Biodegradation of azo dye compounds

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Azo dyes are one of the oldest industrially synthesized organic compounds characterized by presence of Azo bond (-N=N-) and are widely utilized as coloring agents in textile, leather, cosmetic, paint, plastic, paper, and food industries. During textile processing, inefficiencies in dyeing result in large amounts of the dyestuff (varying from 2% loss when using basic dyes to a 50% loss when certain reactive dyes used) being directly lost to the wastewater, which ultimately finds its way into the environment. The physico-chemical method of industrial effluent treatment does not remove the dyes effectively. Microbial degradation and decolorization of azo dyes has gained more attention recently because of eco-friendly and inexpensive nature. Microbes and their enzymes could decolorize the dyes by both aerobic and anaerobic metabolism. This review provides a general idea of decolorization and biodegradation of azo dyes with various microbes and highlights the application of for the treatment of azo dye-containing wastewaters.

Keyword: Azo dye, biodegradation, decolorization, dyestuff, wastewater, enzymes, microbes

INTRODUCTION

There are more than 100,000 different synthetic dyes available on the market, produced in over 700,000 tons annually worldwide (Adedayo et al., 2004). They are used in the textile, paper, cosmetics, food and pharmaceutical industries due to their ease of production, fastness and variety in colour compared to natural dyes. Some of them are dangerous to living organisms due to their possible toxicity and carcinogenicity. Disposal of azo dyes from dyestuff synthesis and textile processing industry into the water resources causes reduction in water transparency and oxygen solubility (Corso and Almeida, 2009) and shows a negative impact on germination and growth of plant species, that imbalances the ecological function. So removal of textile dyes from the effluent before its disposal in the water bodies is very important. In the last few decades, several physicochemical methods have been developed for removal of dye from textile effluent, but these methods are not suitable due to the production of large amounts of toxic sludge, aromatic amines, and secondary waste products (Alhassani et al., 2007).

Numerous biotechnological approaches have been suggested to overcome the problem of physicochemical treatment methods using microorganisms for the treatment of textile dyes and industry effluent as microorganisms play crucial roles in the mineralization of xenobiotic compounds (Kurade et al., 2012). The biodegradation of textile dyestuff is used widely because of their cost effective, eco-friendly nature, and as well as produces less toxic and/or non-toxic compounds (Wang et al., 2008).

Such bioremediation includes the use of fungal, yeast and bacterial cultures for the removal of dye from textile effluent (Stajic et al., 2006; Zhao et al., 2006; Waghmode et al., 2012a).

Dyes make up an abundant class of organic compounds characterized by the presence of unsaturated groups (chromophores) such as −C=C−, −N=N− and −C≡N−, which are responsible for the dye colours, and of functional groups responsible for their fixation to fibres, for example, −NH₂, −OH, −COOH and −SO₃H (Molinari et
Dyes may also significantly affect photosynthetic activity in aquatic life by reducing light penetration intensity and may also be toxic to some aquatic fauna and flora due to the presence of aromatics, metals, chlorides, etc. (Dhaneshvar et al., 2007). Colour in the effluent is one of the most obvious indicators of water pollution and the discharge of highly colored synthetic dye effluents is aesthetically displeasing and can damage the receiving water body by impeding penetration of light. Moreover, azo dyes as well as their breakdown products are cytotoxic or carcinogenic (Khehra et al., 2006).

Dyes are synthetic aromatic organic compounds, which are normally used for coloration of various substances. During textile processing, inefficiencies in dyeing result in large amounts of the dyestuff (varying from 2% loss when using basic dyes to 50% loss when certain reactive dyes used) is being directly lost to the wastewater, which ultimately finds its way into the environment. Among all the chemical classes of dyes, azo dyes are considered to be recalcitrant, non-biodegradable and persistent (Saratale et al., 2010). Dye containing wastewater treatment is considered to be one of the challenging areas in the environmental fraternity.

