Jurnal Sains dan Teknologi Lingkungan Volume 16, Number 1, January 2024 Page. 56-69
p-ISSN:2085-1227 dan e-ISSN:2502-6119

# Biological Decolorization of Synthetic Dyes Textile Wastewater by Aspergillus niger: A Review

**Diah Ayu Prawitasari**
Department of Environmental Engineering, Universitas Islam Indonesia, Yogyakarta, Indonesia
Korespondensi: diahayuprawitasari@uii.ac.id

**Abstrak**

The textile industry's wastewater is mainly comprised of synthetic dyes. Synthetic dyes are complex organic compounds that offer significant resistance to environmental conditions and highly harmful to ecological systems. The decolourization process can be enhanced by biological agents. The brown rot fungus, Aspergillus niger, is a biological agent with potential for the decolorization of synthetic colours. This article discusses information and literature review of investigations on the decolorization capacity of synthetic dyes by Aspergillus niger fungi. The literature review involved the analysis of qualitative data, observation, and the derivation of conclusions from previous research journals. The study's results demonstrate Aspergillus niger fungi significant potential of synthetic dye removal can up to 90% via simultaneous biodegradation and biosorption processes. Many variables effect the removal procedure, including pH, agitation settings, temperature, initial dye concentration, and nutritional content.

**Keyword** : Elementary school, mapping, noise level.

## 1. INTRODUCTION

The textile industry is a dominant sector in Indonesia that contributes significant liquid waste, including waste containing synthetic dyes. Approximately 8.2% of the national liquid waste comes from this industry (Kasih, 2021). The characteristics of textile wastewater typically include dyes, metals, and other pollutants (Yaseen & Scholz, 2019). In the dyeing process, 10-15% of the dye can escape and be discharged into the effluent with an average dye concentration of 50-2500 (Pt-Co) (Yaseen & Scholz, 2019; Lellis et al., 2019). This component has a complex organic structure that is difficult to degrade naturally, potentially leading to the accumulation of xenobiotic compounds in the food chain. Therefore, efficient and environmentally friendly processing methods are needed.

Synthetic dyes are complex organic components that are relatively resistant to environmental conditions, thereby damaging the ecological environment at high concentrations (Kuradea et al., 2018). The components of the discarded dye accumulate into xenobiotic compounds and can enter aquatic environments, reaching the trophic levels of higher organisms (Przyztas et al., 2015). The characteristics of the organic components of dyes generally have two to three azo bonds that dominate (R1–N=N–R2). Synthetic dyes are derivatives of aromatic hydrocarbons, such as benzene, toluene, naphthalene, and anthracene (Yaseen & Scholz, 2019). The types of dyes used as coloring agents are pretty diverse, including dispersed dyes, reactive dyes, and others. Based on Decree of Indonesia Ministry of

*Dikirim/submitted: 07 Januari 2024*
*Diterima/accepted: 30 Januari 2024*

Environment Regulation on Wastewater Quality Standards 2014, dyes are organic compound which must reach quality standard of 8–150 mg/L to environment body.

The mechanism of removing synthetic dyes can be carried out through chemical, biological, and physical processes. Commonly physical and chemical processes are considered more effective in dye removal, but they spend high cost and more toxic. Therefore, biological treatment processes are prefered due to less harm and cheaper (Abbasi, 2017). Biological dye removal process generally uses a mixed culture of bacteria using activated sludge technology (Abbasi, 2017). Besides bacteria, other organisms, such as fungi also have a good ability to degrade organic pollutants.

*Aspergillus niger* is a species of fungi that can grow on house walls or organic food waste (Cohen et al., 2021). Several studies have shown the efficiency of dye removal by *Aspergillus niger* can reach 70–90%, although this research has not been as extensively explored (Espinosa-Ortiz et al., 2021). *Aspergillus niger* ,commonly known as black mold fungus, is a fungus widely used for biotechnological purposes. It can produce robust spore production as a result easier to cultivate compared to white rot fungi.

