Chapter 4
Environmental and Health Effects of Textile Industry Wastewater

Sana Khan and Abdul Malik

Abstract The textile production industry is one of the oldest and most technologically complex of all industries. The fundamental strength of this industry flows from its strong production base of a wide range of fibers/yarns from natural fibers like cotton, jute, silk, and wool to synthetic/man-made fibers like polyester, viscose, nylon, and acrylic. With escalating demand for textile products, textile mills and their wastewater have been increasing proportionally, causing a major problem of pollution in the world. Many chemicals used in the textile industry cause environmental and health problems. Among the many chemicals in textile wastewater, dyes are considered important pollutants. Worldwide environmental problems associated with the textile industry are typically those associated with water pollution caused by the discharge of untreated effluent and those because of use of toxic chemicals especially during processing. The effluent is of critical environmental concern since it drastically decreases oxygen concentration due to the presence of hydrosulfides and blocks the passage of light through water body which is detrimental to the water ecosystem. Textile effluent is a cause of significant amount of environmental degradation and human illnesses. About 40 % of globally used colorants contain organically bound chlorine, a known carcinogen. Chemicals evaporate into the air we breathe or are absorbed through our skin; they show up as allergic reactions and may cause harm to children even before birth. Due to this chemical pollution, the normal functioning of cells is disturbed and this, in turn, may cause alteration in the physiology and biochemical mechanisms of animals resulting in impairment of important functions like respiration, osmoregulation, reproduction, and even mortality. Heavy metals, present in textile industry effluent, are not biodegradable; hence, they accumulate in primary organs in the body and over time begin to fester, leading to various

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symptoms of diseases. Thus, untreated or incompletely treated textile effluent can be harmful to both aquatic and terrestrial life by adversely affecting the natural ecosystem and causing long-term health effects. Environmental hazards and health problems associated with chemicals used in textile industry are discussed in this chapter.

Keywords Dyes · Effluent · Environment · Heavy metals · Textile industry

4.1 Textile Industry: An Overview

Industrialization is considered to be the key for the development in economic terms. At the same time, it is also recognized to be the root cause for environmental pollution. Due to different types of industries, environmental pollution is one of the vital problems presently facing India and the world (Paul et al. 2012).

The textile and garment industry is one of the oldest manufacturing sectors in India. The industry plays an important role in the Indian economy. It is a significant contributor to many national economies, encompassing both small- and large-scale operations worldwide. In terms of its output or production and employment, the textile industry is one of the largest industries in the world (Verma et al. 2012). It is a major foreign exchange earner and, after agriculture, it is the largest employer with a total workforce of 35 mn. The industry covers a wide range of activities, which include the production of natural raw materials such as cotton, jute, silk, and wool, as well as synthetic filament and spun yarn. In addition, an extensive range of finished products is made. India accounts for about 14 % of the world's production of textile fibers and yarns. This includes jute, of which it is the largest producer. India is the second largest producer of silk, cellulose fiber and yarn and the fifth largest producer of synthetic fiber and yarn.

The modern world needs textiles for a vast array of applications, and from the carpets beneath our feet, to the clothes on our backs, to the architectural textiles shielding us from the elements—textiles are ubiquitous (Thiry 2011). Today, much of the textile and dyeing industry is located in developing countries, often with poor wastewater treatment. It can be said that India may be the major contributor of textile wastewater in South Asia. India has a large network of textile industries of varying capacity. The textile industries in India are mainly located in Mumbai, Surat, Ahmadabad, Coimbatore, Ludhiana, and Kanpur (Verma et al. 2012). Now, the industries are well developed and a large number of small textile-processing units are scattered all over the country (Garg and Kaushik 2007).

The environmental pollution caused by textile wastewater effluent poses a worldwide threat to public health and it gives rise to new initiatives for environmental restoration for both economic and ecological reasons. Textile industries have been placed in the category of most polluting industries by the Ministry of Environment and Forests, Government of India (Garg and Kaushik 2007). The effluent generated by the textile industry is one of the sources of pollution. Contamination of air, soil, and water by effluents from the industries is associated with a heavy disease burden (WHO 2002), and this could be part of the reasons for the current shorter life expectancy in the country (WHO 2003) when compared to the developed nations (Yusuff and Sonibare 2004). Moreover, textile industries are one of the most chemically intensive industries on the earth and one of the biggest users of water and also the major polluter of potable water (Verma et al. 2012). The most important chemical constituent used in textile industries is dye.

