, dye concentration, biosorbent dose, and time on the removal of Drimaren Turquoise CL-B using *S. commune* biomass.

pH	C_e (mg/L)	$C_i - C_e$ (mg/L)	q (mg/g)	% removal
1	18.51	31.49	15.745	62.98
2	27.24	22.76	11.38	45.52
3	42.91	7.09	3.545	14.18
4	45.52	4.48	2.24	8.96
5	47.25	2.75	1.375	5.5
6	48.53	1.47	0.735	2.94
7	48.91	1.09	0.545	2.18
8	49.25	0.75	0.375	1.5
9	49.35	0.65	0.325	1.3
Temperature (K)				
303	18.73	31.27	15.635	62.54
313	16.72	33.28	16.64	66.56
323	19.06	30.94	15.47	61.88
333	21.015	28.985	14.4925	57.97
343	23.98	26.02	13.01	52.04
Dye concentration (mg/L)				
25	3.73	21.27	10.63	85.08
50	19.33	30.67	15.33	61.34
75	30.225	44.77	22.38	59.69
100	44.55	55.45	27.72	55.45
200	93.96	106.04	53.02	53.02
300	149.26	150.74	75.37	50.24
Biosorbent dose (g)				
0.05	17.09	32.91	32.91	65.82
0.1	14.93	35.074	17.53	70.148
0.15	13.81	36.19	12.06	72.38
0.2	11.19	38.81	9.70	77.62
0.3	11.19	38.81	9.70	77.62
Time (min)				
0	48.28	1.72	0.86	3.44
30	24.25	25.75	12.875	51.5
60	22.39	27.61	13.805	55.22
120	21.57	28.43	14.215	56.86
240	20.52	29.48	14.740	58.96
360	20.52	29.48	14.740	58.96
960	20.67	29.33	14.66	58.66
1440	20.67	29.33	14.66	58.66

are not substrate specific, so they are produced to display their function on a wide range of substrates. Removal was done by all the substrates, but maximum removal was shown by glucose. Fructose is a monosaccharide with keto-group and shows furanose ring structure. Fructose showed 91.65% removal. Minimum removal was done by rice bran i.e. 57.90%. Wheat bran also showed less removal (78.95%). Maltose is a disaccharide of glucose and showed 88.75% removal.

3.1.4. Evaluation of Nitrogen Sources. Various sources of nitrogen were added to the medium to evaluate their effects on removal process (Table 4; Figure 3) and have shown variable effects. Another study reported that nitrogen addition had no considerable effect on dye removal using *B. adusta* along with *P. tremellosa*. Moreover, nitrogen source have made great contribution in reduction of removal time [55]. The maximum removal was observed using ammonium nitrate as a nitrogen source. All the other sources have shown less removal than nitrates, and the minimum was observed by peptone 42.5%.

3.1.5. Inoculum Size. To find out the outcome of inoculum size on the removal process of dye, 2 to 6 mL of inoculum were added. It has been observed that first there is an increase in the removal of Drimaren Turquoise CL-B by an increase in the inoculum size, but further increase in inoculum size caused less removal. Maximum removal was shown by 3 mL inoculum size, i.e., 94.4%.

3.1.6. Mediators. The inducers or mediators have a great contribution for the production of ligninolytic enzymes when used along with WRF. For this reason, various inducers/mediators including veratryl alcohol, xyloidine, veratraldehyde, 3,4,5-trimethoxy, and cinnamic acid have been employed to evaluate the induction of ligninolytic enzymes of WRF. Veratryl alcohol is nonphenolic compound and is better substrate for LiP. On the other hand, it is not relatively good substrate for MnP [56].

3.2. Biosorption Study

3.2.1. Effect of pH. The acidity and basicity of medium play a pivotal role with reference to removal process. In this study, pH value ranges from 1 to 9 were applied for evaluation of effect of pH on removal of Drimaren Turquoise CL-B using *S. commune* (Table 5; Figure 4). We found decrease in equilibrium sorption capacity with rise in pH. The highest (15.74 mg/g) and lowest (0.325 mg/g) dye removal was noted at highly acidic and highly basic conditions, respectively. This shows that acidic medium favors the removal of dye and also helps the binding of dye with cationic fungal biomass. A similar result was described in previous study [57] for the removal of Reactive Navy-4 dye. In another study, maximum biosorption of Remazol Navy reactive dye was monitored at pH 2 [58].

