ACCSCIENCE PUBLISHING

Explora: Environment and Resource

REVIEW ARTICLE

A critical review on environmental pollution caused by the textile industry

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Abstract

Environmental pollution is one of the most critical challenges facing modern society, and the textile industry is a significant contributor to this problem. As global demand for textiles rises, so does the environmental toll of textile production. This study explores the various ways in which the textile industry contributes to pollution and endangers both ecosystems and human health. A major source of pollution is the industry's high energy consumption, often fueled by coal, oil, and natural gas. The burning of these fossil fuels releases greenhouse gases and other harmful emissions, contributing to air pollution, climate change, acid rain, and ozone depletion. Another major issue is the use of toxic chemicals and dyes in textile processing. Improperly treated wastewater from dyeing and finishing processes is frequently discharged into rivers, contaminating water sources, harming aquatic life, and threatening human health. Synthetic fibers like polyester, nylon, and acrylic also pose serious environmental risks. These non-biodegradable materials release microplastics during washing, which enter water systems, harm marine animals, and may even enter the human food chain. In addition, the industry generates significant solid waste, much of which ends up in landfills and releases toxic substances as it degrades. Human health is also directly impacted, particularly for those living near or working in textile facilities, who may suffer from respiratory diseases, skin disorders, and even life-threatening illnesses due to prolonged exposure to pollutants. In conclusion, addressing textile pollution requires stricter environmental regulations, sustainable production practices, better waste management, and increased awareness. Without urgent action, the negative impacts will continue to escalate.

Keywords: Textile industry; Pollution; Chemical wastes; Environment pollution; Plastics; Ecosystem; Soil; Ozone depletion; Synthetic fabrics

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Citation: Rofi MRI, Rahman MR. A critical review on environmental pollution caused by the textile industry. *Explora Environ Resour*. 2025;2(2):025160032. doi: 10.36922/EER025160032

Received: April 18, 2025

Revised: May 13, 2025

Accepted: May 20, 2025

Published online: June 6, 2025

1. Introduction

According to Dadi *et al.* industries are frequently seen as the "engine" of economic growth, helping many nations achieve rapid economic expansion.[1] One of the most significant subsectors of the manufacturing sector, the textile industry contributes substantially to the economic transformation of nations such as Nigeria, Bangladesh, India, Vietnam, China, and Turkey.[2,3] For instance, in Bangladesh, the textile and apparel industry employs 50% of the industrial labor force and generates over 77% of the nation's foreign exchange profits.[3] Since the 1990s, consumer behavior has shifted toward more

regular garment purchases; nonetheless, this trend has resulted in an increase in textile waste in landfills.[4,15] To put this into perspective, the amount of clothing discarded annually by Americans has doubled in <20 years, and without corrective measures, it is projected to triple.[4] A primary driver of this sharp increase is fast fashion.[4,15] Many merchants make cheap, low-quality apparel to meet the demand for ever-changing fashion fads.[4] Fast fashion brands such as Forever 21, Zara, and others may release new items several times per month in response.[4]

Millions of men and women are employed in the textile industry worldwide, earning their livelihoods from this sector.[5] While the industry provides economic benefits, it also poses serious threats to the environment and ecosystems.[5] The textile industry produces a vast volume of goods annually, generating approximately USD 1 trillion and accounting for 7% of global export goods.[5] The industry employs around 35 million workers globally.[6] However, it contributes significantly to environmental pollution in various ways.[6,12] Due to its large scale, the industry consumes large amounts of energy, most of which is derived from the combustion of fossil fuels.[7] This energy consumption results in the emission of large amounts of toxic gases, including nitrogen oxides (NO_x) and sulfur oxides (SO_x), which are harmful to human health and contribute to global warming by raising atmospheric temperature.[7] Furthermore, the textile industry is a major water consumer, particularly for processes such as cleaning and dyeing.[8] It also generates substantial wastewater, which is frequently discharged through drainage systems into natural water bodies such as rivers, canals, and oceans or infiltrates into the soil.[1,8,13,14] This water pollution reduces the availability of clean, usable water and, in some countries, has led to increased water costs.[9,10,16] In addition, the pollutants degrade soil quality and reduce its fertility due to the accumulation of toxic substances.[9,17] As a result of these various forms of pollution, the natural cycles of the Earth's ecosystems are disrupted.[10,18] The environmental damage caused by the textile industry is not only a present concern but also a threat to future generations, with significant implications for global climate change.[4,5,11,19]

The objective of this article is threefold: (1) to describe various kinds of environmental pollution caused by the textile industry; (2) to examine the various types of pollution involved; and (3) to discuss the responsibilities of the textile industry in contributing to environmental pollution.

