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REVIEW ARTICLE

Phytoremediation: Potential flora for synthetic dyestuff metabolism

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Abstract Dumping of dye-laden effluents into different environmental compartments adversely affects equilibrium and integrity of ecological systems. Being genotoxic, mutagenic and carcinogenic these dyes are quite damaging to health of biota (either aquatic or terrestrial). Many of these dyes are resistant to degradation and remediation under natural conditions and through conventional treatment methods. This situation has necessitated the development of effective and efficient wastewater treatment strategies without further stressing the environment and endangering other life forms. To date many biological systems including microorganisms and plants have been assessed for metabolism of dyestuffs. Phytoremediation catalyzed by natural solar driven pumps (green plants) and their associated metabolic processes has emerged as a comparatively new approach and has proven to be one of the most effective environmental friendly strategies for removal, detoxification and decolorization of dyes. Hence, this review quotes the literature of applied aspects of various plant species and their inherent metabolic as well as extractive potentials which enable them to effectively deal with various coloring agents.

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Contents

1. Introduction

Since antiquity humans are interfering and interacting with natural environment for their survival and well-being. The nature and extent of these interactions and interferences in natural processes have a profound impact on the environment and in turn on the human well-being as well. Water, for instance, is one of the essential natural resources for sustenance of life. About 97% of water covers the planet earth as sea water, which is unusable for drinking purposes because of elevated concentrations of salt while remaining 3% is found as freshwater, most of which (79%) is locked up in the form of glaciers and polar ice caps, only 21% of freshwater reserves is available as groundwater (20%) or accessible surface water (1%) for human use. However, with the passage of time, these existing freshwater resources are becoming contaminated and subsequently scarce due to anthropogenic and industrial activities (Research priorities for earth science and public health, 2007; Reddy and Lee, 2012). Moreover, exponentially growing population and progressing industrialization are putting more demands on these dwindling water reserves, thus making it unavailable in various parts of the world, for example, it has been reported that approximately 80% of population is facing water security threats all over the globe (Schwarzenbach et al., 2006; Vörösmarty et al., 2010).

Among anthropogenic and industrial activities, dumping of dye containing effluents originating from various industrial operations (such as dyestuff manufacturing units and dyeing processes) into water pools and surrounding industrial areas is of major concern (Moosvi et al., 2005; Abo-Farah, 2010; Mugdha and Usha, 2012). Application of dyes in a variety of industrial processes including paint and pigment manufacturing, pulp and paper processing, leather tanning, textile dyeing etc. results in the generation of highly colored wastewater (with considerably different volume and effluent composition containing a variety of synthetic dyes) where subsequent dumping of such dye containing effluents into water pools adversely affects ground and surface water resources, and soil properties as well (Sen and Demirer, 2003; Moosvi et al., 2005; Sandhaya et al., 2005; Abo-Farah, 2010). Hence these circumstances have necessitated the development of effective and efficient water treatment strategies for recycling and replenishment of these valuable water resources (Mugdha and Usha, 2012). This article attempts to reconnoiter and evaluate the potential applicability of phytoremediation techniques for decolorization and/or degradation of color rich effluents as an economic, feasible and publically acceptable alternative in comparison to conventional techniques.

2. Dyes and their classification

Complex aromatic compounds that are utilized for coloration of various substrates like fabrics, papers, leather etc. are termed as dyes. Natural dyes, extracted from plant or animal sources, are used in the coloring of food stuff, leather and natural protein fibers such as silk, cotton and wool. However, the provision of narrow or dull range of colors along with exhibition of low color fastness on exposure to washing and sunlight has limited their applicability (Maddhinni et al., 2006; Samanta and Agarwal, 2009; da-Silva et al., 2010). Conversely, aromatic compounds produced via chemical synthesis, termed as synthetic dyes, provide a wide range of colors that are colorfast and bright as well (Kant, 2012). These dyes contain aromatic rings in their chemical structure that in turn hold delocalized electrons along with different functional groups attached to them. The auxochrome groups (as electron donors) are responsible for dyeing capacity while chromogene chromophore (as electron acceptors) imparts color to these dyes. The major chromophoric groups include –C═C–, –C═O, –C═N–, $–NO_2$, –N═N– and quinonoid rings while auxochromic groups include –COOH, –OH, $–SO_3H$, and $–NH_2$ etc. (Carmen and Daniela, 2012; Singh et al., 2012).