*Aspergillus niger* can produce laccase, manganese peroxidase (MnP), and lignin peroxidase (LiP). Those enzymes are capable of breaking down complex organic compounds composing synthetic azo dyes. Extracellular enzymes are produced simoultanously with growth of *Aspergillus niger* in response avaibility of substrate. In this case, textile dyes also serve as a substrate source that can be utilized. Therefore, this journal aims to determine the ability of *Aspergillus niger* as an agent for degrading synthetic dyes from textile waste which remains an environmental issue to this day by reviewing several research findings on the removal of dyes by *Aspergillus niger*.

## 2. METHODOLOGY

This study is a literature review from several Journals indexed by SINTA and reputable International Journals over the past 15 years. The journals were used as sources of data and information from journal publications related to the research on the removal of synthetic dyes by the fungus *Aspergillus niger* with the keywords "synthetic dye," "biodegradation," "fungi," and "*Aspergillus niger*." This review refers to the ability of the *Aspergillus niger* species to remove synthetic dyes.

## 3. RESULTS AND DISCUSSION

### Decolorization Mechanism of Synthetic Dyes by Biological Agents

Decolourisation of dyes through biological processes involves varied organisms. The target of certain types of organic pollutants as electron donors will influence the type of degrading enzymes produced by specific microorganisms, so the conditions of the pollutants and the environmental conditions must be determined to support the growth of microorganisms. The mechanism of dye biodegradation with specific biological agents involves breaking down complex compounds into smaller structures. Biodegradation process of synthetic dyes occurs in two stages: (i) reduction cleavage of the azo bond, resulting in the formation of new compounds, specifically colourless substances that have the potential to be harmful aromatic amines, and (ii) degradation of these aromatic amines. The reduction of synthetic dyes can generally be carried out under anaerobic conditions, whereas the degradation of aromatic amines is completely degraded under aerobic conditions (Alabdraba & Albayati, 2014). The -N=N- bond will be the target in the degradation process of dye compounds (**Figure 1**) (Alabdraba & Albayati, 2014).

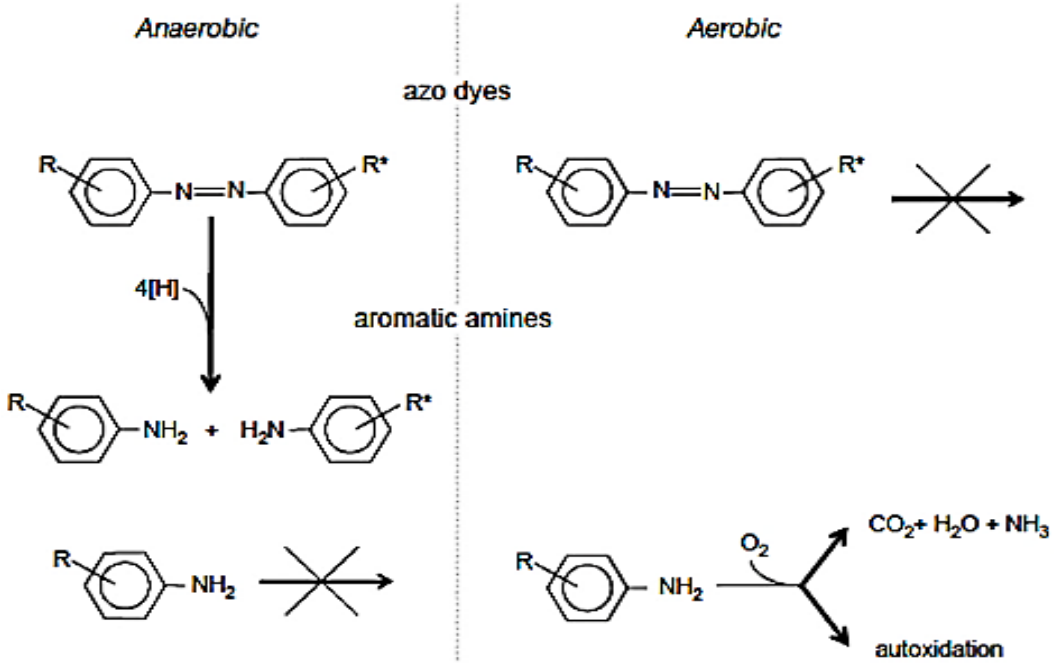


**Figure 1.** Reduction and Biodegradation Mechanism of Azo Dyes
(Source: Alabdraba & Albayati, 2014)

Based on the research by Asses et al. (2018), the synthetic pathway for the decolorization of Congo Red dye, as observed through LC-MS/MS, occurs through several

