# Biosorption of Crystal Violet Dye Solution by *Aspergillus striatus, Bacillus megaterium, Chlorella vulgaris* and *Fusarium equiseti*

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**Abstract:** Crystal violet is a synthetic triphenylmethane dye that serves as a biological stain which can also be used in dyeing textile materials. It is toxic and remains in the environment for longer periods, as such needs to be treated before discharge. This study was carried out to assess the biosorption potentials of *Aspergillus striatus, Bacillus megaterium, Chlorella vulgaris* and *Fusarium equiseti* on crystal violet dye. This was achieved through inoculation of pure cultures of the organisms into the dye solution. The highest percentage biosorption for all the test organisms was obtained at 24 hours after inoculation, with *Fusarium equiseti* recording 94.7%, *Aspergillus striatus*, 89.5%, *Chlorella vulgaris*, 77.1% and *Bacillus megaterium*, 68.8%. The results indicated no significant difference in dye removal among the four species with *Fusarium equiseti* having the highest biosorption potential and *Bacillus megaterium* the least. A multilayer biosorption pattern was predicted as the biosorption process fitted with the Freundlich's isotherm. To avoid further environmental contamination more eco-friendly strategies for generating dye-degrading organisms that can detoxify dyes should be introduced.

**Keywords**: *Aspergillus striatus*, *Bacillus megaterium, Chlorella vulgaris*, Crystal violet, *Fusarium equiseti*

## INTRODUCTION

One of the main sources of pollution worldwide is the textile industry and its dye-containing wastewater. Many of the dyes released into the environment and their breakdown products are undesirable due to their persistent colour, toxicity, carcinogenicity or mutagenicity to life forms (Zaharia *et al*., 2009: Mesania *et al*., 2014; Bafana *et al*., 2020). The persistent colour of dye in wastewater which is stable and fast makes it difficult to degrade, rendering receiving water bodies unfit for their intended use. Cases of long-term exposure to synthetic dyes resulting in tumor, cancer, liver and kidney malfunctions have been reported by many investigators (Sajjala *et al*., 2008). These dyes can remain in the environment for longer periods of time without proper treatment. The removal of such dyes from industrial wastewater/effluents can be achieved through physical, chemical or biological treatments, of which, the latter is cheaper, effective and eco-friendly (Robinson *et al*., 2001; Roy *et al*., 2018). Physical and chemical effluent treatments are often unable to completely remove dyes, are exorbitantly expensive and they tend to generate other toxic substances that may elevate pollution in the receiving environments (Shah, 2013; Bhattacharya *et al*., 2018). Due to aforementioned reasons, the use of microbial biomass to biosorp and/or degrade pollutants contained in effluents was employed (Bumpus and Brock, 1988; Yang *et al*., 2009; Lavanya *et al*., 2014; Ledakowicz and Pazdzior, 2021; Singh *et al*., 2021). Microorganisms remove dyes from the environment mainly through biomass sorption or enzymatic degradation (Chen *et al*., 2019). Apart from microorganisms, other high aquatic plants (macrophytes) such as water hyacinth, lettuce, ferns, penny worts, duck weeds and macroalgae (*Chara* and *Scenedesmus* species) have been reported in successful degradation and precipitation of some synthetic dyes (Mesania *et al*., 2014; Patil *et al*., 2015).

Microorganisms such as bacteria, fungi and algae have been proven to be very effective in treatment of textile wastewater containing a wide variety of toxicants such as dyes (Gupta *et al*., 2015). Bacterial species from the genera *Bacillus, Alcaligenes, Aeromonas, Pseudomonas, Sphingomonas, Rhodococcus, Corynebacterium, Escherichia, Agrobacterium* and *Mycobacterium* were reported with high remediation potentials as such are used in treatment of dye effluents/wastewater and soils of industrial

sites (Vidali, 2001; Parshetti *et al*., 2011; Pokharia and Ahluwalia, 2013; Osama *et al*., 2014).

Also, researches have shown various fungal species belonging to the genera, *Aspergillus, Phanerochaeta, Hirschioporus, Inonotus, Phlebia, Ceriporia, Coriolus, Candida, Fusarium* and *Rhizopus* with the ability to remediate synthetic dyes (Jebapriya and Gnanadosa, 2013; Rani *et al*., 2014; Singh *et al*., 2015; Hefnawy *et al*., 2017; Wang *et al*., 2017; Yucel, 2018; Ortiz-Monsalve *et al*., 2019).

Algae are regarded as efficient bioremediators due to their photosynthetic capabilities aiding them in metabolic processes like absorbing carbon dioxide from the atmosphere, converting solar energy into useful biomasses, incorporating nutrients and other pollutants through bioaccumulation and biosorption. They have also been proven to remove dyes through various mechanisms such as biosorption, bioconvertion and bioagulation (Khalaf, 2008; Ayele *et al*., 2021). It was also stated that algal dye remediation may be either by enzymatic action or biosorption with live or dead biomass, which is dependent on optimized pH, temperature, biosorbent concentration and agitation (Paul *et al*., 2011).

