Textile Industry: Pollution Health Risks and Toxicity

Tasneem Sarwar and Sardar Khan

1 Introduction

Being the oldest industry, the roots of the textile industry trace back to scraps found in a cave of Egypt at about 5000 B.C. [110]. The textile industry is comprised of making yarns and threads from either natural or synthetic fibres through the process of weaving and knitting, resulting in fabrics. The final step is the dyeing and finishing of yarn or threads and sometimes the fabrics are dyed [40]. The textile sector includes different characteristics which determine the textile sectors' sub-division into subsectors due to traits, length of the manufacturing process, and variety of technical process, such sector can also be divided into several ways, which depends on the production process and final products achievement [122]. Hence, the textile industry is subdivided into many fragments depending on various traits of the subsectors.

The textile industry is a key driver of the economy for every country, which not only fulfils the needs of individuals but also raises the quality and standard of living along with unemployment reduction [46]. Being the second-largest cloth exporter after China, Bangladesh not only makes 80% of total annual export, i.e., $24 billion, but also contributes to 45% of industrial employment and 5% to the total national income. Also, Indian textile sector studies revealed the contributing role of the textile sector by providing 14% of total industrial production, 3% of GDP, and a source of employment while providing jobs to more than 35 million individuals [37]. In Pakistan, textile accounts for 60% income of expert income, a source of employment for 38% of the total labour force, and fourth-largest exporter of cotton [154]. So, no

T. Sarwar · S. Khan (✉)
Department of Environmental Sciences, University of Peshawar, Peshawar 25120, Pakistan
e-mail: sardar.khan2008@yahoo.com

S. Khan
Kohat University of Science and Technology, Kohat, Pakistan

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Table 1 Top 10 textile-producing countries

No.	Country	2020 outputs in global shares (%)
1	China	52.2
2	India	6.9
3	United States	5.3
4	Pakistan	3.6
5	Brazil	2.4
6	Indonesia	2.4
7	Turkey	1.9
8	South Korea	1.8
9	Thailand	1.1
10	Mexico	0.9

Source [168]

industry can compete with textile to bring foreign reserves and generate employment for individuals.

China leads the world in exporting textiles to other countries globally. Therefore, China was considered in the top list of textile exporters in 2016 with a net value of 106 billion US dollars. The 28 countries of the European Union were ranked second after China with a net value of 65 billion USD, while other countries like Turkey, India, and USA were ensuing with net values of 11, 16, and 13 billion USD [150]. In 2016, China and 28 countries of the EU were considered among the top two exporters of cloth followed by other countries like Bangladesh, Vietnam, India, Hong Kong, and Turkey. In 2016, the values of textile exports and apparel exports were 284 billion USD and 443 billion USD demonstrated by the World Trade Statistical Review (Table 1).

2 Textile Industry Processes

2.1 Yarn Manufacturing

The manufacturing processes in the textile sector include yarn preparation, which is obtained from natural plants and animals. The mechanical processes are involved in yarn preparation like fibre blae opening, blending, mixing, clearing, drawing, roving, and finally spinning [66]. Further detailed processes of such production are described via material processing and technical control. The important and useful topics in the textile are staple-yarn technology, rolling-drafting, ring spinning, advancements in fibre production technologies, air open-end rotor spinning, and jet spinning [90]. The yarn-producing technology is considered as an important study in the preparation of yarn containing different processes [92].

2.2 Fabric Manufacturing

Three different techniques like weaving, non-weaving, and knitting are used to produce fabrics via fibre/yarn interlacing. The plain and simple weaves, such as tabby or plain, and satin and the fancy weaves, such as pile, jacquard, dobby, and gauze, are the most common forms of woven fabric manufactured [162]. The second most common form of cloth is knitted fabric, which is used after woven fabric. Knitted fabric has different properties like fitting the body shape and allowing for ease of movement, which remain an especially pleasant sports fabric structure, leisure wear, and undergarments. Woven textiles include warp and weft kinds, as well as raschel and tricot [162].

Interlaced fabric designs such as net, lace, and braid are also valuable. Non-woven fabric usage is continuously increasing in the market. The interlaced-fabrics textiles are finding intriguing applications in industrial and residential settings. Non-woven textiles include felting and bonding compounds. Laminating methods are also becoming more important, and new progress involves needle weaving and sewing-knitting [162].