3.2.2. Influence of Temperature. Temperature is very vital for the biosorption process. Since the textile dye effluents are discharged around (50–60°C), so temperature is vital design factor disturbing the sorption capacity using biomass. The biosorption of Drimaren Turquoise CL-B onto WRF performed at different temperatures exhibited that the sorption is an exothermic process. The sorption potential is decreased with increase in temperature. The maximum (16.64 mg/g) and minimum (13.01 mg/g) dye removal was recorded at 313 K and 343 K, respectively. Aksu and Tezer [59] explored the effect of heat change on the sorption of dye Remazol Black-B with the assistance from *R. arrhizus*. They have demonstrated that optimum temperature was 35°C for removal of

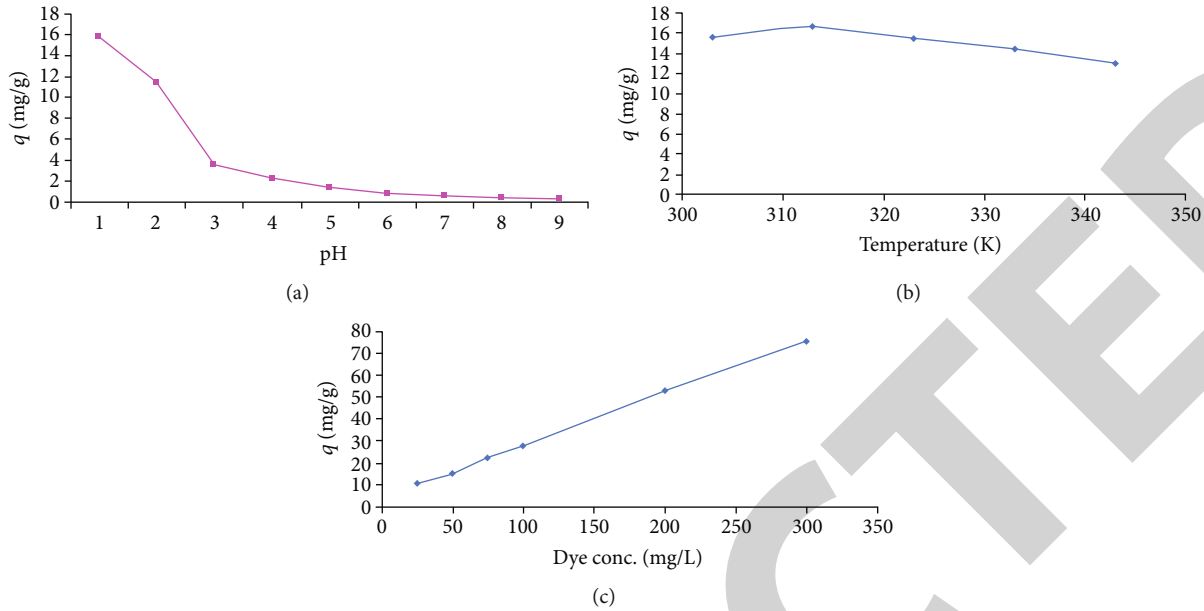

Figure 4: Effect of (a) pH, (b) temperature, and (c) dye concentration on the removal of Drimaren Turquoise CL-B by *Schizophyllum commune* biomass.

Table 6: Comparison of Langmuir, Freundlich isotherms, pseudo-1st-order, and pseudo-2nd-order kinetics model parameters for removal of Drimaren turquoise CL-B.

Dye	Langmuir isotherms parameters			Freundlich isotherm parameters				Experimental values
	q_{max} (mg/g)	K_L (L/mg)	R^2	q_{max} (mg/g)	K (mg/g)	$1/n$	R^2	q_{max} (mg/g)
	117.65	0.0094	0.6569	75.03	6.88	0.1704	0.9852	75.37
Drimaren Turquoise CL-B	Pseudo-first-order kinetic model			Pseudo-second-order kinetic model				Experimental values
	qe (mg/g)	$k_{1,ads}$(min^{-1})	R^2	qe (mg/g)		$k_{2,ads}$ (mg/g)	R^2	qe (mg/g)
	2.11	0.00276	0.6938	14.68		0.135	1	14.74