A number of physico-chemical methods, such as adsorption, coagulation, precipitation, filtration and oxidation, have been used to treat dyestuff effluents, but these methods have many disadvantages and limitations. It is, therefore, important to develop efficient and cost-effective methods for the decolorization and degradation of dyes in industrial effluents and contaminated soil (Bhatt et al., 2000). Biological methods of removal involve use of microorganisms such as bacteria and fungi to convert the pollutants into nontoxic harmless substances. Biological processes convert organic compounds to water and carbon dioxide, have low cost sustainable and are easy to use.

**DYES**

**Dye classification**

The compounds which absorb electromagnetic energy in the visible range (~350-700 nm) are colored. These colored compounds are known as dyes. Dyes contain chromophores (delocalised electron systems with conjugated double bonds), and auxochromes (electron-withdrawing or electron donating substituents). The chromophore imparts the color to the dye molecule and auxochrome intensifies the color of the chromophore by altering the overall energy of the electron system. Usual chromophores are C=C, C=N, C=O, N=N, -NO₂, -SO₃H and -OH (Zollinger, 1987). The dyes are classified on the basis of chemical structure or chromophore viz. azo (monoazo, disazo, triazo, polyazo), anthraquinone, phthalocyanine, triarylmethane, diarylmethane, indigoid, azine, oxazine, thiazine, xanthene, nitro, nitroso, methine, thiazole, indamine, indophenol, lactone, aminoketone, hydroxyketone stilbene and sulphur dyes.

**Azo Dyes**

Azo dyes are commonly used in several industries including textile, dyeing, printing and cosmetic industries (Table 1). Azo dyes have diversity in structure but their most important structural feature is presence of azo linkage -N=N-. This linkage may be present more than one time and thus mono azo dyes have one azo linkage while two in diazo and three in triazo respectively. These azo groups are connected on both sides with aromatics like benzene and naphthalene moiety. Sometimes aromatic heterocyclic units are also present being connected with azo groups. (Zollinger, 1991). Different shades of the same dye having various intensities of color are due to these aromatic side groups. Azo dyes containing sulfonate groups as substituent are called as sulphonated azo dyes. Azo groups in conjugation with aromatic substituents or enolvable groups make a complex structure which lead to huge expression of variation of colors in dyes (O’Neil et al., 2000).

**Toxicity of dyestuffs**

Many dyes are visible in water at very low (1 mg l⁻¹) concentrations. The dye concentrations in the textile processing wastewaters are in the range of 10-20 mg l⁻¹. Therefore, usually the discharge of highly colored wastewater in open waters presents aesthetic problem. As dyes are designed to be chemically and photolytically stable, they are highly persistent in natural environments. The release of the dyes in a natural environment may cause the ecotoxic hazard.

The azo group of dyes binds to an aromatic ring. Through mineralization, this dye can be broken down into an aromatic amine, an arylamine that is suspected to be carcinogenic. Most of the azo dyes are water soluble and readily to absorb through skin contact and inhalation leading to the risk of cancer and allergic reactions, an irritant for the eyes and highly toxic, if inhaled or consumed For example, Para-phenylene diamine (PPD) also called 1,4-diamino benzene or 1,4-phenylene diamine, is an aromatic amine, which is a major component of azo dyes. PPD-containing azo dyes are toxic and causes skin irritation, contact dermatitis, chemosis, lacrimation, exophtalmimose, and permanent blindness. Ingestion of PPD products leads to the rapid development of oedema on face, neck, pharynx, tongue and larynx along with respiratory distress. (Sudha, M. et al 2014) Some azo dyes are linked to human cancer, splenic sarcomas, hepatocarcinomas, and nuclear anomalies in experimental animals and chromosomal
### Table 1. Azo dye structure and characteristics.
Characteristics of methyl red and congo red