stages. The degradation of the dye begins with the simultaneous processes of deamination and oxygenation. Deamination is the mechanism of cleavage amine bond resulting in smaller compounds, such as benzene (Ikram et al., 2022). After both lose sodium atoms during the deamination process, the compound will degrade into smaller compounds. Some of compounds have been deaminated, followed by cleavaging of the C-N bond between the aromatic ring by asymmetric peroxidase. The azo group will loses a sodium atom then forming a small intermediate compound. The C-N bond that will be deprotonated also forms intermediate compounds. Then, benzene ring will open and dehydrogenate to form many small intermediate compounds by peroxidase mechanism. The peroxidase cleavage mechanism produces compounds with lower molecular weights and greater stability, such as sodium naphthalene sulfonate and cycloheptadienylium (Asses et al., 2018).

The mechanism of biodegradation of synthetic dyes by enzymes also works in conjunction with bioabsorption (Ekanayake & Manage, 2022). Cell biomass will form pellets that will be used as adsorbates, where the synthetic dye will be absorbed or enter the cell pores. The fungal cell wall is composed of glycoproteins, chitin, and glucan, which can create binding sites that interact with synthetic dyes (Lu et al., 2017). Fungal mycelium can also form stable pellets, which can enhance cell immobilization, affect the separation of liquid-solid phases and preventing reactor clogging (Espinosa-Ortiz et al., 2016; Lu et al., 2017).

**Optimum Conditions of *Aspergillus niger* Fungi for Decolorization**

*Aspergillus niger* has a brownish-black filamentous color and can thrive in conditions with a water activity of 0,88; pH 1,5 – 9,8; and temperature 6 - 47°C. The optimal conditions for this fungus are generally at a temperature of 30 – 37°C, pH 6-7 and water activity of 0,99. The classification of this fungus is as follows:

Kingdom : Fungi
Phylum : Ascomycota
Class : Eurotimycetes
Order : Eurotiales
Family : Trichocomaceae
Genus : *Aspergillus*
Species : *Aspergillus niger*

The inoculum of *Aspergillus niger* has a conidial head and black conidia that are pretty dense, as seen in **Figure 2**, where *Aspergillus niger* is cultivated on Potato Dextrose Agar (PDA) medium.

**Figure 2.** Inoculum of *Aspergillus niger* in PDA medium

*Aspergillus niger* grows as a saprophyte with a strong spore distribution, especially in protein secretion, and is supported by its rapid growth (Wakai et al., 2017; Gnanasekaran et al., 2019; Li et al., 2022). *Aspergillus niger* is capable of degrading complex polymer components in agricultural waste, paper industry waste, and textile waste. This fungal species can grow on solid media (Solid State Fermentation) and liquid media (Submerge Fermentation). Several studies have identified various factors that influence the optimal conditions for *Aspergillus niger* to degrade azo dyes, including temperature, pH, and nutrient ratio, among others (Table 1). These optimum conditions will affect the production of fungal biomass and various types of extracellular enzymes. This also affects the decolorization process of the dye as the target substrate. In addition, the continuously growing cell biomass can be used as a bioabsorbable for the adsorption process of azo dyes. The biosorption of azo dyes by the surface of fungal cell biomass involves carboxyl, sulfonate, amide, and amine groups (Bouras et al., 2017; Chen et al., 2019).