An ecological approach to make fabrics from raw bottles is also an environment-friendly process [124]. Fabric producers are encouraged by the ease and low cost of producing recycled polyester yarn. Chopped and grounded plastic bottles into little bits that soften and melt as they pass through a series of tiny holes, resulting in thin strands. The thin strands produced are then currently used in the woven and knit industries to make fabric [124]. Strong recommendations should be made in order to use environment-friendly processes to mitigate the textile wastes.

2.3 Product Planning

Production planning is a difficult aspect of any industrial business. Textile planning is complex due to the variety of fibres, counts, yam, spinning systems, processes of preparation, and final products. All of these issues, when paired with the customer's needs for accurately completed orders and quick delivery dates, hinder the production planning process. Furthermore, since severe international rivalry has influenced the market, competent planning for production in the textile sector has become increasingly important [121].

The fibres are removed from other components such as capsule fragments, leaves, twigs, and soil and also from the seeds in the first phase of the methods outlined in a set of spinning drums and moving carding bars fitted with metal combing teeth comb the fibres in a carding machine. Consequently, the product formed is a soft homogenous fibre band. The silver has been holding between the parallel fibres as a result of friction among parallel fibres, which in turn provides rigidity in further manufacturing processes. Basically, the spinning process is responsible for transforming a loose fibre bundle into a real yarn. The twisting of the pack of similar fibres provides the yarn its toughness. The most widely used spun techniques in the industry are open-end spinning, ring spinning, and air jet spinning [105].

Knitting, the most popular way of interloping and producing textile goods, necessitates a reasonably fine, smooth, and robust yarn with high elastic recovery characteristics. The outdone system has been shown to be particularly appropriate for spinning yarns used for knitted garments, socks, and outerwear, while the combed cotton system has proven to be highly appropriate for spinning yarns used for undergarments, sports, and socks. The production of innovative fibres and texturing methods have been especially advantageous to the knitting business, resulting in a tight relationship between the two sectors [105]. Weft and warp techniques are used to synthesise yarns in knitting processes. The distinction between weft and warp knitting stems from the movement of the needles during manufacturing and how the yarn is supplied. Weft knitting is a one-fibre method, which implies that the stitches are constructed using only one fibre. The needles are manipulated independently, whereas the warp knitting needles are moved concurrently. As a result, all needles require the fibre material simultaneously [149].

Braiding is a fabric-making technique that takes at least three yarns. The braid is produced by alternately interweaving the strands according to a certain algorithm. Braids are "real or large bodies with a regular thread density and a closed product surface, whose braid bobbin yarns are intertwined slantwise towards the product edge". A woven fabric, on the other hand, has threads that are interwoven perpendicular to the product edge and can have a biaxial or triaxial structure [42].

Lastly, finishing is a modification that is applied to a cloth to alter its look, handling—touch, or durability. The intention of finishing is that the fabric will be more appropriate for its intended use and involves any common treatment given to clean and iron fabrics. Finishing also creates exclusive variations of fabrics by using chemical treatments, dyeing, printing, and other techniques to make the fabric attractive and appealing. Finishing is divided into two processes: chemical and mechanical. Chemical finishing refers to treatments that modify the performance of a textile fabric and in which the chemical is the primary component of the change. Mechanical finishing refers to mechanical devices that physically change the cloth. The finish processes assist to improve the appearance and look of the fabric; provide diversity in fabrics through dyeing and printing; improve the fabric texture; make the fabric more usable; increase the draping ability of lightweight fabrics; and make the fabric appropriate for an end purpose [105].

2.4 Processes Responsible for Environmental Pollution Especially for Dyes

The pollution generated by textile effluents has become a major problem since it endangers both human health and the environment [132]. The dyeing process is connected with an environmental issue since washing coloured cloth and discharging dye wastewater may release 10–50% of different chemicals related to dyestuff into the environment. The inefficient dyeing and finishing process might result in the discharge of 200,000 tonnes of wasted dyestuff into the environment globally [28].

Textiles are offered varied functions through the finishing procedures. Formaldehyde is widely used as a glueing agent, softener, and cross-linking resin. Because of the release of formaldehyde, such textile goods can cause eye irritation, skin itching, and allergies [82]. Perfluoroalkyl chains with eight or more fluorinated carbons are utilised to provide resistance to oil stain and also water repellence in textile products [138]. Perfluorooctanoic acid and perfluoro octane sulphonate form a long chain, which degrades and produces harmful impacts for all living species [76]. Many finishing compounds used to provide flame retardancy, like polybrominated diphenyl ethers, have been proven to be extremely hazardous to people [134].