2. Methodology

This study adopts a qualitative research approach through a comprehensive literature review to examine the environmental pollution caused by the textile industry. The methodology involves collecting, analyzing, and synthesizing data from previously published research articles, industrial reports, environmental assessments, and relevant case studies.

Sources were selected from peer-reviewed journals, reports from governmental and non-governmental organizations, and recognized environmental databases. The literature was reviewed with a specific focus on identifying the types and sources of pollution in textile manufacturing processes—specifically air, water, and solid waste pollution. Further, the study assessed the environmental impact of various textile processing stages, such as dyeing, printing, and finishing.

Data collection was conducted by searching electronic databases like Google Scholar, ScienceDirect, ResearchGate, and other academic repositories, using keywords such as "textile industry pollution," "environmental impact of textile production," "textile wastewater," "air emissions in textile industry," and "solid waste from textile processing." Articles published between 2000 and 2023 were prioritized to ensure relevance and currency of the information.

The findings were thematically categorized to highlight key environmental concerns and the pollution footprint of different textile manufacturing stages. Where applicable, comparative data and statistics were tabulated or referenced to support critical analysis.

3. Literature review

The textile industry is one of the large sectors contributing significantly to the stabilization of the global economy. Many countries depend on this sector for remittance generation. It also fosters international trade by establishing commercial relationships between countries for the exchange of textile goods. Air pollution from the textile industry arises mainly from the release of nanofibers and microfibers, as well as from the combustion of fossil fuels used in various production processes. During dyeing operations, the emission of toxic gases further contributes to atmospheric contamination. Workers exposed to such environments may develop long-term respiratory and systemic diseases due to continuous inhalation of polluted air.

3.1. Toxic nature of textile dye

Heavy metals such as iron, lead, nickel, copper, zinc, and chromium are found in trace amounts in textile dyeing effluents.[18] The synthetic azo dyes used in textile manufacturing are particularly toxic and carcinogenic, posing a serious health risk to humans.[18] These dyeing effluents are released into nearby water sources,

agricultural areas, irrigation channels, and ultimately into rivers and seas.[9,18] Industrial wastewater from textile and dyeing processes can constantly change the turbidity, odor, noise level, temperature, pH, and other physical, chemical, and biological characteristics.[18] These changes adversely affect biodiversity, livestock, wildlife, fish populations, and community health. The dyes present in the wastewater groundwater are unsuitable for human use, contributing to the spread of waterborne illnesses, including dermatitis, mucous membrane and nasal septal perforation, and severe respiratory tract irritation. Adulteration of these aquatic systems poses serious socioeconomic and public health threats.[18]

Figure 1 illustrates the effluent load from textile industries across various states in India, depicting the types and quantities of effluents discharged during textile processing and showcasing the environmental burden imposed by these pollutants. The total effluent load presented in the figure includes: biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), pH level, and heavy metals.

The BOD indicates the amount of biodegradable organic matter present in the water. High BOD levels in textile effluent point to significant organic pollution, which depletes dissolved oxygen in aquatic systems and threatens aquatic life. COD represents the total quantity of both biodegradable and non-biodegradable chemicals in the wastewater. High COD levels reflect a high pollution load and pose a toxicity risk to the ecosystem. TSS consists of small solid particles suspended in wastewater that

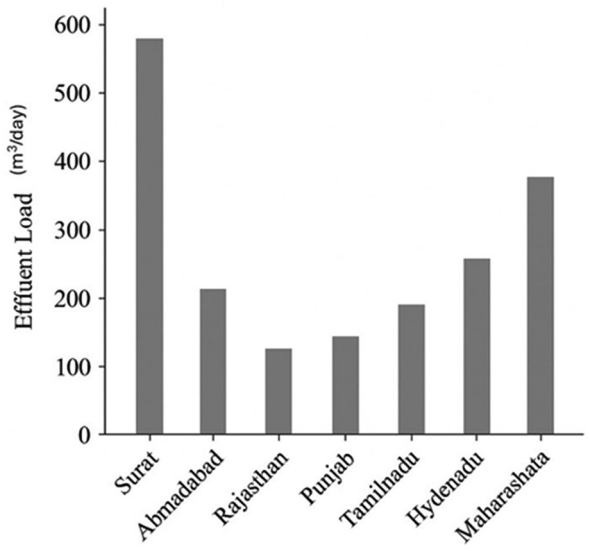

Figure 1. Effluent load from textile industries in selected Indian states and cities

increase turbidity, reduce sunlight penetration, and may carry heavy metals and toxic substances. TDS includes salts, minerals, and metals dissolved in water. High TDS levels compromise water quality, making it unsuitable for drinking and agricultural purposes. The pH of textile effluents often deviates from the neutral range, becoming either highly acidic or alkaline. Such pH levels harm aquatic organisms and can corrode infrastructure. Elements such as chromium, lead, and copper are often found in dyes and pigments used in textile processing. They are toxic, bioaccumulative, and carcinogenic, posing serious risks to human health and biodiversity.

