Chapter 16
Microbial Degradation of Azo Dyes:
The Role of Azoreductase to Initiate Degradation

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ABSTRACT

Azo dyes are considered as xenobiotic compounds, which are often recalcitrant to be biodegraded. Many dyes are relevant for staining in industries, especially textile and food related. Among other environmental problems, one obvious issue is the coloring effect on effluents from industrial sites and thus the release of xenobiotics into nature. Microorganisms (algae, fungi, yeast, and bacteria) have been found to decolorize a number of azo dyes. Decolorization of azo dyes by microbial cultures is summarized and this is mostly linked to initial activation or even cleavage of the azo bond (e.g., by azoreductases). However, it does not necessarily mean that the compound is degraded to non-toxic products. Various mechanisms of microbial decolorization processes were discovered, including adsorption, enzymatic degradation, or a combination of both. Oxidases and reductases were found to be involved, which contain azoreductase, lignin peroxidase, Mn peroxidase, laccase, tyrosinase, and so on. A focus is on the azoreductases including classification, activity, and applicability.

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INTRODUCTION

Dyes and Their Application

Dyes are natural or chemical substances, which can impart colors to various materials. Mankind has a long history to use dyes. The earliest written record about the dyeing with plants, barks and insects was found in China 2600 BC (Bafana *et al.,* 2011). Also, tyrian purple was described as early as about 1500 BC, and is still known as the color of nobility (McGovern & Michel, 1985). Dyes were initially made from natural plants or animal products. However, William Henry Perkin introduced the world's first synthetic dye in 1856, marking the start of dye manufacturing industry (Bafana *et al,.* 2011). Compared to natural dyes, synthetic dyes are cheaper to produce, easier to apply, and could provide more abundant colors. This is why these synthetic dyes are now widely used in textile, print, food, cosmetics and pharmaceutical industries.

In 1876, Otto Witt developed a theory that a colored dye should have a chromophore group and an auxochrome group. Chromophores are capable of absorbing light in the visible region (e.g. nitro, azo, quinoid groups), while auxochromes deepen the color when introduced into a colored molecule (e.g. -COOH, -OH, $-SO_3H$ and $-NH_2$). However, Witt's theory was later replaced by the modern electronic theory. According to this theory, color is from the excitation of valance π electrons by visible light (Murrell, 1973). Generally, dyes are classified according to two aspects: chemical composition and application class (Garfield, 2002). In terms of chemical composition, it can be divided into azo, nitro, nitroso, diarylmethane, triarylmethane, xanthene, anthraquinoid, acridine, cyanine, quinoneimine, pthalocyanine and thiazole dyes. Alternatively, based on the application method, dyes can also be divided into acid, azoic, basic, direct, disperse, mordant, reactive, sulfur and vat dyes (Booth *et al.,* 2000). Some typical dyes applied in industries and research are presented in Figure. 1.

Textile Industry: An Overview of the Problem

The textile industry contributes a part in world economy and to a country's growth as it generates more income and wages for people. It leaves a significant trail, with each step of the process causing more environmental problems. It primarily utilizes large volumes of water and chemicals for desizing, scouring, bleaching, dyeing, printing, and finishing. These chemicals vary from inorganic materials to polymers and organic products (Banat *et al.,* 1996). Among these chemicals, a large number can be attributed to dyes as 10,000 different dyes, with a yearly production of more than $7x10^5$ metric tons, are just used for dyeing and printing (McMullan *et al.,* 2001) and 5 to 10% are released with wastewater (Alalewi & Jiang, 2012).

One of the most significant environmental problems is the presence of color in water courses. Though some of the colors in the aquatic ecosystem are product of biological activities, a considerable amount can be pointed out to industrial effluents (Alalewi & Jiang, 2012). A trace concentration of it is highly undesirable as it leads to aesthetic pollution, eutrophication and perturbation in the aquatic ecosystem. Their presence and by-products are not removed easily by conventional treatments (Kurade *et al.,* 2011).

The synthetic dyes are already recognized as toxic around the globe and more natural dyes enter the market (Kant, 2012).