# Role of Fungi in Dye Removal

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Rajeev Kumar, Nikita Dhiman, Sushma Negi, I. B. Prasher, and Chander Prakash

**Abstract**

Rapid urbanization and industrialization result in the discharge of harmful and toxic waste into the water bodies which are not easy to degrade thereby causing environmental pollution. Out of so many waste discharges, dye waste is noxious for aquatic life and for human as well; therefore, removal of these toxic compounds from water is one of the major environmental concerns today. The reported methodology like chemical and physical process is often costly, requires higher energy, and is not eco-friendly. In today's world, biological methods are trying to minimize pollution by environment-friendly way. Mycoremediation is one of the techniques which is effective and affordable for degradation and decolorization of dye-bearing effluents. The chapter concludes the potential of mycoremediation in dye removal, its mechanism, and optimizing the conditions for efficient removal of dyes.

## 20.1 Introduction

The earth has been called a blue planet due to abundant availability of water on its surface which approximately covers 70% of the earth's surface. About 97% of all water on earth is in oceans, sea, and bays; it means that only 3% of all water on earth is considered to be fresh. But that remaining water is not completely available for us to

R. Kumar (✉) · N. Dhiman · S. Negi
Department of Environment Studies, Panjab University, Chandigarh, India
e-mail: rajeev@pu.ac.in

I. B. Prasher
Department of Botany, Panjab University, Chandigarh, India

C. Prakash
Department of Chemistry, M.L.S.M. College, Sunder Nagar, Himachal Pradesh, India



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use as 2/3 of it, which is 2%, is present in the form of ice and glaciers, so only 0.62% of freshwater is available which is present in lakes, rivers, and groundwater. Reconsidering the environmental pollution from the last decade has shown that waste such as dyes, paints, medicines, disinfectants, pesticides, laundry detergents, and food additive released by various chemical industries serves as a major threat to the environment and human health (Michael 1993). More and more organic and inorganic compounds get accumulated due to the development of these chemical technologies; as earth's population continues to grow, pressure on the water resources also increases. Now the efforts are made for the efficient and judicious use of water. Pollution explosion increases a large amount of wastewater and makes it crucial to develop such kind of cost-effective technologies for wastewater treatment. Especially the textile sector produces large volume of wastewater which contain dye and other chemicals that cause severe water pollution. Therefore, it becomes vitally important to treat the contaminated water before discharging into the environment. Physical and chemical properties of water bodies get altered due to the presence of large amount of certain chemicals, bleaches and salts, which ultimately lead to eutrophication. Theses dyes and chemicals obstruct the light penetration which affects the water ecosystem. Because of the multiplex structure and synthetic origin, colorants are very strenuous to degrade (Fernandez et al. 2010). So these dyes remain persistent in the aquatic environment that affect the water ecosystem by biomagnification. As the water resources (rivers, lake, and groundwater) get contaminated, there will be a growing need to remediate this issue (Fernandez et al. 2010). Utilization of treated waste water in agriculture will be a step towards treated wastewater best use. Although various physiochemical procedures have been studied for the removal of such compounds, they are not environment-friendly and also produce hazardous by-products which need further step for removal. On the other hand, biological methods are nontoxic, cheap, and environment-friendly (Gomes 2009; Srinivasan et al. 2001). But fungi are recognized as superior from any other microorganism as they produce different types of extracellular enzyme, precursor, and a wide range of metabolites which are non-specific in nature. Due to the presence of such a wide range of applicable metabolites, fungi are attracting a considerable attention in the transmutation of different dyes.

## 20.2 Brief Introduction to Fungi

Fungi are non-photosynthetic organisms that include molds, mushrooms, rusts, and yeast which are globally estimated to be approx. 1.5–5.1 million (Tedersoo et al. 2014). The cell of a fungus is surrounded by a nucleus having chromosome with the genomic material, for example, deoxyribonucleic acid (DNA) organelles which are bounded by the membrane-like mitrochondria and a cell wall made out of chitin and glucans. Growths are fundamentally heterotrophic in nature implying that these organisms obtain their nutrition from nonliving natural resources, for example, the saprophytic fungi which nourish on lifeless or rotting natural ingredients. Very less number of fungi do exist as unicellular individuals, such as yeast; this organism develops into barrel-shaped string-like structures, having a size of 2–10 cm recognized as hyphae. These hyphae might be either septate or nonseptate. The hyphae are the fundamental structure