<table>
<thead>
<tr>
<th>Name</th>
<th>Methyl Red</th>
<th>Name</th>
<th>Congo Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Name</td>
<td>Acid red-2</td>
<td>Other Name</td>
<td>Direct red 28</td>
</tr>
<tr>
<td>Color</td>
<td>Red</td>
<td>Color</td>
<td>Red</td>
</tr>
<tr>
<td>Structure</td>
<td><img src="structure.png" alt="Methyl Red Structure" /></td>
<td>Structure</td>
<td><img src="structure.png" alt="Congo Red Structure" /></td>
</tr>
<tr>
<td>Moleculer Formula</td>
<td>C&lt;sub&gt;15&lt;/sub&gt;H&lt;sub&gt;15&lt;/sub&gt;N&lt;sub&gt;3&lt;/sub&gt;O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Moleculer Formula</td>
<td>C&lt;sub&gt;32&lt;/sub&gt;H&lt;sub&gt;22&lt;/sub&gt;N&lt;sub&gt;6&lt;/sub&gt;Na&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;6&lt;/sub&gt;S&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Weight</td>
<td>269.29</td>
<td>Weight</td>
<td>696.66</td>
</tr>
<tr>
<td>Melting Point</td>
<td>179 to 182°C</td>
<td>Melting Point</td>
<td>&gt;360°C</td>
</tr>
<tr>
<td>PH</td>
<td>4.4 to 6.2</td>
<td>PH</td>
<td>3.0 to 5.2</td>
</tr>
<tr>
<td>IUPAC Name</td>
<td>2-(N,N-Dimethyl-4-aminophenyl) azobenzenecarboxylic acid</td>
<td>IUPAC Name</td>
<td>Disodium 4-amino-3-[4-{4-(1-amino-4-sulfonato-naphthalen-2-yl)diazenylphenyl]phenyl}diazenyl-naphthalene-1-sulfonate</td>
</tr>
<tr>
<td>Use</td>
<td>Use for dyeing of nylon &amp; silk, cloth, paper, leather etc.</td>
<td>Use</td>
<td>Use for dyeing of nylon &amp; silk, cloth, paper, leather etc.</td>
</tr>
<tr>
<td>Types of Dye</td>
<td>Azo dye (N=N)</td>
<td>Types of Dye</td>
<td>Azo dye (N=N)</td>
</tr>
</tbody>
</table>

aberrations in mammalian cells (Puvaneswari et al., 2006).

### Dye removal techniques

Textile dyestuff and wastewater is recalcitrant to the degradation. Several physicochemical and biological techniques can be employed to remove color from the dye containing wastewaters. Several factors, including dye type, wastewater composition, dose or costs of required chemicals, operation costs, environmental fate and handling costs of generated waste products determine the technical and economic feasibility of each single technique. In general, each technique has its own limitations. The use of one individual process may often not sufficient to achieve complete decolorization.

### Importance of biological treatment relative to physicochemical methods

Together with industrialization, awareness towards the environmental problems arising due to effluent discharge is of a critical importance. A dye house effluent typically contains 0.6–0.8 g 1<sup>−1</sup> dye (Gahr et al., 1994). Pollution caused by dye effluent is mainly due to durability of the dyes in the wastewater. Therefore both color creating and the color using industries are compelled to search for novel physicochemical treatments and technologies which are directed particularly towards the decolorization of the dyes from the effluents. There are many reports on the use of physicochemical methods for color removal from dyes containing effluents (Vandevivere et al., 1998). The various physical/chemical methods such as adsorption, chemical precipitation, photolysis, chemical oxidation and reduction, electrochemical treatment were used for the removal of dyes from wastewater effluent.

### Physical and chemical methods:

In advanced countries, the coagulation–flocculation is most widely used method in textile wastewater treatment plants. It can be used either as a pre-treatment, post-treatment, or even as a main treatment system (Gahr et al., 1994). This method can efficiently remove mainly sulphur and disperse dyes, whereas acid, direct, reactive and vat dyes presented very low coagulation–flocculation capacity (Vandevivere et al., 1998). Filtration methods such as ultrafiltration, nanofiltration and reverse osmosis have been used for water reuse and chemical recovery. In the textile industry, these filtration methods can be used for both filtering and recycling. It is not only pigment-rich streams but also mercerizing and bleaching wastewaters.