Throughout history, there have been several articles of clothing and dye colors that have had significant impacts on society. Historical records of the use of natural dyes extracted from vegetables, fruits, flowers, certain insects, and fish dating back to 3500 BC have been found. Earlier, fabric was being dyed with natural dyes. Synthesis of natural dyes was a long and tedious process. This was the common practice until the mid-1800s (Joseph 1977). These techniques were used to decorate clothing, utensils, and even the body. This was a religious as well as functional practice. These, however, gave a limited and a dull range of colors. Besides, they showed low color fastness when exposed to washing and sunlight.

WH Perkins in 1856 discovered the first synthetic dye, mauve. Synthetic dyes have provided a wide range of colorfast, bright hues (Kant 2012). Mauve was prepared using coal and tar. The vibrant color that was created not only had a tremendous impact on the fashions of the day but also spurred many other scientific discoveries. The synthetic dyestuff industry developed rapidly soon after this discovery with the introduction of another very important dye, magenta. The subsequent development of water-soluble azo dyes represented a landmark in the synthetic dye industry.

4.2 Processes in Textile Manufacturing

The most common textile-processing technology consists of desizing, scouring, bleaching, mercerizing, and dyeing processes (EPA 1997):

4.2.1 Sizing

This is the first preparation step, in which sizing agents such as starch, polyvinyl alcohol (PVA), and carboxymethyl cellulose are added to provide strength to the fibers and minimize breakage.

4.2.2 Desizing

This process is used to remove sizing materials prior to weaving. The nature of this process depends upon the type of size applied. Water-soluble size may simply be washed out, whereas water-insoluble size must first be subjected to chemical or enzymatic degradation.

4.2.3 Scouring

Natural impurities such as waxes, pectins, and proteins must be removed. This process removes impurities from the fibers by using alkali solution (commonly sodium hydroxide) to breakdown natural oils, fats, waxes, and surfactants, as well as to emulsify and suspend impurities in the scouring bath.

4.2.4 Bleaching

The step is used to remove unwanted color from the fibers by using chemicals such as sodium hypochlorite and hydrogen peroxide.

4.2.5 Mercerizing

Mercerization is a treatment specific to cotton. It is a continuous chemical process used to increase dye ability, luster, and fiber appearance. In this step, a concentrated alkaline solution is applied and an acid solution washes the fibers before the dyeing step.

4.2.6 Dyeing and Printing

This is the process of adding color to the fibers, which normally requires large volumes of water not only in the dye bath but also during the rinsing step. Textile materials can be dyed using batch, continuous, or semicontinuous processes. The kind of process used depends on many characteristics including type of material such as fiber, yarn, fabric, fabric construction and garment, and also the generic type of fiber, size of dye lots, and quality requirements in the dyed fabric. Among these processes, the batch process is the most common method used to dye textile materials (Perkins 1991). Depending on the dyeing process, many chemicals like metals, salts, surfactants, organic processing aids, sulfide, and formaldehyde may be added to improve dye adsorption onto the fibers. Whereas dying conveys a uniform color, printing allows a range of different colors to be applied. Usually between five and ten pastes are required for a single pattern. Color may be supplied by either pigments or dyes.

4.2.7 Finishing

Textile finishing represents the most variable area in the production process. A wide and ever-growing range of finishes are now available; these either improve the properties of the garment or provide “performance” properties.

4.3 Chemicals Used in Textile Industry

The textile industry has been condemned as being one of the world's worst offenders in terms of pollution because it requires a great amount of two components:

- Chemicals: As many as 2,000 different chemicals are used in the textile industry, from dyes to transfer agents.
- Water: This is a finite resource that is quickly becoming scarce and is used at every step of the process both to convey the chemicals used during that step and to wash them out before beginning the next step. Textile industries consume large volumes of water and chemicals for the wet processing of textiles. More textiles than ever are now manufactured and used, and chemicals are added for an ever-increasing number of purposes. The water becomes full of chemical additives and is then expelled as wastewater which in turn pollutes the environment: by the effluent's heat; by its increased pH; and because it is saturated with dyes, de-foamers, bleaches, detergents, optical brighteners, equalizers, and many other chemicals used during the process.

