Rhizoremediation of Azodyes by Constructed Wetland Technology using *Typha latifolia*

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Abstract

Synthetic azodyes used in textile industries generate hazardous waste and adverse effect on soil and water, probably affects the whole environment. The traditional treatment technologies used for synthetic dyes are costly and adversely affect the biota. Phytoremediation, an arising new technology that generally uses the aquatic macrophytes to reduce, stabilize and also remove toxic pollutants in an ecofriendly and cost effective way. However, the stress on plants results in slow growth and low biomass and its rhizospheric bacteria will enhance the degradation potential and reduce the stress on plants. The chapter describes the bioremediation of azodyes by the combination of plant and root associated bacteria of *Typha latifolia* in constructed wetland system.

13.1 Introduction

Textile industries are one of the major users of synthetic dyes in the world and release huge quantities of dyes, which are generally discharged out from these industries, causing serious damage to the environment related to the bleaching and dying process. In India, in the year 2010 water consumed by the textile industry was around 1900 mm^3 (Million cubic meters) and effluent water generated was approximately 75% of its total intake. The color in water for the most part restrains the entrance of sunrays in to the water body and also it decreases the level of photosynthetic and dissolved oxygen in water (Shehzadi et al. 2014). Furthermore, dye waste water is extremely hard to treat since it regularly changes its high pH, COD, colour

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and its degradation intermediates contain high organized polymers (Neppolian et al. 1998). However different treatment technologies such as coagulation, flocculation, adsorption on activated carbons, oxidation, ion exchange etc have been used for treating dye wastewater, but these processes are with high cost and also having environmental impacts (Kharub 2012). The introduction of phytotechnology is an emerging field that implements solutions to scientific and engineering problem by using plants and its associated microorganism by the construction of artificial wetlands. Now a days plant-based technology have become alternatively used in cleanup strategies generally in light of their low expenses, high success rates, low upkeep requirements and also its elegant nature. Phytoremediation technologies generally incorporate with a wide a scope of innovations that utilized different types of plants to expel, minimize, degenerate, and cripple natural toxins from soil and water and then restore the contaminated goals to a generally perfect, non-lethal environment.

Phytoremediation is a naturally occurring process, in which plants removes inorganic and organic pollutants, through certain process such as degradation, sequestration, or transformation (Pilon-Smits and John 2006). Phytoremediation innovations are arranged into various classes, for example, phytodegradation or rhizodegradation (degradation of toxins by rhizosphere microorganisms), phytoextraction, phytostabilisation and phytostimulation. The most conventional treatment technology is the combination of plants and its associated microorganism in constructed wetland technology. Developed constructed wetland, is an outlined simulated wetland, gives off an impression of being a most encouraging for the treatment of color wastewater. This chapter generally features the role of constructed wetland by using macrophytic plants and its associated rhizosphere bacteria in the degradation of azodyes.

13.2 Toxicity of Textile Dyes in Water

Dyes can be generally classified according to its different structural varieties like acidic, basic, disperse, azo, anthraquinone, phthalocyanine, triaryl methane, diaryl methane, indigo dyes, ketazines, oxazine, aldazines, Leuco, phthalein dyes, indamines dyes, hydroxyl ketonestilbene and sulphur dye compounds (Shah 2014). Azo compounds are the most vital textile colours which are classified, as indicated by their solvency, into soluble and insoluble azo dyes and azo pigments. These are generally synthesized from arylamines by diazotation and coupling (Platzek et al. 1999). Azo dyes are considered as carcinogenic and they are generally produced by the dye manufacturing industries causing serious defilement to water bodies. The disposal of these dyes is very much essential due to its hazardous effect to the whole environment. Synthetic dyes, which were used in the textile industries, have the ability to produce strong covalent bond to textile fibers. Exposure of these synthetic dyes may cause potential health hazards and it is mutagenic and carcinogenic and are either toxic to flora and fauna (Nilsson et al. 1993). Various technologies are been introduced to treat wastewater; however, multifunctional treatment technologies are reviewed as a productive treatment technology for the proper removal of synthetic dye from textile dye industry by a single treatment (Saba et al. 2015).

Textile dye industries are considered to be the largest water consuming and waste water generating industries by its different dyeing and finishing processes. Effluent water produced from textile industries are rich in color content, containing high deposits of residual matter, toxic chemicals, and complex components with suspended solid (Wang et al. 2011). These textile wastes are extremely dangerous to organisms in the water body that also exhibit genetical disorder and change in its physiological condition. Different treatment technologies were available for the treatment of textile effluent wastewater but they are not suggested because of its high maintenance cost and also the generation of secondary pollutants due to the use of chemicals (Pundlik et al. 2013). By observing these views development of economical and feasible technology to restrict the textile effluent pollution and tremendous water utilization is exceptionally fundamental.