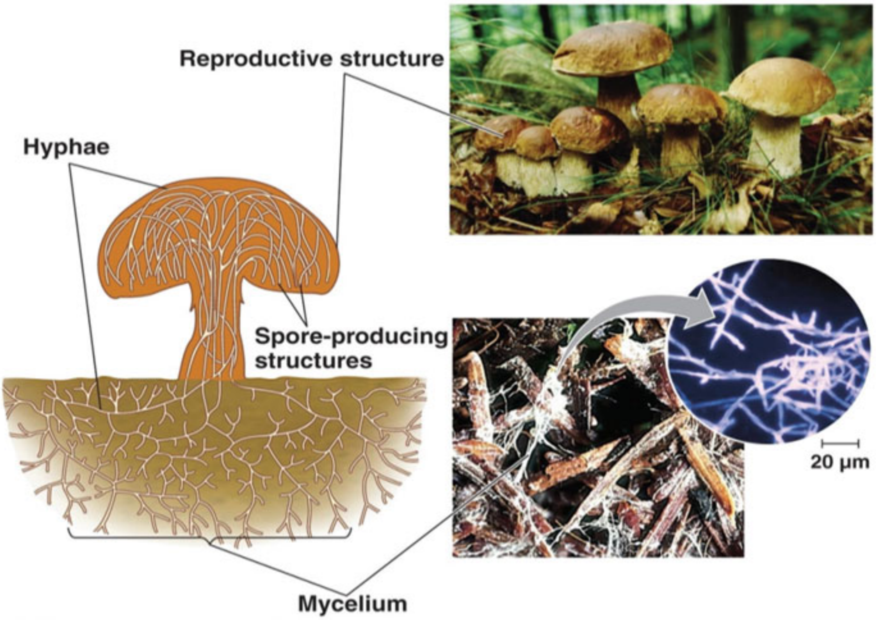


**Fig. 20.1** Structure of fungus. (Pearson Education Inc.; Publishing as Pearson Benjamin Cummings 2008)

of fungi and constitute a mycelium. Finely fanned mycelium covers very huge surface zone in the soil and produces a scope of compounds for its growth and development. The fungi can procreate both sexually and asexually, e.g., through different types of spores, and abiogenetically by the process of binary fission or budding. These organisms are exceptionally different and play an extensive variety of parts in their encompassing condition, for example, potential decomposers, plant mutualists, and beneficial endophytes of plants, and also act as harmful pathogens and significant predators. The fungal hyphae are the essential component of earth's food networks since these establish a nourishment hotspot for soil micro- as well as macrobiota, whereas the fungal sporocarp provides sustenance to bigger organisms (Fig. 20.1).

Classification of fungus includes seven different phyla: *Chytridiomycota*, *Ascomycota*, *Glomeromycota*, *Blastocladiomycota*, *Neocallimastigomycota*, *Basidiomycota*, *Zygomycota*. *Chytridiomycota* is a division of zoosporic organisms that may degrade chitin and keratin. *Blastocladiomycota* contrast from the *Chytridiomycota* in generation since they display diverse types of meiosis, they have motile spores and gametes, and they can survive in water and soil. *Glomeromycota* live in close cooperative connection with the underlying foundations of plants and trees show a few highlights indistinguishable to bring down growths, e.g., they have coenocytic without septate mycelia, and the greater part of these provides no information about recognized sexual stages. They duplicate across huge thick-walled abiogenetic spores, generally recovered from soils. The higher fungal phylum has a unique appearance having two perfect cores in a hyphal cell called dikaryon. The biggest fungal phylum is *Ascomycota*, and this phylum has a distinctive saclike structure, which bears spores, called asci; these are produced in large amount during the process of sexual reproduction. *Neocallimastigomycota* is anaerobic fungi present in the gut of animals related to core chytrids. *Basidiomycota* is a filamentous fungus. *Zygomycota* is also called as conjugation fungi; they include molds, which grow over bread and different food items and form zygospores during their sexual generation phase and do not bear hyphal cell wall except in propagative fungal structures (Fig. 20.2).

## 20.3 Role of Fungi

Fungi are considered as an important part of biosphere as they act as a recycler of nutrients in different terrestrial habitats because fungi are decomposers which break down the complex components into simpler ones. Fungi are efficient in degrading natural substances like plant polymers, cellulose, waxes, insect cuticle, animal flesh, and a wide variety of waste generated by anthropogenic activities like pharmaceutical waste, hydrocarbon, polyaromatic hydrocarbon, metals, pesticides, and synthetic dye from industries. These compounds are recalcitrant in nature (Pointing 2001). Synthetic dyes are considered toxic for the environment, and due to their complex chemical structure, they are not easy to degrade (Lu et al. 2009). These dyes are used in wide varieties of industries like paper, color photography, textile, food, beauty products, and leather industries (Rafi et al. 1990; Kuhad et al. 2004; Couto 2009). Approximately 280,000 L has been discharged every year (Jin et al. 2007a, b). For decolorization a wide range of dye is achieved by various microorganisms which include algae; filamentous freshwater species of *Spirogyra* (Gupta et al. 2006); various species of *Chlorella* (Acuner and Dilek 2004); bacteria *Pseudomonas luteola* (Chang et al. 2001), *Staphylococcus aureus*, and *E. coli* (Kalyanaraman and Vaithilingam 2015); *E. coli* $NO_3$ (Chang et al. 2000); and fungi *A. niger* (Fu and Viraraghavan 2002), *Aspergillus lentulus*, and *Saccharomyces cerevisiae* (Phugare et al. 2011).

