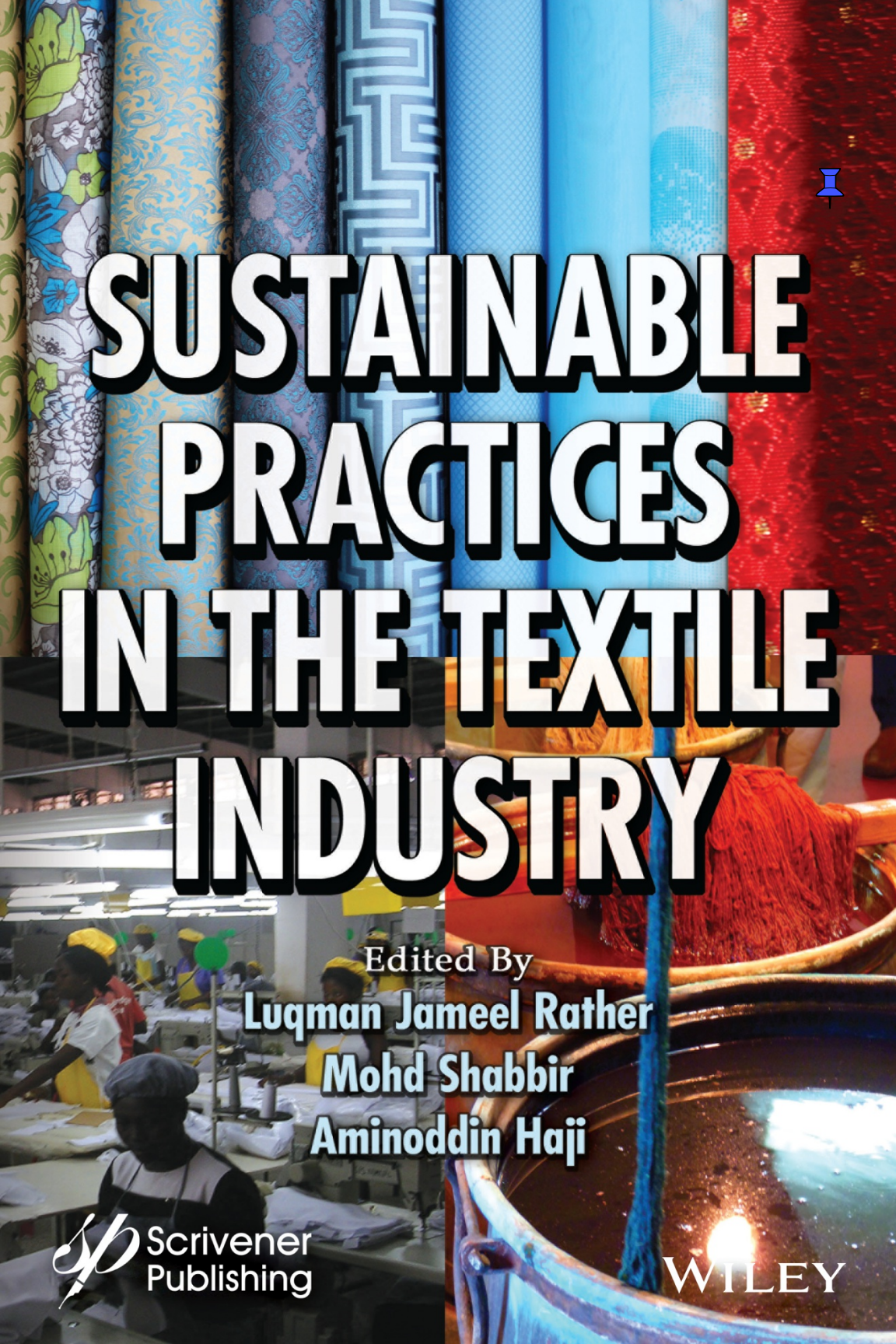
SUSTAINABLE PRACTICES IN THE TEXTILE INDUSTRY
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Scrivener Publishing
WILEY

Sustainable Practices in the Textile Industry

Scrivener Publishing
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Beverly, MA 01915-6106

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This edition first published 2021 by John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA and Scrivener Publishing LLC, 100 Cummings Center, Suite 541J, Beverly, MA 01915, USA

For more information about Scrivener publications please visit www.scrivenerpublishing.com.