Water is used at each stage like wet finishing, transferring chemicals to textiles, and washing materials before going on to the next phase. Aside from these textile operations, water is consumed during boiler, cooling water, steam drying, and cleaning [165]. A medium-sized textile industry manufacturing roughly 8000 kg of cloth per day spends around 1.6 million litres on water. One-fifth of this amount is spent on dying, while the other half is spent on printing. Depending on the colour used in the dyeing, 30–50 l of water are consumed per kilogramme of cloth. Approximately 60 l of water are used per kilogramme of yarn during the dyeing process. The wastewater produced during the dyeing process accounts for approximately one-fifth of the total effluent. Water is also necessary to attain the requisite fastness values and to clean the equipment. The quantity of water used to make fabric for a couch cover is around 500 gallons [73]. Approximately two hundred thousand kilos of water are polluted during traditional dyeing and finishing procedures of 1000 kg of cloth, and a large amount of steam and hot water is required for energy during these phases [153]. A cotton shirt requires around 2500–3000 l of water to manufacture [56].

3 Environmental Pollution and Textile Industries

Many environmental issues are raised by textile waste [17]. Numerous studies were carried out to identify the environmental consequences of the business and mitigate its harmful effects.

3.1 Water Pollution

The textile business is global in scope, generating over $1 trillion in revenue, accounting for 7% of entire global exports, and employing approximately 35 million people worldwide [36]. Despite unquestionable significance, the industrial sector is one of the most polluting in the world, using large amounts of chemicals and fuels [14]. The massive consumption of drinking water is in different activities of its production chain, including washing, bleaching, and dyeing [65]. The ineffective dyeing and finishing processes might result in the discharge of 200,000 tonnes of wasted dyestuff into the environment globally [28]. 1.6 million litres of water are consumed to produce 8000 kg of clothes in a medium-sized textile mill. About 30–50 l of water are in each kilogramme of cloth production [73].

The textile sector is responsible for a wide range of environmental effects [108]. Particulate matter and dust, oxides of nitrogen and sulphur, and volatile organic compounds are among the pollutants released into the atmosphere. The major solid waste consists of fragments of textile fabrics and yarns, as well as wasted packaging. The textile sludge, on the other hand, exposes issues linked to excess quantities and undesirable composition, frequently exhibiting large loads of organic matter, micronutrients, heavy metal cations, and pathogenic microorganisms [14].

3.2 Soil Pollution

The effluent from the textile industry pollutes the land. The topsoil is the most significant medium for growing plants, shrubs, and crops, among other things. The quality of crops is determined by the condition of the soil. As a result, as the quality of the soil deteriorates due to contaminated industrial effluent, so do the quantity and quality of crops. It has also been observed that the lower areas are becoming more contaminated than the upper regions. Such contamination is attributed due to the position of the lower ground [72]. The solid wastes dispose into the underground water through porous soils and also contaminate land [155, 81].

3.3 Textile Aerial Pollution

Carbon dioxide, aerosol fumes and gases, toxic gases, smoke, and dust are all examples of air pollutants. The majority of textile mill processes emit pollutants into the atmosphere. Gaseous emissions have been recognised as the textile industry's second most serious pollution concern [72]. The primary source of air pollution in the textile sector is during the finishing phases when various procedures are used to coat the textiles. Lubricating oils, plasticisers, paints, and water repellent chemicals are examples of coating materials. Organic substances such as oils, waxes, or solvents, acid vapour, odours, and boiler exhausts are examples of coating materials [96]. Cleaning and production modifications produce sludge in the tanks containing process chemicals, which may contain hazardous compounds and metals [104].

Table 2 Dye pollution data reported from different countries

Dye conc. (mg/l)	Countries	References
100	China	[158]
3.9	Kenya	[173]
100–2000	China	[181]
50	India	[145]
100	Bangladesh	[77]
200	Turkey	[33]

3.4 Dye Pollution

Dyes are solvable organic chemicals, particularly those categorised as reactive, direct, basic, and acidic [95]. Dyes have a very high dissolution property in water, making it difficult to remove them using traditional techniques [59]. The capacity of dyes to transmit colour to a particular substrate is one of its characteristics due to the occurrence of chronographic groups in molecular structure [137]. Nevertheless, the ability to fix colour to the material is associated with auxotrophic groups, which are polar in nature and may bind to polar groups of textile fibres [174].

