Waste Management in Textile Industry

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Abstract The textile industry is one of the critical industries that fulfils one of the fundamental requirements of human beings and, subsequently, becomes an unavoidable part of human life. Furthermore, the consumption of textile products is increasing rapidly over time, both locally and globally, due to population growth. The increased consumption of textile products has been a concern regarding both increased textile waste streams and environmental impacts. It is because of harmful chemicals and high water and energy consumption. Due to the widespread use of non-biodegradable packaging materials, this industry produces significant volumes of wastewater, sludge, gaseous waste, fabric waste, yarn waste, and fiber waste. The manufacture of textiles may be well controlled while producing the least amount of waste possible. Small quantities of resources used in the textile business, such as raw materials, water, energy, chemicals, and auxiliary materials, result in environmental, social, and economic sustainability. The kinds, origins, management practices, and advantages of textile waste are covered in this chapter. Recommendations are given for efficiently handling textile waste at the chapter's conclusion.

Keywords Waste management · Sustainability · Environmental effect · And degradation of textiles

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1 Introduction

Waste management in the textile industry is a mammoth topic, and it can't be elucidated in a single chapter of a book, as this topic covers a wide range of elements. Many universities have recently included such courses in their academic curriculum. It is also found that a limited number of books or book chapters related to this field can be valuable references for students.

Humankind considers textiles to be the second most crucial need. The rapid development of fashion has resulted in significant diversification in textile manufacturing and consumption [1]. Unfortunately, garments are discarded after five to seven uses. A study showed that 20% of used products are collected for recycling [2]. Therefore, the final destinations of those products are dumping grounds, landfills, or garbage [3]. Universally, from 1975 to 2018, per-capita garment material production increased from 5.9 to 13 kg per person [4]. As a consequence, the amount of textile waste in landfill is getting higher every day. Additionally, the textile industry is considered one of the anthropogenic practices that are accountable for a broad list of natural issues [5]. Textile waste is made both when clothes are being made and when they are being worn.

The maximum volume of waste is generated during the manufacturing stage, specifically during wet processing. It involves extensive use of water, dyes, and chemicals. Solid waste (sludge) and wastewater (effluent) affect the ecological system unless they are discharged into the environment with proper treatment. The direct discharge of chemical waste into nature is responsible for the erosion of sewer lines and groundwater contamination, which results in an expansive capital investment to control multidimensional adverse effects [6]. Currently, industries are concerned about environmental issues and are focusing on innovative goods, processing, manufacturing, and purchasing. It creates awareness among consumers and enterprises to develop eco-design and environmentally friendly products and manufacturing processes. Therefore, proper waste management and maintenance have become unavoidable options for reducing textile waste and achieving sustainable production [7, 8].

2 Types of Textile Wastes

Textile and Apparel (T & A) industry is regularly condemned for its harmful impact on the environment (such as waste generation, resource consumption, and carbon footprint). A lot of energy, water, and other natural resources are used in the creation of clothes, along with a lot of trash. Figure 1 illustrates how waste from the garment industry may be divided into three main categories: manufacturing waste, pre-consumer waste, and post-consumer waste. The details of this waste are discussed below.

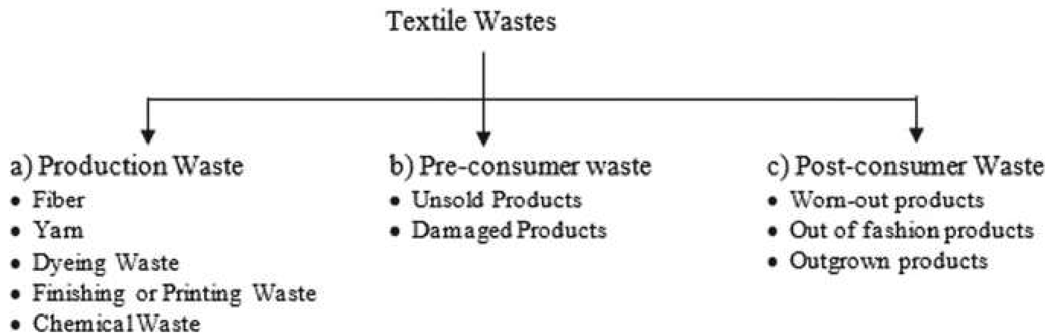

Fig. 1 Types of Textile wastes [9–15]

(a) Production Waste

Production waste includes all kinds of garbage that is generated during the manufacturing of textile products. Textile manufacturing processes generate waste, including spinning, weaving, coloration, finishing, and apparel production. Even final packaging generates considerable waste. Different methods generate different types of waste, and the amount varies. A good illustration of this can be found in the garment manufacturing section, where such things as the rolled ends of fabric and fabric cut-offs create tremendous waste [9]. In addition, fabric defects during operation are also responsible for waste production. Different types of chemical processing also discharge effluents in the form of waste. The single-fibre type carpet also generates a lot of waste [10].

(b) Pre-consumer Textile Waste

Pre-consumer waste is also known as manufacturing waste, because it is created when clothes are manufactured. It is also known as fabric waste. Pre-consumer waste is also generated from the manufacturing of fibre and yarn. Among all these, fabric waste is the most notable waste that may be converted into assets. It is mainly produced due to mistakes in different garment manufacturing stages such as design, pattern, cutting, and sewing [11]. It is reported that only in China will the amount of pre-consumer waste exceed about 100 million tons in 2021 [12]. Furthermore, products from dead stock, unworn, unsold garments, and returned by customers are all considered pre-consumer textile waste. According to one survey, just one-third of all imported clothing from various EU nations is sold at full retail price, another one-third is sold at a discount price, and the remaining three-quarters are left unsold. However, this data has not been verified [13].