Wiley Global Headquarters
111 River Street, Hoboken, NJ 07030, USA

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Library of Congress Cataloging-in-Publication Data

ISBN 978-1-119-81888-5

Cover image: Pixabay.Com
Cover design Russell Richardson

Set in size of 11pt and Minion Pro by Manila Typesetting Company, Makati, Philippines

Printed in the USA

10 9 8 7 6 5 4 3 2 1

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Preface

In recent years, the textile industry has been the focus of rising interest in global markets due to varied and changing world market conditions. Increasing environmental and health concerns owing to the use of large quantities of water and hazardous chemicals in conventional textile finishing processes, has led to the design and development of new dyeing strategies and technologies. Effluents produced from the textile wet processing industry are very diverse in chemical composition, ranging from inorganic finishing agents, surfactants, chlorine compounds, salts and total phosphate to polymers and organic products. This has forced Western countries to exploit their high technical skills for the advancement of textile materials with high quality technical performances, and the development of cleaner production technologies for cost-effective and value-added textile materials. *Sustainable Practices in the Textile Industry* is a collection of the current sophisticated ways used to minimize the use of bioresource products to improve dye extraction and dyeing properties. Highlighted in this book are the innovative ways in which wet chemical processing methods are used to alleviate the environmental impacts arising from this sector. The major challenge in the textiles and fashion sector is that it requires massive sustainable innovation in terms of material and end-use products to mitigate the huge environmental impacts arising from chemical processing. Therefore, this book also contains innovations in eco-friendly methods for textile wet processes and applications of enzymes in textiles in addition to advancements in the use of nanotechnology for wastewater remediation.

The book is compiled of 13 chapters from various research areas dealing with the application of different sustainable technologies for enhancing the dyeing and comfort properties of textile materials with substantial reduction in wastewater problems. Chapter 1 deals with the sustainable extraction of natural dyes from plant sources and their subsequent applications in the textile industry. Chapter 2 deals with the advancements in non-aqueous dyeing systems. Chapter 3 gives a brief account of structural coloration of different textiles achieved as a result of scientific observations

of nature. Chapter 4 deals with the use of enzymes for enhancing dyeing properties of different textiles. Chapter 5 deals with the use of sustainable processes for textile coating. Chapters 6 through 8 give a detailed account of the functional finishing properties achieved on different textiles using different dyeing methods with natural and synthetic functional finishing agents. Chapter 9 provides up-to-date information regarding sustainable development for brands and manufacturers in the textile industry. Finally, the remaining Chapters 10 through 13 deal with the advanced techniques used for wastewater remediation.

The authors who contributed to this book are specialists in fields involved in using different dyeing systems other than aqueous solvent, employing enzymes in dyeing procedures, surface modifications, sustainable developments for textile manufactures, functional finishing and different advanced techniques for wastewater remediation. Thus, the editors hope that students, researchers and academicians of various fields, such as textile dyeing, chemical engineering, environmental science, materials science among others, will find this book of great interest and useful in their curriculum. We expect it will definitely be helpful for engendering new ideas in textiles research, leading to interdisciplinary research collaborations.

Now the time has come to thank those who supported this book in any way. We acknowledge the great efforts of the eminent authors without whom this book would have been unimaginable. We also appreciate the interest shown and the support given by the publisher, which allowed us to compile this reference book.