## 20.4 Textile Dye

The compounds which add color to textile are called "dye." By different processes like absorption or dispersion, these compounds get incorporated into the fiber. Dyes with chemical and physical properties act differently at times; they show resistance to sunlight, washing, alkalies, etc. They show affinity to different fibers: their reaction to various cleaning materials, water solubility, and the methods of application to fibers (Fig. 20.3).

### 20.4.1 Pigment Dyes

Pigment dyes are one of the most widely used colorants. They are insoluble and nonionic in nature, and they do not undergo any physical and chemical changes

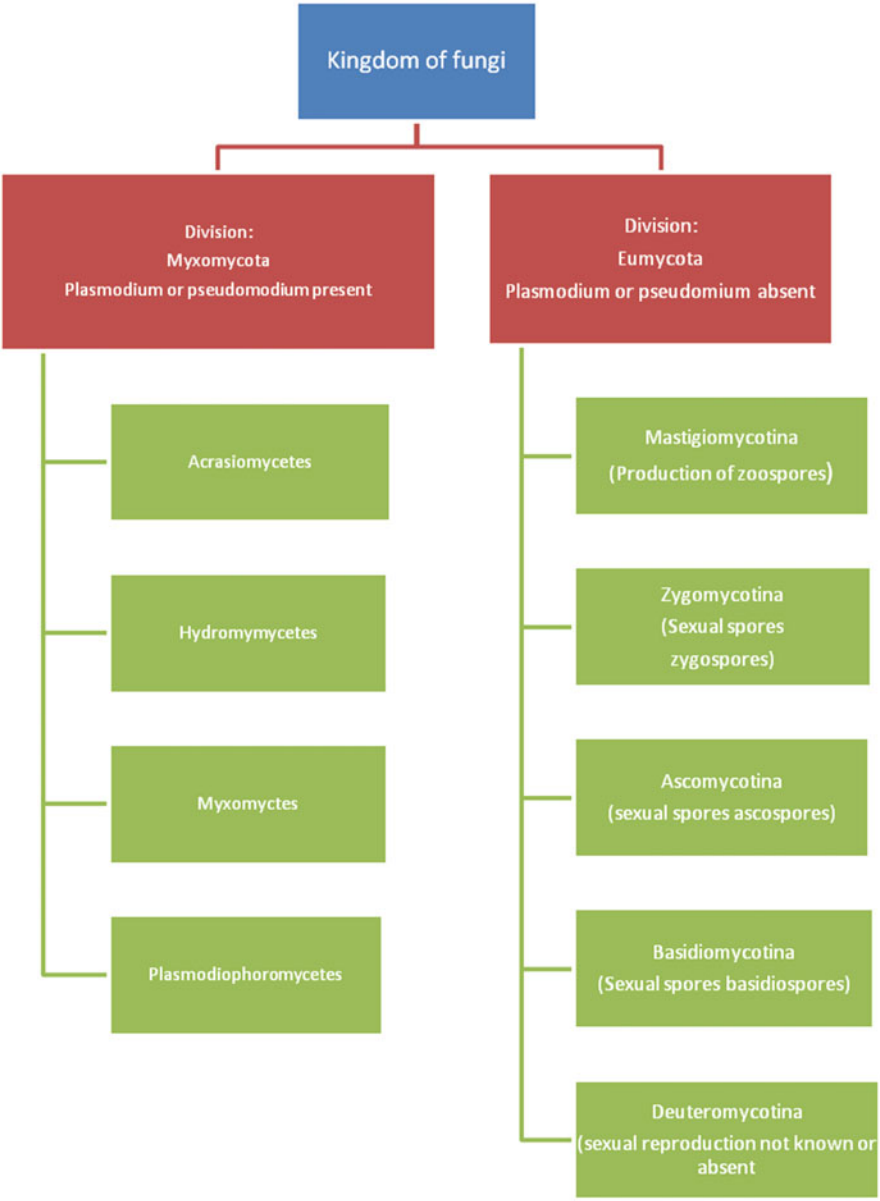


**Fig. 20.2** Division of fungi on the basis of plasmodium presence or absence: Ainsworth (1973) is commonly followed

throughout the application. Pigment dyes are attained from the dispersed solution, so they require dispersing agents. Most of the pigment dyes include yellow-colored dye, acetoacetic acid and anilide pigments; red-colored dye, azoic pigments; and