The main drawbacks of membrane technology are the high investment costs, the potential membrane fouling, produces secondary waste streams which need further treatment (Robinson et al., 2001). A very good option would be to consider an anaerobic pre-treatment followed by aerobic and membrane post-treatments in order to recycle the water.
Biological methods

Bioremediation is the microbial clean up approach is on the front line and priority research area in the environmental sciences. This field has recent origin and grown exponentially over the last two decades. In this system microbes can acclimatize themselves to toxic wastes and new resistant strains develop naturally, which can transform various toxic chemicals to less harmful forms. The mechanism behind the biodegradation of recalcitrant compounds in the microbial system is because of the biotransformation enzymes (Saratale et al., 2009). Several reports suggest the degradation of complex organic substances, which can be brought about by an enzymatic mechanism like; laccase, tyrosinase (Zhang and Flurkey, 1997), hexane oxidase (Saratale et al., 2009) and aminopyrine N-demethylase etc. A number of biotechnological approaches have been suggested by recent research as of potential interest towards combating this pollution source in an ecoefficient manner; mainly the use of bacteria and often in combination with physicochemical processes. Azo dyes constitute the largest class of dyes used in industries, which are xenobiotic in nature and found to be recalcitrant to biodegradation.

The isolation of new strains or the adaptation of existing ones to the decomposition of dyes will probably increase the efficacy of bioremediation of dyes in the near future. The use of microbial or enzymatic treatment method for the complete decolorization and degradation of an industrial dyes from textile effluent possess has considerable advantages; 1) eco-friendly nature, 2) cost-competitive, 3) less sludge producing properties, 4) the end products with complete mineralization or non toxic products and 5) could help to reduce the enormous water consumption compared to physicochemical methods (Saratale et al., 2009). Moreover, the effectiveness of the microbial decolorization depends upon the adaptability and the activity of selected microorganisms. Large number of species has been tested for the decolorization and mineralization of various dyes and steadily increasing in recent years (Pandey et al., 2007). The isolation of potent species and there by degradation is one of the interest in biological aspect of effluents treatment (Mohan et al., 2002). A wide variety of microorganisms are capable of decolorization of a wide range of dyes using wide range of microorganisms including bacteria (Parshetti et al., 2006; Kalyani et al., 2008; Saratale et al., 2009), fungi, yeasts (Saratale et al., 2009), actinomycetes (Parshetti et al., 2006), algae (Daneshvar et al., 2007) and plants (Phytoremediation) capable of decolorize and even completely mineralize many azo dyes under certain environmental conditions.

Mechanism of color removal

Azo compounds are susceptible to biological degradation under both aerobic and anaerobic conditions (Field et al., 1993). Decolorization of azo dyes under anaerobic conditions is thought to be a relatively simple and non-specific process, involving fission of the azo bond to yield degradation products such as aromatic amines. The efficacy of various anaerobic treatment applications for the degradation of a wide variety of synthetic dyes has been many times demonstrated. Under anaerobic conditions a low redox potential (<50 mV) can be achieved, which is necessary for the effective decolorization of the dyes. Color removal under anaerobic conditions is also referred as dye reduction in which literature mostly covers the biochemistry of azo dye reduction.

The mechanism of microbial degradation of azo dyes involves the reductive cleavage of azo bonds (–N=N–) with the help of azo-reductase under anaerobic conditions involves a transfer of four-electrons (reducing equivalents), which proceeds through two stages at the azo linkage and in each stage two electrons are transferred to the azo dye, which acts as a final electron acceptor, resulted into dye decolorization and the formation of colorless solutions. The resulting intermediate metabolites (e.g., aromatic amines) are further degraded aerobically or anaerobically (Chang et al., 2000). Thus in the presence of oxygen usually inhibits the azo bond reduction activity since aerobic respiration may dominate utilization of NADH; thus impeding the electron transfer from NADH to azo bonds (Chang et al., 2001). The potential toxicity, mutagenicity, and carcinogenicity of such compounds are well documented and have been reviewed elsewhere (Chung et al., 1992).