Crystal violet is a synthetic triphenylmethane dye commonly used in human and veterinary medicine as a biological stain, and as well for dyeing fabric in textile processing industries (Au *et al*., 1978; Azmi *et al*., 1998). It is known for being recalcitrant, toxic and remains in the environment for longer periods. It is also referred to as a mitotic poisoning agent and/or biohazard substance as it promotes tumor growth in some aquatic organisms, as such termed also as a potent carcinogen/clastogen (Au *et al*., 1978; Fan *et al*., 2009). Various chemical and physical methods have been employed in remediation of Crystal violet which have proven to be effective for smaller volumes generating toxic compounds as end products (Azmi *et al*., 1998; Robinson *et al*., 2001; Cheng *et al*., 2008). Other researches have also proven that remediation of Crystal violet dye can be achieved through membrane bound fraction and air bubble bioreactor packed with *Pseudomonas aeruginosa* (Jones and Falkinham, 2003; El-Naggar *et al*., 2004). The study aimed at assessing the potentials of *A. striatus, B. megaterium, F. equiseti* and *C. vulgaris* in remediation of Crystal violet dye.

## MATERIALS AND METHODS

### Microorganisms

Microorganisms used in this study were *Aspergillus striatus, Bacillus megaterium, Chlorella vulgaris* and *Fusarium equiseti*. Pure cultures of the above mentioned species were collected from the staff research laboratory, Faculty of Life Sciences, Bayero University, Kano and further sub-cultured using streak culture and direct isolation methods on potato dextrose broth (fungi), nutrient broth (bacteria) and bold basal (algae) media (Benson, 1998; Lee *et al*., 2013; Al-Mohanna, 2016). Crystal violet dye solution was prepared by dissolving 1 gram of its powder in 2 L of distilled water, from which 1 ml of the dye solution was subsequently added to a test-tube containing 5 ml of normal saline serving as the control.

### Biosorption Assay

*Aspergillus striatus* and *Fusarium equiseti* were cultivated on potato dextrose broth for 5 days at room temperature (37 °C) as described by Al-Mohanna (2016) and 0.1 grams mycelia were harvested for the biosorption assay. *Bacillus megaterium* biomass was generated according to the method of Ngui *et al*. (2013), which involved sub-culturing on nutrient broth medium at 37 °C for 24 hours in an incubator shaker (Innova 4000) at 150 rpm. After 24 hours, the solution was centrifuged (Centromix Selecta 540) at 10,000 rpm for 10 minutes, to separate the supernatant and pellet (bacterial cells), and $2.39\times10^3$ cells/ml was used for the assay. Bold basal medium was used for cultivation of *C. vulgaris* at 30 °C with proper aeration (with an air pump - Shining beach SB660) and $2.24\times10^4$ cells/ml was generated with the aid of a cytometer.

The biomass for each of the species was separately placed in individual test-tubes containing 1 ml of dye solution and 5 ml of normal saline (Verma *et al*., 2015). The solution was mixed with an auto-vortex mixer and incubated at 37 °C.

The absorbance of inoculated dye solution was recorded using a spectrophotometer (model 722) at wavelength 650 nm after 8, 16 and 24 hours. The amount of dye adsorbed per gram of the biomass and percentage biosorption of the dye by the biomass of individual species were calculated using equations 1 and 2 respectively.

$$Qe = A - B \times \frac{V}{M} \quad - \quad - \quad - \quad 1$$

$$Biosorption\ (\%) = \frac{(A-B)}{A} \times 100 \quad - \quad 2$$

Where, Qe = Concentration of dye at equilibrium, A = Initial concentration of dye in solution, B = Final concentration of dye in solution, V = volume of solution in millilitre and M = quantity of biomass (Ngui *et al*., 2013; Verma *et al*., 2015; Vikrant *et al*., 2018).

Preparation of assays was in triplicates and the numerical values recorded were expressed as mean ± standard error and further analyzed by one-way analysis of variance (ANOVA) using Microsoft Excel 2007. Readings were considered significant when P is less than 0.05. Freundlich's isotherm was used to further explain the pattern of the biosorption process (Mahmoud *et al*., 2016).

Freundlich's equation is given by;

$Qe = K_f \times B^N$

Where, Qe = Concentration of dye at equilibrium, $K_f$ = Freundlich's constant and N = Slope of graph (log Qe versus log B) (Abel *et al*., 2020).