Luqman Jameel Rather
Aminoddin Haji
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Part 1

SUSTAINABLE DYE EXTRACTION AND DYEING TECHNIQUES

1

Extraction and Application of Natural Dyes

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Abstract

Environmental pollution and population explosion are becoming the world's biggest issues. Eco friendly products and practices are popularizing day by day due to present national and international awareness on environmental situations. Textile industries are one of the reasons of environmental pollution and affect all forms of life adversely. Textile dyeing process generally uses chemical dyes and synthetic mordants. Chemicals in the dyeing process began with the discovery of "Mauve" by WH Perkin in 1856. These synthetic dyes are manufactured from coal tar, petrochemicals and many other chemicals, which cause allergies such as contact dermatitis, respiratory diseases, skin irritation and cancer etc. Naturally dyed textile materials are in demand globally because of harmful effects of chemical dyeing and continuous efforts of researchers in this field. Natural dyes can be obtained from natural resources like plants, minerals, insects and fungi but most of the dyes are taken from plant parts i.e. leaves, barks, flowers, fruits and roots. Natural dyes have some special properties like soothing color, biodegradable, non-hazardous, non-carcinogenic and antimicrobial resistance etc. Natural dye extraction process requires plant parts and sometimes their by-products as a raw material. Natural dyeing practices enhance the cultivation of flowering crops, which provides an extra source of income to farmers. Thus, large scale production of naturally dyed fabric in future will solve the problem of human as well as environmental health.

***Keywords*:** Natural dyes, source, fiber, mordant, dyeing, fastness, antibacterial, UV-protection

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Luqman Jameel Rather, Mohd Shabbir and Aminoddin Haji (eds.) Sustainable Practices in the Textile Industry, (3–42) © 2021 Scrivener Publishing LLC

1.1 Introduction

In the present scenario people are more inclined to be nature-friendly, health conscious and become aware about the environment. The meticulous environmental standards are being imposed by many countries in response to the toxic and allergic reactions associated with synthetic dyes. It has created a revolution in research and development in eco-friendly and non-toxic colorant. Environmental considerations are now becoming vital factors during the selection of consumer goods including textile as well as in cosmetic, pharmaceutical and food industry all over the world. Coloring agent or dyes play an important role in all these industries during manufacturing and other production process. Both qualitative and quantitative research investigations have been undertaken all over the world on safe coloring substance. Natural dyes are widely used in following application (Figure 1.1):

a. Textile Coloration
Coloring of textile material is called dyeing. Dyeing is a process to enhance the beauty of fiber or fabric by coloring them. The coloring compounds can be synthetic or natural and capable of being fixed to fabric defined as dye. India is a diverse country of region and culture. Dyeing practices varied immensely due to availability of local dye-yielding plants and minerals, the natural sources. Until year 1856, these natural sources were used in coloring but with the discovery of chemical dyes, the use of natural dyes decreased. The side effects of the continuous use of chemical dyes gradually began to

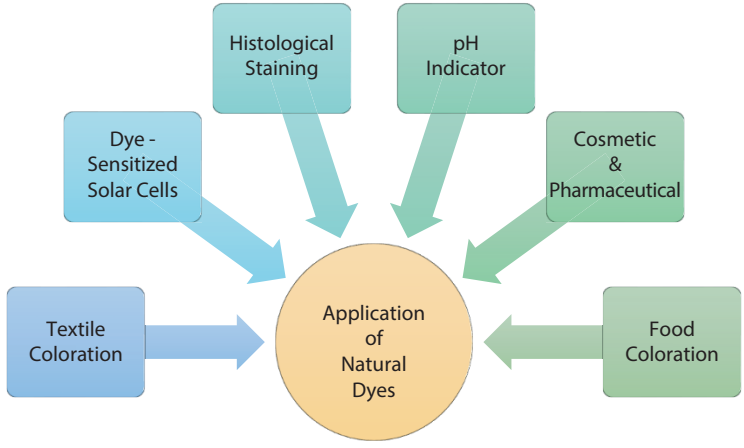

Figure 1.1 Schematic representation of applications of natural dyes.