Biodegradation of textile dyes

Filamentous fungi are found ubiquitous in the environment, inhabiting ecological niches such as soil, living plants and organic waste material. The ability of fungi to rapidly adapt their metabolism to varying carbon and nitrogen sources is an integrated aspect for their survival. This metabolic activity achieved through the production of a large set of intra and extracellular enzymes able to degrade complex various kinds of organic pollutants. In addition to the production and secretion of number of enzymes, filamentous fungi can secrete a great diversity of primary and secondary metabolites (e.g. antibiotics) and perform many different complex conversions such as hydroxylation of complex polyaromatic hydrocarbons, organic waste, dye effluents and steroid compounds (McMullan et al., 2001). Fungal systems appear to be the most appropriate in the treatment of colored and metallic effluents (Ezeronye and Okerentugba, 1999). The ability of these fungi to degrade such a range of organic compounds results from the relatively non-specific nature of their ligninolytic enzymes, such as lignin peroxidase (LIP), manganese peroxidase (MnP) and laccase. Fungal degradation of aromatic
Table 1.1. Characteristics of acid black 210

<table>
<thead>
<tr>
<th>Name</th>
<th>Acid black 210</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Name</td>
<td>Acid black BRL. Setannderm black NT.</td>
</tr>
<tr>
<td>Color</td>
<td>Black</td>
</tr>
<tr>
<td>Structure</td>
<td>![Structure Diagram]</td>
</tr>
<tr>
<td>Molecular Formula</td>
<td>C_{34}H_{25}K_{2}N_{11}O_{11}S_{3}</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>938.02</td>
</tr>
<tr>
<td>Melting Point</td>
<td>300°C</td>
</tr>
<tr>
<td>PH</td>
<td>8.5 to 9.5</td>
</tr>
<tr>
<td>IUPAC Name</td>
<td>Disodium6-hydroxy-5[(4-sulfophenyl)azo]-2-naphthalenesulfonate</td>
</tr>
<tr>
<td>Use</td>
<td>Use for dyeing of nylon &amp; silk, cloth, paper, leather etc.</td>
</tr>
<tr>
<td>Types of Dye</td>
<td>Azo dye (N=N)</td>
</tr>
</tbody>
</table>

structures is a secondary metabolic event that starts when nutrients (C, N and S) become limiting. Therefore, while the enzymes are optimally expressed under starving conditions, supplementation of energy substrates and nutrients are necessary for the propagation of the cultures (Christian et al., 2005).

Most studies on an azo dye biodegradation have focused on the fungal cultures mainly belonging to white rot fungi and used to develop bioprocesses for mineralization of azo dyes (Parshetti et al., 2006). The *Phanerochaete chrysosporium* is the most widely studied of white-rot fungi, as well as *Trametes (Coriolus) versicolor, Bjerkandera adusta, Pleurotus, Aspergillus* and *Pheobia* species, and variety of other isolates also studied for the degradation of various textile dyes (Swamy and Ramsay 1999; Pointing et al., 2000). A detailed investigation was also carried out on isolated *Geotrichum candidum Dec1* capable of decolorization a number of anthraquinone dyes. The broad substrate specificity exhibited by this isolate is due to production of extracellular peroxidase-type enzymes and glycosylated haem-based peroxidase (DyP) (Kim and Shoda 1999a).

However, application of white-rot fungi for the removal of dyes from textile wastewater have inherent drawbacks; long growth cycle, requiring nitrogen limiting conditions, naturally white rot fungi not found in wastewater, hence the enzyme production may be unreliable (Robinson et al., 2001), long hydraulic retention time for complete decolorization still limit the performance of the fungal decolorization system (Saratale et al., 2009) as well as preservation in bioreactors will be a matter of concern (Stolz, 2001).

Much of the experimental work involving the anaerobic decolorization of dyes (predominantly azo dyes) was conducted using mono cultures. Species of *Bacillus, Pseudomonas, Aeromonas, Proteus, Micrococcus* and purple non-sulphur photosynthetic bacteria were found to be effective in the anaerobic degradation of a number of dyes (Chang et al., 2001; Saratale et al., 2009). The anaerobic reduction of azo dyes utilized in the textile industry by a strain of *Bacillus cereus* isolated from soil. However, the permeation of the dyes through biological membrane into the microbial cells was cited as the principal rate-limiting factor for decolorization.