The chemical reagents used are very diverse in chemical composition, ranging from inorganic compounds to polymers and organic products (Mishra and Tripathy 1993; Juang et al. 1996). The chemicals used can be subdivided into:

1. Textile auxiliaries: This covers a wide range of functions, from cleaning natural fibers and smoothing agents to improving easy care properties. Included are such chemicals as:
   - Complexing agents, which form stable water-soluble complexes
   - Surfactants, which lower the surface tension of water so that grease and oil could be removed more easily
   - Wetting agents, which accelerate the penetration of finishing liquors
   - Sequestering agents
   - Dispersing agents
   - Emulsifiers
2. Textile chemicals (basic chemicals such as acids, bases, and salts).
3. Colorants, such as:
   - Dyes
   - Dye-protective agents
   - Fixing agents
   - Leveling agents
   - pH regulators
   - Carriers
   - Ultraviolet (UV) absorbers
4. Finishes.

4.3.1 The Most Important Constituents—Dyes: Structure and Properties

Dyes are natural and synthetic compounds that make the world more beautiful through colored products. Textile dyes represent a category of organic compounds, generally considered pollutants, discharged into wastewaters resulting mainly from processes of chemical textile finishing (Zaharia et al. 2009; Suteu et al. 2009a). It is estimated that over 10,000 different dyes and pigments are used industrially and over 7×10^5 t of synthetic dyes are annually produced worldwide (Zollinger 1987; Robinson et al. 2001; Ogugbue and Sawidis 2011). A dye is used to impart color to a material, of which it becomes an integral part. An aromatic ring associated with a side chain is usually required for resonance and thus to impart color. The characterization of dyes is based on their chemical structure and application. Dyes are composed of the atoms responsible for the dye color called chromophores as well as an electron-withdrawing or electron-donating substituent that causes or intensifies the color of chromophores, called auxochrome (Christie 2001). To be a dye, a compound must contain both the chromophore and auxochrome(s) (Verma et al. 2012). The most important chromophores are azo (–N=N–), carbonyl (–C=O), methine (–CH=), nitro ($–NO_2$), and quinoid groups. The most important auxochromes are amine ($–NH_3$), carboxyl (–COOH), sulfonate ($–SO_3H$), and hydroxyl (–OH) (Welham 2000). In general, azo dyes can occur in two tautomeric forms, azo (–N=N–) or hydrazone (=N–NH–). The latter is said to be more prone to oxidative fading, which is the most common photodegradation mechanism in the presence of light, moisture, and oxygen (Mirghani et al. 2008).

In general, textile fibers can catch dyes in their structures as a result of van der Waals forces, hydrogen bonds, and hydrophobic interactions (physical adsorption). The uptake of the dye in fibers depends on the dye's nature and its chemical constituents. But, the strongest dye–fiber attachment is a result of a covalent bond with an additional electrostatic interaction where the dye ion and fiber have opposite charges (chemisorption) (Carmen and Daniela 2012).

Reactive dyes, including many structurally different dyes, are extensively used in the textile industry because of their wide variety of color shades, high wet fastness profiles, ease of application, brilliant colors, and minimal energy consumption (Wang et al. 2009). The three most common groups are azo, anthraquinone, and phthalocyanine dyes (Axelsson et al. 2006), most of which are toxic and carcinogenic (Acuner and Dilek 2004). All dyes used in the textile industry are designed to resist fading upon exposure to sweat, light, water, many chemicals including oxidizing agents, and microbial attack.

The textile azo dyes are characterized by relatively high polarity (log K_{ow} up to 3) and high recalcitrance. Recalcitrance is difficult to evaluate because of the dependence of degradation on highly variable boundary conditions (e.g., redox milieu or pH). Furthermore, azo dyes are relevant in terms of eco- and human toxicity, industrially produced in high quantities, and known to occur in hydrosphere. Azo dyes also have great structural diversity, high molar extinction coefficients, and medium-to-high fastness properties in relation to light as well as to wetness. Depending on pH value, azo dyes can be anionic (deprotonated at the acidic group), cationic (protonated at the amino group) or nonionic. Accordingly, knowledge of the acidity constants is indispensable for the characterization of azo dye behavior. Environmental partitioning is influenced by substituents as well as the number of carbon atoms and the aromatic structure of the carbon skeleton.