(c) Post-consumer Textile Wastes

Post-consumer textile waste includes both natural and synthetic fibers, as well as additional materials including metallic zippers, acrylic buttons, wood buttons, shell buttons, and metallic snap fasteners. Trash is difficult to degrade due of its nature [14]. The post-consumer textile waste does not break down easily in the soil, leading to desirable diseases, inducing pests, and emitting odours into the atmosphere. The advanced waste management policy encourages the recycling or reusing of 60–80% of post-consumer waste. The economic value of this waste is about $200 billion [15].

3 Sources of Textile Wastes

The life cycle of clothing has a substantial negative influence on the environment in the textile industry. The waste produced during the processing of raw materials and during the creation of the finished product is where the environmental effect begins. Climate change is significantly impacted by trash. According to a research, between 2005 and the present, the effects of climate change have multiplied by 1.5 [16]. From raw materials until the conclusion of a textile product's life cycle, nearly every stage of manufacturing produces textile waste. As a result, the sources of textile waste may be divided into three categories: manufacturing wastes, post-production wastes, and other sources. The waste produced by the textile industry can be categorized as solid, liquid, or gaseous. Table 1 displays the solid wastes produced by the textile and clothing industries.

The solid wastes as shown in Table 1 from the textile and apparel sectors are not the same. Table 2 shows the waste from the textile and apparel industries. The textile wastes are mainly generated during the production process, whereas the apparel industry wastes are final products that come from excess product and rejected product in different stages.

Nine groups comprise the functioning of the textile industry in terms of waste streams. Table 3 [17] displays the substantial volume of textile waste from different sources.

Table 1 List of material waste in textile production stage

Sectors	Raw materials	Waste
Spinning	Cotton and other natural fibers, synthetic fibers	Damaged yarn, unfinished cones, and cotton lint
Knitting/ weaving	Natural and synthetic yarn	Fly and contaminated fiber, scarp yarn, grey fabric
Wet processing	Grey/unfinished fabric	Excess finished fabric and rejected colored fabric
Apparel	Finished fabric	Cut-off pieces of fabric, additional development samples, and excess clothing

Table 2 Textile apparel manufacturing waste

Textile industry wastes	Apparel industry wastes
Fly fiber, greige textiles, rejected fabrics, completed fabrics, cotton lint, damaged yarn, and cutting wastes	Overproduction, faulty clothing, rejected clothing, and merchandise with canceled shipments

Table 3 Sources of textile waste generation during manufacturing and its type

Sources	Variety of wastes
Ginning	Scrap metal, cotton dust fly, cotton wastes and dust
Spinning	Blow room cotton dust, floor sweeper, iron scrap, paper cone, plastic scrap, rubber scrap, cotton dander, cotton flat waste, flat strips, Waste that lingers, Sliver cut, filter waste, noils, lap wastes, cotton dust from cards, spinning sweep, containers, drums, cones, tubes, and Waste from paper and clothing
Sizing of warp yarn	Cotton dust, cardboard, paper cones, iron trash, polypropylene bags, tota (thread ropes), discharged sizing chemicals,
Modern power looms	5 foot thread ropes, a brass bora, paper cones, scratched paper cones, polypropylene bags, cotton dust, dropper iron hoops, kara iron wire, and metal debris are all often used materials
Knitted fabric section	Oily discard products, iron and plastic scrap, paper cone, polythene bags, Type-B garments, wastage yarn, ragged white and colour garments
Textile coloration	Iron barrels, containers of plastic, flat cardboard, coloured threads, plastic pieces, polypropylene and brass bag, discharge effluent dyes and chemicals
Packing of finished products	Cutting rags, both white and coloured, over lock, polypropylene bags, cardboard, petroleum-based fusing, brass bag
Stitching	B-category and cut piece garments, cutting rags, polypropylene bags
Textile materials accept apparel	Cutting rags, polypropylene and brass bags, paper cone, rubbery scrap, ball bearing, cotton dirt and dust, soil, hard waste, iron container, plastic scrap, colour damage. Sweep spinning, cut pieces of various fibres, open end sweep

4 Textile Waste and Present Scenario

About 70.4% of the total solid waste produced by the textile industry is attributable to the fabric and clothing manufacturing processes. The percentage of solid waste produced at various stages in the textile industry is shown in Fig. 2. "Jhut" refers to the textile waste produced by Bangladesh's apparel industry. Garbage, or solid trash, accounts for around 59% of the total waste generated locally. The cutting part generates the second-highest amount of trash, as seen in Fig. 3, followed by the dying section. Nearly half of the 577,000 tons of trash produced by Bangladesh's textile and apparel sectors, or 250,000 tons, is comprised completely of recyclable cotton. This garbage has a commercial worth of around $100 million.

Additionally, it is anticipated that between 2015 and 2030, global textile waste would increase by 60% annually, resulting in the production of 148 million tons of rubbish overall, plus an additional 57 million tons per year. Clothing and shoes account for the majority of textile waste [18]. The amount of water used in the plant, particularly during the dyeing process, determines how much liquid waste is produced. Research shows that 38% of the water is used for bleaching, followed by 16% for dyeing, 8% for printing, 14% for the boiler, and 24% for other applications.

