

TEXTILES AND CLOTHING

Environmental Concerns and Solutions

Edited by **Mohd Shabbir**



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Preface

Counted among mankind's other basic needs, the fascination with textiles and clothing has resulted in a great amount of attention being invested in their evolution, which in turn has had a direct effect on environmental ecosystems. Due to current worldwide concern for these ecosystems, the impact that the manufacturing, finishing, and utilization of textile fibers has on the environment needs to be addressed. Since it is imperative that environmental rehabilitation occur, there is a demand for more sustainable green processes in the textile and clothing industry. Therefore, greater emphasis needs to be placed on research into eco-friendly processes particularly suited for this industry. With this goal in mind, all environmental aspects relating to the textile and clothing industry are discussed in this book.

Included in the 11 informative chapters herein are topics covering the correlation between the environment and the processing and utilization of textiles and clothing. Chapter 1 discusses the direct impact that the textile industry has on the environment. The hazardous environmental consequences that synthetic dyes used to color textiles have on the environment are highlighted in Chapter 2. Greener alternatives to dyeing are discussed in Chapters 3 through 5, and eco-friendly ways of finishing textiles are discussed in Chapters 6 and 7. Finally, solutions to address the environmental hazards associated with the textile industry are presented in Chapters 8 through 11.

Textiles and Clothing: Environmental Concerns and Solutions is a book that will definitely be helpful in achieving a more sustainable textile industry, and researchers from both textile and environmental domains can benefit from reading it.

In conclusion, this is the perfect opportunity for me to thank all the eminent authors for their contributions to this book. I am very sure that the readers will benefit from their insights. I also wish to express my appreciation to my

colleagues for their invaluable suggestions and to my family for their moral support. In particular, I would like to express my gratitude and appreciation to Scrivener Publishing for agreeing to the compilation of this book.

Dr. Mohd Shabbir

March 2019

Introduction to Textiles and the Environment

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Abstract

The textile industry highly influences the environment, whether it is due to dyeing or manufacturing of the textiles, and it is considered as the number one pollutant after agriculture. Clothing is a basic need for everyone, and a lot of choices are there when it comes to clothing. Huge consumption of water and discharging of effluents from textile manufacturing and dyeing units lead to environmental hazards. Recent past evidences of increased awareness about ecofriendly techniques and products for textiles industry, supplement the research motivation towards ecofriendly textiles. This chapter is about the relationship of textiles and the environment and describes the various aspects of industrial effects on the environment.

Keywords: Textiles, environment, effluents, dyeing, water

1.1 Introduction

Textiles play an important role in human life and are considered as a basic need along with food and shelter. With the population explosion and varied choices of human beings, the textile industry is pressured to produce more to meet the current demands. The textile industry is known for its high effluent production and for creating environmental pollution. Textile production starts from fiber manufacturing and processing and ends with finishing them to make them wearable to humans. All the steps involve

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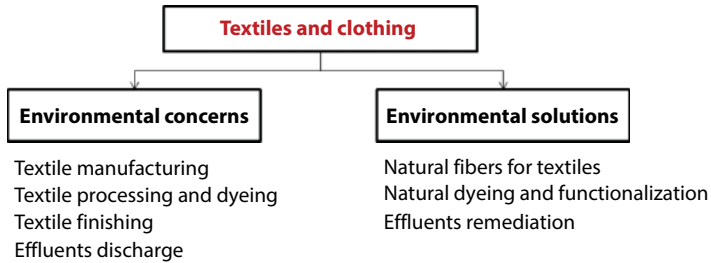


Figure 1.1 Processes responsible for environmental concerns and solutions in the textile industry.

utilization of water and other chemicals that may be hazardous to the environment and mankind. This direct relation of the textile industry and environment is a great concern to textile chemists as well as to environmental chemists.

Environmental protection nowadays is being implemented as an administrative philosophy. Rapid degradation in environmental conditions has made industrial managers to consider ecology a significant factor while taking decisions related to industrial management. Chemicals discharged into air, water, and soil are the parameters responsible for environmental pollution (Figure 1.1). Companies are now well aware of the relationship between environmental quality and prospects within the framework of economic development, and this environmental quality and responsibility factor highly affects the success of companies. Consumer demands guide companies to include certain environmental issues in addition to quality, cost, and production flexibility. Demand for environmentally friendly products manufactured under natural conditions from food products to clothes has made companies more sensitive to the environment [1].

