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Recent advances based on the synergetic effect of adsorption for removal of dyes from waste water using photocatalytic process

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A B S T R A C T

The problem of textile dye pollution has been addressed by various methods, mainly physical, chemical, biological, and acoustical. These methods mainly separate and/or remove the dye present in water. Recently, advanced oxidation processes (AOP) have been focused for removal of dye from waste water due to their advantages such as ecofriendly, economic and capable to degrade many dyes or organic pollutant present in water. Photocatalysis is one of the advance oxidation processes, mainly carried out under irradiation of light and suitable photocatalytic materials. The photocatalytic activity of the photocatalytic materials mainly depends on the band gap, surface area, and generation of electron–hole pair for degradation dyes present in water. It has been observed that the surface area plays a major role in photocatalytic degradation of dyes, by providing higher surface area, which leads to the higher adsorption of dye molecule on the surface of photocatalyst and enhances the photocatalytic activity. This present review discusses the synergic effect of adsorption of dyes on the photocatalytic efficiency of various nanostructured high surface area photocatalysts. In addition, it also provides the properties of the water polluting dyes, their mechanism and various photocatalytic materials; and their morphology used for the dye degradation under irradiation of light along with the future prospects of highly adsorptive photocatalytic material and their application in photocatalytic removal of dye from waste water.

Contents

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Introduction

Environmental pollution is one of the greatest problems the world is facing today, increasing with every passing year and causing serious and irreparable damage to the earth. Environmental pollution consists of three basic types of pollution, namely: air, water, and soil (Legrini et al., 1993; McLaren and Williams, 2015). Among these, the causes of water pollution are industrial discharge, excess use of pesticides, fertilizers in agriculture sector, pharmaceutical residue, and landfilling of domestic waste (Lianos, 2011). Various organic compounds such as solvents, dioxins, dibenzofurans, pesticides, polychlorinated biphenyls (PCBs), chlorophenols, and dyes are found in the contaminated water (Reddy and Kim, 2015; Nguyen and Juang, 2015; Shinde et al., 2014; Jo and Tayade, 2014a). These dyes are serious contributors to pollution as the most of the industries use dye and their industrial waste water discharge contains large amount of dye (Jo and Tayade, 2014b). Some of the dyes are often difficult to decompose in water as they have composite molecular structures that turn them to be more stable toward light and resistant to biodegradation (Mckay, 1979).

The use of natural dye for textile dyeing has been practised since the last 5000 years. The discovery of synthetic dyes was stated in 19th century, which has suppressed the use of natural dye. The synthetic dyes can be produced largely and can be utilized in various industries such as fabrics, leather, paper, food, cosmetics, agricultural research, pharmaceuticals, electroplating, and distillation. They can be grouped into different classes: acid, basic, direct, disperse, metallic, mordant, pigment, reactive, solvent, sulphur and vat dyes, which reflect their macroscopic behaviour and also their prevailing functionalities. More than one lakh commercial dyes are currently available in the market and throughout the world more than 7×10^5 tons of dyestuff are produced annually (Ajmal et al., 2014). It is estimated that 10–15% of dyes are lost in wastewater during manufacturing and application processes (Natarajan et al., 2013a).

A variety of synthetic dyestuffs released by various industries pose a threat to environment and public health. The contamination in wastewater due to the dyes can be recognized quite easily as a very small amount of synthetic dye in water (<1 ppm) are highly visible, affecting the aesthetic merit, transparency of water bodies. They adsorb and reflect the sunlight entering water, thereby interfering with the aquatic species growth and hindering photosynthesis. Additionally, they can have acute and/or chronic effects on organisms depending on their concentration and length of exposure. So the degradation of dyes from the wastewater is the major concern toward environmental pollution abatement.

A wide range of technologies has been developed for the removal of dyes from waters and wastewaters to decrease their environmental impact. These methods can be classified into four categories: (1) Physical (2) Chemical (3) Biological and (4) Acoustical, Radiation and Electric processes (Gupta and Suhas, 2009). Various methodologies such as sedimentation (Cheremisinoff, 2002), filtration (microfiltration, ultrafiltration, nanofiltration and reverse osmosis) using various types of membranes (Avlonitis et al., 2008; Linsebigler et al., 1995; Marmagne and Coste, 1996; Al-Bastaki, 2004), chemical treatments (coagulation and filtration) (Shi et al., 2007; Zhou et al., 2008), oxidation (chemical oxidation and ultraviolet (UV) assisted oxidation using chlorine, hydrogen peroxide, fenton's reagent, ozone, or potassium permanganate) (Namboodri et al., 1994; Hage and Lienke, 2006; Wang, 2008), electrochemical (electro-oxidation, electro-coagulation, and electro-degradation) (Dogan and Turkdemir, 2005), advanced oxidation process (photo-fenton's reagent oxidation, ultraviolet oxidation, photocatalysis, photolysis and sonolysis) (Bandala et al., 2008; Aguedach et al., 2005; Hong et al., 1999; Maezawa et al., 2007), and biological (aerobic, anaerobic, combined aerobic and anaerobic treatments) (Barragan et al., 2007; Rai et al., 2005; Delee et al., 1998) fall under the above mentioned categories. In addition to this, adsorption process has been also widely used for the removal of dyes from the waste water (Bansal and Goyal, 2005; Danis et al., 1998).

Physical methods such as membrane-filtration processes (nanofiltration, reverse osmosis, electrodialysis) and sorption techniques; chemical methods such as coagulation or flocculation combined with flotation and filtration, precipitation flocculation, electro-flotation, and electro-kinetic coagulation found to be suitable for the removal of various dyes. These methods do not degrade the dye but only decrease the dye concentration in water bodies by converting it from one form to another, thereby creating secondary pollution. Also, biological methods such as aerobic and anaerobic microbial degradation, and the use of pure enzymes were also reported in literature for dye removal from waste water. The disadvantages of the biological methods are that they are time consuming, even some dyes are resistant to aerobic treatment. It has also been reported that the production of carcinogenic compounds such as aromatic amines can occur during the anaerobic treatment of dyes (Freeman, 1989).

In the recent past, advanced oxidation processes have gained much attention for the removal of pollutant from waste water. These processes are ecofriendly, economic, and capable to degrade many dyes or organic pollutants present in waste water. These advanced oxidation processes were carried out in the presence of solar and ultraviolet irradiation.