4.3.1.1 Textile Dye classification

Textile dyes can be classified in several ways. Previously, the dyes were divided into:

(a) **Natural dyes**, the dyes extracted from vegetable and animal resources and mainly used in textile processing until 1856
(b) **Synthetic textile dyes,** which were firstly discovered in 1856

Recently, textile dyes are mainly classified in two different ways:

(a) Based on their application characteristics (i.e., Colour Index (CI) Generic Name such as acid, basic, direct, disperse, mordant, reactive, sulfur dye, pigment, vat, azo insoluble)
(b) Based on their chemical structure (i.e., CI Constitution Number such as nitro, azo, carotenoid, diphenylmethane, xanthene, acridine, quinoline, indamine, sulfur, amino- and hydroxy ketone, anthraquinone, indigoid, phthalocyanine, inorganic pigment, etc.)

Considering only the general structure, textile dyes are also classified as anionic (direct, acid, and reactive dyes), nonionic (disperse dyes), and cationic dyes (azo basic, anthraquinone disperse, and reactive dyes) (Robinson et al. 2001).

A systematic classification of dyes according to chemical structure is the CI (Table 4.1). This scheme is also useful for estimating the possible biodegradability of dyes (Wesenberg 2003).

The major textile dyes can be included in the two high classes: azo or anthraquinone (65–75 % of total textile dyes).

Azo Dyes The annual world production of azo dyes is estimated to be around 1 million t, and more than 2,000 structurally different azo dyes are currently in use (Vijaykumar et al. 2007). Azo dyes (Fig. 4.1), which are aromatic compounds with one or more –N = N– groups, constitute the largest class of synthetic dyes used in commercial applications (Zollinger 1991), constituting 60–70 % of all dyestuffs produced (Carliell et al. 1995). This linkage (–N = N–) may be present more than once and thus mono azo dyes have one azo linkage while there are two linkages in diazo dyes and three in triazo dyes. Azo dyes have one or more azo groups (R1-N = N-R2) having aromatic rings mostly substituted by sulfonate groups. These complex aromatic substituted structures make a conjugated system and are responsible for the intense color, high water solubility, and resistance to degradation of azo dyes under natural conditions (O'Neill 2000; Rajaguru 2000).

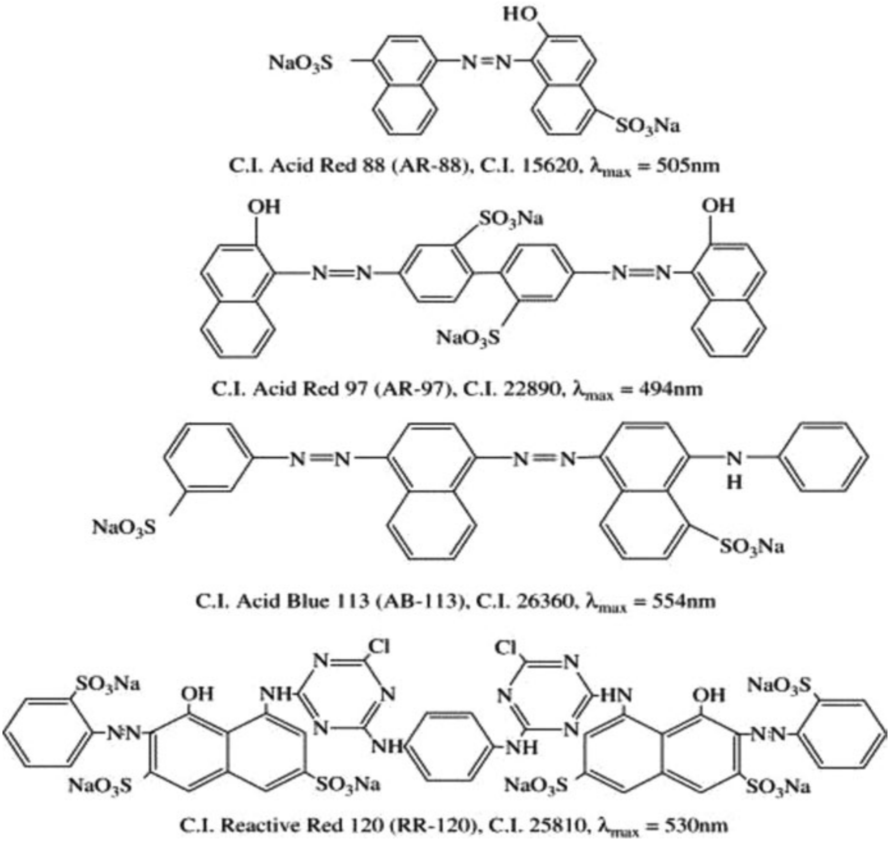

Fig. 4.1 Chemical structure and principal characteristics of some azo dyes

Azo dyes are synthesized via the following reaction. A primary amine (R-NH_2) is converted to a diazonium salt and this is reacted with another aryl unit.