3.2. Air pollution

Air pollution is the second most significant form of pollution caused by the textile industry. It is measured by the concentration of gases such as carbon dioxide (CO_2), carbon monoxide (CO), various metal-related gases, SO_x, and NO_x.[4] Air pollution in the textile industry mainly originates during the finishing stages of fabric production.[9] This stage involves the application of dyes, coating chemicals, and paints, which, when processed—especially using boilers—release toxic gases and harmful substances into the atmosphere.[9]

The main source of nitrogen dioxide (NO_2), one of the most harmful air pollutants, is mainly formed through the oxidation of nitric oxide (NO), which itself is created at high temperatures from nitrogen and oxygen present in the air.[4] NO_x gases are precursors to ozone and particulate matter, and they contribute to the development of photochemical smog, reduced visibility, acid rain, and ozone depletion. Due to their chemical properties, NO, NO_2, and other NO_x gases can penetrate deep into the lungs, reaching the alveoli and bronchioles, potentially leading to chronic respiratory conditions, and in severe cases, early death.[4]

Furthermore, NO_2 contributes to the formation of nitric acid in the atmosphere, exacerbating acid rain and negatively affecting ecosystems. According to Hussain and Luo (2019),[4] an increase in SO_2 emissions corresponds to a 1.01% rise in mortality risk due to respiratory complications.

The textile industry is frequently criticized for its detrimental effects on the environment, largely due to its extensive use of dangerous chemicals and the emission of harmful air pollutants like SO_2 and NO_x throughout the entire production chain — from raw material purchasing to final product finishing.[4]

3.3. Water pollution

Water is an essential element for life and its availability is fundamental to survival.[9] The textile industry is one of the

largest consumers of water among manufacturing sectors, particularly during wet processing operations such as washing, bleaching, sizing, dyeing, and printing.[9] Surface water is often used in these processes, and when wastewater from these operations is discharged untreated into rivers and other water bodies, it causes significant pollution.[9] This ongoing contamination has led to the severe degradation of surface water quality in many regions, rendering it unsafe for consumption. In some areas, surface water has become undrinkable, contributing to a shortage of potable water.[5,9] As a result, the cost of drinking water has increased. Water pollution also severely disrupts marine and freshwater ecosystems. Pollutants impair the natural food chain, making it difficult for fish to find uncontaminated food sources. Consequently, many fish die, further polluting the water and posing health risks to humans who consume them. In industrial areas, the food available to fish often consists of industrial waste, making the fish toxic and hazardous to human health.

Figure 2 presents the pH levels of wastewater discharged from textile industries across different regions in Bangladesh.[18] The ideal pH range for wastewater, according to environmental standards, is between 6.5 and 8.5. However, in several surveyed locations, the pH of textile wastewater falls outside this safe range, indicating acidic or alkaline pollution. Highly acidic (low pH) wastewater can corrode pipelines and harm aquatic life, whereas alkaline (high pH) discharges can disrupt the natural balance of water bodies. Abnormal pH levels suggest inadequate wastewater treatment in textile-producing areas. The discharge of untreated or partially treated wastewater poses a serious threat to aquatic ecosystems, soil health, and human health—especially for communities using nearby surface water for daily activities. This highlights the urgent need for effective monitoring and enforcement of wastewater pH regulations to minimize environmental and health hazards.

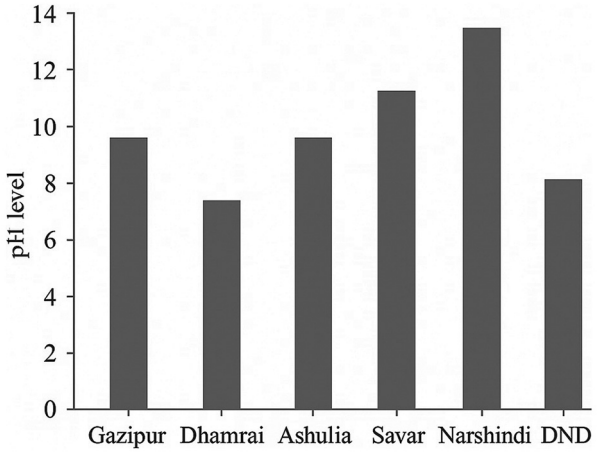

Figure 2. pH levels of wastewater from textile industries in various areas of Bangladesh
Abbreviation: DND: Dhaka-Narayanganj-Demra area.