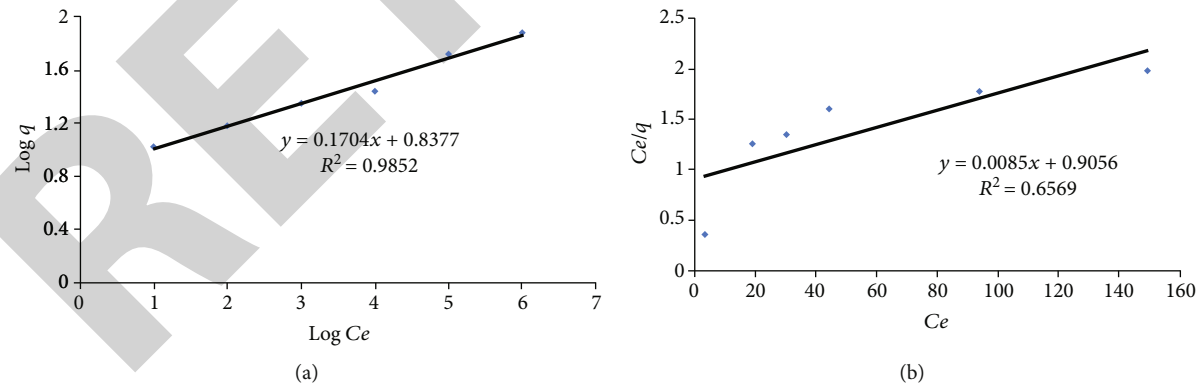

Figure 5: Adsorption isotherms. (a) Freundlich and (b) Langmuir for the removal of Drimaren Turquoise CL-B using *S. commune* biomass.

dye and sorption capacity decreased rise in temperature. This may be attributed to the reduced surface activity.

3.2.3. Effect of Initial Dye Concentration. Color removal efficiency is affected by dye initial concentration. Predominantly, the concentration brings a vital force to overwhelm the mass transfer phases of dye. The higher the initial concentration is, the higher the removal process will be. The removal of dye was analyzed using different initial dye concentrations (25, 50, 75, 100, 200, and 300 mg/L) of fungal biomass. With the rise in dye concentration, the increase in the amount of dye adsorbed was observed. Almeida et al. [60] reported the removal of MB with different concentration and concluded that MB was highly retained by the adsorbent as the initial dye concentration increased. Chu and Chen [61] inspected the consequence of concentration

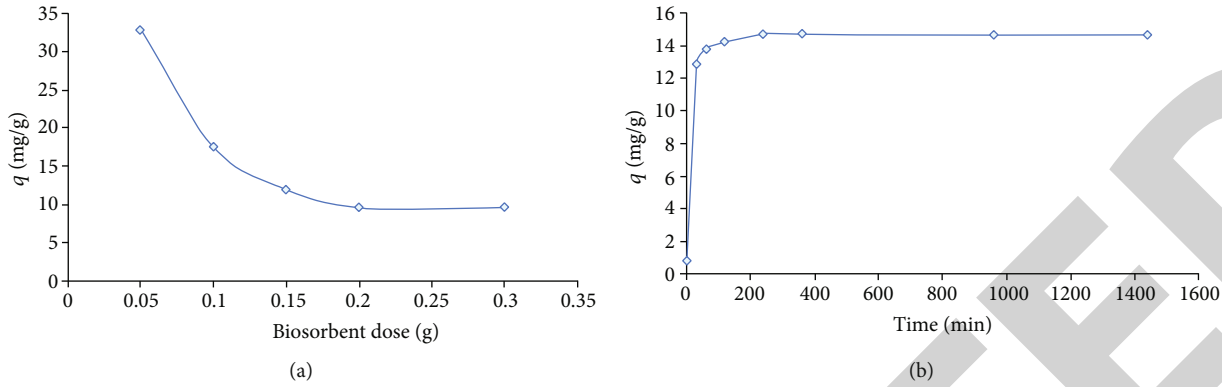

Figure 6: Effect of (a) biosorbent dose and (b) time on the removal of Drimaren Turquoise CL-B.

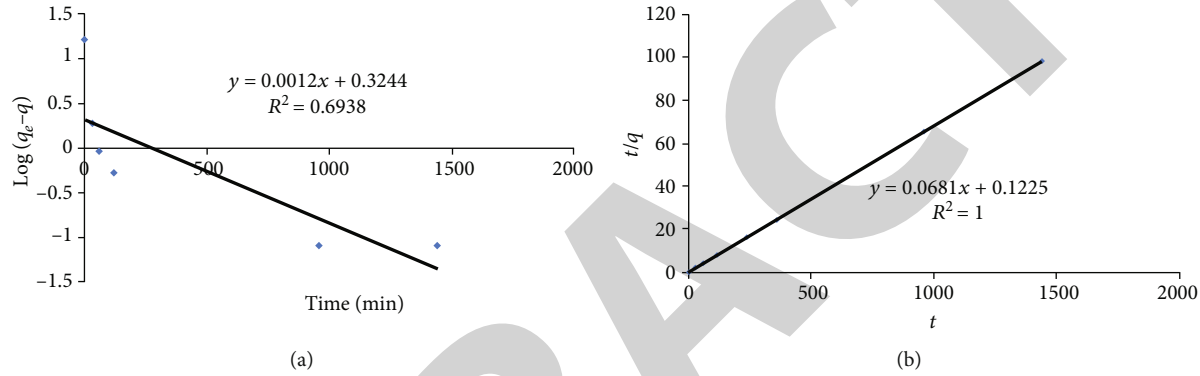

Figure 7: Reaction kinetics plots. (a) Pseudo-1st-order and (b) pseudo-2nd-order for the removal of Drimaren Turquoise CL-B.

on removal of dye with the help of sludge. In their observation, they reported that sorption of dye increased with rise in dye concentration.