Anthraquinone Dyes: Anthraquinone dyes constitute the second most important class of textile dyes, after azo dyes (Baughman and Weber 1994). These dyes have a wide range of colors in almost the whole visible spectrum, but they are most commonly used for violet, blue, and green colors (Christie 2001; Fontenot et al. 2003).

4.3.1.2 Toxicity of Dyestuffs

Dyes are the most important chemical constituents used in the textile industry, which impart color to yarn or cloth. Several adverse health effects and potential adverse effects have been defined for this group of substances. Wastewater effluent, generated from the textile industry, is a complex mixture of many polluting substances ranging from organ chlorine-based pesticides to heavy metals associated with dyes and the dyeing process. During dyeing processing, a large amount of the dyestuffs is released due to inefficiencies in the dyeing process and is directly lost to the wastewater, which ultimately finds its way into the environment. In addition, antimicrobial agents resistant to biological degradation are frequently used in the manufacture of textiles, particularly for natural fibers such as cotton (O'Neill et al. 1999; Couto 2009). For instance, azo dyes, which amount to around 60 % of textile dyes, display strongly adverse effects on the growth of methanogenic bacterial cultures (Hu and Wu 2001). This toxicity may be due mainly to the azo functional group itself rather than to the products of reductive cleavage (Razo-Flores et al. 1997). Therefore, the effluent is also resistant to biodegradation. The toxic effects of the azo dyes may result from the direct action of the agent itself or of the aryl amine derivatives generated during reductive biotransformation of the azo bond (Rajaguru et al. 1999). The azo dyes entering the body by ingestion can be metabolized to aromatic amines by the azoreductases of intestinal microorganisms. If the dyes are nitro dyes, they can be metabolized by the nitroreductases produced by the same microorganisms (Umbuzeiro et al. 2005). Mammalian liver enzymes and other enzymes may also catalyze the reductive cleavage of the azo bond and the nitroreduction of the nitro group. In both cases, if N-hydroxylamines are formed, these compounds are capable of causing DNA damage (Arlt et al. 2002; Umbuzeiro et al. 2005).

Unfortunately, heavy metals have often been used in dye fixatives and also in dyes (Mirghani et al. 2008). Typically, transition metals such as chrome, copper, nickel, and cobalt are used. These metals can form multiple bonds with organic dyestuffs and/or fibers (Walters 2005). Metals can be present in dyes for two reasons: first, metals are used as catalysts during the manufacture of some dyes and can be present as impurities; second, in some dyes the metal is chelated with the dye molecule, forming an integral structural element.

Toxic chemicals sometimes found in the dyeing process include:

- Dioxin—a carcinogen and possible hormone disrupter.
- Toxic heavy metals such as chrome, copper, and zinc—known carcinogens.
- Formaldehyde—a suspected carcinogen.
- Azo dyes group—which give off carcinogenic amines.

4.4 Characteristics and Composition of Textile Wastewater

In addition to the problem caused by the loss of dye during the dyeing process, the textile industry is generating large volumes of effluent. These effluents are complex mixtures of many pollutants, ranging from original colors lost during the dyeing process to associated pesticides and heavy metals (McMullan et al. 2001), and if these pollutants will not be properly treated, they can cause serious contamination of the water sources.

Textile industries utilize a huge amount of water. The amount of water used varies widely, depending on the specific processes operated at the mill, the equipment used, and the prevailing philosophy of water use (Verma et al. 2012). The daily water consumption of an average-sized textile mill having a production of about