New ecolabels for textile products and tighter restrictions on wastewater discharges force textile wet processors to reuse process water and chemicals. This challenge has prompted intensive research in new advanced treatment technologies, some of which are currently making their way to full-scale installations [2]. Eco textiles include products that are manufactured using materials and methods that do not pose any harm to people and nature from textile fiber production to the makeup of the finished textile (textile fiber production, dyeing, chemicals, energy and water consumption) and that can be disposed of (decomposition, recycling) without harming human health and nature [1].

1.2 Textile Fiber Manufacturing/Processing and the Environment

The textile industry is shared between natural fibers, such as wool, silk, linen, cotton, and hemp, and man-made ones, such as polyamide and acrylic made from petrochemicals. Textile fibers are classified into three categories on the basis of their origin: natural, synthetic, and semi-synthetic fibers (Figure 1.2). Natural fibers are considered as ecofriendly relatively but their production also leads to some environmental disturbance.

Cotton is considered as an environment friendly, renewable, and biodegradable cellulosic fiber. However, cotton also has other environment issues, such as this crop needs higher use of pesticides and insecticides, as it is prone to insects and diseases. Scouring (removal of the waxy outer layer on cotton), mercerization, press finishing, and bleaching need aqueous sodium hydroxide, formaldehyde, and other chemicals associated with health hazards. Such hazards are tried to be overcome by using some alternatives such as citric acid, chitosan, etc. on cotton to improve characteristics [3–5]. Wool is another fiber produced naturally and is considered an ecofriendly textile substrate, but it also requires some alkaline or chemical processing that may lead to a slight negative impact on the environment. Naturally produced textile substrates (wool, silk, cotton, etc.) are expected to be superior to synthetic ones in terms of environmental impacts [6].

Regenerated cellulosic fibers (Rayon, Tencel), also known as semi-synthetic fibers, produced from cellulosic materials utilize a large amount of waste but use of harsh chemicals in production leads to environmental imbalance. A lot of developments have been carried out in the past for the production of regenerated cellulosic fibers that are sustainable

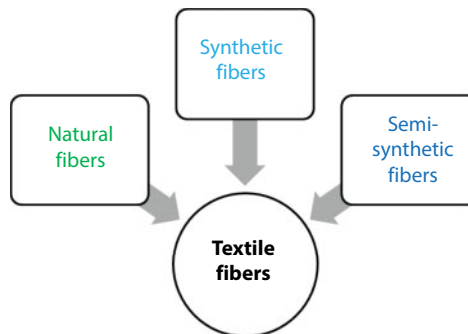


Figure 1.2 Classes of textile fibers on the basis of their origin.

and ecofriendly, and the use of environment-incompatible chemicals is restricted to some extent [7].

Nowadays, most of the clothes in our wardrobes contain polyester, elastane, or Lycra of synthetic origin. These cheap and easy-care fibers are becoming the textile industry's miracle solution. However, their manufacture creates pollution and they are hard to recycle [8]. There are concerns about the use and disposal of hazardous chemicals in the production of synthetic textile fibers. Recycling, reuse of synthetic fibers, and use of natural fibers over synthetic ones are essential to restrict the hazardous impact on the environment.

1.3 Textile Finishing and the Environment

Textile finishing is an important step in textile manufacturing before making them usable. Many of the steps such as scouring, bleaching, and mercerization are being carried out as finishing of textiles or textile fibers and have important roles to enhance the characteristics of textiles. Scouring removes substances that have adhered to the fibers during production of the yarn or fabric, such as dirt, oils, and any sizing or lint applied to warp yarns to facilitate weaving. Bleaching, a process of whitening fabric, is usually carried out by means of chemicals selected according to the chemical composition of the fibers. Chemical bleaching is usually accomplished by oxidation, destroying color by the application of oxygen, or by reduction, removing color by hydrogenation. Cotton and other cellulosic fibers are usually treated with heated alkaline hydrogen peroxide; wool and other animal fibers are subjected to such acidic reducing agents as gaseous sulfur dioxide or to such mildly alkaline oxidizing agents as hydrogen peroxide. Synthetic fibers may be treated with either oxidizing or reducing agents, depending on their chemical composition. Mercerization is a process applied to cotton and sometimes to cotton blends to increase luster, to improve strength, and to improve affinity for dyes to them. The process involves immersion of fiber or textile under tension in sodium hydroxide solution, which is later neutralized in acid [9, 10]. All these finishing steps involve use of chemicals with high content of water, and all chemicals discarded to water bodies lead to environmental (water) pollution.