## RESULTS

The colonial and microscopic view of the organisms and the results for their biosorption of crystal violet dye are presented in Figures 1-3. The lower case alphabets 'a' and 'b' in Figure 1 represent the colonial and microscopic appearance of the species respectively. Figure 2 shows the percentage biosorption taken at an interval of 8 hours, to which the highest percentage was at 24 hours for all species. The visual decrease in dye coloration is presented in Figure 3, where, the test-tube inoculated with *F. equiseti* (b) had a clearer solution than that of the other three species. There was no statistical significant difference in the biosorption of dye by the four species as $P > 0.05$ ($P = 0.12$). Table 1, provides regression data for crystal violet biosorption by the four species in accordance with Freundlich's isotherm

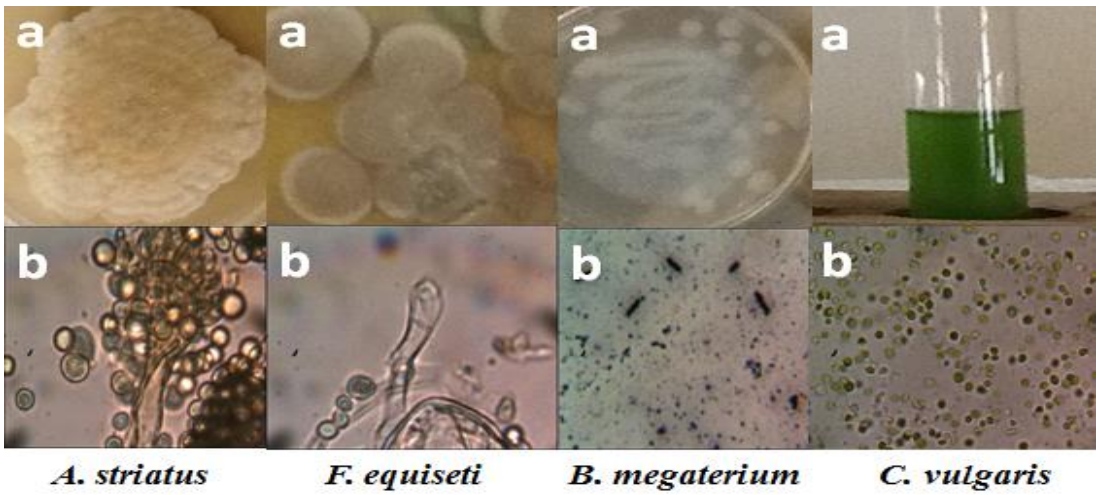


Fig. 1: Colony (a) and microscopic view (b) of the four species (mg. ×1/3 for colonies and mg. ×100 for microscopy)

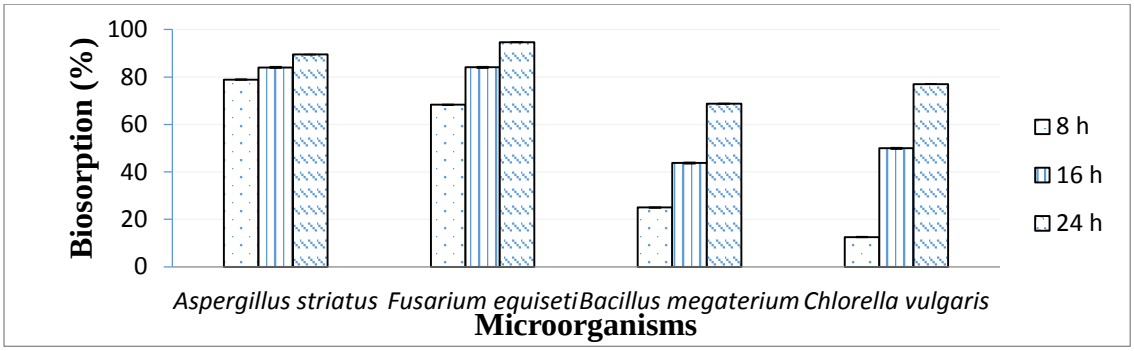


Fig. 2: Percentage Biosorption of Crystal Violet Dye within 24 Hours by the Four Species

In Figure 2 above, *F. equiseti* had the highest percentage (94.7 %) and *B. megaterium* the least (68.8 %).