8,000 kg of fabric per day is about 1.6 million liters. Sixteen percent of this is consumed in dyeing and 8 % in printing (Rita 2012). Textile industries typically generate 200–350 m^3 of wastewater per ton of finished product (Ranganathan et al. 2007; Gozálvez-Zafrilla et al. 2008) resulting in an average pollution of 100 kg chemical oxygen demand (COD) per ton of fabric (Jekel 1997). The dye house releases two types of wastewater, namely, dye bath water and wash water/rinse water. The dye bath water mainly consists of complex dyestuff and various intermediate complexes. It was noticed that in a typical factory the effluent from the dye bath had COD 5000–6000, total dissolved solids (TDS) 52,000, Suspended Solids 2,000 mg L^{-1}, and pH 9. After dyeing, the fabrics are washed by rinsing in water to remove the excess dye present. The wastewater generated due to this operation is commonly called "wash water" having COD 400–860, TS 4,000, TDS 3,200 mg L^{-1} and pH 8. Effluents contain a high organic load and biochemical oxygen demand, low dissolved oxygen concentrations, strong color, and low biodegradability.

During dyeing processes, the entire dye is not fixed to the fiber and a certain amount of the dye remains in dye bath, which is released with effluents. During textile processing, inefficiencies in dyeing result in large amounts of the dyestuff being directly lost to the wastewater, which ultimately finds its way into the environment. The amount of dye lost is dependent upon the class of dye application used, varying from only 2 % loss when using basic dyes to a 50 % loss when certain reactive dyes are used (O'Neill et al. 1999). Very low concentrations of dyes in effluent are highly visible and their presence is undesirable (Nigam et al. 2000). A huge amount of effluent from textile mills is being discharged on land or into watercourses. This effluent is characterized by high biological oxygen demand (BOD), COD, sodium and other dissolved solids as well as micronutrients and heavy metals.

Water is also needed for cleaning the printing machines to remove loose color paste from printing blankets, printing screens, and dyeing vessels (Wasif and Kone 1996; Vijaraghavan 1999). The other feature of this industry, which is a backbone of the fashion garment industry, is the large variation in the demand for type, pattern, and color combination of fabric resulting in significant fluctuation in waste generation volume and load.

4.5 Environmental and Health-Related Issues of Textile Wastewater

The environmental issues associated with residual dye content or residual color in treated textile effluents are always a concern for each textile operator that directly discharges, both sewage treatment works and commercial textile operations, in terms of respecting the color and residual dye requirements placed on treated effluent discharge (Zaharia et al. 2011).

Water pollution caused by industrial effluent discharges has become a worrisome phenomenon due to its impact on environmental health and safety. Textile industries contribute immensely to surface water deterioration and are categorized among the most polluting of all industrial sectors (Odjegba and Bamgbose 2012). Effluents from textile industries are complex mixtures of chemicals varying in quantity and quality.

These industries can generate both inorganic and organic waste mixed with wastewaters from the production processes, which leads to change in both biological and chemical parameters (Fig. 4.2) of the receiving water bodies (Gomez et al. 2008).

4.5.1 Environmental Issues

One of the most critical problems of developing countries is improper management of vast amount of wastes generated by various anthropogenic activities. More challenging is the unsafe disposal of these wastes into the ambient environment (Kanu et al. 2011). The key environmental issues associated with textile industry are water use, treatment, and disposal of aqueous effluent (Odjegba and Bamgbose 2012). Water scarcity is the most important sustainability issue facing the textile industry. The environmental risk is a function of environmental exposure (concentration and duration) and polluting potential (hazard characteristics or toxicity). Hence, reducing the emissions into the various environmental pathways can reduce the environmental risk (Shaikh 2009).

Textile wastewaters generated from different stages of textile processing contain huge amounts of pollutants that are very harmful to the environment if released without proper treatment (Verma et al. 2012). The extent of environmental pollution due to dye bath water is very high (Selvakumar et al. 2010). Environmental pollution caused by the release of a wide range of azo dyes through industrial wastewater is a serious problem in the present day (Mahmood et al. 2011). There are large numbers of mechanical and chemical processes involved in the textile industry and each process has a different impact on the environment. The presence of sulfur, naphthol, vat dyes, nitrates, acetic acid, soaps, chromium compounds, heavy metals like copper, arsenic, lead, cadmium, mercury, nickel, and cobalt, and certain auxiliary chemicals all collectively makes the effluent highly toxic. The mill effluent is also often of a high temperature and pH, both of which are extremely damaging (Kant 2012). Also, the accumulation of color hinders sunlight penetration, disturbing the ecosystem of the receiving water (Georgiou et al. 2003; Merzouk et al. 2010).