In Bangladesh, there were around 1,700 wet processing facilities for washing, dying, and finishing textiles. A study showed that in Bangladesh, textile factories

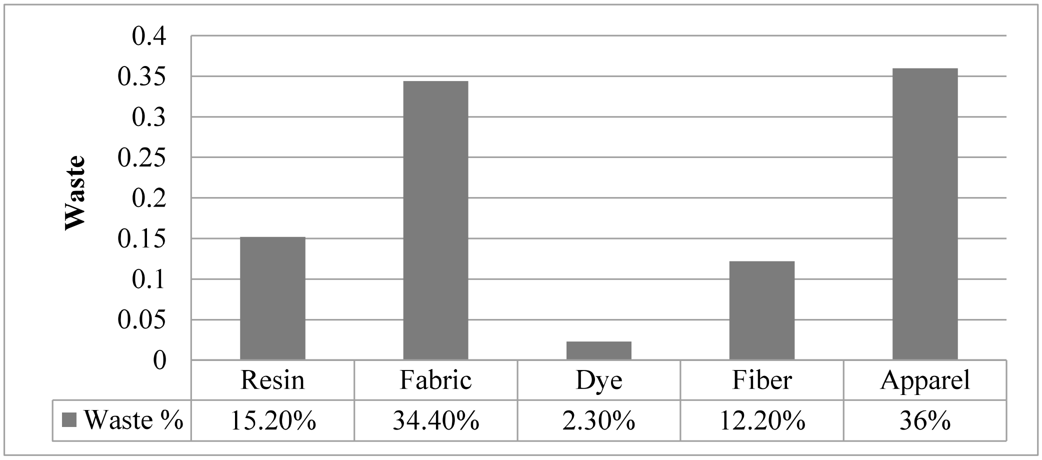

Fig. 2 Percentage of solid waste generated from textile industries in Bangladesh [18]

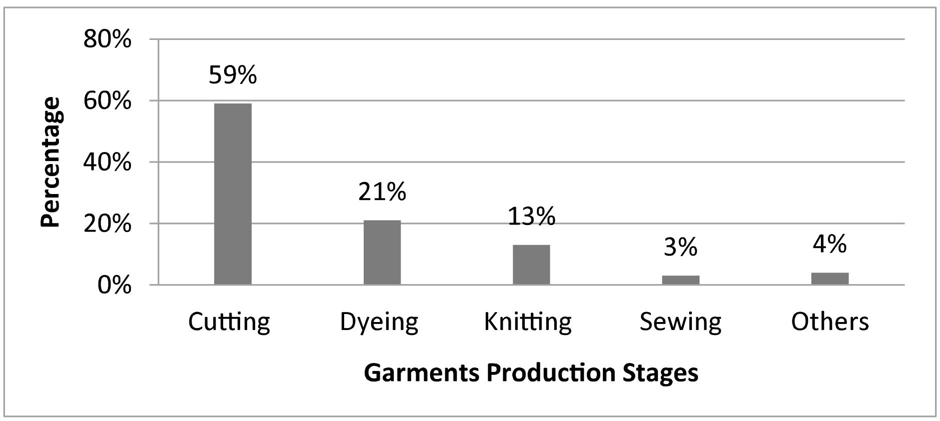

Fig. 3 Percentage of waste in different production stages [18]

utilize between 250 and 300 L of water for each kilogram of cloth produced. In 2016, textile industries in Bangladesh generated about 2.17 million m^3 of waste from the wet processing stage to have about 1.8 million metric tons of textile cloth.

In addition, chemicals are used extensively during the cleaning and dyeing steps of the textile manufacturing process. As a result, textile effluents include significant levels of harmful contaminants. Most of these effluents are dumped into rivers without adequate treatment, leading to significant water pollution and what is thought to be the cause of two-thirds of waterborne illnesses. Compared to other polluting industries in Bangladesh, the textile industry comes out on top.

5 Waste Management System

The industries of Bangladesh's economy that are contributing to increased pollution are labeled as red under the environmental conservation regulations (ECR) of 1997. For these industries to receive the Environmental Clearance Certificate, an effluent treatment plant (ETP) is necessary (ECC). ECR 1997 is really not taken seriously by many sectors, which results in a surge in environmental pollution. Additionally, the ETPs are frequently turned off purposefully to lower operating costs or make them appear to be inoperable. But a study report from the Bangladesh Bureau of Statistics indicates that at least 37.6% of the country's industrial units lack waste management systems, and 61% lack waste recycling facilities, which significantly contaminates the environment [19].

Industries are immediately discharging or dumping garbage into the ecosystem without any thought for environmental protection, causing contamination of the water, air, and land or soil. Garbage management entails all the procedures and tasks necessary to control waste from its creation to its final disposal. It relates to the numerous strategies for managing and getting rid of various wastes, which include throwing them away, breaking them up into smaller bits, recycling, reusing, or stopping the production of trash altogether. The reduction of ineffective materials and the mitigation of possible dangers to human health and the environment are the main goals of waste management. The collection, transportation, retrieval, and removal of garbage are all considered to fall under the definition of waste management according to the European Union, which also include acts carried out in the capacity of a merchant or broker. For managing trash at every stage, from creation and collection to final transfer, it comprises a wide range of methods and procedures. Waste management encompasses many methods of hazardous, liquid, gaseous, or solid substance disposal.