appear as health problems and skin diseases that resulted by wearing synthetic dyed fabric for decades. Hazardous chemicals were used in the manufacture of dyes in large scale for rapid growth of textile industries. All those synthetic, hazardous chemicals disposed of in nature after dye preparation, coloring and printing, which ultimately created various pollution problems in the environment. Keeping this situation in mind, many experiments are being done by scientists and researchers for the development of new sources and techniques of natural colors, so that it can be adopted by textile industries on a large scale. There is an increasing awareness among humans about their health and nature, due to which the demand for eco-friendly clothes is also increasing. Natural clothes can be obtained at a higher price from some small scale industries and handlooms, but they are not able to meet the demand of all people. In the past few years, many research works related to natural dye have been done. In this chapter, an attempt has been made to exhibit how natural dyes are used on clothes and their significance for human health and nature.

b. Food Coloration

Human appetizer and choice of food are influenced by color. Food colors are used in processed food, drinks and condiments. They are often added to maintain and improve the appearance of the food. The addition of saffron, turmeric and other spices are reported from ancient times. Commercially available colors are made of chemicals that can be harmful to human and environment. Therefore, natural food colors are in demand again. Most commonly used natural food dyes are saffron, turmeric, annatto, beetroot and carrot etc.

c. pH Indicator

pH is measure of relative amount of free hydrogen and hydroxyl ions in water. The range of pH is in between 0 and 14, where 7 is considered neutral. pH greater than 7 indicates the base, whereas pH less than 7 indicates acidity. A pH indicator is a compound that changes color in solution over a narrow range of pH value. Small amount of indicator compound is sufficient to produce a visible color change. There are many colors of indicators in nature thus, influenced by change in pH range. Some of the natural dyes show color changes with variation of pH. Red cabbage dye is very good example of natural pH indicator [1].

d. Histology Staining

Study of the microanatomy of cells, tissue and organs is called histology. Observations of cells are performed with the help of a microscope. Staining is the technique to highlight and differentiate the structure of tissue. Stain

and dyes are applied in staining on tissue and cells. Dyes also can be used to color cells, tissue, organelles as well as microorganism such as bacteria and fungi [2]. Saffron, a natural dye extracted from *Saffron crocus* was the first stain in histology used by Antonie van Leeuwenhoek, the father of microbiology [3]. Hematoxylin stain is a naturally occurring dye found in Logwood tree widely used in histological study. Researchers also found *Punica granatum*, *Curcuma longa*, *Syzygium cumini* and *Sorghum bicolor* effective in staining [4–7].

e. Cosmetics and Pharmaceutical
Cosmetic products are used to clear, improve or change the complexion, skin, hair and nails. Colors or dyes are the most important ingredient in production of cosmetics. Henna is traditionally used for coloring hands and hair. Saffron and turmeric also examples of natural dyes utilized in cosmetics. In pharmaceutical field colors of medicine are used to differentiate the dosage. Imparting color to drugs helps in their distinctive appearance. The colorant employed in pharmaceuticals is considered safe such as beet root, paprika and annatto.

f. Dye-Sensitized Solar Cells
Dye-sensitized solar cell is third generation photovoltaic (solar) cell that converts any visible light into electrical energy. It is low-cost solar cell belonging to the group of thin film solar cells. Performances of dye sensitized solar cells are mainly based on dye used as a sensitizer [8]. Godibo *et al.*, attempted the preparation of Dye Sensitized Solar Cells using flowers of *Amaranthus caudatus*, *Bougainvillea spectabilis*, *Delonix regia*, *Nerium oleander*, *Spathodea companulata* and a mixture of the extracts [9].

In addition to the above mentioned applications, there is a growing interest for using natural dyes to dye leather, stain wood, pulp, some plastics [10–14]. This chapter intends to discuss the application of natural dyes in textile.