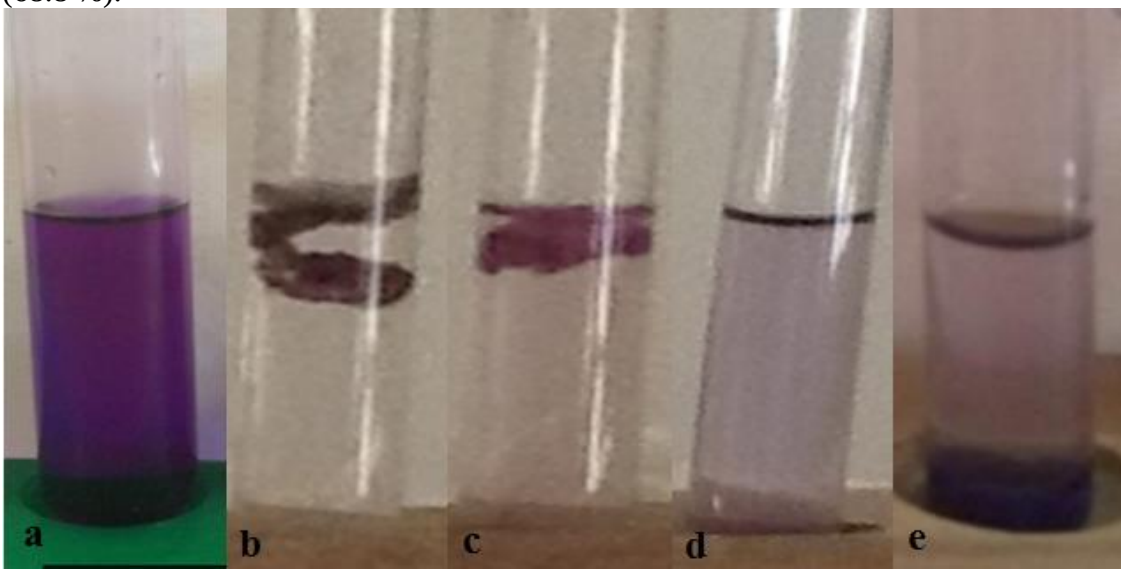


Fig. 3: Visual Decrease in Dye Colouration at 24 Hours after Inoculation

(a) Crystal violet dye solution (Control), (b) Crystal violet dye solution inoculated with *F. equiseti* (c) Crystal violet dye solution inoculated with *A. striatus* (d) Crystal violet dye solution inoculated with *C. vulgaris* (e) Crystal violet dye solution inoculated with *B. megaterium*

Table 1: Linear Regression Data for Freundlich's Isotherm for Crystal Violet Dye Biosorption by the Four Species

| Microorganism | $K_f$ (L/mg) | N | $R^2$ |
|---|---|---|---|
| *A. striatus* | 2.59E-01 | 0.18 | 0.9859 |
| *F. equiseti* | 3.13E-01 | 0.18 | 0.9192 |
| *B. megaterium* | 5.50E+04 | 1.2 | 0.9362 |
| *C. vulgaris* | 1.85E+04 | 1.36 | 0.8563 |

In Table 1, the $K_f$ values especially that of *B. megaterium* and *C. vulgaris* indicate high biosorption capacity. All $R^2$ values were less than one, thus, showing the occurrence of a multilayer biosorption pattern.

## DISCUSSION

The study determined the biosorption potential of 4 species (*A. striatus, B. megaterium, F. equiseti* and *C. vulgaris*) on Crystal violet dye under static conditions, pH 6.98 and temperature 37 °C for 24 hours. The results are presented in Figures 1-3. The highest percentage dye removal for all the species was recorded at 24 hours, with *F. equiseti* revealing the highest percentage

(94.7%), *A. striatus* (89.5%), *C. vulgaris* (77.1%) and *B. megaterium* (68.8%) (Figures 2 and 3).

The findings of this study is in line with several researches in this field, for example, Asad *et al*. (2007) observed that bacterial species from different genera can completely degrade and mineralize synthetic dyes such as crystal violet under optimized conditions (Jones and Falkinham, 2003; Al-Garni *et al*., 2013; Pokharia and Ahluwalia, 2013). In another study, *Bacillus* species was reported to have decolourized crystal violet dye within 2.5 hours of incubation (Ayed *et al*., 2009). *Bacillus substilis* decolourized crystal violet dye at pH 8, temperature 35 °C under static condition in the presence of carbon and nitrogen sources (Kochher *et al*., 2011). *Bacillus* species are known for high effectiveness in degradation of dyes and other pollutants in industrial effluents and soils which is due to possession of various enzymes such as lignin peroxidase, laccase, azo reductase and biotransformation enzymes (Azmi *et al*., 1998; Telke *et al*., 2008; Parshetti *et al*., 2010; Akhtar *et al*., 2019).

A number of fungal species belonging to different genera have been proven to be effective bioremediators of dyes and other contaminants in aquatic and terrestrial habitats (Azmi *et al*., 1998; Shahid *et al*., 2013; Marcharchand and Ting, 2017; Ortiz-Monsalve *et al*., 2019). Remediation of crystal violet dye by a variety fungal species (like *Phanerochaete chrysosporium, Pleuroteus ostreatus, Piptoporus betulinus, Funalia trogii, Coriolus vesicolor, Cyathus stariatus, Irpex lacteus, Bjerkandera adusta, Cunninghamella elegans, Mucor mucedo, Lenzites betulina, Polyporus elegans, species of Aspergillus, Fusarium, Penicillium, Trametes* and *Trichoderma*) have been reported by several researchers (Bumpus and Brock, 1988; Azmi *et al*., 1998; Moturi and Singara, 2009; Yang *et al*., 2009; Shahid *et al*., 2013; Al-Jawhari, 2015; Gupta *et al*., 2015; Ali *et al*., 2016; Chen *et al*., 2019; Gao *et al*., 2020), which is in agreement with findings of this research. Another study revealed *Diaporthe schini* and *Candida krusei* to have biosorp and degraded Crystal violet and Basic violet 3 respectively (Deivasigamani and Das, 2011; Grassi *et al*., 2019; Slama *et al*., 2021).