Most textile industries are used different standards and globally recognized concepts to establish an acceptable waste management system which are:

- Waste Management Hierarchy
- Zero Waste Concept for Waste Management
- 3R Waste Manage Technique

Waste Management Hierarchy: The waste management hierarchy as shown in Fig. 4, reflects priority order in waste removal.

6 Benefits from Waste Management System

The textile and clothing industries in Bangladesh have created a lot of garbage. These wastes are viewed as jewels and can receive several advantages by just adding value to them. The handling of textile waste has produced several environmental, economic, and social advantages. Along with advantages for businesses and communities, it

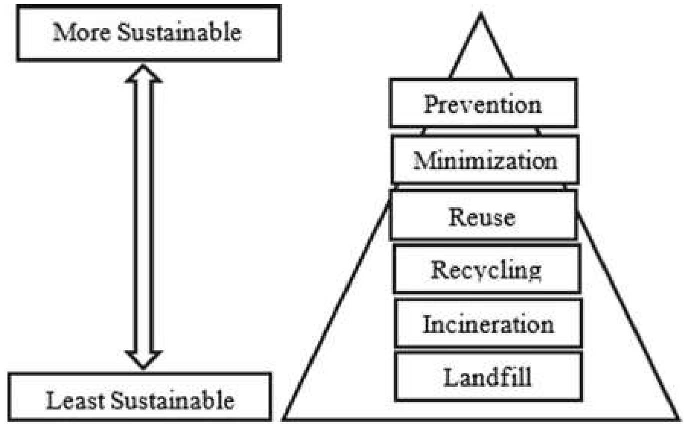

Fig. 4 Waste management methods hierarchy

also helps consumers, service providers, and employees who are directly involved. As a result, the advantages of using textile wastes are divided into three categories: environmental advantages, economic advantages, and social advantages.

(a) **Environmental Benefits**

Textile wastage accelerates carbon emissions extensively and is considered the primary source of greenhouse gas (GHG) emissions. All activities related to textile and clothing sectors such as production, consumption, transportation of raw materials, usage, and disposal of textile products posture a genuine risk to carbon impression. Therefore, an effective waste management policy is mandatory and leads to a healthier and greener environment. Although right management cannot eliminate all the hazardous elements, reduces the impact, and intensity of harmful matters. For instance, the polyester fabric creates more carbon footprint than fabric from cotton. However, recycling cotton brought zero risk to the environment whereas polyester releases carbon dioxide gases, and increases the size of the footprint. With a proper waste management system, it is possible to diminish the consumption of natural resources by utilizing recycled materials to make innovative products as well as packaging. Besides, by using proper waste removal methods, air quality has improved significantly [20].

On the other hand, the quality of wastewater that releases from several stages in wet processing can improve by using an appropriate wastewater management system. An effective waste management system can improve the decay of the ecosystem, and save aquatic lives as well other organisms and soil degradation. The production of agricultural products depends on the soil quality. Some of the textile waste takes a longer period to decay in the soil which has a significant impact on pollution, therefore an effective waste management system may enhance the quality of soil and the extraction of resources along with dropping contamination and enhancing energy utilization.

(b) **Economic Benefits**

A good waste management system, particularly one that encourages recycling and reuse, contributes to socioeconomic benefits. The method for managing garbage is essential to creating a robust economy. A study showed that recycling and reuse significantly reduce trash while creating job opportunities. The recycling and reuse business has also contributed more than $1 billion USD and ten thousand new jobs. It is not essential to mention that waste management can help firms save money on overall production expenses over time.

Additionally, recycling promotes the preservation of raw materials and natural resources like glass, plastic, paper, and oil. Reusing those materials reduce the burden on our natural resources and cut down on production expenses. The consumer's living standard is enhanced and results in getting financial rewards.

(c) **Social Benefits**

Throwing away textile waste causes pollution, odors, and other environmental damage. The health of the workforce is substantially impacted by this pollution, which also makes life dangerous. Additionally, it deters customers and workers from going to textile factories. The burden of dumping textile waste into the land is lessened by an improved waste management system. Additionally, waste management is a multi-billion dollar industry that promotes social inclusion by generating job possibilities, social development and security, economic benefits, volunteer programs, training, and a host of other initiatives. A successful waste management system promotes environmentally friendly behavior and maintains public and workplace safety [20].

7 Waste Management Scenario

The environment, economics, culture, and technology are all instantly impacted by waste. Environmental protection and the preservation of natural resources for future generations depend on effective waste management. Deliberations, research, focused studies, and inventions are therefore essential to minimizing the harmful consequences of rubbish on the ecosystem. Waste management includes the procedures and methods needed to control waste at every stage of its life cycle. To establish an efficient waste management system, the majority of textile industries use the basic waste management concepts. The majority of textile firms use a waste management hierarchy, zero waste ideas, and a 3R waste hierarchy to implement their waste management system. According to a research, the US Environmental Protection Agency (EPA) recorded a recycling rate of 14.7% for clothing and footwear in 2018. (or roughly 2.5 million tons). In 2018, 3.2 million tons (9.3%) of textile waste was burned with energy recovery, and landfills received 7.7% of the total (11.3 million tons) [18]. Figure 5 shows the present status of managing textile waste in the US.