3.2.4. Modeling for Equilibrium Studies. Demonstrating the equilibrium statistics provides detailed evidence for comparison among different materials under diverse working circumstances. This kind of data modelling is ultimate for dye removal process. To understand the removal process, a number of theories have been presented. Langmuir and Freundlich equations are the best tool to examine the association between sorbed (q_e) and aqueous concentrations (C_e) at equilibrium. The Langmuir isotherm model defines the monolayer formation of solute molecules on the biosorbent surface. The following linearized form of equation relates the q_{max} (mg/g) and other parameters:

$$\frac{C_e}{q_e} = \frac{1}{q_{max} K_L} + \frac{C_e}{X_m} \quad (2)$$

where q_e is the dye sorbed (mg/g), C_e the equilibrium concentration of dye solution, and K_L is Langmuir constants. The heterogeneous capacity, q_e (mg/g) of *S. commune* biomass for Drimaren Turquoise CL-B, was also determined using Freundlich isotherm:

$$\log q_e = \frac{1}{n} \log C_e + \log K \quad (3)$$

where q_e is the dye sorbed (mg/g), C_e the equilibrium concentration of dye solution (mg/L), and K and n are Freundlich constants. The constants K and $1/n$ were determined by linear regression from the plot of log q_e against log C_e. K is a measure of the degree or strength of removal. The magnitude of the experimental q_{max} for *S. commune* biomass was found to be 75.37 mg/g (Table 6). The data suggest that Freundlich (Figure 5) model better represented the sorption process.

3.2.5. Effect of Biosorbent Dose and Contact Time. Biosorbent dose is considered a significant contributor in biosorption process. Figure 6 represents the biosorbent dose effects on dye removal using fungal biomass. When the biosorbent dose was initially increased, the removal of dye increased but it was up to a certain limit (0.2 g). Following on, there was no effect of increase in biosorbent dose on the dye removal. The maxima (77.62%) were found at 0.2 g dose. Almeida et al. [60] have also elaborated similar effects for the MnP biosorption. The effect of contact time on dye removal process has been shown in Figure 6. The removal efficiency of dye was fast. Equilibrium time for the biosorption of Turquoise Reactive dye was found to be 240 min (q_e 14.74 mg/g).

3.2.6. Kinetic Modeling. To describe the kinetics of dye biosorption, several reaction-based and diffusion-based models were tested for the simulation of the obtained experimental data [62]. In this study, the biomass was employed as a free

cell suspension where binding sites were readily available for dye uptake. So, the biosorption rate can be safely assumed. The pseudo-1st-order Lagergren model is generally expressed as

$$\log (q_e - q) = \log q_e - \frac{k_{1ads}}{2.303} t \quad (4)$$

where q_e (mg/g) and q are the amounts of adsorbed dye on the biosorbent at the equilibrium and at any time t, respectively; and k_{1ads} is the Lagergren rate constant of the first-order biosorption. The pseudo-2nd-order model (Figure 7) is based on the assumption that the rate of occupation of removal sites is proportional to the square of the number of unoccupied sites:

$$\frac{1}{q} = \frac{1}{k_{2ads}.q_e^2} + \frac{1}{q_e} t \quad (5)$$

where k_{2ads} is the rate constant of the 2nd-order biosorption (g/mg.min). The Lagergren model failed to estimate q_e since the experimental values of qe were different from estimated. The biosorption process followed 2nd-order mechanism as indicated by a close agreement between experimental and estimated q_e values along with higher R^2. Other researchers reported almost similar kinds of results for removal of dyes [16, 63–69].

4. Conclusions

The following conclusions are drawn.

A large amount (10-15%) of the dyes are discharged in the textile effluents during the dyeing process. The textile industries are not following the chemical and physical treatments for dye wastewater due to high cost and disposal problems. Nowadays, the industries are looking towards some green, cost-effective biosorbents for the removal of pollutants. WRF are efficient for the removal of dyes owing to their extra cellular ligninolytic enzyme system. Reactive dye, Drimaren turquoise CL-B, was decolorized using *S. commune*. Different parameters effecting the removal process were optimized, and maximum removal (95.45%) was obtained at pH 4.5 and 35°C. As far as enzymatic activity is concerned, laccase and LiP activity was totally absent while MnP activity was dominant. Maximum biosorption was achieved at pH 1 and 313 K. There is a need to be more focused on such microorganisms and the conditions for their optimized working, which are able to biodegrade synthetic dyes in wastewater.

Data Availability

Data will be made available on demand.