Many researchers have reported positive degradation of synthetic dyes by *Chlorella vulgaris* (Chu *et al*., 2009; Kosha *et al*., 2013; Arteaga *et al*., 2018; Naji and Salman, 2019; Raymond and Omo, 2019; Chin *et al*., 2020; Ishchi and Sibi, 2020). Species from the genera *Chlorella* and *Oscillatoria* have been reported to possess potentials for remediating Azo Dyes to aromatic amines which are further metabolized to simple organic compounds (Wen-Tung and Ming-Der, 2011). Algae and cyanobacteria species are capable of utilizing some Azo dyes to obtain carbon and nitrogen (El-Sheekh *et al*., 2018; Hussein *et al*., 2018). In a study conducted by El-Sheekh *et al*. (2018), an algal species (*Chlorella vulgaris*) and cyanobacterium (*Aphanocapsa elachista* and *Nostoc carneum*) were able to degrade and mineralize synthetic dyes within 7 days (Hussein *et al*., 2018). Another study revealed the ability of *Hydrocoleum oligotrichum* and *Oscillatoria limnetica* to decolourize and degrade certain synthetic dyes (Abou-El-Souod and El-Sheekh, 2016). Srashti (2013) reported *Spirulina platensis* with effective degradation of dyes.

## CONCLUSION

In conclusion, the results of the study revealed that all the four species had the capacity to biosorp crystal violet dye as there was significant decrease in dye colouration visually and spectrophotometrically. The highest percentage biosorption was recorded after 24 hours of inoculation, with *F. equiseti* having the highest value, then, *A. striatus, C. vulgaris* and *B. megaterium*. The results revealed no significant difference in dye biosorption by the species. The biosorption process indicated a multilayer biosorption pattern, as it fitted with the Freundlich's isotherm.

## RECOMMENDATION

Introduction of adequate strategies for extraction of dye-remediating enzymes from organisms which could be used to detoxify dyes in effluents/wastewater before discharging into the environment to avoid further contamination is strongly recommended.

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## REFERENCES

Abel, U.A., Habor, G.R. and Oseribho, O.I. (2020). Adsorption studies of oil spill clean-up using coconut coir activated carbon (CCAC). *IOSR J Appl Chem*, **13**(11): 42-56.

Abou-El-Souod, G.W. and El-Sheekh, M.M. (2016). Biodegradation of basic fushin and methyl red by the blue green algae *Hydrocoleum oligotrichum* and *Oscillatoria limnetica*. *Environ Engr Manage J*, **15**(2): 279-286.

Akhtar, K., Zerin, T. and Banik, A. (2019). Biodegradation of textile dyes by bacteria isolated from textile industry effluents. *Stamford J Microbiol*, **9**(1): 5-8.

Al-Garni, S.M., Ghanem, K.M., Kabli, S.A. and Biag, A.K. (2013). Decolourization of crystal violet by mono and mixed bacterial culture technologies using optimized culture conditions. *Polish J Environ Stud*, **22**(5): 1297-1306.

Ali, H.M., Shehata, S.F. and Ramadan, K.M.A. (2016). Microbial decolourization and degradation of crystal violet dye by *Aspergillus niger*. *Intl J Environ Sci Technol*, **13**: 2917-2926.

Al-Jawhari, I.F.H. (2015). Decolourization of methylene blue and crystal violet by some filamentous fungi. *Int J Environ Bioremed Biodegrad*, **3**(2): 62-65.

Al-Mohanna, M.T. (2016). Origin of OTA: *Methods of fungal enumeration, isolation and identification*, chapter 7, 155-241, DOI: 10.13140/RG.2.2.12515.96809.

Arteaga, L.C., Zavaleta, M.P., Eustaquio, W.M. and Babadilla, J.M. (2018). Removal of aniline blue dye using live microalgae *Chlorella vulgaris*. *J Ener Environ Sci*, **2**(1): 6-12.

Asad, S., Amoozegar, M., Pourbabace, A.A., Sarbolouki, M. and Dastgheib, S. (2007). Decolourization of textile azo dyes by newly isolated halophilic and halotolerant bacteria. *Biores Technol*, **98**: 2082-2088.

Au, W., Pathak, S., Colie, C.L. and Hsu, T.C. (1978). Cytogenetic toxicity of gentian violet and crystal violet on mammalian cells *in-vitro*. *Mutent Res*, **58**(3): 269-276.

Ayed, L., Cheriaa, J., Laadhari, N., Cheref, A. and Bakhrouf, A. (2009). Biodegradation of crystal violet by an isolated *Bacillus* species. *Annals Microbiol*, **59**(2): 267-272.

Ayele, A., Getachew, D., Kamaraj, M. and Suresh, A. (2021). Phycoremediation of synthetic dyes: an effective and eco-friendly algal technology for the dye abatement. *Hindawi J Chem*, **2021**(9923643): 1-14.