The textile industry is one of Bangladesh's fastest growing and most lucrative economic sectors. The textile industry has made a significant financial contribution to Bangladesh. Still, it has done a lot of damage to the environment, especially to the soil, the water supply, and the air quality. As a result, Bangladesh's ecology has been drastically degrading during the past few years. The environment, particularly

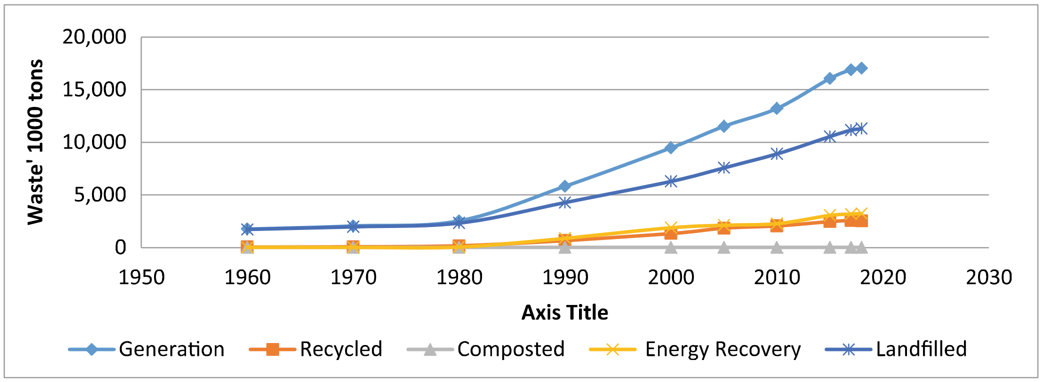

Fig. 5 Present scenario of textile waste management [18]

in Dhaka, has deteriorated dramatically and turned the city into one of the most polluted globally.

More than 92 million tons of waste were generated by the worldwide textile industry in 2014, according to several estimates. Most of it is either burned or dumped in landfills, with just a small part being recycled or used again. According to statistics, Bangladesh's textile and clothing industries generate about 577,000 tons of rubbish, of which 250,000 tons, or almost half of the total, are textile and apparel waste composed completely of 100% recyclable cotton and are worth around USD 100 million. The amount of textile waste generated worldwide is anticipated to increase by 60%, or 57 million tons per year, between 2015 and 2030 [21].

8 Waste Management Policy

Generally, two types of waste are produced, such as (i) solid waste and (ii) liquid waste. In the textile industry, solid wastes include fiber, fabric, packages, cartons, accessories, trimmings, etc. Liquid waste, waste is from several wet processes like dyeing, washing, printing, etc. Solid waste is dumped or thrown away directly into the landfill, which leads to clogs, smells, and pollution of the air, water, and soil. Alternatively, wastewater is either released now or extracted after treatments. It contains colored water and fiber, or fabric wastes in a dissolved state. Liquid waste is more hazardous than solid waste as it contains dyes and chemicals. Solid textile waste can be recycled or reused, but liquid waste needs to be treated afterward with ETP.

To reduce environmental effect, the Bangladeshi government has put in place a number of laws, policies, and norms. Environmental protection legislation in Bangladesh include the Marine Fisheries Ordinance of 1983, the Brick Burning (Control) Act of 1989, and the Bangladesh Wildlife (Preservation) Order of 1973. Before Bangladesh obtained its independence, a few additional significant conservation legislation were established. These laws include the Forest Act of 1927, the Protection and Conservation of Fish Act of 1950, the Agricultural and Sanitary

Improvement Act of 1920, the Public Parks Act of 1904, and the Agricultural and Sanitary Improvement Act of 1904. Prior to the 1993 passage of the Act, three plans were developed: the National Environment Management Action Plan (NEMAP), the Forest Policy, and the Forestry Master Plan (1993–2012). In 1989, the Ministry of Environment and Forestry was created. The Bangladesh Environment Conservation Act (BECA) was passed on May 30th, 1995.

The Bangladeshi government has also established a number of strong environmental protection legislation, including the Environment Court Act of 2002, the Environment Conservation Rules of 1997, and the Environment Conservation Act of 1995. Even though these policies are still in place, not enough is being done to put them into practice. Additionally, the top-down implementation of policies in the majority of government programs today utterly disregards bottom-up initiatives [22].

8.1 Recycling of Textile Waste

The textile sector and consumer services are intimately intertwined. Therefore, the more textile products are produced, the more trash there will be. Recycling and reuse are effective solid waste management practices for solving this problem. In the past, the best way to get rid of textile waste was to bury it, where it would eventually break down and pollute the groundwater, aquatic life, people, and the environment. When solid waste is burned, high temperatures are produced, and dioxin is released, which builds up in the environment and food chain. According to research, waste management has an impact on human health in 46.8% of cases. Furthermore, the landfill's impact was 1.5% lower than that of incineration [23].

Recycling is one of the best and most effective ways to eliminate textile waste and stop it from getting worse. The reuse and manufacturing of materials from textile waste are known as textile recycling. The biodegradable waste generated by the textile industry is already recyclable and environmentally friendly. Recycling textile waste is a viable business practice that is also environmentally friendly. Textile waste can be recycled in various ways, including physically, chemically, and thermally.