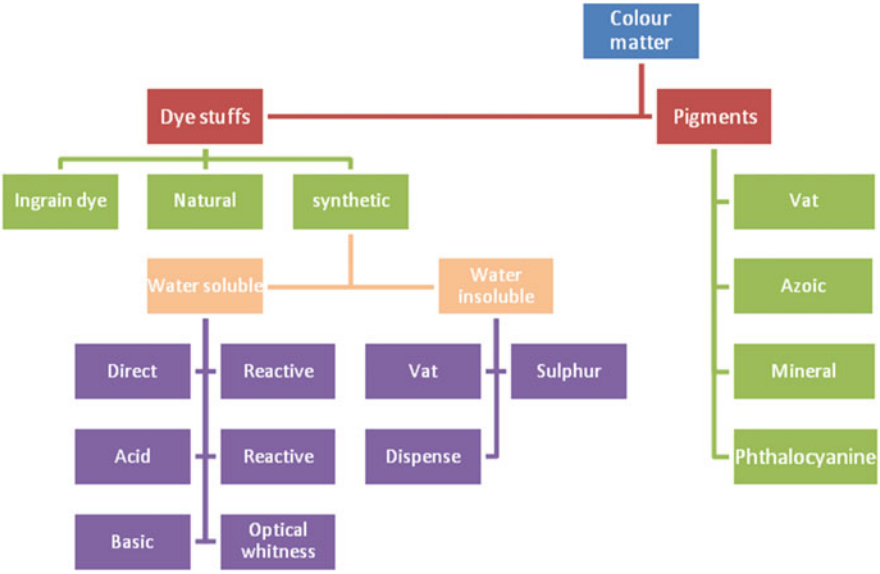


**Fig. 20.3** Classification of dyes: according to method of applications. (Singh RL Applied Environmental Biotechnology for Sustainable Future 2017)

green- or blue-colored dye, phthalocyanine pigments. Moreover, the anthraquinone and quinacridone pigment dyes are also used for dyeing different varieties of fibers (Robinson et al. 2001).

### 20.4.2 Sulfur Dyes

Sulfur dyes are mostly used for different kind of cellulosic materials. These dyes are cheap and easy to apply and generally have good washfastness. Sulfur dyes are water-insoluble in nature. Alkali treatment around 80 °C is given to make them soluble as the bond between the dyes breaks down into simpler compounds; hence, they can be absorbed by the fabric. Sulfur dyes are absorbed by the cotton fibers and are oxidized by suitable oxidizing agents and get converted into insoluble parent dye, which gives good colorfastness. They are mainly used in dyeing cellulose fibers, viscose, and cotton (O'Neill et al.1999; Teli et al. 2001).

### 20.4.3 Solvent Dyes

A solvent dye is a very versatile dye. They are used for different organic solvents like waxes, hydrocarbon fuels, oil, paraffins, and other aliphatic and aromatic hydrocarbons. Their molecules are typically nonpolar in nature or little polar, and they do not form any ions therefore insoluble or very little soluble in water. Solvent dyes can also be used for marking inks, glass coloration, and inkjet inks (O'Neill et al. 1999; Dixit and Patel 2010).

### 20.4.4 Azoic and Ingrain

The synthetic dyes having insoluble azo group (-N=N-) are called azoic dye. These dyes are produced by the coupling of two components (usually naphthols, phenols, and acetoacetyl amides), and a diazotized aromatic amine in suitable and proper environment and the final color are controlled by components coupling. These dyes are used for silk, crayons, cellulose acetate, paints, and polyester (O'Neill et al. 1999).

### 20.4.5 Vat Dyes

They are considered as the superior dyes. When it comes to washing and fastness to light, these dyes are incapable of dyeing fibers as they are insoluble in water. Vatting is the process by which insoluble dye is converted into soluble dye. Eighty percent of the vat dyes belong to the group of anthraquinones and indigoid compounds (Slokar and Marechal 1997; Teli et al. 2001).

### 20.4.6 Reactive Dyes

In 1956 reactive dyes were prepared commercially and used for dyeing different fabric materials. The presence of reactive group helps them to form a chemical bond with the fiber. Because of the presence of reactive groups, they form covalent bond with carbon atoms of dye molecule and different functional groups in fibers. It is considered to be as a most permanent of all dye types. These dyes can be used for dyeing nylon and woolen fibers. They are concluded as the second largest dye class in Colour Index. This class of dye contains metal complex of different azo compounds (O'Neill et al. 1999).

### 20.4.7 Basic or Cationic Dyes

Basic dyes are positively charged cationic colorants. These are water-soluble in nature and can be used for a variety of fibers like silk, wool, cotton, and modified acrylic fibers. Sometimes organic compounds are used in the dye bath as it can take up the dye. This type of dye is just fair when it comes to fastness to light and washing. Diarylmethane, triarylmethane, anthraquinone, and azo compounds are some of the common dyes used for dyeing purposes (O'Neill et al. 1999).