The type of substrate available greatly influences the optimum growth conditions for the fungus Aspergillus niger. This is evident from the study of dye removal using Aspergillus niger. Each type of dye provides different conditions for *Aspergillus niger* to utilize in removing the dye. Each type of dye has its unique characteristics in terms of chemical groups and molecular weight, which affect the decolorization conditions when using Aspergillus niger.

**Influence of pH Conditions**

*Aspergillus niger* can grow in both acidic and alkaline environments. Most studies have found that the optimum conditions for *Aspergillus niger* are in the pH range of 5-7.

Research by Ameen et al. (2021) shows that the optimum condition for *Aspergillus niger* is at pH 7 for the degradation of Acid Blue 29, Disperse Red, and Congo Red, which reaches 84-96% (Mahmoed et al., 2017; Ameen et al., 2021). In the study by Lu et al. (2017), the optimum conditions for degrading the compounds Eriochrome Black T and Procion Red MX-5B were found to be at an acidic pH, achieving 96.4% and 94% degradation, respectively. The acidic pH range between 2 to 6 can also increase the adsorbing process, which affects the surface of the cell to actively grow to form adsorbate and the presence of a van der Waal force between virgin negative anions and cell positive cations (Kaushik & Malik, 2019; Tian et al., 2013; Bankole et al., 2019). According to the research of Asses et al. (2018), the optimal activity of manganese peroxidase and lignin peroxidase is in the pH range of 5-6. Enzyme activity correlates with pH conditions, where pH is a key factor in catalyzing the reaction of enzymes. Although *Aspergillus niger* can grow in acidic conditions, a pH that is too acidic or too alkaline can also react with certain azo compounds. Therefore, initial pH conditioning is necessary for the characterization of certain azo dyes.

**Table 1.** Elimination of Several Types of Synthetic Dyes with *Aspergillus niger*.

| Num. | Types of Synthetic Dyes | Optimum Conditions | %Dye Removal | Reference |
|---|---|---|---|---|
| 1 | DB 201; Cibanone Gold Yellow RK (CGY); Barrel Green FFB (VG); | - pH 7<br>- Temperature 24 °C<br>- Nutrient: Kirk medium glucose 2 g/L<br>- Initial concentration 100 mg/L<br>- Incubation time 14 days | - DB 201: 98.65%<br>- Cibanone Gold Yellow RK (CGY) : 88.2%<br>- Barrel Green FFB (VG) : 95.4% | Ekanayake & Manage (2022) |
| 2 | Pink Bengal | -pH 7<br>-Temperature 28 °C<br>-Nutrient: glucose 12 g/L & peptone 4.5 g/L | Bengal Rose: 90.1% | Zhou et al., (2022) |

| | | | | |
|---|---|---|---|---|
| | | -Initial concentration of 0.05% in 100 ml<br>Incubation time 3 days | | |
| 3 | Acid Blue 29; Disperse Red 1; Congo Red | -pH 7<br>-Temperature 30 ºC<br>-Nutrient: glukosa (10 g/L) & ammonium sulphate (1.5 g/L)<br>-Initial dye concentration: 100 mg/L<br>-Incubation time 7 days | - Acid Blue 29: 92 – 93%<br>- Disperse Network 1: 84 – 90%<br>- Congo Red: 92 – 96% | Ameen et al., (2021) |
| 4 | Thiazold Yellow G | -pH 5-6<br>-Temperature 25 ºC<br>-Nutrient: medium *Potato Dextrose Broth* glucose (20g/L) & peptone (4 g/L)<br>-Initial dye concentration: 10 mg/L<br>-Incubation time 5 days | Thiazold Yellow G: 97 – 99% | Bankole et al., (2019) |
| 5 | Congo Red | -pH 6<br>-Temperature 30 ºC<br>-Nutritent : glucose 10 g/L & peptone 2 g/L<br>-Initial dye concentration 250 mg/L<br>-Incubation time 7 days | Congo Red: 97% | Asses et al., (2018) |
| 6 | Eriochrome | - pH 3 | Eriochrome black | Lu et al., |

| | | | | | |
|---|---|---|---|---|---|
| | black T | - Temperature 27 ºC<br>- Nutrients: Glucose (0.3 g/L) and NH4Cl (0.03 g/L)<br>- Incubation time 3 days | | T: 96.4% | (2017) |
| 7 | Procion Red MX-5B | - pH 4<br>- Temperature 30 ºC<br>- Incubation time 14 days | | Procion Red MX-5B: 94% | Almeida & Corso (2014) |