Textile dyes' colour may not only contribute to aesthetic harm to the aquatic environment [135], but also hinders light permeation through water [59], resulting in a drop-in photosynthesis rate [71] and (DO) dissolved oxygen levels, impacting the whole aquatic biota [59]. Textile dyes are also toxic, mutagenic, and carcinogenic agents [84]. The dyes act as important environmental pollutants as shown in Table 2 and transverse whole food chains, giving biomagnification [131], which in turn makes the prey more contaminated as compared to organisms at a higher level [111]. So, the azo-dyes due to their non-binding capacity to clothes contaminate water, which requires attention because such contaminated water is then used for irrigation and other purposes in poor countries [127]. Lastly, the microbes in the soil and germination and growth of plants are greatly influenced by the utilisation of azo chemicals [71, 127].

4 Health Risks

4.1 Air Pollution and Health Risks

The majority of operations in the wet processing industry emit air pollution shown in Table 3. Gaseous air has been recognised as the second most significant pollution concern for the dyeing and printing sectors. Air pollution is caused by the release of several gases such as Nitrogen dioxide (NO_2), Carbon dioxide (CO_2), Sulphur dioxide (SO_2), and others [163]. SO_2 is the causing agent of irritation in the respiratory system and bronchitis, while CO_2 inhibits oxygen into body cells causing

Table 3 The gases emission into the atmosphere and their health risks

Pollutant	Amount	Health risks	References
CO_2	500–5000 ppm	Psychomotor abnormalities, complications in the cardiovascular and respiratory system	[99]
SO_2	75 ppb	Effects on airway epithelial cell function, amplification of allergic irritation, and a possible increase in neurogenic inflammation due to chemical nuisance properties	[128]
NO_2	4700 ug/m^3	Bronchoconstriction	[167]
	–	Respiratory infection	[123]
	–	Increase mortality	[7]
Arsenic	0.5 ug/kg	Leucomelanosis, melanosis, and keratosis	[126]
		High blood pressure, obstetric problems, diabetes mellitus, neurological disorders, and respiratory system diseases	[4]
Cadmium	3 ug/kg	Damage to kidney, liver, skeletal muscles, and cardiovascular system	[87]
		Steroidogenesis, menstrual cycle disorders, delay in puberty and menarche, miscarriages, premature births, and reduced birth weight	[157]
Chromium	100 ppb	Carcinogenic	[152]
		Nausea, headache, or even oral cavity cancer as well as genetic damage	[45]

unconsciousness [102]. The production of artificial fibres is the result of greenhouse gases emissions because of the energy requirement [12].

The amount of greenhouse gases was 2.69–8.6 kg CO_2 eq/kg fibre [164]. Higher results were stated, i.e., 35.7-kg CO_2 eq/kg fibre. It is estimated that the cytotoxic capability of acrylic fibre production is linked to the emission of As, Cd, zinc (Zn), and Cr into both air and water [12]. One kilogramme of acrylic fibre produces approximately 0.013-kg SO_2 equivalent. For every kilogramme of acrylic fibre produced, 0.007 kg of NO_2 is discharged into the closest disposal canal via effluent discharge. The carcinogenic risk of acrylic fibre is owing to the emission of As, Cd, Zn, and Cr into both air and water during the production process [179].

4.2 *Land Pollution and Health Risks*

The effluent from the textile industry contaminates the land. The soil is the most significant medium for growing plants, shrubs, and crops, among other things. The quality of crops is determined by the condition of the soil. As a result, as the quality of the soil deteriorates by contaminated industrial effluent, so do the quantity and quality of crops. It has also been observed that the lower areas are becoming more contaminated than the upper regions [72]. In landfills, the solid waste decomposes to create methane (CH_4), a powerful greenhouse gas. This ameliorates climate change by causing the ozone layer to deplete. The ecosystem suffers as a result of inappropriate disposal of biodegradable garbage, often known as unlawful dumping. Leaching is the process by which solid waste enters the pores in the soil and pollutes groundwater, thereby contaminating the land [148, 155].

Textile industry sewage mostly comprises alkali, residual colours, starches, soluble salts, cellulose primarily calcium and sodium, silicate, oil, and other pollutants. Due to a lack of economically feasible treatment methods, the industrial effluent created by these rapidly growing textile and dying plants is typically dumped untreated onto the ground surface. Consequently, such processes result in contamination of soil level along with groundwater and the possibility of pollution of other biophysical resources along the discharged region. It has been demonstrated that textile industry wastewater has a direct influence on the physicochemical characteristics of soil [98].