3.4. Soil pollution

Textile wastewater also contributes significantly to soil contamination. Soil serves as the most vital medium for the growth of plants, crops, and vegetation.[9] The quality of the soil directly affects agricultural productivity; thus, when industrial wastewater contaminates the soil, both the quantity and quality of crops decline.[9] As textile effluents are typically discharged into low-lying areas, these regions suffer greater soil degradation compared to upland areas.[9] Contaminants in the wastewater, such as metal ions and salts, accumulate in the soil, disrupting its natural composition and nutrient balance. This pollution not only degrades the physical structure of the soil but also severely affects the population of essential microorganisms, which are vital for soil fertility and ecosystem balance.

3.5. Hazardous pollution

The textile industry is also a source of hazardous pollutants. For example, chlorophenols, which are frequently found in textile dyeing sludge, are highly toxic and persistent in the environment.[19] Even when used appropriately, many textile-related chemicals remain hazardous to both the ecosystem and human health. The situation worsens when these substances are disposed of improperly—without adequate treatment or containment—leading to the formation of hazardous waste.[9] While industrial processes are the primary source of hazardous waste, households also contribute to this issue. Items such as old batteries, paint thinners, and insecticide spray cans are common domestic hazardous wastes. Regardless of their source, the improper disposal of hazardous waste can severely contaminate air, water, and soil, posing long-term threats to public health and the environment.[9]

The environmental pollution caused by the textile industry leads to multiple forms of impact, which can be categorized into physical, chemical, biological, and human health effects. The most direct physical impact is the ingestion of microplastics by living organisms. Nano- and microplastics can accumulate in vital organs and tissues, causing damage. The central nervous system is also affected by microplastics.[3]

In terms of chemical impact, the plastic, synthetic fibers, and dyes used in textile manufacturing release harmful hydrophobic pollutants into the environment.[1,3] These pollutants resist degradation and tend to accumulate in biological systems, increasing the environmental persistence and toxic potential of chemical waste.[3]

The biological impact includes hazardous pollutants from textile industries adversely affecting freshwater ecosystems, marine biodiversity, and the deterioration of the atmospheric ozone layer.[3]

In terms of human health, humans are increasingly exposed to hazardous pollutants through food and water contaminated with microplastics. Seafood is a significant pathway for microplastic ingestion. Long-term exposure may result in chronic toxicity.[3]

4. Discussion

Environmental and public health concerns arising from wastewater released by the textile industry have long been prevalent worldwide.[1] Textile effluents often contain high concentrations of hazardous chemicals and organic compounds that exceed permissible limits. These pollutants can alter the physical and chemical characteristics of soil, water, air, and the biological systems of humans, animals, and plants.[1] Textile pollution also carries indirect economic consequences, including increased costs for clean drinking water, rising healthcare expenses, and reduced agricultural productivity.[1]

This study highlights the various types of pollution caused by the textile. China is one of the countries known for textiles, and it causes many harmful effects on the environment. These impacts are very damaging to our daily life, and this pollution will increase rapidly if we no immediate and effective measures are taken. Some recommended solutions include reducing wastewater by treating water with chemicals in treatment plants and using chemical filters in chimneys to reduce metals and metal ions from gas. There are many chemical substances which can be used to help reduce wastewater contamination. By applying these solutions, one can potentially reclaim and utilize water resources that are typically polluted. It is important to consider such approaches as part of sustainable water management.

5. Conclusion

The environment is polluted in many ways, and the textile is a major contributor. It pollutes our environment and damages the ecosystem, affecting vital components of nature such as air, soil, and water.

Toxic dyes used in textile processing are major sources of chemical pollution. These pollutants can pollute surface and groundwater sources, decrease soil fertility and productivity, harm the ozone layer, and cause various diseases among vulnerable populations such as children and the elderly. Water and air pollution are the main issues—water pollution affects soil and freshwater sources, while air pollution impacts the entire environment. Heavy metals from air pollution can cause lung problems and cancer.

As the textile industry is one of the top polluting industries globally, with multidimensional environmental impacts, a thorough inspection and regular monitoring of pollution levels are necessary to combat this growing threat. The use of non-biodegradable dyes and chemicals poses a long-term threat to ecosystems. There is a critical need for sustainable practices, including the adoption of eco-friendly dyes and chemicals, the implementation of efficient wastewater treatment systems, and recycling and reusing industrial water and materials. Furthermore, government policies, strict regulation enforcement, and increased awareness among stakeholders are essential to mitigating environmental damage.

Acknowledgments

We would like to express our sincere gratitude to our parents and friends for their unwavering mental support and encouragement throughout the completion of this review.

Funding

None.

Conflict of interest

The authors declare no competing interests.

Author contributions

Conceptualization: All authors
Writing – original draft: Md Rofiul Islam Rofi
Writing – review & editing: All authors

Ethic approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Not applicable.

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