**Comparison of Strengths and Weaknesses of the Cited Studies**

The cited studies provide valuable insights but vary in strengths and weaknesses. Strengths include experimental rigor in optimizing conditions, such as Ameen et al. (2021) and Asses et al. (2018), which used LC-MS/MS for pathway elucidation, offering mechanistic depth. Recent study has shown excel in real-world applicability, testing multiple dyes and effluents with high decolorization (>90%) and toxicity assessments via seed germination. Ekanayake & Manage (2022) strengths lie in broad dye coverage and long-term incubation data.

Weaknesses include limited scalability; many studies including Bankole et al., 2019; Lu et al., 2017 are lab-scale without pilot testing, potentially overestimating efficiency. Older studies like Almeida & Corso (2014) lack advanced analytics (e.g., genomics), while some recent ones (Salem et al., 2019) focus narrowly on one dye, reducing generalizability. Variability in strains and conditions hinders direct comparisons, and few address by-product toxicity (exception: Asses et al., 2018). Overall, strengths in enzymatic focus are offset by needs for integrated, large-scale validations.

**Influence of Temperature Conditions**

Temperature is one of the factors that affect the growth of fungi, namely the degradation process of azo compounds. *Aspergillus niger* is a semiophilic fungus that can grow in the temperature range of 20-40 ºC can even survive at a minimum temperature of 6oC

up to a maximum of 60 oC (INSPQ, 2016). Research by Ameen et al. (2022) shows that optimal conditions for *Aspergillus niger* at 30 °C reached 96.5% for Congo Red dye. Bankole et al. (2019) even showed the results of optimal conditions at a temperature of 40 °C, because the biosorption condition remains active as the temperature increases, which affects the interaction of cell biomass with the azo dye Thiazole Yellow (Bankole et al., 2019). According to previous research, Synozol red HF-6BN was degraded to 90% with an incubation period of 28 days. Laccase enzymes were extracted and purified to assess their activity by conditioning without dye substrates, allowing optimal conditions to be obtained at a temperature of 40 °C, reaching 232%. Ekanayake and Manage (2022) demonstrated that temperature changes have no significant effect on the degradation of azo DB 201 dye, which is consistent with optimal conditions for fungal growth in general. The results of Asses et al. (2018) indicate that the optimum temperature for Congo Red degradation is 30°C, with a degradation rate exceeding 90%. However, when the temperature exceeds 30 oC, the degrading ability decreases. This is influenced by the decreasing viability of cells, along with the increase in temperature, resulting in the activation of degrading enzymes (Asses et al., 2018).

**Influence of Incubation Time Conditions**

The length of the incubation time significantly affects the growth of the fungus as it utilizes its substrate. The incubation time affects the production of degrading enzymes, such as lacase, manganese peroxidase, and lignin peroxidase. The activity of lignin peroxidase was detected at its maximum on day 5, and that of manganese peroxidase on day 6, for the degradation of Congo Red by *Aspergillus niger* (Asses et al., 2018). The incubation time is also correlated with the fungal growth curve. The degradation process increases during the exponential phase, when the fungus utilizes its substrate extensively to grow (Pagarra, 2016). The growth curve of fungi depends on the availability of the type of dye and the concentration of the substrate given (Lameiras et al., 2018).This can be demonstrated by the varied optimal incubation times for degrading azo dyes in the studies examined. Research by Zhou et al. (2022), Ameen et al. (2021), Bankole et al. (2019), Asses et al. (2018), and Lu et al. (2017) provides a condition of sparing for less than or equal to 7 days. However, the research of Ekanayake & Manage (2022) and Ilyas & Rehman (2013) is optimal for more than 7 days. This indicates that the transition from the exponential phase to the stationary phase in *Aspergillus niger* can take 7–24 days, depending on the type of substrate it targets and other

external factors. Cell biomass that has reached the death phase will only act as a dye bioadsorbent, achieving a dye adsorption efficiency of 8.4% (Ekanayake et al., 2022).