1.4 Dyeing and the Environment

The color of textiles always fascinates mankind, and a long range of textile colors are available to people. This step of textile processing is very crucial

with respect to environmental concerns, as a large amount of unadsorbed dyes is discarded into water bodies.

Dyes are also classified as natural and synthetic on the basis of their origin. Natural dyes have been used to color textiles in ancient times, but in the 19th century, synthetic dyes replaced natural dyes after discovery of mauve colorant [11]. The expansion of the use of synthetic dyes overburdened the pressure on environment and consequently increased pollution. Some azo dyes, a class of synthetic dyes, are banned for their carcinogenic effects on human health. Synthetic dyes are nonbiodegradable and nonbiocompatible and disturb the water ecosystem with high impacts. Minimum use of synthetic dyes or replacement of these dyes with natural dyes, which are known for their biodegradability and biocompatibility, can be of great help to minimize the negative impact on the environment. Natural dyes also have less substantivity towards textile fibers or textiles and require use of metals as mordants for the fixation of dyes on textile surfaces, and these metals are responsible for the contaminated water bodies [12]. The dyeing process, whether it is by natural or synthetic dyes, has an impact on the environment to some extent as a result of spilling out of nondegradable dye compounds or hazardous metal ions used as mordants to fix dye molecules on textile surfaces.

Methods used for dyeing textiles are quite important to decide the extent of polluting the environment. Microwave and sonicator dyeing and the application of compounds with pad-dry cure method are considered as effective dyeing processes that lead to high adsorption of dyes and to ultimately protecting the environment [13]. The use of ecofriendly or natural compounds such as chitosan and biomordants to enhance the substantivity of dyes towards textiles in place of toxic metals may be a great step towards a safe environment and ecofriendly dyeing [14]. The use of ecofriendly chemicals, dyes, and suitable techniques for maximum output without simultaneous generation of waste would be important aspects to establish a safe relationship between the textile industry and the environment today and in the future.

1.5 Technologies and Methods to Cure the Textile-Infected Environment

Textile production/manufacturing, processing, dyeing/finishing, and discarding after use as waste lead to infecting the environment as discussed earlier in this chapter. It would be better to take care of the environment during the processing steps as well as in later stages for the things left out

particularly in water bodies. Even if care is taken to minimize waste, there will still be waste to treat. Textile manufacturing, dyeing, and finishing processes produce waste containing both organic and inorganic compounds. Removal of these substances from wastewater is expensive and difficult to achieve [15].

Today, almost everywhere in the world, there is ongoing research on treatment of wastewater to meet the demands of mankind. Almost 70% of Earth is covered with water, but only a small fraction of it is utilized for drinking. A large number of methods and techniques are used to cure wastewater, classified mainly into three categories: chemical, physical, and biological (Figure 1.3).

The coagulation and flocculation technique can be used for the removal of various hazardous components from wastewater from textile industry effluents. Colloidal or suspended particles are charged and stable in water. Coagulation destabilizes these charged particles in wastewater, leading to aggregation and formation of floccules. The addition of a specific coagulant (with a charge opposite of the particles) is required to stabilize the colloidal particles, and the efficiency is estimated by the factors in the wastewater such as type and concentration of flocculant and coagulant, final pH, intensity, and duration of mixing [15]. The use of membranes and nanofiltration is one of the methods to cure wastewater. It removes most of the organic molecules, viruses, and the natural organic matter as well as some salts. Nanofiltration does not remove dissolved compounds.

Chemical oxidation aims at oxidizing organic pollutants or even some inorganic components into less dangerous or harmless components. Complete oxidation sometimes results in the production of CO_2 and H_2O . Chemical oxidation processes use different reacting systems involving oxidants such as ozone, hydrogen peroxide, sodium hypochlorite, peroxyacetic acid, and oxygen. These are all characterized by the same chemical

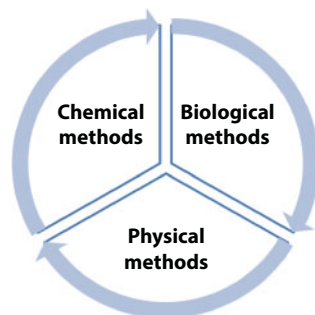


Figure 1.3 Various methods to treat textile industry effluents.

feature of production of OH radicals. OH radicals are extraordinarily reactive species and they attack the most part of organic molecules with high rate constants. Fenton's process, photocatalysis, electrochemical oxidation, and ozone systems are other advanced chemical oxidation processes for the treatment of wastewater from the textile industry [16]. Degradation (aerobic and anaerobic) of pollutants or discoloration of effluents can also be achieved via the application of bacteria, fungi, and algae, which is a form of biological treatment [17].