In addition when this effluent is allowed to flow in the fields, it clogs the pores of the soil resulting in loss of soil productivity. The texture of soil gets hardened and penetration of roots is prevented. The wastewater that flows in the drains corrodes and incrustates the sewerage pipes. If wastewater is allowed to flow in drains and rivers, it affects the quality of drinking water in hand pumps making it unfit for human consumption. The color in watercourses is accepted as an aesthetic problem rather than an eco-toxic hazard. Therefore, the public seems to accept the blue, green, or brown color of rivers but a “nonnatural” color such as red and purple usually causes the most concern (Carmen and Daniela 2012). Wastewater also leads to leakage in drains increasing their maintenance cost (Kant 2012). Other environmental issues of equal importance are air emission, notably volatile organic compounds (VOC)s, and excessive noise or odor as well as workspace safety.

Most processes performed in textile mills produce atmospheric emissions. Textile mills usually generate nitrogen and sulfur oxides from boilers. Other significant sources of air emissions in textile operations include resin finishing and drying

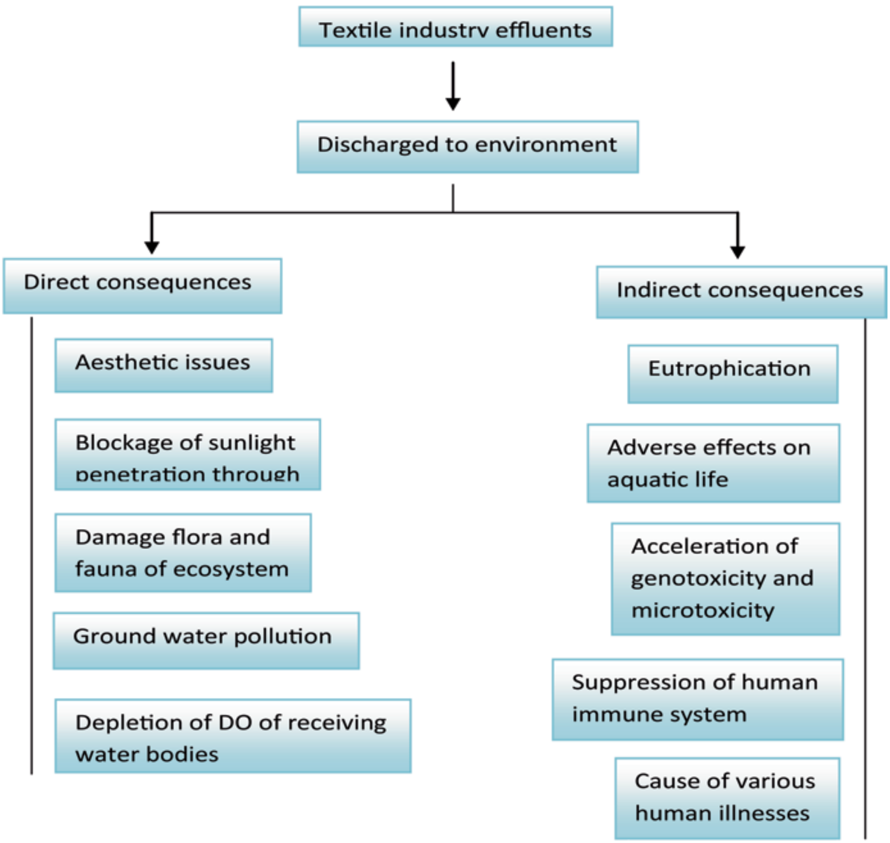

Fig. 4.2 Schematic representation of the effects of textile wastewater discharged into the environment

operations, printing, dyeing, fabric preparation, and wastewater treatment plants. Hydrocarbons are emitted from drying ovens and from mineral oils in high-temperature drying/curing. These processes can emit formaldehyde, acids, softeners, and other volatile compounds (Carmen and Daniela 2012).

4.5.2 Health Problems

The direct discharge of textile wastewater into water bodies like rivers, etc., pollutes the water and affects the flora and fauna (Shaikh 2009). Depending on exposure time and dye concentration, dyes can have acute and/or chronic effects on exposed organisms. Depletion of dissolved oxygen in water is the most serious effect of textile waste as dissolved oxygen is very essential for marine life. This also hinders the self-purification process of water.