1.2 What are Natural Dyes?

Natural dyes can be derived from natural sources such as plants, animals and minerals. A large number of herbs, shrubs, trees, insects, animals, microbes and minerals have been identified for extraction of coloring compounds [15]. Red, yellow, brown, blue, black, green and orange color can be obtained from natural dyes.

1.3 Why Natural Dyes?

Natural dyes are recommended to be applied on textile materials. Following points support the use of natural dyes on a large scale.

1. Eco-friendly: Natural dyes are extracted from natural sources therefore they are environment safe.
2. Biodegradable: These dyes are capable of being decomposed by microorganisms.
3. Renewable: Replaced by the new material obtained from nature.
4. No health hazard/Non-toxic: Natural origin of these dyes makes them harmless.
5. Variety of shades: Varieties of color, shades and hues present in nature itself.
6. Soothing, soft and lustrous color: Natural dyes are soft and relaxing.
7. Utilization of waste material: Many agriculture waste products can be used in the dyeing process.
8. Antibacterial/UV Protective: Naturally dyed fabrics get special properties like antibacterial and UV protection.

As there are many advantages in using natural dyes but they also have some drawbacks:

1. Expensive: Natural dyes are expensive due to being limited in source.
2. Faded easily: Sometimes their poor attachment on fabric makes them fade easily.
3. Difficult to produce/collect: Collection is somewhat difficult in large amounts.
4. Time consuming: The complete process like collection of dye takes long time.
5. Reproducibility of shades is difficult to control: Natural dyes produced by secondary metabolic activities of plants or by very special processes in other animals, which depend on climate conditions, age and seasonal variations. Thus, one particular shade cannot be achieved again and again by a single dye.

1.4 What are Synthetic Dyes?

Synthetic dyes are made by organic molecules. They are derived from coal tar hence also known as coal tar dyes. William H Perkin synthesized "Mauve" the first synthetic dye in 1856 in the United Kingdom. Then, a significant number of dyes were discovered and industries quickly adopted them to grow, mainly in the United Kingdom, Switzerland and Germany [16].

The Sudan I (Solvent Yellow 14) is one of the members of azo-dyes widely used in textile industry [17]. It is enzymatically transformed, through the action of the intestinal flora, into carcinogenic aromatic amines, when present in the bodies of animals or humans [18]. In the case of azo-dyes, especially, carcinogenicity can be produced by both the dye itself and its own converted compounds [19]. The study of National Toxicology Program confirmed the neoplastic liver nodules in rats by the presence of Sudan I dye [20]. The Basic Red 9 dye, used in the textile, leather, paper and ink industries [21], develops carcinogenic potential in humans [22], and high toxicity to environment [23]. Under anaerobic conditions, it breaks down into carcinogenic aromatic amines, and when disposed in water bodies can cause allergic dermatitis, skin irritation, and cancer [24]. According to the *in vivo* tests on rats, it causes local sarcomas and tumors in the liver, bladder [25], mammary glands and hematopoietic system [26].

The Crystal Violet dye, shows an intense color [27], and is a member of the cationic triphenyl methane group, and is responsible for mitotic poisoning and abnormal accumulation of metaphases [28] as well as the *in vitro* clastogenic effects observed in Chinese hamster ovules [29], which induce chromosomal damage too [30]. According to Bharagava *et al.*, this powerful carcinogenic agent promotes fish tumors [28, 31] and hepatocarcinoma, reticular cell sarcoma in various organs, such as the vagina, uterus, ovary and bladder [32] as well as hardened gland adenoma and ovarian atrophy in rats. In humans, it is capable of generating respiratory and renal failure, chemical cystitis, skin irritation and digestive tract disorder [28].

Advantages/Merits of Synthetic dyes

1. Easy preparation.
2. Available in large numbers and quantities.
3. Quality of fast colors
4. Cost effective.

Disadvantages/Demerits of Synthetic dyes

1. Production on high temperature

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