1.6 Reuse of Wastewater from the Textile Industry

Reusing rinse water from one process to another cleaning process is an example of on-site recycling or reuse. It involves collecting waste and reusing it in the same or different parts of the production. Nonpreventable wastes can be recycled or vend as an offshoot [18]. The textile industry uses large amounts of water and is highly responsible for wastewater production. The textile industry's wastewater contains various nondegradable dyes and finishing chemicals. It is quite necessary to reuse the wastewater after treatment, and there are various methods discussed earlier to treat wastewater. It is important to install the textile industry near water to fulfill the requirements of water, and simultaneously, there should be a wastewater treatment plant installed. This parallel treatment of wastewater leads to an increase in the cost of production, but as per the freshwater resources are shrinking, this is the demand of the current scenario and we need to compromise on increased costs. If not all, at least some of the steps of manufacturing can use the treated water in place of freshwater.

1.7 Conclusion and Perspectives

The textile industry and the water ecosystem used to have a strong bond. It is well known that the textile industry needs a lot of water in all steps of manufacturing and finishing of textiles and a large amount of effluents are discarded into water bodies. Today, human beings have a wide range of choices of clothing and also the number of products to be used. To maintain balance between textile processes and the environment, sustainable approaches and the use of ecofriendly techniques are needed. Optimum use of natural fibers such as wool, silk, cotton, jute, flex, etc. (produced without or with minimum pesticides or insecticides) and natural dyes in place of synthetic ones can overcome the load on petrochemical products

and on environmental disturbance. There is a lot to do for the remediation of textile effluents and protection of contamination of water bodies. Development of wastewater treatment techniques of high efficiency and maximum recovery of the pollutants are the main concerns for the future, and researchers all over the globe are looking seriously into it.

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Synthetic Dyes: A Threat to the Environment and Water Ecosystem

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Abstract

The textile industry is among the most complex and oldest industries. Dyeing is the process in textiles that highly influences the choice of people for their clothing. Synthetic dyes are highly used for textile coloration since these are expected to have a wide range of colors with high substantivity to textiles. Along with these beneficial characteristics, dyes are associated with environmental hazards, particularly that concerning the water ecosystem. Effluents generated during the synthesis of dyes and application on textiles cause adverse effects on biological life in water bodies. This chapter aims to summarize the relationship between synthetic dyes and the environment or the water ecosystem, the impact on biological life in water, and advanced approaches to deal with these associated hazards.

Keywords: Textile industry, dyeing, environment, effluents, synthetic dyes

2.1 Introduction

To make things look aesthetic and colorful, colored additives (mainly dye molecules) are added from ancient human civilizations. Early dyes were obtained from mineral, animal, and vegetable sources, with no to very little processing. By far, the greatest source of dyes has been from the plant kingdom, notably, roots, berries, leaves, and wood/bark. The documentation of past civilizations had been investigated by several research groups through various archaeological periods for the dyestuffs used as coloring materials. Studies revealed that in the Ancient Stone Age, many antiquity documents

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and descriptions showed that people used various colored nature-derived minerals and dyes that were applied to their hair, body parts, occasional dressings, items of clothings, their house paintings, etc. [1–3]. In the ancient and medieval world, Tyrian purple and crimson kermes dyes were highly prized luxury items with brilliant and permanent fixation. Other plant-origin dyes such as madder, henna, indigo, woad, saffron, etc. were economically important. The first synthetic dye, *Mauveine* or *Mauve*, was discovered serendipitously by Sir William Henry Perkin in 1856 when he synthesized quinine medication to treat malaria fever, which exists in a wider color range with brighter shades [2, 4].

However, the commercial role of synthetic dyes day by day has been increasing thoroughly. At present, they possess diversified angles of coloration such as textiles and clothings, leather, fur, photography, refined petroleum products, food, paper, printing, plastic, fashion and design, body art, paint, etc. Many industries globally discharge a million volumes of effluents containing dyes, heavy metals, acids, bases, and other inorganic and organic chemicals. All of these discarded substances make effluents toxic and highly hazardous to the aquatic as well as aerial ecosystems. Nowadays, more than 3600 individual textile dyes are being manufactured worldwide that use approximately 8000 chemicals in various processes [4]. Synthetic dyes are utilized as coloring agent in numerous industrial sectors such as textile, food and beverage, leather, paper, cosmetics, pharmaceuticals, etc. It is assumed that about 10–15% of synthetic dyes are suspended during different processes of the textile industry as effluent. United Nations Statistics Division (UNSD), New York, estimated that the global import and export market for acid dyes containing the azo ($-N=N-$) group chiefly was found to be 680,000 tons in 2011 [5]. Various dyes and chemicals used in several textile industries in huge quantities possess environmental risks [3, 6]. Therefore, the effluent carries dyes and other additives in large amounts, which can be transported easily through sewers and rivers especially because of their high water solubility and are difficult to remove from the environment. After the degradation process, these pollutants form unpleasant as well as undesirous products that are highly toxic, hazardous, and even carcinogenic [7]. Thus, they are associated with potential hazards to living organisms. An overview is presented in this chapter towards the impact of synthetic dyes on environmental ecosystems.