Conflicts of Interest

The authors declare no competing financial interests.

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References

[1] S. G. Subramanian, R. Rajkumar, and T. Ramkumar, "Characterization of natural cellulosic fiber from Cereus hildmannianus," *Journal of Natural Fibers*, vol. 18, no. 3, pp. 343–354, 2021.

[2] G. Ke, K. Zhu, and M. H. Chowdhury, "Dyeing of cochineal natural dye on cotton fabrics treated with oxidant and chitosan," *Journal of Natural Fibers*, vol. 18, no. 3, pp. 317–329, 2021.

[3] T. Deng, L. Cheng, Y. Peng et al., "Structure and properties of Bombyx mandarina silk fiber and hybrid silk fiber," *Journal of Natural Fibers*, vol. 18, no. 3, pp. 330–342, 2021.

[4] U. H. Siddiqua, S. Ali, T. Hussain, M. Iqbal, N. Masood, and A. Nazir, "Application of multifunctional reactive dyes on the cotton fabric and conditions optimization by response surface methodology," *Journal of Natural Fibers*, vol. 19, no. 3, pp. 1094–1106, 2022.

[5] R. Naveed, I. A. Bhatti, S. Adeel et al., "Microwave-assisted extraction and dyeing of cotton fabric with mixed natural dye from pomegranate rind (Punica granatum L.) and turmeric rhizome (Curcuma longa L.)," *Journal of Natural Fibers*, vol. 19, no. 1, pp. 248–255, 2022.

[6] V. V. Priyan, T. Shahnaz, E. Suganya, S. Sivaprakasam, and S. Narayanasamy, "Ecotoxicological assessment of micropollutant diclofenac biosorption on magnetic sawdust: phyto, microbial and fish toxicity studies," *Journal of Hazardous Materials*, vol. 403, article 123532, 2021.

[7] A. M. Awwad, M. W. Amer, N. M. Salem, and A. O. Abdeen, "Green synthesis of zinc oxide nanoparticles (ZnO-NPs) using Ailanthus altissima fruit extracts and antibacterial activity," *Chemistry International*, vol. 6, no. 3, pp. 151–159, 2020.

[8] J.-X. Li and Z.-X. Du, "A binuclear cadmium (II) cluster based on $\pi\cdots\pi$ stacking and halogen···halogen interactions: synthesis, crystal analysis and fluorescent properties," *Journal of Cluster Science*, vol. 31, no. 2, pp. 507–511, 2020.

[9] J. Nisar, S. Hassan, I. Khan Muhammad et al., "Hetero-structured iron molybdate nanoparticles: synthesis, characterization and photocatalytic application," *International Journal of Chemical Reactor Engineering*, vol. 18, no. 2, 2020.

[10] A. Jamil, T. H. Bokhari, T. Javed et al., "Photocatalytic degradation of disperse dye Violet-26 using TiO_2 and ZnO nanomaterials and process variable optimization," *Journal of Materials Research and Technology*, vol. 9, no. 1, pp. 1119–1128, 2020.

[11] M. Iqbal, M. Fatima, T. Javed et al., "Microwave assisted synthesis of zinc vanadate nanoparticles and photocatalytic application," *Materials Research Express*, vol. 7, no. 1, article 015070, 2020.

[12] H. Chaudhry, N. Nisar, S. Mehmood, M. Iqbal, A. Nazir, and M. Yasir, "Indian mustard *Brassica juncea* efficiency for the accumulation, tolerance and translocation of zinc from metal contaminated soil," *Biocatalysis and Agricultural Biotechnology*, vol. 23, article 101489, 2020.

[13] H. N. Bhatti, Y. Safa, S. M. Yakout, O. H. Shair, M. Iqbal, and A. Nazir, "Efficient removal of dyes using carboxymethyl

cellulose/alginate/polyvinyl alcohol/rice husk composite: adsorption/desorption, kinetics and recycling studies," *International Journal of Biological Macromolecules*, vol. 150, pp. 861–870, 2020.

[14] R. Arshad, T. H. Bokhari, K. K. Khosa et al., "Gamma radiation induced degradation of anthraquinone reactive Blue-19 dye using hydrogen peroxide as oxidizing agent," *Radiation Physics and Chemistry*, vol. 168, article 108637, 2020.

[15] A. M. Alkherraz, A. K. Ali, and K. M. Elsherif, "Removal of Pb (II), Zn (II), Cu (II) and Cd (II) from aqueous solutions by adsorption onto olive branches activated carbon: equilibrium and thermodynamic studies," *Chemistry International*, vol. 6, no. 1, pp. 11–20, 2020.

[16] A. M. Awwad, N. M. Salem, M. M. Aqarbeh, and F. M. Abdulaziz, "Green synthesis, characterization of silver sulfide nanoparticles and antibacterial activity evaluation," *Chemistry International*, vol. 6, no. 1, pp. 42–48, 2020.