Azmi, W., Sani, R.K. and Banerjee, U.C. (1998). Biodegradation of triphenylmethane dyes. *Enzyme Microbiol Technol*, **22**(3): 185-191.

Bafana, A., Khan, F. and Suguna, K. (2020). Purification, characterization and crystal structure of YhdA-type azoreductase from *Bacillus velezensis*. *Wiley Proteins Struct Funct Bioinform*, **89**: 483-492.

Benson, H.J. (1998). *Microbiological applications; laboratory manual in general microbiology*, 7th edition, Mc-Graw Hill Company, New York, 44-45.

Bhattacharya, S., Gupta, A.B., Gupta, A. and Pandey, A. (2018). Introduction to water remediation: importance and methods. In: *Water remediation*. Singapore, Springer, 3-8. DOI: 10.1007/978-981-10-7551-3_1.

Bumpus, J.A. and Brock, B.J. (1988). Biodegradation of crystal violet by the white rot fungus *Phanerochaete chrysosporium*. *Appl Environ Microbiol*, **54**(5): 1143-1150.

Chen, S.H., Chew, Y.L., Ng, S.L. and Ting, A.S.Y. (2019). Biodegradation of triphenylmethane dyes by non-white rot fungus *Penicillium simplicissimum*; enzymatic and toxicity studies. *Int J Environ Res*, **13**(2): 273-282.

Cheng, M., Song, W., Ma, W., Chen, C., Zhao, J., Lin, J. and Zhu, H. (2008). Catalytic activity of iron species in layered clays for photodegradation of organic dyes under visible irradiation. *Appl Catalysis B: Environ*, **77**(4): 355-363.

Chin, J.Y., Chng, L.M., Leong, S.S., Yeap, S.P., Yasin, N.H.M. and Toh, P.Y. (2020). Removal of synthetic dye by *Chlorella vulgaris* microalgae as natural adsorbent. *Arab J Sci Engr*, **45**(9): 7385-7395.

Chu, W.L., See, Y.C. and Phang, S.M. (2009). Use of immobilized *Chlorella vulgaris* for the removal of colour from textile dyes. *J Appl Phycol*, **21**: 641-648.

Deivasigamani, C. and Das, N. (2011). Biodegradation of basic violet 3 by *Candida krusei* isolated from textile wastewater. *Biodegrad*, **22**: 1169-1180.

El-Naggar, M.A., El-Naggar, S.A. and Barakat, K.I. (2004). Bioremediation of crystal violet using air bubble bioreactor packed with *Pseudomonas aeruginosa*. *Water Res*, **38**(20): 4313-4322.

El-Sheekh, M.M., Abou-El-Souod, G.W. and El-Asrag, H.A. (2018). Biodegradation of some dyes by the green alga *Chlorella vulgaris* and the cyanobacterium *Aphanocapsa elachista*. *Egypt J Bot*, **58**(3): 311-320.

Fan, H.J., Huang, S.T., Chung, W.H., Jan, J.L., Lin, W.Y. and Chen, C.C. (2009). Degradation pathways of crystal violet by fenton and fenton-like systems: condition optimization and intermediate separation and identification. *J Haz Mat*, **171**(3): 1032-1044.

Gao, T., Qin, D., Zuo, S., Peng, Y., Xu, J., Yu, B., Song, H. and Dong, J. (2020). Decolourization and detoxification of triphenylmethane dyes by isolated endophytic fungus, *Bjerkandera adusta* SWUS14 under non-nutritive conditions. *Res Square*, 1-16.

Grassi, P., Reis, C., Drumm, F.C., Georgin, J., Tonato, D., Escudero, L.B., Kuhn, R., John, S.L. and Dotto, G.L. (2019). Biosorption of crystal violet dye using inactive biomass of the fungus *Diaporthe schini*. *Water Sci Technol*, **79**: 709-717.

Gupta, V.K., Khamparia, S., Tyayi, I., Jaspal, D. and Malviya, A. (2015). Decolourization of mixture of dyes: a critical review. *Global J Environ Sci Manage*, **1**(1): 71-94.

Hefnawy, M.A., Gharieb, M.M., Shaaban, M.T. and Soliman, A.M. (2017). Optimization of culture conditions for enhanced decolourization of direct blue dye by *Aspergillus flavus* and *Penicillium canescens*. *J Appl Pharm Sci*, **7**(2): 83-92.

Hussein, M.H., Abou-El-Wafa, G.S., Shaaban-Dessuki, S.A. and El-Morsy, R.M. (2018). Bioremediation of methyl orange onto *Nostoc carneum* biomass by adsorption: kinetics and isotherm studies. *Global Adv Res J Microbiol*, **7**(1): 6-22.

Ishchi, T. and Sibi, G. (2020). Azo dye degradation by *Chlorella vulgaris*: optimization and kinetics. *Int J Bio Chem*, **14**(1): 1-7.