### 20.4.8 Acid Dyes

Acid dyes work best when applied to acid bath. These dyes have a wide variety of color and have better lightfastness than basic dyes. They are highly soluble in nature and used for a wide variety of fibers such as silk, mohair, linen, and leather. Azo, anthraquinone, and triarylmethane are the three main groups of acid dyes (Kaushik and Malik 2010).

### 20.4.9 Direct Dyes

Direct dyes contain wide range of color and are easy to use; these dyes are not fast to washing, and with the help of other treatments, its fastness can be improved. These dyes are bound by Van der Waals forces to the cotton fiber; alkaline or neutral conditions are maintained for the dyeing bath, by adding certain salts. They are mostly used on protein fibers, viscose rayon, leather, synthetic fiber, and nylon. Direct dyes contain multiple azo, phthalocyanine, stilbene, and oxazine (De las Marias 1976).

### 20.4.10 Disperse Dyes

Disperse dye is a kind of an organic substance which does not contain any free ionizing group. They are water-insoluble in nature. These dyes are finely grounded with dispersing agent and mostly in the form of a paste. Disperse dyes are mostly used to dye polyester but can also be used for dyeing nylon, Vilene, synthetic velvet, paintings, and PVC. In some cases, high temperature up to 130 °C is used for dyeing, their fine-sized particles provide a large surface area which allows dye to adhere to the fiber, and dyeing rate is dependent upon the choice of dispersing agents (Slokar and Marechal 1997).

### 20.4.11 Mordant Dyes

Mordant dyes are the substances used to set dyes on fabrics as they form complex structure which help in attachment with the fiber; these dyes are used for dyeing only when they are combined with different chemicals (chromium complexes, dichromates, iron, and tin). These dyes are mostly used for navy and black shades of colors. Mordant helps in fixing the dye to the fiber. It is very important to choose the right mordant because they can significantly affect the final color (Ingamells 1993) (Fig. 20.4).

## 20.5 Dyeing Process: Figure 20.4 Explains the Dyeing Process

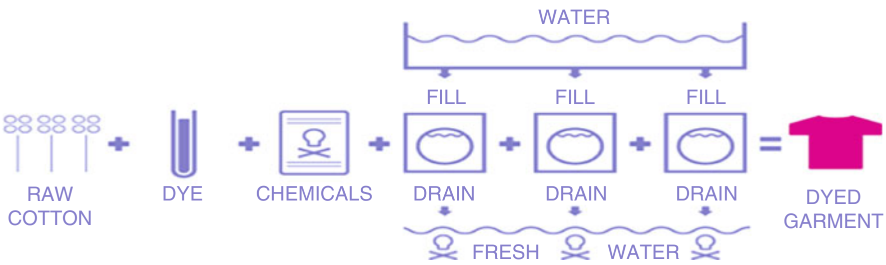


**Fig. 20.4** Dyeing process of textile industry. (Dyeing Environmental Impact http://www.colorzen.com/dyeing-environmental-impact)

## 20.6 Toxicity of Dyes and Their Environmental Impacts

Wastewater from dye industries is very difficult to treat. Textile dye that gets dumped into the nearest water body without being treated can cause many problems like:

1. Today's environmental concern with the dyes is their absorptive nature, and they reflect back the sunlight entering the water surface, hence reducing the photosynthetic activity which adversely affects the food chain.
2. When dyes break down, they produce harmful products which are carcinogenic in nature and reprotoxic (Novotny et al. 2006; Mathur and Bhatnagar 2007).
3. Dyes cause various diseases like cancers and also effect the renal and urinary system of the dye workers (Puvaneswari et al. 2006).
4. Benzidine dyes also cause various dermal and immunological diseases. The workers who get exposed to such dyes have urinary system problems (Van der Zee et al. 2002; Golka et al. 2004).
5. Dyes also affect the transparency of water bodies and cause damage to the aquatic ecosystem (Rocha 1992).
6. The highly toxic dye effect, penetration of light rays, cause deficiency of oxygen and limit the downstream beneficial uses such as recreation, irrigation and drinking water (Van der Zee et al. 2002; Golka et al. 2004).
7. Azo dyes are hazardous in nature, when they enter the body and get metabolized by microorganisms causing DNA damage (Van der Zee et al. 2002; Golka et al. 2004).

## 20.7 Removal Process

Various methods of treatment are available for the dye removal from the wastewater. Many chemical, biological, and physical methods are generally used to remove dyes from the industrial effluent.

### 20.7.1 Physicochemical Techniques

Different methods are used for the removal of dye (Lin and Liu 1994). And many physicochemical techniques include ozonation, ion exchange, adsorption, membrane filtration, precipitation, electrokinetic coagulation, ultrasonic mineralization, electrolysis, and chemical reduction, but these processes alone are not sufficient for the removal of toxic waste. In several studies, many techniques have not been able to achieve decolorization because of their expensive nature, large energy requirements, limited lifetime, formation of unwanted by-products, foaming, etc. And the by-products formed by these removal processes are harmful and recalcitrant. Thus, the extent of the mineralization in waste decolorization should be evaluated (Fu and Viraraghavan 2002).