[17] H. A. Shindy, M. A. El-Maghraby, M. M. Goma, and N. A. Harb, "Novel styryl and aza-styryl cyanine dyes: synthesis and spectral sensitization evaluation," *Chemistry International*, vol. 5, no. 2, pp. 117–125, 2019.

[18] T. Shahnaz, V. C. Padmanaban, and S. Narayanasamy, "Surface modification of nanocellulose using polypyrrole for the adsorptive removal of Congo red dye and chromium in binary mixture," *International Journal of Biological Macromolecules*, vol. 151, pp. 322–332, 2020.

[19] B. Tegegne, A. Belay, and T. Gashaw, "Nutritional potential and mineral profiling of selected rice variety available in Ethiopia," *Chemistry International*, vol. 6, no. 1, pp. 21–29, 2020.

[20] M. Alasadi, F. I. Khaili, and A. M. Awwad, "Adsorption of Cu(II), Ni(II) and Zn(II) ions by nano kaolinite: thermodynamics and kinetics studies," *Chemistry International*, vol. 5, no. 4, pp. 258–268, 2019.

[21] E. C. Jennifer and O. P. Ifedi, "Modification of natural bentonite clay using cetyl trimetyl-ammonium bromide and its adsorption capability on some petrochemical wastes," *Chemistry International*, vol. 5, no. 4, pp. 269–273, 2019.

[22] G. N. Iwuoha and A. Akinseye, "Toxicological symptoms and leachates quality in Elelenwo, Rivers State, Nigeria," *Chemistry International*, vol. 5, no. 3, pp. 198–205, 2019.

[23] E. B. Hassen and A. M. Asmare, "Predictive performance modeling of Habesha brewery wastewater treatment plant using artificial neural networks," *Chemistry International*, vol. 5, no. 1, pp. 87–96, 2019.

[24] F. Deeba, N. Abbas, M. T. Butt, and M. Irfan, "Ground water quality of selected areas of Punjab and Sind Provinces, Pakistan: chemical and microbiological aspects," *Chemistry International*, vol. 5, no. 4, pp. 241–246, 2019.

[25] N. E. Ibisi and C. A. Asoluka, "Use of agro-waste (Musa paradisiaca peels) as a sustainable biosorbent for toxic metal ions removal from contaminated water," *Chemistry International*, vol. 4, no. 1, pp. 52–59, 2018.

[26] M. Bilal and H. M. N. Iqbal, "Lignin peroxidase immobilization on ca-alginate beads and its dye degradation performance in a packed bed reactor system," *Biocatalysis and Agricultural Biotechnology*, vol. 20, article 101205, 2019.

[27] I. Bibi, S. Javed, S. Ata et al., "Biodegradation of synthetic orange G dye by *Plearotus sojar-caju* with *Punica granatum* peal as natural mediator," *Biocatalysis and Agricultural Biotechnology*, vol. 22, article 101420, 2019.

[28] K. Agrawal and P. Verma, "Biodegradation of synthetic dye Alizarin Cyanine Green by yellow laccase producing strain *Stropharia* sp. ITCC-8422," *Biocatalysis and Agricultural Biotechnology*, vol. 21, article 101291, 2019.

[29] A. M. Othman, M. A. Elsayed, A. M. Elshafei, and M. M. Hassan, "Application of central composite design as a strategy to maximize the productivity of *Agaricus bisporus* CU13 laccase and its application in dye decolorization," *Biocatalysis and Agricultural Biotechnology*, vol. 14, pp. 72–79, 2018.

[30] C. Cantele, R. C. Fontana, A. G. Mezzomo et al., "Production, characterization and dye decolorization ability of a high level laccase from *Marasmiellus palmivorus*," *Biocatalysis and Agricultural Biotechnology*, vol. 12, pp. 15–22, 2017.

[31] T. Shahnaz, V. V. Priyan, S. Pandian, and S. Narayanasamy, "Use of nanocellulose extracted from grass for adsorption abatement of ciprofloxacin and diclofenac removal with phyto, and fish toxicity studies," *Environmental Pollution*, vol. 268, no. Part B, article 115494, 2021.

[32] K. L. Yu, X. J. Lee, H. C. Ong et al., "Adsorptive removal of cationic methylene blue and anionic Congo red dyes using wet-torrefied microalgal biochar: equilibrium, kinetic and mechanism modeling," *Environmental Pollution*, vol. 272, article 115986, 2021.

[33] M. Arshad, S. Ehtisham-ul-Haque, M. Bilal et al., "Synthesis and characterization of Zn doped WO3nanoparticles: photocatalytic, antifungal and antibacterial activities evaluation," *Materials Research Express*, vol. 7, no. 1, article 015407, 2020.