2.2 Environmental Hazards Parallel to Dye Applications

Almost every industrial dye process involves a solution of a dye in water/solvent during the dyeing process and generates large volumes of effluents

that are complex mixtures of many pollutants, ranging from original colors lost during the dyeing processes associated with mordants/metals including:

- Auxiliaries and basic chemicals (e.g., alkalis, metals and acid salts, reducing/oxidizing agents, etc.)
- Dyes (excessive and unused)
- Other contaminants (e.g., residues of finishing agents and fibers used)

In general, when one's body is warm and skin pores have opened to allow perspiration, textiles and clothing come into direct contact with our skin, and therefore some sensitive and toxic chemicals are often absorbed by the skin epithelial tissues. The symptoms of sensitivity and toxicity of dyes as well other chemicals from wearing range from skin rashes, dizziness, difficulty breathing, irregular heartbeat, to seizures, to name a few. Indeed, textile and the relevant dye industry produce high levels of dyes and floating solid materials. These sensitive and toxic substances are dumped in the form of effluent merged into rivers/canals/canalizations, and when not properly treated, they can cause serious contamination of the water sources. Thus, the materials that are dumped into the water ecosystems are effluents containing high organic pollutants with a strong/dark color, low visibility, high biochemical oxygen demand, low dissolved oxygen concentrations, and low biodegradability [8, 9].

2.2.1 Impact on Human Health

Although synthetic dyes have brilliant technical characteristics, they are found to have several adverse effects on working people in the industry. Also, it is noteworthy that there are numerous adverse responses to dyes because of the large number of chemicals associated with them. Human health concerns fall under two categories: acute toxicity and genotoxicity. Acute toxicity caused by reactive dyes involves oral ingestion and inhalation and the chief negative responses are skin sensitization and irritation, for example, contact dermatitis, allergic conjunctivitis, rhinitis, asthma, or other allergic reactions. ETAD (Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers) had published the directives on the list of reactive dyes that have caused respiratory or skin sensitization in associated dye industry workers on occupational exposure, out of which immediate allergic reactions are less common (Table 2.1). For textile fibers, the symptoms of immediate allergy to textile products

Table 2.1 Synthetic dyes (reactive and disperse) classified as respiratory/skin sensitizers based on ETAD directives [11].

Dye color	Color index number (reactive)	Color index number (disperse)
Yellow dyes	Reactive Yellow 25 Reactive Yellow 39 Reactive Yellow 175	Disperse Yellow 1 Disperse Yellow 9 Disperse Yellow 3 Disperse Yellow 39 Disperse Yellow 49
Red dyes	Reactive Red 29 Reactive Red 65 Reactive Red 66 Reactive Red 123 Reactive Red 219 Reactive Red 225	Disperse Red 1 Disperse Red 17 Disperse Red 15
Orange dyes	Reactive Orange 4 Reactive Orange 12 Reactive Orange 14 Reactive Orange 16 Reactive Orange 64 Reactive Orange 67 Reactive Orange 86 Reactive Orange 91	Disperse Orange 1 Disperse Orange 3 Disperse Orange 37
Blue dyes	Reactive Blue 114 Reactive Blue 205	Disperse Blue 1 Disperse Blue 3 Disperse Blue 7 Disperse Blue 35 Disperse Blue 106 Disperse Blue 124
Violet dyes	Reactive Violet 33	NA
Black dyes	Reactive Black 5	NA

include redness, rash, wheals, respiratory and circulatory problems, and even anaphylactic shock [10].

Genotoxicity is defined in genetics as a destructive effect on a cell's genetic material (i.e., DNA, RNA) that affects its integrity either whole or partially. In other words, genotoxins are mutagens that can cause mutations including both radiation and chemical agents. Certain dyes are proven to