4.3 Water Pollution and Health Risks

Textiles consume and pollute water more and ranked 2nd after agriculture portrayed in Table 4 [112]. Direct effluents from textiles into water bodies are the main source of water pollution [14]. Such discharge of effluents is 80% of total wastes produced by the textile industries [172]. In making a single cotton shirt, it is estimated that 2500–3000 l of water is used [151]. A case study was conducted to better understand how a conventional finishing factory operates and what may be accomplished via modernisation [156]. Without paying attention to the toxics in effluents, the waste from the textile is disposed into the water. Such wastewater contains high (BOD) Biological Oxygen Demand, (COD) Chemical Oxygen Demand, high (SS) total suspended solids, grease and oil, sulphides, sulphates, phosphates, Cr, copper (Co), and/or the salts of other heavy metals [160].

Improper or apparently processed wastewaters contain varying levels of heavy metals such as As, lead (Pb), nickel (Ni), Cd, Co, Mercury (Hg), Zn, and Cr, which have the potential to harm crops grown under such irrigation condition [139, 143]. The contamination of heavy metals is a growing issue in our seas, lakes, and rivers. Heavy metal deposition in fish, oysters, sediments, and other aquatic ecosystem components has been observed globally [144]. These hazardous heavy metals that enter the aquatic environment are adsorbed on top of particulate matter, despite the fact that they can form free metal ions and soluble complexes that are readily available [144].

Table 4 Water pollution due to textile and health risks

Pollutant	Short-term effects	Long-term effects	References
Zinc	–	Support cancer development	[23, 75]
		Involved in the pathogenesis of Alzheimer's disease	[171]
		Age-related degenerative diseases	[103]
		Influence Type I and Type II diabetes	[130]
	Cramps in the stomach, vomiting, and nausea may occur. Ingesting high levels of Zn may cause anaemia, pancreas damage, and drop in levels of high-density lipoprotein cholesterol in the body	–	[11]
	Inhalation exposure to Zn for up to 3 days caused severe damage to liver and lung tissues	–	[169]
Mercury	–	Increased cardiovascular health effects	[129]
		Atherosclerosis disease and acute coronary insufficiency	[166]
		Mercuric chloride ($HgCl_2$) and methylmercury (CH_3Hg) are cancerous to humans; these can damage the human nervous system; high levels of exposure can permanently damage the kidney, brain, and foetuses; and effects on the brain may result in irritability, shyness, tremors, changes in eye sight or hearing loss, and memory problems	[101]
	Short-term exposure to high levels of metallic mercury vapours may cause lung damage, nausea, diarrhoea, vomiting, increased blood pressure or heart rate, skin diseases, and eyes diseases		[101]
Sulphates	Insufficient evidence about the toxicity of Sulphates to humans	–	[175]
	Increase in stool volume, moisture, and reduced intestinal transit time if exposure exceeds more than 500 mg/l		[41]

(continued)

Table 4 (continued)

Pollutant	Short-term effects	Long-term effects	References
		Not found yet	[29]
Sulphides	Severe mitochondrial swelling in support cells and olfactory neurons, thus resulting in olfactory epithelial necrosis and sloughing	–	[16]
	Hyperpnea, Unconsciousness, apnea, and death	–	[114]
	Neurological disorders such as headaches, dizziness, loss of balance, lack of concentration, recent and long-term memory loss, mood swings, irritability, excitement, and sleep disturbances. Behaviour changes such as anger, depression, tension, confusion, anxiety, fatigue, and vigour. The respiratory symptoms may include apnea, cough, noncardiogenic pulmonary edema, and cyanosis. Eye irritations like conjunctivitis, lacrimation, and photophobia and skin symptoms include itching, dryness, and redness	–	[170]
		Damage to the nervous system, status epilepticus, bronchospasms, and delayed respiratory failure	[141]
		Neuronal olfactory damage, sense of smell is disturbed, and rhinitis	[39]
Phosphates	Hypocalcaemia and related signs including tetany, hypotension, and tachycardia, deposition of calcium phosphate crystals in various tissues, including often fatal cardiovascular calcification	–	[125]
		Cancer, affects the metabolism of Vitamin D, effect the nervous systems, adverse reproductive outcomes, as well as adversative mental development in infants	[64]

(continued)

Table 4 (continued)

Pollutant	Short-term effects	Long-term effects	References
Copper	Short-term effects from ingestion of high levels of Co can cause gastrointestinal distress with symptoms such as nausea, vomiting, and pain in abdomen. Also, liver toxicity was seen in doses high enough that resulted in death. High levels of exposure to Co can cause damage to red blood cells, possibly resulting in anaemia	–	[97]
		Carcinogenic, damage to liver and kidney	[97]
Nickle	–	Decreased body weight, heart and liver diseases, and irritation of the skin	[107]
	–	Lung, nose, larynx and prostate cancer, Sickness and dizziness, Asthma and chronic bronchitis, Allergic reactions, and pneumonitis	[97]