[34] N. Qureshi, S. Ehtisham-ul-Haque, M. Abbas et al., "Synthesis of fluorescent di-dansyl substituted ethoxy compound: a selective sensor for antimony and thallium metals detection," *Journal of Materials Research and Technology*, vol. 8, no. 1, pp. 1576–1580, 2019.

[35] S. Nouren, M. Sarwar, G. Muhi-ud-Din et al., "Sweet lime-mediated decolorization of textile industry effluents," *Polish Journal of Environmental Studies*, vol. 28, no. 1, pp. 283–289, 2019.

[36] N. Nisar, O. Ali, A. Islam et al., "A novel approach for modification of biosorbent by silane functionalization and its industrial application for single and multi-component solute system," *Zeitschrift für Physikalische Chemie*, vol. 233, no. 11, pp. 1603–1623, 2019.

[37] A. Nazir, S. Iftikhar, M. Abbas, M. Iqbal, and I. Ahmad, "Toxicity evaluation of tannery effluents using bioassays," *Current Science Perspectives*, vol. 5, no. 3, pp. 29–39, 2019.

[38] N. U. H. Khan, H. N. Bhatti, M. Iqbal, and A. Nazir, "Decolorization of basic turquise blue X-GB and basic blue X-GRRL by the Fenton's process and its kinetics," *Zeitschrift für Physikalische Chemie*, vol. 233, no. 3, pp. 361–373, 2019.

[39] S. Jabeen, S. Ali, M. Nadeem et al., "Statistical modeling for the extraction of dye from natural source and industrial applications," *Polish Journal of Environmental Studies*, vol. 28, no. 4, pp. 2145–2150, 2019.

[40] T. H. de Koker, J. Zhao, S. F. Allsop, and B. J. H. Janse, "Isolation and enzymic characterisation of south African white-rot fungi," *Mycological Research*, vol. 104, no. 7, pp. 820–824, 2000.

[41] R. L. Gilbertson, "Wood-rotting fungi of North America," *Mycologia*, vol. 72, no. 1, pp. 1–49, 1980.

[42] M. Asgher, S. Batool, H. N. Bhatti, R. Noreen, S. Rahman, and M. J. Asad, "Laccase mediated decolorization of vat dyes by

Coriolus versicolor IBL-04," *International Biodeterioration & Biodegradation*, vol. 62, no. 4, pp. 465–470, 2008.

[43] M. Tien and T. K. Kirk, "Lignin peroxidase of *Phanerochaete chrysosporium*," *Methods in Enzymology*, vol. 161, pp. 238–249, 1988.

[44] H. N. Bhatti, N. Akram, and M. Asgher, "Optimization of culture conditions for enhanced decolorization of Cibacron Red FN-2BL by Schizophyllum commune IBL-6," *Applied Biochemistry and Biotechnology*, vol. 149, no. 3, pp. 255–264, 2008.

[45] Z. Aksu and G. Karabayır, "Comparison of biosorption properties of different kinds of fungi for the removal of Gryfalan Black RL metal-complex dye," *Bioresource Technology*, vol. 99, no. 16, pp. 7730–7741, 2008.

[46] H. N. Bhatti, R. Khalid, and M. A. Hanif, "Dynamic biosorption of Zn(II) and Cu(II) using pretreated *Rosa gruss an teplitz* (red rose) distillation sludge," *Chemical Engineering Journal*, vol. 148, no. 2-3, pp. 434–443, 2009.

[47] H. N. Bhatti, A. Jabeen, M. Iqbal, S. Noreen, and Z. Naseem, "Adsorptive behavior of rice bran-based composites for malachite green dye: isotherm, kinetic and thermodynamic studies," *Journal of Molecular Liquids*, vol. 237, pp. 322–333, 2017.

[48] I. A. Bhatti, S. Adeel, M. A. Jamal, M. Safdar, and M. Abbas, "Influence of gamma radiation on the colour strength and fastness properties of fabric using turmeric (Curcuma *longa* L.) as natural dye," *Radiation Physics and Chemistry*, vol. 79, no. 5, pp. 622–625, 2010.

[49] M. Asgher, S. Noreen, and H. N. Bhatti, "Decolorization of dye-containing textile industry effluents using Ganoderma lucidumIBL-05 in still cultures," *Water Environment Research*, vol. 82, no. 4, pp. 357–361, 2010.

[50] A. S. Khan, K. Arif, B. Munir et al., "Estimating total phenolics in Taraxacum officinale (L.) extracts," *Polish Journal of Environmental Studies*, vol. 28, no. 1, pp. 497–501, 2019.