Toxic textile dyes in water bodies that are released from the textile industry decrease the dispersal of light, which consequently, reduces the photosynthetic rate of algae and other aquatic vegetation (Khandare and Govindwar 2015). These activities generally lower the dissolved oxygen concentration and increase the concentration of inorganic salts and acid, which will lead to long-term adverse effects in the aquatic environment. These colored synthetic compounds have complex structure, are xenobiotic and after absorption, they are distributed in the whole body and force to change some kind of action (Chequer et al. 2011).

These complex structures of synthetic dyes especially amino azo derivatives may lead to health hazard and this may increase the risk of malignancy (Garg et al. 2002). According to the study of IARC has listed benzene derivatives dyes to the great degree of cancer causing agent to human beings (IARC 1982). Sharma et al. (2007) studied the toxicity of textile wastewater in swiss albino rats. Malachite green is a water soluble cationic dye and its metabolite lecuomalachite may cause malignancy or tumor in rats and this malachite green colors will cause hepatic and cellular damages in certain fishes (NTPC 2005; Khandare and Govindwar 2015). Srivastava et al. (1995) reported that malachite green can cause reduction in calcium and protein and also increase cholesterol level in blood of *Heteropneustes fossilis*.

13.3 Constructed Wetland Technology with Aquatic Plants

Constructed wetland treatment system involves the use of a well-designed engineered system, which is generally being utilized as a natural process. These designed systems generally mimic natural wetland system by using wetland plants, soil and also its associated microorganisms to minimize contaminants from wastewater. Generally, common types of constructed wetlands are the Free Water Surface (FWS) systems, the Subsurface Flow (SSF) systems including horizontal or vertical flow. FWS act as like natural wetlands in which, the wastewater flows horizontally over the sediment. In SSF, effluent water flows horizontally or vertically through different material or substance, which is mainly layered by clay, sandy soil, gravel or with other substrates (Zhang et al. 2009). Aquatic macrophytes are the major component of constructed wetlands. They absorb contaminants in their plant parts and the plant enzymes which may act as a catalyst for the degradation of pollutants. The diversity rhizosphere bacteria in the root zone area will also help the plants to improve their efficiency in the removal contaminants (Jenssen et al. 1993; Hadad et al. 2006).

Treatment performance in constructed wetlands is a combination of aerated and non aerated treatment mechanisms that store, change, and expel organic matter and its related toxins (Wallance et al. 2008). The plants utilized in constructed wetlands were planned for wastewater treatment ought to be tolerant to highly natural and nutrient loadings and these are effectively degraded under anoxic and anaerobic conditions (Vymazal and Lenkropfelova 2008; Kvet et al. 1999). Macrophytic plants that were growing in constructed wetlands showed a couple of properties in connection with the treatment technique. These findings make these plants to hold a major part in the plan of constructed wetlands in relation to its physical effects such purification; control erosion etc. and also its root associated microorganisms influence the plant growth and also maintain the hydraulic properties of the substrate (Haberl et al. 2003).

Anjana and Salom Gnana Thanga (2011) studied the decolourization of synthetic dyes using aquatic macrophytes. In 2012, Dorota and Krzyszt of reported the decolourization of dye acid orange using different aquatic macrophytes in constructed wetlands. Aquatic macrophyte *Phragmites* showed a maximum growth in textile wastewater than its control, Lemna and spirodela are been strongly recommended for the toxicity assessment study of textile dye effluents (Sharma et al. 2005). Water hyacinth is a nuisance aquatic weed showed a maximum biosorption capacity to reduce the concentration of dye stuff, heavy metals and also minimize the COD, BOD, TDS in textile wastewater (Sanmuga Priya and Senthamil Selvan 2017). This can also been used in water bodies contaminated with dye wastewater (Tan et al. 2016). *Leucaena leucocephala* plant remediates the dye contaminated soil and also act as a biodegradable organic phytostabiliser for dyes (Jayanthy et al. 2014). The role of adventitious roots of *Ipomoea hederifolia* along with endosymbiont *Cladosporium cladosporioides* decolorized synthetic dye; such synergistic approaches increase the efficiency of phytoremediation (Patil et al. 2016). Plant species like *Pistia stratiotes*, *Eichhornia crassipes* and *Dichanthium annulatum* plays a pivotal role in remediation of toxins from textile effluents (Yasar et al. 2013).