**Effect of Initial Concentration Conditions of Azo Dye**

Initial conditioning is performed by determining the initial concentration of the azo dye to improve the optimization of the allowance. The studies studied showed varying initial concentrations of dyes. Research Ekanayake & Manage (2022) for dyes DB 201, Cibanone Gold Yellow RK (CGY), and Vat Green FFB (VG) and research Ameen et al., (2021) for the dyes Acid Blue 29 and Disperse Red 1showed optimum at a concentration of 100 mg/L. According to the study by Bankole et al. (2019), *Aspergillus niger* degrades Thiazol Yellow G optimally at a concentration of 10 mg/L. Meanwhile, Congo red optimum is degraded at a concentration of 250 mg/L (Asses et al., 2018). This suggests that the initial characterization of the dye should be done before the process of decolorization. Each dye has a different character and even different levels of dye toxicity also affect the bidegradation process. Excessive concentrations can inhibit growth, inactivate enzymes, and form by-product that are toxic (Vijayaraghavan et al., 2013; Ameen et al., 2021). High concentrations of dyes can also cause saturation of the surface of fungal cells thus reducing the bioadsorption performance of cells (Iscen & Kiran, 2007; Bankole et al., 2019).

**Influence of Nutrient Composition Conditions**

Carbon, nitrogen, phosphorus, potassium, and sodium are essential nutrients that microbes use for growth (Mishra et al., 2021). The appropriate nutrient composition can support the growth of fungi and increase the degradation process of azo dyes. Based on the research of Manikandan & Viruthagiri (2010), the optimal C:N ratio for fermentation of *Aspergillus niger* reaches 32,5, while the ratio required by *Aspergillus niger* to produce its single-cell protein is 10 (Goldgerg, 1985). Research by Ameen et al., (2021) shows that optimal conditions for color degradation occur when glucose (10 g/L) and ammonium sulfate (1,5 g/L) are added with a C:N ratio of approximately 12,6. Bankole et al. (2019) used Potato Dextrose Broth as the medium (24 g/L) with a C:N ratio of approximately 12,5. Asses et al. (2018) also added glucose (10 g/L) and peptone (2 g/L) with a C:N ratio of 12,5. Lu et al. (2017) used a medium with a composition of glucose (0,3 g/L) and NH4Cl (0,03 g/L), resulting in a C:N ratio of approximately 15,38. A sufficient nutrient composition plays an important role in supporting cell biomass growth, which also contributes to the elimination of dye substances. The composition of synthetic pollutants that can be degraded or converted into a source of nutrients for microbial growth is also known as the bioavailability of

pollutants (Mishra et al., 2021). The C:N ratio in favor will increase the bioavailability of pollutants or in this case synthetic dyes. Fungi can also utilize these sources of carbon and nitrogen to convert into important components, such as the synthesis of extracellular enzymes where these enzymes will also be utilized to attack the target of dye substrates (Singh, 2017).

## 4. CONCLUSION

The fungus *Aspergillus niger* has considerable potential for removing textile dyes. The fungus *Aspergillus niger* exhibits a high rate of spore production, making it easier to grow. Some studies show that the percentage of elimination of synthetic dyes by *Aspergillus niger* can be as high as ±90%. The mechanism of *Aspergillus niger* dye removal involves biodegradation by several enzymes produced, including laccase, manganese peroxidase, and lignin peroxidase. Additionally, the bioabsorption process, facilitated by the biomass of fungal cells, plays a crucial role, allowing the mechanisms of biodegradation and bioabsorption to work in tandem. Several supporting factors can improve the optimization of the dispensing process, including pH, agitation conditions, temperature, initial concentration of synthetic dyes, and nutrient composition. The initial characterization of the types of synthetic dyes and textile waste was conducted because the conditions of the sorting process with fungi depend on the type of dye encountered.

