GREEN CHEMISTRY FOR DYES REMOVAL FROM WASTE WATER

Research Trends and Applications

Edited by

Sanjay K. Sharma

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100 Cummings Center, Suite 541J
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Publishers at Scrivener
Martin Scrivener(martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

This book is for Kunal – Kritika....my twin angels on their 15th Birthday, with love.

Preface

Writing a preface for a book always has been a challenge as things are to be looked upon not only from the eyes of an editor, but also from a reader's perception and expectations; all the while keeping in mind not to do any injustice to the zeal of a contributor who has worked so hard to pen the text.

"Green Chemistry" two decade's old philosophy, has been attracting the attention of scientists worldwide. Academicians as well as industrialists are equally interested in this *new* stream of chemical science. Researchers, all over the world, are conducting active research in different fields of engineering, science and technology by adopting green chemistry principles and methodologies to devise new processes with a view towards helping, protecting, and ultimately saving the environment of our planet from further anthropogenic interruptions and damage. Achieving sustainability and renewability of resources is the basic spirit of green chemistry; it inspires us to try alternative "green" approaches in place of traditional "gray" practices in everyday industrial and scientific activities.

Water pollution is a matter of great concern. It's quality and potability is equally important for both domestic purposes and industrial needs. But, at the same time, industrial effluents pollute the available water resources. Dyes, as one of the pollutants, cause various serious health hazards and socioeconomic problems. It spoils the "productivity" of soil; which in turn may be the reason for other related issues, especially in developing countries. Removal of dyes from water or wastewater is therefore an important task. But, removing dyes at a cost to the environment should be avoided when considering which technique to use. So, the far important challenge is to make a removal technique sufficiently "green."

Water pollution is often discussed with respect to various pollutants and their treatments, but water pollution due to the presence of synthetic dyes has not been discussed sufficiently in the literature. So, the treatment of wastewater produced from industries using dyes (directly or indirectly)

has tremendous scope worldwide. That is why dye removal is an important issue which needs to be addressed seriously.

The chapters in this book are the outcome of the scholarly writing of researchers of international repute with stellar credentials, who have tried to present an overview of the problem and its solution from different angles. These problems and solutions are presented in a genuinely holistic way using valuable research-based text from world-renowned researchers. Discussed herein are various promising techniques to remove dyes, including the use of nanotechnology, ultrasound, microwave, catalysts, biosorption, enzymatic treatments, advanced oxidation processes, etc., all of which are "green." The book contains eleven chapters, all of which focus on the theme of green chemistry and discuss tools and techniques which are eco-friendly, non-hazardous and, moreover, low waste generating.

The textile industry produces a large amount of dye effluents which are highly toxic as they contain a large number of metal complex dyes. The use of synthetic chemical dyes in various industrial processes, including paper and pulp manufacturing, plastics, dyeing of cloth, leather treatment and printing, has increased considerably over the last few years, resulting in the release of dye-containing industrial effluents into the soil and aquatic ecosystems. The textile industry generates highly polluting wastewaters and their treatment is a very serious problem due to high total dissolved solids (TDS), presence of toxic heavy metals, and the non-biodegradable nature of the dyestuffs present in the effluent. There are many processes available for the removal of dyes by conventional treatment technologies including biological and chemical oxidation, coagulation and adsorption, but they cannot be effectively used individually. Different types of dyes, their working and methodologies and various physical, chemical and biological treatment methods employed so far are comprehensively discussed in Chapter 1.

Adsorption is widely acknowledged as the most promising and efficient method because of its low capital investment, simplicity of design, ease of operation, insensitivity to toxic substances and ability to remove pollutants even from diluted solutions. In recent years, nanotechnology has introduced a myriad of novel nanomaterials that can have promising outcomes in environmental cleanup and remediation. Particularly, carbon-based nanomaterials such as carbon nanotubes and graphene are being intensively studied as new types of adsorbents for removal of toxic pollutants from aquatic systems. This extraordinary interest stems from their unique morphology, nanosized scale and novel physicochemical properties. Thus, Chapter 2 focuses on the use of nanotechnology in the treatment of dye removal.

Textile dyeing industries expend large volumes of water, which is ultimately discharged with intense color, chemical oxygen demand (COD), suspended/dissolved solids and recalcitrant material as unfixed dye residuals and spent auxiliaries. A typical reactive dyebath effluent contains 20–30% of the input dye mass (1500–2200 mgL^{-1}) and traces of heavy metals (i.e., cobalt, chromium and copper) that arise from the use of metal-complex azo dyes. The challenge to destroy dye residuals in biotreated wastewater effluents seems to be resolved by the introduction of advanced oxidation processes (AOP), whereby highly reactive hydroxyl radicals are generated chemically, photochemically and/or by radiolytic/sonolytic means. Hence, AOPs not only offer complete decolorization of aqueous solutions without the production of huge volumes of sludge, but also promise a considerable degree of mineralization and detoxification of the dyes and their oxidation/hydrolysis byproducts. The potential of ultrasound as an AOP is based on cavitation phenomenon, i.e., the formation, growth and implosive collapse of acoustic cavity bubbles in water and the generation of local hot spots with very extreme temperatures and pressures. Application of AOPs in dye removal is comprehensively discussed in Chapters 3 and 7.

The heterogeneous photocatalysis process has shown huge potential for water and wastewater treatment over the last few decades. Chapter 4 summarizes the photocatalytic oxidation process for dye degradation under both UV and visible light, application of solar light and solar photoreactor in dye degradation, and then finally discusses the dependence of different parameters (pH, photocatalyst loading, initial dye concentration, electron scavenger, light intensity) on dye degradation.