4.4 Dye Pollution

Dyes are present in varying concentrations in effluents when released containing numerous processes. The dye content in the discharged wastewater ranges from 20 to 200 ppm [54]. The aquatic life is largely influenced by the release of toxics into water producing mutagenic and carcinogenic effects [30]. The 4-aminobiphenyl induces chromosomal instability and damage to DNA along with other serious complications [25, 93]. Similarly, gastrointestinal issues are caused by sunset yellow dye, while quinoline yellow dye, which is used in the pharmaceutical sector, can induce itching, sneezing, and hyperactivity in youngsters when consumed [31]. Headache, vomiting, ulcer, nausea, and other cardiac complications are attributed to exposure to methylene blue dyes [83]. Hence, dyes can alter the rate of photosynthetic activity in phytoplankton, which in turn is responsible for global warming [78].

Dye concentrations in textile effluent have been recorded in a variety of ranges. The ranges include the dye level in textile effluent is 10–50 mg/l [89]. The reactive dyes in cotton mills are allegedly discharged in concentrations of 60 mg/l [140] and 100–200 mg/l [55]. An extremely high concentration of reactive dyes has been reported, i.e., 7000 mg/l [86]. About 20–50 mg/l of dye concentration has been reported in samples collected from 14 Ramadhan Textiles in Iraq [2]. Moreover, the dye Acid orange-10 concentration was 45 mg/l [146], while 10–250 mg/l of dye concentration was found in disposals from houses [53].

4.5 Dye Classification and Health Effects

Dyes, metals, and other toxins are mixed with the effluents emitted by textile producers. Natural and synthetic dyes are the two types of colourants. Synthetic dyes are cheaply manufactured, come in a variety of colours, and are distinguished by their fastness, making them more commonly utilised as compared to natural dyes [85]. Synthetic dyes are categorised into various groups according to their chemical structure, i.e., azo, sulphur anthraquinone, phthalocyanine, and triarylmethane, and according to their mode of application, i.e., reactive, direct, disperse, basic, and vat dying [120]. The production of dyes is approximately 70 million tonnes, and 10 thousand dyes are used in textile processes throughout the world [22].

Different toxics are present in the textile effluents containing a high load of salts, alkalis, binders, dispersants, volatile organic compounds, surfactants, chlorobenzenes, reducing agents, dioxin, phthalates, phenols, pentachlorophenol, detergents, and heavy metals [63, 68, 180]. The yearly disposal of about 0.4–0.5 million tonnes containing dyes and compounds flow into water bodies, creating pollution, health issues shown in Table 5, and other environmental difficulties [15].

Natural dyes like Indigoid dyes, Anthraquinone dyes, Naphthoquinone dyes, Benzoquinone dyes, Flavonoid dyes, Carotenoid dyes, and Tannin-based dyes are the classified on the basis of chemical structures of dyes [133]. Natural dyes are extracted from plants, animals, minerals, and microorganisms [93]. Some of the examples include blue colour dye obtained from indigo plants, red colour dye from madder and morinda, and yellow from various plants like turmeric barberry and marigold. Dyes obtained from animals include red colour dye from insects and Tyrian purple obtained from sea molluscs [133]. The textile standard has suggested that synthetic dyes be used within acceptable limits and that natural resources not be depleted for dye extraction. So, because the extraction of natural dyes utilising natural resources is not a sustainable choice when the entire globe is suffering the detrimental effects of climate change, synthetic dyes are favoured over natural colours [26, 108].

4.6 Colouring Agents

Textile colourants give colour to a textile item as a result of physical entrapment or chemical binding inside or around the textile substance, generally with a high degree of permanence. The textile material can take various forms, including fibre, yarn, fabric, garment, and so on. Textile colourants are available in liquid and solid forms, such as powders, granules, solutions, and dispersions. In some cases, precursors are applied to textile materials in order to create the colourant in situ within the cloth [159]. To colour textile items, both dyes and pigments are used [182]. Dyes are present in solution either at any stage during its application, while pigments are insoluble. The process by which dyes stay within a cloth is determined by the type of colourant used. Intermolecular forces work between dye and fibre following