## REFERENCES

Abbasi, B. (2017). Removal of Dye by Biological Methods Using Fungi. *International Journal Medical Review, 4(4), 112-118*

Alabdraba, W., & Albayati, M. (2014). Biodegradation of Synthetic Dyes —A Review. *International Journal of Environmental Engineering and Natural Resources, (1),179-189.*

Almeida, E., & Corso, C. (2018). Decolorization and removal of toxicity of textile Synthetic dyes fungal biomass pelletized. *International Journal of Environmental Science and Technology, (16), 1319–1328*.

Ameen, F., Dawoud, T. M., Alshehrei, F., Alsamhary, K., & Almansob, A. (2021). Decolorization of acid blue 29, disperse red 1 and congo red by different indigenous fungal strains. *Chemosphere, (271), 129-532.*

Asses, N., Ayed, L., Hkiri, N., & Hamdi, M. (2018). Congo Red Decolorization and Detoxification by Aspergillus niger: Removal Mechanisms and Dye Degradation Pathway. *BioMed Research International*, (*2018), 1–9.*

Bankole, P. O., Adekunle, A. A., & Govindwar, S. P. (2019). Demethylation and desulfonation of textile industry dye, Thiazole Yellow G by *Aspergillus niger* LAG. *Biotechnology Reports, (23), 327,*

Bouras, H.D., Yeddou, A.R., Bouras, N., Hellel, D., Holtz, M.D., Sabaou, N., Chergui, A., Nadjemi, B. (2017) Biosorption of Congo red dye by Aspergillus carbonarius M333 and Penicillium glabrum Pg1: Kinetics, equilibrium and thermodynamic studies. *Journal of Taiwan Institute of Chemical Engineering, (80), 915–920.*

Chen, S. H., Cheow, Y. L., Ng, S. L., & Ting, A. S. Y. (2019). Biodegradation of Triphenylmethane Dyes by Non-white Rot Fungus Penicillium simplicissimum: Enzymatic and Toxicity Studies. *International Journal of Environmental Research, 13(2), 273-28.*

Cohen, Y., Shulhani, R., Rot, Y., Zemach, H., Belausov, E., Grinberg-Baran, M., Borenstein, M., Pivonia, S., Ezra, D., Shtienberg, D. (2021). Aspergillus niger, the causal agent of black mould disease in date fruits, infects and colonizes flowers and young fruitlets. *Plant Pathology, 70(5), 1195–1208.*

Ekanayake, M.S., & Manage, P. (2022). Mycoremediation Potential of Synthetic Textile Dyes by *Aspergillus niger* via Biosorption and Enzymatic Degradation. *Environment and Natural Resources Journal, 20(3), 234-245.*

Espinosa-Ortiz, E., Rene, E., & Gerlach., R. (2021). Potential use of fungal-bacterial co-cultures for the removal of organic pollutants. *Critical Reviews in Biotechnology*, *42(3),361-383*

Espinosa-Ortiz, E. J., Rene, E. R., Pakshirajan K., van Hullebusch, E. D., Lens, P. N. L., (2016). Fungal pelleted reactors in wastewater treatment: Applications and perspectives. *Chemical Engineering Journal, 283, 553– 571*.

Gnanasekaran, R., Dhandapani, B., Iyyappan, J. (2019). Improved itaconic acid production by Aspergillus niveus using blended algal biomass hydrolysate and glycerol as substrates. *Bioresource Technology, (283), 297-302*.