### 20.7.2 Biological Decolorization Methods

There are numerous classes of microbes which are involved in disintegration of various synthetic colors and also cleaning mechanized wastewater. It has been reported that application of potential microbes such as bacterial, fungal, algal strains, actinomycete, microbial diverse cultures, or using the enzymes of microbes which take part in decolorization of synthetic colors (Thummar and Ramani 2014). A wide range of microflora are being used for the removal of various classes of synthetic dyes; it includes some efficient bacterial strains such as various species of *Escherichia coli*, *P. luteola* (Chang et al. 2001), *A. hydrophila* (Chen et al. 2003), and various species of *Kurthia* (Saini and Banerjee 1997); algae also play a role in dye remediation, of which commonly used are species of *Spirogyra* (Gupta et al. 2006) and *C. vulgaris* (Acuner and Dilek 2004); common fungal species used are *A. niger* (Fu and Viraraghavan 2002), *A. terricola*, *P. chrysosporium* (Saikia and Gopal 2004), and *P. chrysosporium* (Fouriner et al. 2004); various species of yeasts have also been used such as *Candida tropicalis*, *C. lipolytica*, and *S. cerevisiae* (Aksu and Donmez 2003).

### 20.7.3 Degradation by Fungi

Bioremediation process includes brown-rot and white-rot fungal species for the removal of dye and other xenobiotics and is termed as "mycoremediation" (Prasad 2017, 2018). Bioremediation of such complex compounds relies upon the extracellular enzyme production by the fungi; these enzymes includes hydrolases and oxidoreductases (Makela et al. 2013). Oxidation and reduction reaction is formed by the oxidoreductase enzyme secreted by fungi that break down the chemical bond which attached to the water molecule. Lignin-modifying enzymes are also secreted by the fungi and are referred as oxidative enzyme. Since they are non-specific in nature, they degrade a wide range of xenobiotic compounds by using wide varieties of enzymes (Harms et al. 2011; Tuomela and Hatakka 2011; Winquist and Steenland

2014). Dye-decolorizing peroxidases are glycoproteins which require $H_2O_2$ for all enzyme reactions. They are named so because they oxidize by different classes of dyes like anthraquinone, and these are not properly oxidized by peroxidase enzyme (Kim and Shoda 1999; Passardi et al. 2005). A significant characteristic of dye peroxidase is having free position for the $H_2O_2$ binding. Due to this characteristic, they offer a wide range of dye degradation like 2′azinobis-3-ethylbenzothiazoline-6-sulfonate, polymeric, triphenylmethane, azo, phthalocyanine, and heterocyclic colors and other phenolic mixes (Petrides and Nauseef 2000). The extracellular ligninolytic enzymes produced by white-rot fungi are a standout among other techniques for color degradation. The ligninolytic enzymes found in organisms which include potential fungal strains such as *T. rubrum*, *P. chrysosporium*, various species of *Ganoderma*, *Irpex lacteus*, *Funalia trogii*, *T. versicolor*, and many more have been broadly utilized for the dye effluent treatment. White-rot fungi (WRF) have such enzymes which can degrade lignin easily.

Decolorization by the fungi is interceded by biosorption and additionally biodegradation tool. *Lentinus sajor-caju* parasitic stain is reported for the expulsion of removal of material color responsible for red (at 800 mg/l). The yeast *Saccharomyces cerevisiae* and unwanted biomass of yeast have been recorded for color removal and eradication of various types of industrial dyes (Phugare et al. 2011). *Coriolus versicolor* species were recorded for reduction of wide varieties of colors from five unique factories, and degradation rate is up to 36% every 5 days. Different species of *Penicillium* are also known for color removal; cotton blue color (50 mg/l) has been decolorized by *Penicillium ochrochloron* in 2.5 h; moreover, efficient fungal strain of *Penicillium* sp. decolorized azo dye effectively under laboratory conditions (Gou et al. 2009). Fungal strains have been considered as highly efficient group of microorganism for synthetic dye biodegradation. On the other hand, the white-rot fungal species have been proved to play a significant role in lignin expulsion (Kubilay 2009). Ligninolytic microorganisms were the conceivable option examined for dye decolorization and degradation. Interestingly the WRF were the first organisms reported for removal of dye (Kubilay 2009); however, few non-ligninolytic fungal species such as various species of *Aspergillus* and few species of *Penicillium* have also been documented to remediate and decolorize various synthetic dye effluents (Winquist and Steenland 2014).