Table 5 Dyes and their harmful effects

Dye classification	Health effects	References
Congo red	Carcinogenic	[177]
Triphenylmethane dyes	Carcinogenic to microbial and mammalian cells, mutagenic to rodents, and cause abnormalities in the reproductive system of fish and rabbits	[24]
Brilliant Cresyl Blue	Harmful impacts on humans and microorganisms	[3]
Rhodamine 6G	Causes human health issues such as irritation to the skin, eyes, and respiratory tracks. Ingestion via drinking water may cause subcutaneous tissue-borne sarcoma, a highly carcinogenic disease	[74]
Rhodamine B	Irritation to skin, eyes, and respiratory tract. It is a chronic neurotoxin and is carcinogenic to humans and animals	[51, 136]
Phenol red	Carcinogenic and toxic that stops the growth of renal epithelial cells irritation in skin, eyes, and respiratory tract. It has been testified that phenol red is mutagenic and is lethal to muscle fibres	[1]
Methylene Blue	Though it is a little toxic due to its effects like cyanosis, vomiting, heartbeat increase, quadriplegia, shock, jaundice, and tissue necrosis in humans	[88]
Crystal violet dye	Mutagenic and poisoning agent. It acts as a potent mutagenic and carcinogen and is responsible for tumour growth in some fish	[113]
Malachite green	It is a great threat to human health and the potential teratogenic, carcinogenic, and mutagenic	[43]
Azure B	Intercalate with the helical structure of DNA	[57]
Disperse Red 1	Increase the frequency if micro nuclei	[48]
	Formation of DNA adducts	[27]
	Mutagenic effects	[67]
Disperse Orange 1	DNA damage and cytotoxic effects	[49]
Sudan-I dye	Enzymatically altered into carcinogenic aromatic amines through the action of the intestinal flora	[117]
Basic Red 9	Breaks down into carcinogenic aromatic amines under anaerobic conditions and their disposal in water bodies has the potential for allergic dermatitis, skin irritation, mutations, and also cancer itself	[147]
	Local sarcomas and tumours in the liver and bladder	[118]
Crystal violet dye	Mitotic poisoning, which is associated with abnormal accumulation of metaphases	[100]
	Damage to chromosome	[111]
	Carcinogenic cause	[13]

(continued)

Table 5 (continued)

Dye classification	Health effects	References
	Chemical cystitis in humans, irritation of the skin and digestive tract, and respiratory and failure of the renal system	[100]

adsorption onto and/or dissolution inside the polymer. The formation of covalent bonds between the dye and the fibre and entrapment of colourant particles within the textile by deposition of an insoluble form of the dye may all contribute to retention [182].

4.6.1 Types of Colouring Agents

Natural Colourants

All textile colourants were derived directly from natural sources, such as insects, plants, and shellfish before the production of picric acid as a yellow dye for silk [34, 182]. In the 1920s, natural colourants were gradually supplanted by synthetic dyes and pigments, which provided a broader and brighter colour range as well as better economy and convenience. While, a recent surge in interest in natural textile colourants due to notions of renewable supply and minimal environmental effect due to non-suitability for industrial usage, have a restricted colour range, and exhibit only modest degrees of fastness at best. Furthermore, natural dyes sometimes need the application of a fixative, known as a mordant, to achieve adequate permanence; conventional metallic mordants are harmful to the environment. Textile colours derived from natural sources, such as Indigo, may now be produced more effectively by chemical synthesis [69].

Synthetic Colourants

A large proportion of textile colourants are chemically synthesised on an industrial scale [61]. Every year, about a million tonnes are generated globally. Since the first commercially effective synthetic textile dye, Mauveine, was produced in the late 1850s, tens of thousands of colourants have been sold [8, 182]. A more methodical approach to textile colourant research, however, spearheaded mostly by the German dye industry, resulted in a greater knowledge of both colour and chemistry structure connections. At the turn of the century, Germany produced 85% of the world's synthetic dyes, with the remaining 10% produced in the United Kingdom, France, and Switzerland. After some decades, manufacturing is centred in Asia, notably China and India, due to lower cost bases. Textile colourants have a multibillion-dollar global market [9]. The clothing sector consumes the most dyes and organic pigments. Some of the most popular textile dyes are quite commodities, produced in large quantities of over 1000 tonnes per year for delivery at a few dollars per kilogramme or even less.

5 Other Aspects of Textile Industries

5.1 Microplastics

Microplastic is the form of a plastic polymer having a particle size of less than 5 mm [6]. Microplastic can be derived from either primary or secondary sources. Also, the European Chemicals Agency (ECHA) is more specific in its proposed definition:

"'Microplastic' means particles containing solid polymer, to which additives or other substances may have been added, and where ≥1% w/w of particles have:

(i) all dimensions 0.1 μm ≤ x ≤ 5 mm, or
(ii) for fibres, a length of 0.3 μm ≤ x ≤ 15 mm and length to diameter ratio of >3" [32].