Jebapriya, G.R. and Gnanadosa, J.J. (2013). Bioremediation of textile dye using white-rot fungi: a review. *Int J Curr Res Rev*, **5**(3): 1-13.

Jones, J.J. and Falkinham, J.O. (2003). Decolourization of malachite green and crystal violet by waterborne pathogenic mycobacteria. *Antimicrob Agents Chemo*, **47**(7): 2323-2326.

Khalaf, M.A. (2008). Biosorption of reactive dye from textile wastewater by non-viable biomass of *Aspergillus niger* and *Spirogyra* sp. *Biores Technol*, **99**: 6631-6634.

Kochher, S., Kumar, S. and Kumar, J. (2011). Microbial decolourization of crystal violet by *Bacillus subtilis*. *Bio Forum - An Int J*, **3**(1): 82-86.

Kosha, M., Farhadian, O., Dorafshan, S., Soofiani, N.M. and Bhatnagar, A. (2013). Optimization of malachite green biosorption by green microalgae - *Scenedesmus aquadricauda* and *Chlorella vulgaris*. Application of response surface methodology. *J Taiwan Ins Chem Engr*, **44**(2): 291-294.

Lavanya, C., Dhahkar, R., Chhikara, S. and Sheoran, S. (2014). Degradation of toxic dyes: a review. *Int J Curr Microbiol Appl Sci*, **3**(6): 189-199.

Ledakowicz, S. and Pazdzior, K. (2021). Recent achievements in dyes removal focused on advanced oxidation processes integrated with biological methods. *Molecules,* **26**: 870-915.

Lee, D.J., Show, K.Y., and Wang, A. (2013). Unconventional approaches to isolation and enrichment of functional microbial consortium – a review. *Biores Technol*, **136** 697-706.

Mahmoud, M.S., Mostafa, M.K., Mohamed, S.A., Sobhy, N.A. and Nasr, M. (2016). Bioremediation of red azo dye from aqueous solutions by *Aspergillus niger* strain isolated from textile wastewater. *J Environ Chem Engr*, **5**(1): 547-554.

Marcharchand, S. and Ting, A.S.Y. (2017). *Trichoderma asperellum* cultured in reduced concentration of synthetic medium retained dye decolourization efficacy. *J Environ Manage*, **203**: 542-549.

Mesania, R., Marjadi, D. and Desai, N. (2014). Phytoremediation of textile wastewater using potential wetland plant: eco-sustainable approach. *Int J Interdisc Multidisc Stud (IJIMS)*, **1**(4): 130-138.

Moturi, B. and Singara, C.M.A. (2009). Decolourization of crystal violet and malachite green by fungi. *Sci World J*, **4**(4): 128-133.

Naji, N.S. and Salman, J.M. (2019). Effect of temperature variation on the efficacy of *Chlorella vulgaris* in decolourization of congo red from aqueous solutions. *Biochem Cell Arch*, **19**(2): 4169-4174.

Ngui, S.N., Azham, Z., Hairul, A.R. and Ahmad, H. (2013). Decolourisation of synthetic dyes by endophytic fungal flora isolated from senduduk plant (*Melastoma malabathricum*). *Hindawi Pub Corp, ISRN Biotechnol*, **2013**(260730): 1-8.

Ortiz-Monsalve, V.S., Poll, P., Jaramillo-Garcia, E., Pegas, H.V.A.J. and Gutteres, M. (2019). Biodecolourization and detoxification of dye-containing wastewaters from leather dyeing by the native fungal strain *Trametes villosa* SCS-10. *Biochem Engr J*, **141**: 19-28.

Osama, M.D., Hassan, M., Wafaa, M.A., Olfat, S.B. and Mohamed, Z.S. (2014). Bioremediation of textile reactive blue (RB) azo dye residues in wastewater using experimental prototype bioreactor. *Res J Pharm, Bio Chem Sci*, **5**(4): 1203-1219.

Parshetti, G.K., Parshetti, S.G., Telke, A.A., Kalyani, D.C., Doong, R.A. and Govindwar, S.P. (2011). Biodegradation of crystal violet by *Agrobacterium radiobacter*. *J Environ Sci*, **23**(8): 1384-1393.

Parshetti, G.K., Telke, A.A., Kayani, D.C. and Govindwar, S.P. (2010). Decolourization and detoxification of sulfonated azo dye methyl orange by *Kocuria rosea* MTCC 1532. *J Haz Mat*, **176**(3): 503-509.

Patil, K.J., Mahajan, R.T., Lautre, H.K. and Hadda, T.B. (2015). Bioprecipitation and biodegradation of fabric dyes by using *Chara* sp. and *Scenedesmus obliquus*. *J Chem Pharm Res*, **7**(8): 783-791.

Paul, J., Rawat, K.P., Sarma, K.S.S. and Sabharwal, S. (2011). Decolourization and degradation of reactive red-120 dye by electron beam irradiation in aqueous solution. *Appl Rad Iso*, **69**(7): 982-987.