(a) **Physical recycling**

Most people think mechanical or physical recycling is the best way to eliminate textile waste [24]. Here, either recoveries or commingled waste treatment is used to deal with goods made or used. Using conventional mechanical recycling, worn-out or defective clothing is transformed into yarns and fibers. After that, recycled yarns can be made into many different things, such as carpets, nonwovens, materials for insulation, filtration, geotextiles, and more. Physical recycling is better than chemical recycling because it is more accessible, practical, and better for the environment [25].

(b) **Chemical recycling**

Molecular weight conversion is made possible through chemical recycling. Compounds with a low molecular weight can be created from high molecular weight polymers. These compounds with low molecular weight can be used as raw materials to make other essential chemicals and polymers. Only synthetic fibres and their mixtures should use this approach. Chemical separation of threads, degradation of fibres, and re-polymerization into new fibres are some of the phases in the chemical recycling process [26]. For example, Nike reuses most of its old sports equipment to make brand-new products [27].

Another example is Teijin Fiber Ltd., a Japanese company that manufactures 100% polyester fabrics. By dissolving into tiny particles or granules, this process separates polyesters from other types of fibres. Through a chemical reaction, these tiny particles break down into dimethyl terephthalate (DMT), a chemical compound between the two. The production of polyethylene terephthalate (PET) can also be done using this [28].

(c) **Thermal recycling**

When fibre waste is burned, thermal recycling is used to get the heat energy back and turn it into more heat or electricity. The pyrolysis method involves heating fibre materials to break down polymers into smaller molecules. The pyrolysis method is used here to heat fibres and break polymer molecules into smaller ones. A cloth loses 74% of its original weight when pyrolyzed, with slightly more than 30% being a light liquid fraction, 42.5 percent being an overwhelming fluid division, 12.5% being solid residue, and 13.5 percent being solid residue non-condensable gases [29]. Depending on the kind of resin, thermal recycling normally occurs between 450 and 700 °C [30]. Utilizing thermocycling, old textiles may be converted into more valuable carbon-based goods. Used acrylic textile fabric may be recycled by thermal recycling [31].

8.1.1 Recycled Products from Textile Pre-consumer and Post-consumer Waste

During the process of making textiles, a lot of leftover cottons, wool, and yarn, among other things, are made. This kind of byproduct can be separated and used as a raw material for recovered goods through efficient waste management. However, after the reprocessing, the yarn quality may somewhat worsen [32]. Table 4 [22] lists recent interests developed from textile waste.

8.2 Wastewater/Effluent Treatment

Textile manufacturing, which includes spinning, weaving, knitting, dying, finishing, and making clothes, is the primary source of textile waste. There is a lot of textile waste because of trends like finishing and washing clothes quickly [33, 34]. Mechanical processes primarily create solid and liquid waste. Effluents are produced during wet processing [35]. The effluent discharged has high COD, BOD, TDS, TSS,

Table 4 Essential repurposed textile waste products

Textile wastages	Recycled product
Semi-synthetic Lyocell fabric (Modified cellulose)	Surface- assimilative fibres for adsorbing heavy and complex metals
Cotton and limestone powder	Building materials
Ash wastes from textile	Bricks for construction
Textile waste ash and basaltic pumice	Bricks for paving
Waste of cotton	Chipboards
Wastages from cotton fibre	Reinforced composites and Nano particles
Cotton fabric wastages	Composites, Microcrystalline cellulose
Open-width woven fabric	Reinforced composites
Cotton polyester blended fabrics	Reinforced composites
CVC (65%/35%) Blended fabrics	Composites

turbidity, alkalinity, etc. It also has both inorganic (heavy metals, sulfur, chlorides, nitrogen, phosphorus, etc.) and organic chemicals (such as phenols, surfactants, insecticides, oils, greases, fats, proteins, carbohydrates, etc.) [36].

Wastewater causes environmental, groundwater, air, and soil pollution and health risks that erode septic systems [6]. According to the government-recommended instruments, those compounds must be neutral and effluent characteristics must be brought under control. If not, they will mix with the freshwater source, making the water more hazardous and leading to conditions like cancer of the kidneys, liver damage, dermatitis, skin problems, etc.

Wet textile processing that uses dyes and chemicals that are safe for the environment and an effluent treatment plan that works well help a lot to solve the problem.

8.2.1 Wastewater Compositions

During pretreatment, dying, printing, finishing, and washing, a lot of energy, dyes, chemicals, and water are generated. Table 5 displays the components of textile sludge and effluent.

8.2.2 Standard Effluent Treatment Policy

The widely recognized criteria for treated wastewater are established by the Bangladeshi government. However, as seen in Table 6, allowable levels vary depending on the circumstances in each nation.

Table 5 The compositions of textile sludge and effluent [37]

Process	Pollutant nature		Effluent composition
	Solid waste	Waste water	
Sizing	Fiber and yarn waste	Metal compounds and/or high TDS, TSS, BOD, COD	Wetting agent, waxes, carboxymethyl cellulose (CMC), polyvinyl alcohol, and starch (PVA)
Knitting/ weaving	Yarn and fabric scraps	Little or no waste	
De-sizing	Fiber lint, yarn waste	High TDS, TSS, BOD, COD	Wax, starch, pectin, PVA, lipids, and CMC
Scouring	Little or no waste	Fats, oils, NaOH, pesticides, and other cleaning agents	Inorganic compounds
Bleaching	Little or no waste	High alkaline, TSS	short fibers, surfactants, Acid, NaOH, Cl_2, H_2O, sodium hypochlorite, and $NaSiO_3$
Mercerizing	Little or no waste	High alkaline, TDS but low BOD	Wax, Sodium hypochlorite
Dyeing	Little or no waste	Heavy metals, colored water, high BOD, COD, and TDS, but low TSS	Wetting agent, reducing agent, acetic acid, dyes, detergents, and urea
Printing	Little or no waste	High colored, BOD, alkaline	Oils, gums, starches, alkalis, acids, thickeners, and agents for printing
Garment washing	Little or no waste	High colored, short fibers, TDS, Alkalinity, TSS, and low BOD and COD levels	Washing agents, acids, alkali