Several technologies have been developed to treat dye-containing effluents (DCEFs) such as coagulation-flocculation, filtration, sedimentation, precipitation-flocculation, electrocoagulation-electroflotation, biodegradation, photocatalysis, oxidation, electrochemical treatment, membrane separation, ion-exchange, incineration, irradiation, advanced oxidation, bacterial decolorization, electrokinetic coagulation and adsorption on activated carbon. From an industrial viewpoint, no single process provides adequate treatment, being that significant reduction of expenses and enhancement of dye removal can be achieved by the combination of different methods in hybrid treatments. "Biosorption" can be employed to treat DCEFs because it combines the advantages of adsorption with the use of natural, low-cost, eco-friendly and renewable biosorbents. Biosorption of organic dyes and related research opportunities and challenges are beautifully discussed in length in Chapters 5 and 8.

The enzymatic process using ligninolytic enzymes, such as laccases and peroxidases, is a relatively new emerging technology for the degradation of xenobiotics, including synthetic dyes in textile wastewater. This unique process employs a hybrid of chemical and biological oxidation using a combination of crude or purified enzymes from plant materials or fungal cultures as a biocatalyst and dissolved molecular oxygen or hydrogen peroxide as a chemical oxidant. This enzymatic process has a number of advantages over conventional physical, chemical and biological processes. Chapter 6 provides a comprehensive literature review on the enzymatic treatment of various synthetic dyes and discusses the recent progress and challenges associated with this technology. In addition, the fungal treatment of synthetic dyes and contaminated effluents, as well as the enzymology of the key ligninolytic enzymes, are covered in this chapter to explore the important roles of fungal enzymes in synthetic dye decolorization.

Adsorption is one of the best treatment methods due to its flexibility, simplicity of design, and insensitivity to toxic pollutants. Recently, clay and its modified forms have been used as adsorbents, and there has been an upsurge of interest in the interactions between dyes and clay particles. Clay may serve as an ideal adsorbent because of its low cost. It has relatively large specific surface area, excellent physical and chemical stability, and other advantageous structural and surface properties. Use of clay (especially three-layer clays) as adsorbent has been elaborately presented by Tolga Depci and Mehmet S. Çelik in Chapter 9.

Chapter 10 is about non-conventional adsorbents including clays, siliceous materials, zeolites, agricultural solid wastes, industrial byproducts, peat, chitin and chitosan, biomass, starch-based derivatives and miscellaneous adsorbents.Their effectiveness as an alternative green approach for the removal of dyes from wastewater and industrial effluents is discussed.

Hen feather is an abundantly available waste material found at poultry houses. It possesses marvelous and proficient structures, which are flexible as well as strong. Hen feather is composed of keratin and is biochemically similar to the substance responsible for creating the fur of mammals, scales of reptiles, horns of animals and fingernails of humans.

It is now well established that hen feather can be used as a potential adsorbent for the removal of hazardous pollutants. Before the year 2006, the use of hen feather as adsorbent was limited to the removal of metal ions only. However, in an innovative initiative first made by Alok Mittal and Jyoti Mittal, it was found that hen feather can also be exploited as a dye scavenger for wastewater. Chapter 11 summarizes the results of the removal of dye contaminants from water using hen feather as an adsorbent. The chapter provides comparable consequences of the effects of various parameters

influencing the adsorption, various adsorption isotherms, kinetics, etc., of the developed dye removal processes.

The main outcome of reading this book will be that the reader is going to have a holistic view of the immense potential and ongoing research in dye removal by green chemistry, and its close connection with modern research and engineering applications. Furthermore, this book can be used as an important platform to inspire researchers in any related fields to develop greener processes for important techniques for use in several fields.

I gratefully acknowledge all the contributors of this book, without whom these valuable chapters could not have been completed. I express my highest gratitude and thankfulness to all of them.

Sanjay K. Sharma, FRSC
Jaipur, India
1st January 2015

Acknowledgements

When you complete a task and take time to rewind your journey and relive it through memories, you find some smiling and encouraging faces that have motivated you to complete the task with untiring efforts to your full ability. Such smiling faces remove the pain of stress which we occasionally face during any journey and encourage us to "Go ahead." They deserve a special mention and gratitude, love and affection.

It is time for me to express my feelings about my friends, colleagues, supporters and well- wishers and to let them know that I was so fortunate to have them and their valuable cooperation during the writing of this book, *Green Chemistry for Dye Removal from Wastewater: Research Trends and Applications.*

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About the Editor

Prof. (Dr.) Sanjay K. Sharma is a very well-known author and editor of many books, research journals and hundreds of articles over the last twenty years.

Presently Prof. Sharma is working as Professor and Head of the Department of Chemistry, JECRC University, Jaipur, India, where he is teaching Engineering Chemistry and Environmental Chemistry to B. Tech Students; Green Chemistry, Spectroscopy and Organic Chemistry to undergraduate and post-graduate students; and pursuing his research interest in the domain of Green Chemistry with special reference to Water Pollution, Corrosion Inhibition and Biopolymers.

Dr. Sharma has had 16 books published on Chemistry by national-international publishers and over 61 research papers of national and international repute to his credit.

He has also been appointed as a Series Editor by Springer, UK, for their prestigious book series "Green Chemistry for Sustainability," where he has been involved in editing 14 different titles by various international contributors so far. Dr. Sharma is also serving as Editor-in-Chief for the *RASAYAN Journal of Chemistry*

He is a Fellow of the Royal Society of Chemistry (UK), member of the American Chemical Society (USA), and International Society for Environmental Information Sciences (ISEIS, Canada) and is also a life-time member of various international professional societies including the

International Society of Analytical Scientists, Indian Council of Chemists, International Congress of Chemistry and Environment, Indian Chemical Society, etc.

drsanjay1973@gmail.com
sk.sharmaa@outlook.com

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