Pokharia, A. and Ahluwalia, S.S. (2013). Isolation and screening of dye decolourizing bacterial isolates from contaminated sites. *Tex Lig Ind Sci Technol*, **2**(2): 54-61.

Rani, B., Kumar, V., Singh, J., Bisht, S., Teotia, P., Sharma, S. and Kela, R. (2014). Bioremediation of dyes by fungi isolated from contaminated dye effluent sites for bio-usability. *Brazilian J Microbiol*, **45**(3): 1055-1063.

Raymond, E.S. and Omo, K.M. (2019). Biodecolourization of yellow dye using *Chlorella vulgaris* and *Sphaerocystis*

*schroeteri*. *American J Bio Environ Sta*, **5**(1): 1-6.

Robinson, T., McMullan, G., Marchant, R. and Nigam, P. (2001). Remediation of dyes in textile effluents. a critical review on current treatment technologies with a proposed alternative. *Biores Technol*, **77**(3): 247-255.

Roy, D.E., Biswas, S.K., Saha, A.K., Sikdar, B., Rahman, M., Roy, A.K., Prodhan, Z.H. and Tang, S. (2018). Biodegradation of crystal violet dye by bacteria isolated from textile industry effluents. *PeerJ*, **6**(e5015): 1-15.

Sajjala, S.R., Bijjam, K. and Nanaga, S.P.R. (2008). Colour pollution control in textile dyeing industry effluents using tannery sludge derived activated carbon. *Bull Chem Soc Ethiopia*, **22**(3): 369-378.

Shah, M.P. (2013). Microbial degradation of textile dye (remazol black B) by *Bacillus* sp. ETL-2012. *J Appl Environ Microbiol*, **1**: 6-11.

Shahid, A., Singh, J., Bisht, S., Teotia, P. and Kumar, Y. (2013). Biodegradation of textile dyes by fungi isolated from north Indian field soil. *Environ Asia*, **6**(2): 51-57.

Singh, A., Pal, D.P., Mohammad, A., Alhazmi, A., Haque, S., Yoon, T., Srivastava, N. and Gupta, V.K. (2021). Biological remediation technologies for dyes and heavy metals in wastewater treatment: new insight. *Biores Technol*, 126154, DOI: 10.1016/j.biortech.2021.126154.

Slama, H.B., Chenari, B., Bouket, A., Pourhassan, Z., Alenezi, F.N., Silini, A., Cherif-Silini, H., Oszako, T., Luptakova, L., Golinska, P. and Belbahri, L. (2021). Diversity of synthetic dyes from textile industries, discharge impacts and treatment methods. *Appl Sci*, **11**: 6255-6275.

Srashti, D. (2013). Effect of textile dyes on *Spirulina platensis*. *J Chem Pharm Res*, **5**(4): 66-80.

Telke, A., Kalyani, D., Jadhav, J. and Govindwar, S. (2009). Kinetics and mechanism of reactive red 141 degradation by a bacterial isolate *Rhizobium radiobacter* MTCC 8161. *Acta Chimica Slavenica*, **55**(2): 320-329.

Verma, S.K., Kumar, A., Lal, M. and Debnath (Das), M. (2015). Biodegradation of synthetic dye by endophytic fungal isolate in *Calotropis procera* root. *Int J Appl Sci Biotechnol*, **3**(3): 373-380.

Vidali, M. (2001). Bioremediation: an overview. *Pure Appl Chem*, **73**(7): 1163-1172.

Vikrant, K., Giri, B.S., Raza, N., Roy, K., Kim, K., Rai, B.N. and Singh, R.S. (2018). Recent advancements in bioremediation of dye: current status and challenges. *Biores Technol*, **253**: 355-367.

Wang, N., Chu, Y., Wu, F.A., Zhao, Z. and Xu, X. (2017). Decolourization and degradation of congo red by a newly isolated white rot fungus *Ceriporia lacerata* from decayed mulberry branches. *Int Biodeter Biodegrad*, **117**: 236-244.

Wen-Tung, W. and Ming-Der, J. (2011). Evaluation of light irradiation on decolourization of azo dyes by *Tsukamurella* sp. J8025. *Appl Mech Mat*, **145**: 304-308.

Yang, X.Q., Zhao, X.X., Liu, C.Y., Zheng, Y. and Qian, S.J. (2009). Decolourization of azo, triphenylmethane and anthroquinone dyes by a newly isolated *Trametes* sp. SQ01 and its laccase. *Proc Biochem*, **44**(10): 1185-1189.

Yucel, T.T. (2018). Investigation of some parameters affecting methyl orange removal by *Fusarium acuminatum*. *Brazilian Arch Bio Technol*, **61**(e18160237): 1-8.

Zaharia, C., Suteu, D., Muresan, A., Muresan, R. and Popescu, A. (2009). Textile wastewater treatment by homogenous oxidation with hydrogen peroxide. *Environ Engr Manage J*, **8**(6): 1359-1369.