8.2.3 Wastewater Treatment Process

The amount of dangerous discharge effluent can be minimal if ETP plants are changed and run well. The ETP treatment combines primary, secondary, and tertiary treatment processes [6, 40].

(a) **Primary Treatment**

Screening, sedimentation, equalization, neutralization, flocculation, and coagulation are the primary treatment steps. The process, referred to as the mechanical treatment process, is designed to eliminate suspended materials found in wastewater.

Table 6 Bangladesh Government Standard for effluent [38–45]

Parameters	Accepted and approved by government of Bangladesh	Effluent parameters of key apparel manufacturing country					
		Bangladesh	China	India	Pakistan	US	EU
COD (mg/L)	200	200	100	156–400	150	100	160
DO (mg/L)	9	6–9	6–9	6–9	6–9	6–9	6–9
BOD (mg/L)	50	200	100	156–400	150	100	160
TDS (mg/L)	300	450	400	500	400	350	350
TSS (mg/L)	100	150	70	200	150	30	30
Turbidity (NTU's)	10						
pH	6–9	6–9	6–9	6–9	6–10	6–9	6–9
Water hardness	170–900						
Heavy metals	10–15						
TOC	8.00–64.2						
Colour	Light brownish/ watery						

Screening: The effluent is cleaned of dense suspended items such rags, fabric fragments, fibers, threads, and lint. The majority of the threads may be removed by contemporary, advanced screening. Otherwise, trickling filters might obstruct carbon beads or seals.

Sedimentation: Following screening, the solids in suspension are physically scraped into hoppers and pumped out during the sedimentation process. Smaller and lighter particles are intended to settle by gravity in the sedimentation tanks. The center-feed circular clarifiers and horizontal flow sedimentation tanks are thought to be the most important pieces of machinery.

Equalization: In a sump pit, previously mixed effluents are placed, and the pit is moved or compressed air is blown into it to agitate it. Solid particles settle more readily in the hole because of their conical bottom.

Neutralization: Textile waste is highly alkaline (pH value 10–12) and must be neutralized before being released into the environment. Treatment with sulphuric acid and flue gas with CO_2 can neutralize the alkalinity. Alkalinity is balanced in the subsequent biological treatment in the secondary treatment category.

Chemical coagulation: Simple sedimentation can separate solids in the air into two groups: colloidal and suspended solids. The solid particles coagulate and are stored in suspension under water.

Mechanical flocculation: Wastewater passes through the tank, coalescing suspended solids and settling them out. The clariflocculator of the sedimentation tank controls the process, forms flocculent precipitant, and produces effluent free from suspension or colloidal state. With mechanical flocculation, 80–90% of the TSS, 40–70% of the BOD, and 30–60% of the COD are taken out of the water.

Moreover, 80–90% of bacteria can also be eliminated. Chemical coagulation is often done with alum, ferric chloride, sulphuric acid, hydrochloric acid, ferric sulfate, ferrous sulfate, lime, and so on.

(b) **Secondary Treatment**

The goal of secondary treatment is to significantly reduce or completely remove BOD, oil, phenols, and other contaminants from wastewater. In secondary treatment, colloidal and colored organic compounds are eliminated from the water by dissolving and stabilizing the organic material. In a biological sense, this elimination of organic substances is carried out by bacteria and other microbes.

Aerated lagoons: In an aerated tank composed of cement, polythene, or rubber, the waste from initial treatment is collected. Floating aerators hold effluents for two to six days. By the time sludge is produced, 99% of BOD has been eliminated. The main drawback is that biological purification takes up a lot of room.

Trickling filters: Circular and rectangular beds of trickling strainers are made of polyvinyl chloride, coal, broken stone, synthetic resins, etc. Wastewater is sprinkled with the help of a rotary sprinkler equipped with orifices or nozzles. This process assists in producing a gelatinous film on the filter surface medium. The film absorbs wastewater and oxidizes it by the bacteria and microorganisms present there.

Activated Sludge process: The biological oxidation treatment method is another term for the activated sludge process. This process results in the biological breakdown of wastewater into CO_2 and waste compounds by aerobic bacterial flora. Synthesizing microorganisms here devour organic materials. Activated sludge is the term for the microorganisms that are still suspended in water. Wastewater sludge is separated by settling and processed before being released.

Oxidation ditch: The conventional activated sludge process is known as the oxidation ditch, where wastewater is passed after screening. The mixed liquor is aerated with the help of a mechanical rotor and recycled on a subsequent treatment cycle. Finally, the sludge is dried on sand drying beds.

Oxidation pond: By bacteria and protozoa, the organic matter is stabilized Algae in the wastewater metabolize oxygen in this location and use CO_2 for photosynthesis.