In contrast, under aerobic conditions, the enzymes mono- and di-oxygenase catalyze the incorporation of oxygen from O_2 into the aromatic ring of organic compounds prior to ring fission. However, in the presence of specific oxygen-catalysed enzymes called azo reductases, some aerobic bacteria are able to reduce azo compounds and
Table 2. Microbes Use in Azo Dye Degradation

<table>
<thead>
<tr>
<th>Strain</th>
<th>Organisms</th>
<th>Dye</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>Galactomyces geotrichum</td>
<td>Yellow 84A</td>
<td>Sanjay et al, 2014</td>
</tr>
<tr>
<td></td>
<td>Enterobacter agglomerans</td>
<td>Methyl Red</td>
<td>Keharia et al., 2003</td>
</tr>
<tr>
<td></td>
<td>Enterobacter sp</td>
<td>CI Reactive Red 195</td>
<td>Kalyani et al., 2007</td>
</tr>
<tr>
<td></td>
<td>Bacillus subtilis</td>
<td>Acid blue 113</td>
<td>Gurukulakshmi et al., 2008</td>
</tr>
<tr>
<td></td>
<td>Brevibacillus laterosporus</td>
<td>Navy blue 3G</td>
<td>Jirasripongpun et al., 2007</td>
</tr>
<tr>
<td></td>
<td>Bacillus Fusiformis kmk 5</td>
<td>Acid Orange 10 &amp; Disperse Blue 79</td>
<td>Kolekar et al., 2008</td>
</tr>
<tr>
<td>Fungi</td>
<td>Geotrichum sp</td>
<td>Reactive black 5, Reactive red 158</td>
<td>Kuhad et al., 2004</td>
</tr>
<tr>
<td></td>
<td>Shewanella sp.NTOVI</td>
<td>Crystal violet</td>
<td>Chen et al, 2008</td>
</tr>
<tr>
<td></td>
<td>Phanaerochaete chrysosporium</td>
<td>Orange II</td>
<td>Sharma et al, 2009</td>
</tr>
<tr>
<td>Yeast</td>
<td>Kluyveromyces marxianus IMB3</td>
<td>Ramazol black B</td>
<td>Meehan et al, 2000</td>
</tr>
<tr>
<td></td>
<td>Saccharomyces cerevisiae MTCC46</td>
<td>Methyl red</td>
<td>Molina-Guijarro et al, 2009</td>
</tr>
<tr>
<td></td>
<td>Streptomyces ipomoea</td>
<td>Orange II</td>
<td>Jadhav et al, 2007</td>
</tr>
<tr>
<td>Actinomycetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Streptomyces ipomoea</td>
<td>Methyl red</td>
<td>Molina-Guijarro et al, 2009</td>
</tr>
<tr>
<td></td>
<td>Spirogyra rhizopus</td>
<td>Acid red 247</td>
<td>Ozer et al, 2006</td>
</tr>
<tr>
<td>Algae</td>
<td>Cosmarium sp</td>
<td>Triphenylmethane dye &amp; Malachite green</td>
<td>Daneshvar et al, 2007</td>
</tr>
</tbody>
</table>