Biological remediation of amaranth color by species of *Ganoderma* has been accounted for the removal of different dyes like triphenylmethane, bromophenol blue, and malachite green (Revenkar and Lele 2007). *Trametes versicolor* strain was reported for the removal of two different benzidine-based dyes: Direct blue 1 and Direct red 128. Fungal strains like *Funalia trogii*, *Coriolus versicolor*, and *Pleurotus ostreatus* have been reported in remediation and decolorization of dye Drimaren Blue CL-BR (DB) and Remazol Brilliant Blue Royal (RBBR) within 48 h. *Pyricularia oryzae* produce laccase that has the capability to decolorize phenolic azo dyes, while *P. chrysosporium* contain enzymes which degrade lignin and also have the capability to decolorize the azo-triphenylmethane dyes into harmless products (Kubilay 2009). A few different compounds like manganese peroxidase and lignin peroxidase from *P. chrysosporium* effectively decolorize wastewater from factories. Also, *Trametes* sp. is considered for the decolorization of other different dyes (Harms et al. 2011).

## 20.8 Mechanism of Dye Decolorization

Physical and enzymatic two steps of mechanisms are used for the degradation of dye (Knapp and Newby 1999). Surface of microbial cell provides a platform for the dye adsorption which is the primary step in the removal of dye. Various extracellular and intercellular enzymes produced by the fungal hyphae and other physical adsorption techniques are used for the color removal (Conneely et al. 2002; Chen et al. 2005, Singh et al. 2006; Chander and Arora 2007; Diwanian et al. 2010). Due to complexity in the structure of dye and its transformation mechanism make the demonstration of pathways a difficult task. Fungi produce various efficient enzymes such as laccase, lignin peroxidase, and manganese peroxidase for biodegradation of lignin, which participate in synthetic dye decolorization. In one report, Conneely et al. (2002) examined that in case of phthalocyanine dye degradation, lac and MnP are involved. Also in the case of *P. chrysosporium*, LiP act as a main decolorizing agent. Abadulla et al. (2000) observed that dyes with different chemical structure were degraded by different enzymes and they have different removal rates. Kirby et al. (2000) demonstrated that *P. tremellosa* produce laccases which efficiently remove textile dyes, but they also examined that there was a certain process which participates in the removal of remaining color which was observed in the absence of detectable level of these enzymes. Wesenberg et al. (2002) examined that lignin-modifying enzyme helps in the decolorization of industrial effluent. T azo dyes are removed by peroxidases which are responsible in the removal of phenolic group and further break down the phenyl diazine and oxidize it by one-electron reaction generating $N_2$ (Paszczynski et al. 1991; Spadaro et al. 1994; Paszczynski et al. 1992) (Table 20.1).

## 20.9 Factors Affecting Adsorption of Dye

Factors which affect the dye adsorption include temperature, pH, and initial dye concentration. Thus, for the large-scale removal of dye, the optimization of above parameters will be necessary.

### 20.9.1 Effect of pH

pH is considered as the crucial factor in the growth of fungus. Initial pH solution affects complexity of dye molecule and fungal biomass (Fu and Viraraghavan 2002). With the increase of pH the biosorption capacity of fungi also changes it get decreased for basic dye and get increased in case of acidic dye (Mahony et al. 2002). At pH 2 higher biosorption capacity (95 mg/g) of *Rhizopus arrhizus* for acidic

**Table 20.1** Dye degradation by various fungi

| Fungi | Dye | Incubation period | Percentage removal | References |
|---|---|---|---|---|
| *Ganoderma* sp. | Cibacron brilliant | 8 h | 96% | Revankar and Lele (2007) |
| Datronia sp. | Reactive black, reactive blue | 5 days | 86% | Pilanee et al. (2010) |
| *Aspergillus lentulus* | Acid magenta, orange HF, acid navy blue, acid sulfone blue, fast red | 7 days | 56% | Kaushisk and Malik (2010) |
| | | | 78% | |
| | | | 82% | |
| | | | 70% | |
| | | | 62% | |
| *Penicillium* sp. | Reactive brilliant red X 3B | 5 days | 70% | Gou et al. (2009) |
| *Saccharomyces cerevisiae* | Textile effluents | 2 days | 78% | Phugare et al. (2011) |
| *Ganoderma* sp. | Reactive orange system | 5 days | 95% | Lima et al. (2014) |
| *Ganoderma lucidum* | Acid orange 7 | 7 days | 77% | Chang et al. (2015) |
| *Aspergillus niger, Aspergillus terreus* | Procion | 7 days | 98% | Almeida and Corso (2014) |
| | Red max-5B | | | |
| *Phanerochaete* | Amido black | 3 days | 98% | Senthil et al. (2011) |
| *Aspergillus niger* | Azo dye | 5 days | 74% | Arumugam et al. 2011) |
| *Trichoderma* sp. | Orange G | | | |
| *Agaricus bisporus* | Acid red 44 | 30 min | 75% | Tamer et al. (2016) |
| *Agaricus bisporus* | Reactive blue 49 | 90 min | 90% | Sibel et al. (2009) |
| *Trametes* sp. | Azo dyes | 5 days | 69% | Yang et al. (2009) |
| *Coriolus versicolor* | Industrial effluents | 3 days | 84.4% | Muhammad Asgher et al. (2009) |
| *A. niger, Spirogyra* | Reactive dye | 18 h | 88% | Mahmoud and Khalaf (2008) |
| | | | 85% | |
| *Trametes versicolor* | Direct red 128, Direct blue 1 | 7 days | 79% | Gulay et al. (2007) |