[51] A. Paszczynski and R. L. Crawford, "Potential for bioremediation of xenobiotic compounds by the white-rot fungus Phanerochaete chrysosporium," *Biotechnology Progress*, vol. 11, no. 4, pp. 368–379, 1995.

[52] M. Chander, D. Arora, and H. Bath, "Biodecolourisation of some industrial dyes by white-rot fungi," *Journal of Industrial Microbiology and Biotechnology*, vol. 31, no. 2, pp. 94–97, 2004.

[53] I. K. Kapdan, F. Kargia, G. McMullan, and R. Marchant, "Effect of environmental conditions on biological decolorization of textile dyestuff by *C. versicolor*," *Enzyme and Microbial Technology*, vol. 26, no. 5-6, pp. 381–387, 2000.

[54] K. Kumar, M. Dastidar, and T. Sreekrishnan, "Effect of process parameters on aerobic decolourization of reactive azo dye using mixed culture," *World Academy of Science, Engineering and Technology*, vol. 58, pp. 952–955, 2009.

[55] T. Robinson, B. Chandran, and P. Nigam, "Studies on the production of enzymes by white-rot fungi for the decolourisation of textile dyes," *Enzyme and Microbial Technology*, vol. 29, no. 8-9, pp. 575–579, 2001.

[56] C. Munoz, F. Guillen, A. Martinez, and M. Martinez, "Induction and characterization of laccase in the ligninolytic fungus Pleurotus eryngii," *Current Microbiology*, vol. 34, no. 1, pp. 1–5, 1997.

[57] G. Bayramoğlu, G. Çelik, and M. Y. Arica, "Biosorption of Reactive Blue 4 dye by native and treated fungus *Phanerocheate chrysosporium*: Batch and continuous flow system studies," *Journal of Hazardous Materials*, vol. 137, no. 3, pp. 1689–1697, 2006.

[58] Z. Aksu and G. Dönmez, "Combined effects of molasses sucrose and reactive dye on the growth and dye bioaccumulation properties of *Candida tropicalis*," *Process Biochemistry*, vol. 40, no. 7, pp. 2443–2454, 2005.

[59] Z. Aksu and S. Tezer, "Equilibrium and kinetic modelling of biosorption of Remazol Black B by *Rhizopus arrhizus* in a batch system: effect of temperature," *Process Biochemistry*, vol. 36, no. 5, pp. 431–439, 2000.

[60] C. Almeida, N. Debacher, A. Downs, L. Cottet, and C. Mello, "Removal of methylene blue from colored effluents by adsorption on montmorillonite clay," *Journal of colloïd and interface science*, vol. 332, no. 1, pp. 46–53, 2009.

[61] H. Chu and K. Chen, "Reuse of activated sludge biomass: II. The rate processes for the adsorption of basic dyes on biomass," *Process Biochemistry*, vol. 37, no. 10, pp. 1129–1134, 2002.

[62] Y. S. Ho and G. McKay, "The kinetics of sorption of divalent metal ions onto sphagnum moss peat," *Water Research*, vol. 34, no. 3, pp. 735–742, 2000.

[63] I. A. Adetutu, G. N. Iwuoha, and H. M. Jnr, "Carcinogenicity of dioxin-like polychlorinated biphenyls in transformer soil in vicinity of University of Port Harcourt, Choba, Nigeria," *Chemistry International*, vol. 6, no. 3, pp. 144–150, 2020.

[64] O. Igwe and F. Nwamezie, "Green synthesis of iron nanoparticles using flower extract of Piliostigma thonningii and antibacterial activity evaluation," *Chemistry International*, vol. 4, pp. 60–66, 2018.

[65] M. Fazal-ur-Rehman, "Methodological trends in preparation of activated carbon from local sources and their impacts on production: a review," *Chemistry International*, vol. 4, no. 2, pp. 109–119, 2018.

[66] N. A. Ayofe, P. O. Oladoye, and D. O. Jegede, "Extraction and quantification of phthalates in plastic coca-cola soft drinks using high performance liquid chromatography (HPLC)," *Chemistry International*, vol. 4, no. 2, pp. 85–90, 2018.

[67] S. Jafarinejad, "Recent developments in the application of sequencing batch reactor (SBR) technology for the petroleum industry wastewater treatment," *Chemistry International*, vol. 3, no. 3, p. 241, 2017.

[68] K. Djehaf, A. Z. Bouyakoub, R. Ouhib et al., "Textile wastewater in Tlemcen (Western Algeria): impact, treatment by combined process," *Chemistry International*, vol. 3, no. 4, pp. 414–419, 2017.

[69] M. A. Jamal, M. Muneer, and M. Iqbal, "Photo-degradation of monoazo dye blue 13 using advanced oxidation process," *Chemistry International*, vol. 1, no. 1, pp. 12–16, 2015.