produce aromatic amines (Stolz, 2001). Table 3 shows some common enzymes used in Biodegradation of Dye. These enzymes, after purification, characterization and comparison were shown to be flavin-free. The aerobic azo reductases were able to use both NAD(P)H and NADH as cofactors and reductively cleaved not only the carboxylated growth substrates of bacteriabut also the sulfonated structural analogues. Recently, cloned and characterized the genetic code of the aerobic azo reductase from *Pagentiphaga kullae* K24. Only few bacteria with specialized azo dye reducing enzymes were found to degrade azo dyes under fully aerobic conditions (Nachiyar et al., 2005). Table II and III Shows Some Microbe and Enzyme used in Decolorization and Degradation of Dye. *Cladosporium* sp. comprise fungi which are not characterized by sexual phase of multiplication, and, therefore, belong to the group Fungi imperfecti. This genus comprises more than 30 species. The most isolated species are *Cladosporium elatum, Cladosporium harbarum, Cladosporium sphaerospermum* and *Cladosporium cladosporioides*. It is interesting that *Cladosporium* sp. can be isolated from the indoor air environment of asthmatics and non-asthmatics, which was confirmed in 26.3% of the cases investigated (Unlu et al., 2003). There is little data on the available literature on the association between the infection caused by *Cladosporium* sp. and findings of specific antibodies to antigens of these fungi. One of the studies done in the recent years has determined that sinusitis caused by moulds are followed by an increase in specific antibodies of IgG class, while bronchitis as a complication is followed by decrease of specific, most probably protective antibodies (Patovirta et al., 2003). Patients on peritoneal dialysis stand for a high-risk group to develop fungal peritonitis caused by filamentous fungi, moulds. This is confirmed by the case of a patient on peritoneal dialysis, hospitalized at the Clinic of Nephrology in Nis,
who got peritonitis caused by *Cladosporium* sp. (Tasic et al., 2006).

**Uses**

Dye are used in the textile, paper, cosmetics, food and pharmaceutical industries due to their ease of production, fastness and variety in color compared to natural dyes. Dye injected into the blood allows the flow through coronary arteries to be viewed by x-ray. Research has involved optimization of conditions for degradation and studies of the biochemical mechanisms by which complex azo dyes are degraded. Dye sublimation printers, which are the best type for producing crystal clear results for your ID cards. Using fluorescent dyes, slices no longer have to be collected using a sharpened blade. Dyed wool, not yet spun, was found. Intravascular injection (should be prevented by checking the needle position with radio-opaque dye ). Dyers bring color into their work using natural or synthetic dyes bring color into their work using natural or synthetic dyes. Hydrocarbons in the environment are biodegraded primarily by bacteria, yeast, and fungi. The reported efficiency of biodegradation ranged from 6% to 82% for soil fungi, 0.13% to 50% for soil bacteria, and 0.003% to 100% for marine bacteria. Many scientists reported that mixed populations with overall broad enzymatic capacities are required to degrade complex mixtures of hydrocarbons (Shah et al/2013).

**CONCLUSION**

As an emerging technique, microbial degradation is one of the best techniques to detoxify the azo dyes. To understand the decolourization and degradation mechanism of azo compounds under aerobic conditions, detailed information is needed about the initial enzymatic transformation of azo linkages. The authors in our laboratory are involved in the isolation of potent fungi and consortium for efficient decolourization of azo dyes from textile effluents.

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**REFERENCES**


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### Table 3. Enzymes mediated Decolorization of some dyes

<table>
<thead>
<tr>
<th>Substrates</th>
<th>Enzyme</th>
<th>Source of Enzyme</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-(4dimethyl amino-1-phenylazo) Benzene sulfonic acid</td>
<td>laccase</td>
<td><em>Trametes villosa</em></td>
<td>Zille et al, 2004</td>
</tr>
<tr>
<td>Acid Orange 6, Acid Orange 7, Methyl Orange and Methyl Red</td>
<td>Mixture of Bacterial Oxidoreductases</td>
<td>Sludge Methonogens</td>
<td>Kalyuzhnyi et al, 2006</td>
</tr>
<tr>
<td>Direct Yellow</td>
<td>Horse radish peroxidases</td>
<td><em>Armoracia rusticana</em></td>
<td>Maddhinni et al, 2006</td>
</tr>
<tr>
<td>Acid Blue</td>
<td>Laccase</td>
<td><em>Cladosporium cladosporioides</em></td>
<td>Vijaykumar et al, 2006</td>
</tr>
<tr>
<td>Tartrazine and Ponceau</td>
<td>Azoreductase</td>
<td>Green algae</td>
<td>Omar, 2008</td>
</tr>
<tr>
<td>Reactive Yellow, Reactive Black, Reactive Red and Direct Blue</td>
<td>Azoreductase</td>
<td><em>Staphylococcus arlettae</em></td>
<td>Franciscon et al, 2009</td>
</tr>
</tbody>
</table>


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