Since their origin, primary microplastics have a micrometre size, such as microplastic fibre generated from fabric washing [109] and cosmetic goods (facial cleanser) labelled as "microbeads" or "microexfoliates" [47]. Secondary microplastics are formed as a result of physiochemical and biochemical mechanisms in the environment that degrade bigger plastic trash [19].

5.1.1 Production of Microplastics from Textile Industries

Many research on the release of microplastics from textiles have concentrated on home washing as a source of fibres entering waterways. Shedding is affected by the qualities of the textile item, such as fibre material, yarn size, fabric structure, fabric weight, and fabric finishing [21]. Polyester fleece, for instance, has been shown in several tests to have greater fibre counts, i.e., >7000 fibres/m^{-2}/l^{-1} as compared to other forms of polyester textiles [5]. Variability in washing equipment and settings, as well as detergents, can also affect the number of fibres released from a garment or item, with both dryers and washers causing textile fibre shedding. Several researchers have discovered that tumble drying increases fibre release by 3.5 times as compared to washing polyester fleece items [116]. Further possible sources of textile-derived microplastics in the environment include ropes and netting fragmentation and the breakdown of carelessly disposed non-woven hygiene items [21].

5.1.2 Process of Microplastic Formation

The rising global manufacturing of synthetic fibres poses a threat that microplastics produced by synthetic textiles will continue to pollute our ecosystem in near future [60]. Fibres are frequently identified as the major ingredient of microplastics discovered in wastewater treatment facilities [80, 106], as well as in a wide range of environmental samples [35, 50]. According to a recent modelling research, fibres from textiles substantially contribute to microplastic emissions into freshwater [79]. As a result, these microplastics are released into the environment, which in turn are present in effluents or trapped by the sludge.

Several inferences about the release processes, however, may still be drawn. Because the washing studies looked at different textiles using different experimental setups and analytical methods, the amount of microplastics released per wash reported varied, ranging from 0.012 mg/g [116] to 3.3 mg/g [142] and from 23 MPF/g [116] to 1273 MPF/g [44]. It is estimated that the release of microplastics from textiles is heavily influenced by the types of textiles and their treatment procedures [20]. Hence, materials utilised in several research ranged from complete garments [18, 58] to textile pieces [44], to double folded and stitched edges [62], and to scissor-cut edges (Table 6).

6 Conclusion

This study focused on the wastes generated by textile industries and their negative influences on humans and the environment. Dyeing may be either natural or artificial, which has serious environmental health issues. About, 200,000 dyes are disposed into our environment every year. Also, colourants are either primary or secondary and have negative effects on the environment in the form of health complications to humans. Different types of microplastics can also have serious effects on the environment and humans.

Table 6 Types of microplastics and their impacts on human health

Types of microplastic	Concentration	Health effects	References
Polystyrene	Short-term exposure (170 mg/m^3) long-term exposure (85 mg/m^3)	Possibly penetrate into the outer cell membrane, intracellular oxygen species endocytosis internalisation, cytotoxicity, oxidative stress, genotoxicity, and even cause damage to DNA	[119, 178]
	–	Low toxicity on cell capability, oxidative stress and membrane reliability and fluidity, disrupt mitochondrial membrane potential and plasma membrane inhibition, Adenosine triphosphate binding cassette	[176]
		Cytotoxic effects, oxidative stress, inflammatory reactions, and disruption of the epithelial layer	[38]
Polypropylene	10 mg/day		[161]
		Asthma, pneumothorax, alveolitis, chronic bronchitis, and pneumonia	[115]
		Cytotoxicity, hypersensitivity, disruptive immune responses, and acute responses such as haemolysis	[70]
		Some degree of cytotoxicity at high dosages, low degree of induction of proinflammatory cytokines, and enhanced histamine release from various cells	[70]
Polyethylene	–	No obvious toxic effect, still some nanoparticles are internalised into endo-lysosomal compartments, which bears a high propensity to cross the intestinal barrier	[94]

(continued)

Table 6 (continued)

Types of microplastic	Concentration	Health effects	References
		Intestinal damage	[91]
		Variations in plasma levels of various metabolic enzymes and immune markers, combined with Cadmium polyethylene can enhance the toxicity of Cadmium	[10]
Polycarbonate	–	Bisphenol-A, a by-product of polycarbonate, is a known endocrine disruptor that may cause colon cancer	[52]

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