Ghanaim, A.M., Mahdy, O.M.E. & Mohamed, H.I. Biodegradation of azo dyes by *Aspergillus flavus* and its bioremediation potential using seed germination efficiency. *BMC Microbiol* **25**, 7 (2025). https://doi.org/10.1186/s12866-024-03703-9

Ikram, M.; Naeem, M.; Zahoor, M.; Hanafiah, M.M.; Oyekanmi, A.A.; Ullah, R.; Farraj, D.A.A.; Elshikh, M.S.; Zekker, I.; Gulfam, N. Biological Degradation of the Azo Dye Basic Orange 2 by Escherichia coli: A Sustainable and Ecofriendly Approach for the Treatment of Textile Wastewater. (2022). *Water ,(14), 2063.*

Institut national de santé publique du Québec (2016). Retrieved July 28, 2022 from Aspergillus niger. Contactwebsite:https://www.inspq.qc.ca/moisissures/fiches/aspergillus-niger

Kasih, A (2021). Retrieved June 27, 2022 from 46 Percent of Indonesian Rivers Polluted by Waste, UP Researchers Provide a Solution.Interactwebsite : https://edukasi.kompas.com/read/2021/08/10/110406171/46-persen-sungai-indonesia-tercemar-limbah-peneliti-up-beri-solusi?page=all

Kurade, M. B., Waghmode, T. R., Xiong, J.-Q., Govindwar, S. P., & Jeon, B.-H. (2019). Decolorization of textile industry effluent using immobilized consortium cells in upflow fixed bed reactor. *Journal of Cleaner Production, (213), 884–891*.

Lameiras, F., Ras, C., ten Pierick, A., Heijnen, J. J., & van Gulik, W. M. (2017). Stoichiometry and kinetics of single and mixed substrate uptake in Aspergillus niger. *Bioprocess and Biosystems Engineering, 41(2), 157–170.*

Lellis, B., Fávaro-Polonio, C., Pamphile, J., & Polonio, J. (2019). Effects of textile dyes on health and the environment and bioremediation potential of living organisms. *Biotechnolgy Resources Innovation*, *275–290.*

Lu, T., Zhang, Q., & Yao, S. (2017). Removal of dyes from wastewater by growing fungal pellets in a semi-continuous mode*. Frontiers of Chemical Science and Engineering, 11(3), 338–345.*

Mishra, M., Singh, S., & Kumar, A. (2021). *Environmental factors affecting the bioremediation potential of microbes :Microbe Mediated Remediation of Environmental Contaminants* (pp. 47-58). Amsterdam: Elsevier

Neves, A. G. D., Silva, R. L. A., Cardoso, K. B. B., Brito Júnior, J. J. R. T. de, Ferreira, K. R. C., Nascimento, T. P., Brandão-Costa, R. M. P., Silva, M. V. da, & Porto, A. L. F. (2024). Exploring Aspergillus biomass for fast and effective Direct Black 22-dye removal. *Revista Brasileira De Ciências Ambientais*, *59*, e2138. https://doi.org/10.5327/Z2176-94782138

Environmental Government Regulations of Inonesia. (2014). *About Wastewater Quality Standards*. Jakarta: Ministry of Environment and Forestry.

Salem, S. S., Mohamed, A., El-Gamal, M., Talat, M., & Fouda, A. (2019). Biological Decolorization and Degradation of Azo Dyes from Textile Wastewater Effluent by Aspergillus niger. Egyptian Journal of Chemistry, 62(10), 1799-1813.

Singh, L. (2017). Biodegradation of synthetic dyes: a mycoremediation approach for degradation/decolorization of textile dyes and effluents. *Journal of Application Biotechnology Bioengineering. 3(5), 430-435.*

Wakai, S., Arazoe, T., Ogino, C., & Kondo, A. (2017). Future insights in fungal metabolic engineering*. Bioresource Technology, (245), 1314–1326.*

Yaseen, D., & Scholz, M. (2019). Textile dye wastewater characteristics and constituents of synthetic effluents: a critical review. *International Journal of Environmental Science and Technology , 16, 1193–1226*.

Zhou, M., Zhang, Y., Chen, Y., Zhang, F., Yang, D. (2022). Optimization of the decolorization conditions of Rose Bengal by using *Aspergillus niger* TF05 and a decolorization mechanism. *Microbiology, 1 (168), 1465-2080.*