group is observed as compared to pH 10 (30 mg/g), and the reason behind this change is the protonation of weak base group at lower pH. Thus base group acquire positive charge and bind themselves with chemical species of acidic group that caries negative charge (anionic group). Similarly Iqbal and Saeed (2007) studied that uptake of acidic dye 100 mg/l Remazol Brilliant Blue R by *Phanerochaete chrysosporium* at pH 2 was 53.46%, but for cationic dyes Maurya et al. (2006) reported that pH increased from 3 to 11.This is due to the fact that there was an increase in electronegativity of biosorbent because of deprotonation of functional group.

### 20.9.2 Effect of Temperature

Temperature also affects the dye absorption rate. By examining various studies, it is concluded that the biosorption capacity of fungus maximizes when temperature increases. Annadurai et al. (1999) used chitin as a biosorbent as they observed that Verofix Red is 28 mg/g at 30 °C and at 60 °C is 38 mg/g. As with the increase in temperature, the structure of chitin get swelled up which enables the dye molecule to get incorporated in the structure. It was observed that with the increase in the temperature, the biosorption capabilities of *Trametes versicolor* also speed up from 5 to 35 °C for Direct Blue 128 and Direct Blue 1, as the kinetic energy and surface activity of dye molecule get increased. In another study Iqbal and Saeed (2007) examined that Remazol Brilliant Blue R dye biosorption by *P. chrysosporium* increases with rise in temperature, i.e., 70% at 30 °C, but with constant increase in temperature (60% at 50 °C), it gets decreased.

### 20.9.3 Ionic Strength Effect

Textile dye is not properly treated before being disposed of into the environment, so they contain various amounts of different chemical impurities; due to the presence of such impurities, ion concentration of the solution which effects the dye removal increases. *Phellinus igniarius* is used for the biosorption of rhodamine; the biosorption rate decreased to 7% as the concentration of dye increases from 0.00001 mmol/l to 0.1 mol/l, and in case of methylene blue due to higher ionic strength, dye removal rate decreases. This suggests there is a probability that there is a competition between the ions $N^+$ and positively charged dye ions (Maurya et al. 2006).

### 20.9.4 Dye Concentration Effect

The dye concentration is a very important factor in adsorption process. Adsorption of dyes concentration determines the adsorption capacity of adsorbent. If initial concentration of dyes is high, the time required for the degradation is also increases, as in the case of biosorption capacity of *R. stolonifer* for bromophenol dye increases from 190 to 700 mg with the increase in the dye concentration also increases at pH 3. But there is an opposite trend for the percentage removal of dye concentration which lessened to 55% from 80% (Zeroual et al. 2006). In case of *Rhizopus nigricans* and *Saccharomyces cerevisiae* (85–30% and 90–30%, respectively), the initial concentration of dye increased from 500 to 200 mg/l (Kumari and Abraham 2007).

### 20.9.5 Physical and Chemical Parameters

Physical and chemical properties play major role in the biosorption. Fu and Viaraghvan (2002) determined the various absorption sites and chemically modified the particular ionic group for different dyes. They examined that two different functional groups including carboxylic and amino group were very effective in binding with cationic dye. And other functional group including phosphate and amino carboxylic bind themselves with anionic dye Congo red. This implies electrostatic force is not the only reason. Certain other chemical and physical treatments like drying and autoclaving organic and inorganic chemicals can also be used so as to increase the biosorption (Aksu 2005).

## 20.10 Conclusion

Wastewater contamination with dye and various kinds of colored compounds is becoming a problem worldwide. Further, addition of effluents from smelting and electroplating industries containing toxic and hazardous chemicals leads to various environmental troubles. Color removal from dye-containing wastewater using different methods is still a challenging task. Taking in view above facts and issues, there is great need to use such methods which are technically sound, feasible, and cost-effective. Among various physical and chemical treatments, the biological treatment appears to be the most efficient and promising choice available for the decolorization of wastewater. Mycoremediation is considered to be the best method to achieve the highest dye removal as they contain non-specific enzyme system which is capable of degrading different classes of dyes. It is believed that the microbial enzyme-based development systems will be the future technologies owing to its simplicity and green effect. In this book chapter, we are throwing light on the fungi and its functioning as dye removal agent. The very first portion deals with the fungi classification and kingdom; further we are discussing about the various dye materials available in the market and their chemical and mechanical methods for removal. In the last section, the emphasis is given in the mycoremediation for the dye removal and its efficiency to be a good biological medium.

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