13.4 *Typha latifolia* and Dye Remediation

Typha latifolia plant is one of the most commonly available and widely used macrophyte in constructed wetland. These narrow leaved cattails wetland plants have an efficiency to decolorize and degrade textile effluent and also have the ability to survive in dye effluents (Nilratnisakorn et al. 2008). *Typha latifolia* species has thick and broad leaf cattail, which may survive in any rough condition and these roots release oxygen and which plays a major role in the degradation of contaminants in the wetlands (Li et al. 2010). These plants also have the dye removal efficiency because of its large biomass rapid propagation and complex metabolism (Chandanshivea et al. 2017). Some of the limiting factors which influence the performance of *Typha latifolia* based constructed wetland remediation are water, oxygen and nutrients. Sánchez-Orozco et al. in 2018 studied that the *Typha latifolia* plant parts showed a high efficiency in the removal of methylene blue. These plant parts are used to prepare activated carbon which act as an adsorbant for the removal of dyes (Jaya Santha Kumari et al. 2015).

13.5 Rhizosphere Bacteria and Degradation of Dyes

Rhizosphere was defined by Hiltner in 1904 as the portion of soil influenced by plant root. This part is the focal point of vigorous organic action, because of its rich nutritional supply; gas exchange and enhanced release of root exudates promote the growth of plants (Prasad et al. 2015). Rhizosphere bacteria occupy a narrow zone of soil immediately adjacent to plant roots which represents a biological niche with in the soil environment. This plays a vital role in the plant growth by mobilizing different enzymes, controlling plant pathogens and also plays a major role in the degradation of different contaminants. These plant-rhizosphere interactions enhance the degradation of different pollutants by uptake, translocation mechanisms and also by tolerance mechanisms (Pilon 2005). Rhizosphere bioremediation is also known as rhizodegradation or plant-assisted bioremediation. This remediation process is an active process that interact both plants and its rhizosphere microbes (Nwoko 2010). In this rhizosphere zone the pollutants can be fixed or debased by the plant roots (Pilon 2005). Exudates are perplexing emissions acquired from the plant roots, which "bolster" the microorganisms by giving carbohydrates, additionally contain characteristic chelating agents that make the ions of both nutrients and contaminants more mobile in the soil, which then results in a more competent degradation of pollutants. On the other hand beneficial microorganisms increment the bioavailability of the toxins to the plants or decrease the harmfulness of the contaminations helping the plants to survive and increment the rate of remediation. The roots of aquatic plants generally require oxygen for their growth and development, so with the help of their developed lacunar system encourages the flow of oxygen from shoot to root (Sculthorpe 1967; Armstrong 1979). By this process radical oxygen loss will occur this lossed oxygen may consumed by the root zone microbes which may fasten the degradation process.

Chaudery et al. in (2005) explained the synergistic action of rhizosphere and plant. Typha showed a maximum growth in textile effluents and also showed the potential to host the maximum endophytic bacteria in its root and shoot; these interactions will increase the efficiency of the constructed wetland (Shehzadi et al. 2015). Khandare et al. in (2011) explored plant and its bacterial synergism and also determine the role of bacterial enzyme in the degradation of Remazol Black B dye.

Introduction of endophytic microbes in Typha species diminished the toxic effects and also it showed an upgradation in plant and also decreases in its genotoxicity (Shehzadi et al. 2014). Bacteria which are isolated from the rhizosphere of plant exhibited 60–100% of decolorization capacity (Shafqat et al. 2017). The endophytic bacteria isolated from mangrove plants showed the degradation of dyes and also act as a potential candidate for dye degrading enzymes (Gayathri et al. 2010). Studies conducted by researchers to detect the role of bacterial consortia and also fungal-bacterial consortia and its efficiency in dye colorization and also its dye degradation (Khandare et al. 2012). Watharkar et al. (2013) reported the role of rhizospheric bacterial isolate *Bacillus pumilus* strain in *Petunia grandiflora* to decolorize dye reactive navy blue. Hairy roots of *Tagetes patula* (Marigold plant) which was induced by *Agrobacterium rhizogenes* showed the ability to decolorize different textile dyes (Patil et al. 2009).

13.6 Advantages of Plant-Microbe Interaction in Textile Dyes

Plant- microbe interaction is an economical technology in dye remediation. Plant and its associated bacteria, such as endophytic bacteria and rhizosphere bacteria play a major part in the degradation of poisonous chemicals in its contaminated site through traditional treatment technology. Phytoremediation is considered as a traditional treatment technology using plants, but the major disadvantage of this technology was its slow process, but the introduction of dye degrading bacteria in the root zone area will increases the growth of plants, enzyme activity, degradation efficiency. This treatment technology looks truly encouraging being a sun powered and profitable in view of low support and irrelevant prerequisites (Cluis 2004; Ma et al. 2011). By several plant – microbe interaction studies proved that these technology will provide better results which definitely help to improve the waste land area in to beautiful avenues (Khandare et al. 2013). *Typha latifolia* plants and other aquatic macrophyte *Eichhornia crassipus* have showed efficiency in the removal of metals in the water bodies with textile effluents (Dipu et al. 2011). So the combination of plant – microbe process showed an extremely high sensible achievability to discover the application in the disposal of synthetic dyes.

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