The dyes used in textile industries are potential health hazards as they may be converted to toxic and/or carcinogenic products under anaerobic conditions

(Chung et al. 1992). Many dyes are toxic to fish and mammalian life; they inhibit growth of microorganisms and affect flora and fauna. Apart from this, several dyes and their decomposition derivatives have proved toxic to aquatic life (aquatic plants, microorganisms, fish, and mammals) (Kim et al. 2004; Ustun et al. 2007). They are also carcinogenic in nature and can cause intestinal cancer and cerebral abnormalities in the fetus (Doble and Kumar 2005). Textile dyes can cause allergies such as contact dermatitis and respiratory diseases, allergic reaction in the eyes, skin irritation, and irritation to mucous membrane and the upper respiratory tract. Reactive dyes form covalent bonds with cellulose, woolen, and polyamide (PA) fibers. It is assumed that, in the same way, reactive dyes can bind with $–NH_2$ and –SH groups of proteins in living organisms. Additionally, fairly intensive studies have inferred that such colored allergens may undergo chemical and biological assimilations, cause eutrophication, consume dissolved oxygen, prevent re-oxygenation in receiving streams, and have a tendency to sequester metal ions accelerating genotoxicity and microtoxicity (Walsh et al. 1980; Foo and Hameed 2010). A high potential health risk is caused by adsorption of azo dyes and their breakdown products (toxic amines) through the gastrointestinal tract, skin, lungs and also formation of hemoglobin adducts and disturbance of blood formation. Median lethal dose (LD50) values reported for aromatic azo dyes range between 100 and 2,000 mg/kg body weight (Börnick and Schmidt 2006). Several azo dyes cause damage to DNA that can lead to the genesis of malignant tumors. Electron-donating substituents in *ortho* and *para* position can increase the carcinogenic potential of these dyes. Some of the best-known azo dyes (e.g., Direct Black 38 azo dye, a precursor of benzidine; azodisalicylate, a precursor of 4-phenylenediamine) and their breakdown derivatives that induce cancer in humans and animals are benzidine and its derivatives and also a large number of anilines (e.g., 2-nitroaniline, 4-chloroaniline, 4,4'-dimethylendianiline, 4-phenylenediamine, etc.), nitrosamines, dimethylamines, etc. (Carmen and Daniela 2012). In addition to the environmental problem, the textile industry consumes large amounts of potable water. In many countries where potable water is scarce, this large water consumption has become intolerable and wastewater recycling has been recommended in order to decrease the water requirements.

Inhaling dust produced during cotton, flax, or hemp handling causes byssinosis, which is a respiratory syndrome. Today, byssinosis is among one of the most significant health problems in the entire textile industry. The noise level resulting from the machines used in the textile industry, especially from the dry processes, may violate the limit allowed by the law and cause hearing problems. The use of dyestuffs and pigments may cause a number of adverse effects to health. Health effects may be exerted directly at the site of application (affecting the workers) and later in the life cycle (affecting the consumers) (Shaikh 2009).

Because clothing comes into prolonged contact with skin, toxic chemicals are absorbed through the skin, especially when the human body is warm and skin pores have opened to permit perspiration. Once absorbed by humans, heavy metals tend to accumulate in the liver, kidney, bones, heart, and brain. The effects on health can be significant when high levels of accumulation are reached. The effect is particularly serious in children because toxic dye and/or heavy metal accumulation may negatively affect their growth and may be their life as well (Mirghani et al. 2008).

4.6 Conclusion

Pollution problems due to textile industry effluents have increased in recent years. The textile industry and its products give rise to a wide range of environmental and toxicological impacts. Without adequate treatment, textile dyes are stable and can remain in the environment for an extended period of time (Hao et al. 2000). Amendments and regulations in some countries have stated that azo-dyestuffs, which can release carcinogenic amines, should no longer be used in dyeing consumer goods (Mirghani et al. 2008).

Public perception of water quality is greatly influenced by the color. Therefore, the removal of color from wastewater is often more important than the removal of the soluble, colorless, organic substances. Removal of the dyes from the textile wastewater is often very costly, but a stringent environmental legislation has stimulated the textile sector to develop wastewater treatment plants. Dye removal from textile effluent is always connected with the decolorization treatment applied to textile wastewater in terms of respecting the local environmental quality requirements and standards (Carmen and Daniela 2012). The new environment regulations concerning textile products have banned the discharge of colored waste in natural water bodies. Therefore, an effective and economic treatment of effluents containing a diversity of textile dyes has become a necessity for clean production technology for textile industries.

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