Anaerobic digestion: In a sludge digester, anaerobic microscopic organisms age or assimilate the slime that results from the sedimentation of necessary and supplemental treatments. The final products are released as CH_4, CO_2, and a little amount of NH_3.

(c) **Tertiary treatment process**

Traditional processes are unable to banish significant amounts of non-biodegradable chemical polymers from wastewater. Therefore, tertiary treatment is obligatory.

Oxidation techniques: This method involves the de-colorization of textile wastes in a decolorizing bath of sodium hypochlorite. Although it is considered a cheap technique, it is responsible for the formation of absorbable contaminated organic halides. Oxygen and free radicals of ozone combine with the coloring agents and destroy the colors.

Electrolytic precipitation and foam fractionation: By using a reduction method, concentrated dye wastes are precipitated in an electrolyte bath. The idea behind foam fractionation is that surface-active solutes gather at gas–fluid interfaces.

Membrane technology: The appropriate membrane technologies include reverse osmosis and electrodialysis. By blocking the membrane with dyes, reverse osmosis removes ions and species from a dye bath (90% effectively). The excess salt concentration can be removed through reverse osmosis and keeps the effluent neutral. On the other hand, electro-dialysis can break down salts by the movement of cations and anions by means of anionic and cationic porous layers.

Electro chemical processes: There is no need for any additional chemicals. No side product is produced through this reaction. However, the problem is that it requires removal of suspended and colloidal solids before electrochemical oxidation unless it can impede the electrochemical reaction.

Ion exchange method: The ion exchange technique is preferable for eliminating undesirable anions and cations from wastewater. In this technique, effluents pass through a series of beds of ion exchange resins. Nowadays, manufactured polymeric materials are used as a popular ion exchange method.

Photo-catalytic degradation: The photoactive catalyst emits UV light, and the generation of highly reactive radicals can degrade organic compounds.

Adsorption: The two immiscible stages exchange materials at their interface. It has significant potential for evacuation of color from wastewater.

Thermal evaporation: In a thermal evaporator, sodium per sulfate works better as an oxidizing agent. Through this process, no sludge is produced, and no toxic chlorine fumes are emitted. Therefore, this technique is called the "eco-friendly technique. Here, sodium per sulfate forms free radicals and thermal evaporation takes place.

9 Textile Waste Reduction

It is not possible to remove wastage from the textile industry completely, but can minimize the amount to a significant extent. The focus on the following points is helpful to reduce textile wastage [46–49].

- **Uses of natural resources**: Textile raw material innovation has made it suitable for smooth, higher, and large-scale production. However, most of those are synthetic and take hundreds of years to decompose in nature. These are responsible for polluting the environment. Only the application of natural raw materials can minimize environmental pollution and can keep our surroundings safe. Therefore, it is mandatory to search for natural-based raw materials for environmentally friendly textile production.
- **Optimization of the resources**: The efficient and proper utilization of existing raw materials and technologies can optimize the manufacturing process. Productivity can be increased by using the same quantity of raw materials.

- **Reducing water consumption**: Water is used extensively during wet processing of textiles. Textile coloration, finishing, and garment washing use a greater amount of water than usual. Therefore, the water source becomes scanty, and the ground water level is lower. By using water-less technology and reducing water applications can minimize the consumption of water, which is a pre-requisite nowadays to build a safer world [50].
- **Reducing the amount of dyestuffs and chemicals**: The increased use of dyestuffs and chemicals results in effluent and sludge. When they mix up with another source of water, it reduces the fertility of the soil, deteriorates the water property and becomes unsuitable for microorganisms. This water is so toxic that it can be dangerous for human health. Hence, usage of a lesser amount of dyestuffs and chemicals can minimize waste generation in the textile industry [50].
- **Energy conservation**: Higher consumption of energy generates large quantities of gaseous waste, resulting in an increase in greenhouse gas emissions, leading to global warming and destroying our natural ecosystem. Such kinds of gaseous waste can be minimized through proper energy conservation as well as alternative energy like renewable energy [51].
- **Consumer awareness**: Consumer awareness of sustainable approaches has made it easier to learn about transparency and company insights. The availability of benchmarks and sustainable measuring tools forced companies to maintain a minimum standard. The Sustainable Apparel Coalition (SAC) has developed multiple tools for assessing environmental sustainability in apparel, footwear, and textile industries [52].
- **Recycling and reuse**: Garments are generally used 5–6 times and are thrown away as disposed of. Only 20% of them are collected. However, less than half of those is reused or recycled. According to another study, less than 1% of clothing is recycled. Therefore, recycling and reuse of clothes can minimize waste quantity to a significant extent [53].
- **Prevention from textile waste**: Waste prevention is a better option to reduce waste generation. The prevention policy can be effective, economical, and a revenue generator. This focuses on designers, stakeholders, consumers, and charitable organizations in manufacturing sustainable products [53].

10 Conclusion

Waste management is addressed in various ways in the textile and garment industries. Every manufacturer must build up efficient waste management procedures and textile setups. Leftover clothing can not only be recycled or used again but it can also be used as a raw material for other goods. A sound waste management system makes it easier and less stressful to dump and get rid of the trash. It also helps set economic policy, create job opportunities, and, most importantly, clean up our environment. Sadly, not much waste is recycled or reused, and liquid trash is taken out without being treated properly. Therefore, the focus should be finding ways to reuse or recycle that textile waste. Waste must be managed by producers, the supply chain, retailers, customers, and regulatory agencies.

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