International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 07 | July - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Integration of Waste Management in Textile Industries of India

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ABSTRACT

The foundation of India's economic growth, the textile sector, has experienced unheard-of growth in recent decades, along with a rise in environmental issues brought on by significant waste generation. This comprehensive study sets out to look into and analyze how waste management techniques are incorporated into the rich history of the Indian textile sector. The study offers a thorough review of current waste management techniques, environmental impact evaluations, and creative solutions influencing the path toward sustainability, bridging the gap between qualitative and quantitative analysis. The introduction sets the context by outlining the mutually beneficial relationship between the expansion of the textile industry and its subsequent environmental load. The clothing industry has gained prominence due to the increase in demand for its products, however, a paradigm shift is required due to the waste generated by this industry. The study aims to perform a thorough analysis of waste management processes, conduct a quantitative assessment of the environmental implications, and investigate comprehensive strategies for sustainable waste management. The chapter on qualitative analysis explores the complex aspects of waste management in the textile industries of India. This section explains the nuances of waste generation at different phases of textile production by carefully examining existing methods, case studies, and industry dynamics. A thorough grasp of the qualitative landscape is revealed, encompassing everything from yarn and fabric waste to the difficulties presented by chemical residues and the disposal of end-of-life textiles. The importance of awareness and corporate responsibility in influencing waste management methods is also highlighted in this section. Case studies of top textile producers present creative approaches and offer insights into the possibilities of technological developments, cooperative efforts, and models of the circular economy. Nonetheless, difficulties ranging from technology constraints to cultural obstacles highlight how difficult it is to smoothly integrate sustainable practices throughout the sector. The chapter on integration strategies looks at potential directions that could change the way waste is managed in the textile industry in India. Models of the circular economy take center stage because they provide a comprehensive approach to production and disposal. Case studies from real-world applications highlight the revolutionary potential of upcycling and sophisticated recycling technology, offering insights into how these strategies could lessen the industry's environmental impact. Co-processing in cement kilns is a two-pronged method that solves waste disposal issues and produces useful resources. The potential for improved trash sorting and identification is demonstrated by the combination of artificial intelligence and data analytics, opening the door to increased process efficiency in waste management. The study's conclusion emphasizes that although the study has been helpful, the search for India's sustainable textile waste management is still an ongoing project. The industry is at a turning point in its evolution, and the factors pushing it in that direction will be sustained research and innovation leading the way toward a time when environmental stewardship and economic prosperity coexist together. Every thread woven into the fabric of the Indian textile industry offers a story of sustainability, adaptability, and responsible

growth; therefore, the success of this journey will depend on the collective duty of industry stakeholders, policymakers, and consumers. Essentially, the goal of this extensive study is to serve as a compass for the Indian textile sector, offering a path forward to a time when environmental conservation and economic growth coexist peacefully.

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

The textile sector is a cornerstone of India's economy, employing millions of people and contributing significantly to the country's GDP. But this industry's rapid expansion has come at a price: a worrying rises in trash production. More than ever, the textile industry needs to adopt sustainable practices as we work to mitigate the effects of climate change and environmental deterioration. This article explores the complexities of waste management in India's textile industries, providing a comprehensive qualitative and quantitative study to examine the situation as it stands and suggest innovative solutions for a more environmentally friendly future.

India has a significant wide-ranging textile sector that includes everything from spinning, weaving, and knitting to dyeing, printing, and clothing production. In addition to being a major driver of employment creation, the industry is also a major participant in the worldwide textile trade. Despite its prominence, it is essential to analyze the industry's environmental impact and highlight sectors where sustainable practices can be effectively incorporated. [1]

Successful management begins with an understanding of the amount of waste generated by the textile sector. The amount and kind of waste produced at different phases of the textile production process are evaluated quantitatively in this thesis. Every stage of the process, from the extraction and processing of raw materials to manufacture and end-of-life disposal, adds to the waste footprint. Our goal in measuring the waste streams is to identify the hotspots and create focused waste reduction strategies.

The qualitative features of textile wastes are just as important as the quantitative ones. The impact on the environment is increased by **non-biodegradable synthetic fibers, the toxic chemicals used in dyeing and finishing techniques, and inadequate production techniques**. We will investigate how these qualitative elements affect human health, ecosystems, and sustainability in general. Policymakers, environmentalists, and business professionals were interviewed to gain a thorough grasp of the issues and possible solutions.

A comprehensive review of present procedures is necessary to fully understand the waste management environment that currently exists in the Indian textile sector. Conventional methods like burning and landfilling are being used by a lot of textile plants, which is quite dangerous for the environment. However, some progressive businesses are exploring novel strategies like upcycling, recycling, and circular economy models. Through an analysis of these approaches, we hope to bring attention to successful cases, highlight weaknesses, and provide a road map for the industry's adoption of sustainable waste management techniques.

It is tough to underestimate the influence of industry initiatives and governmental laws on waste management methods. This thesis will examine and evaluate the current regulatory structure controlling waste management in the textile industry. We will also look at partnerships, certifications, and industry-led programs that support ethical conduct. It is essential for the effective integration of waste management methods to understand the role that stakeholders play in bringing about change.

There are challenges in the way of the textile industry's transition to sustainable waste management. **Typical obstacles include lack of knowledge, opposition to change, and financial limitations.** Nonetheless, these difficulties offer chances for innovation and cooperation. We will learn how some businesses have transformed constraints into opportunities by looking at case studies and real-world examples, proving that sustainability may promote economic growth.

The textile industry's waste management landscape can only be transformed by combining state-of-the-art technologies with industry best practices. The industry is changing due to a number of advances, which range from the usage of sustainable fabrics to waterless dyeing procedures. We shall examine these developments in this part, highlighting their viability, scalability, and possible environmental effects.

We will present a future roadmap that aims to establish a sustainable and circular textile sector in India as we draw to a close this extensive study. There will be a focus on the need for cooperation between environmental groups, legislators, and industry players. We hope to offer a comprehensive view on waste management in the Indian textile sector by combining the quantitative and qualitative information presented in this article, encouraging a team effort to create a more sustainable and greener future.

CHAPTER – 2

REVIEW OF LITERATURE

2.1 TEXTILE INDUSTRIES OF INDIA

This study offers a thorough analysis of India's textile industry, a field with a rich cultural legacy and economic relevance. The thesis includes a synopsis of the industry, major obstacles, new advancements, and potential futures. The thesis attempts to provide useful insights for industry players, policymakers, and researchers interested in the dynamics of India's textile sector by integrating qualitative and quantitative analysis. [1]

In India's economic structure, the textile sector is crucial since it generates a large amount of jobs and export revenue. The objective of this study is to investigate the complex aspects of the Indian textile sector, providing insights into its past development, present condition, and prospects. India's textile industry has centuries-old roots, steeped in a rich legacy of handloom weaving and artistry. One major change came with the arrival of automation during the British colonial era. Today's industry fosters a dynamic and diversified sector by integrating new technologies with traditional craftsmanship. The textile industry in India as of **2023** includes a broad range of operations, such as spinning, weaving, dyeing, printing, and clothing production. The industry is diverse and vibrant due to the contributions of both organized and unorganized sectors. **Gujarat, Maharashtra, Tamil Nadu, and Uttar Pradesh are important textile hubs.**

The textile industry's significant contribution to India's GDP and employment highlights its economic significance. For millions of people, from farmers growing cotton to skilled artisans and industrial workers engaged in various phases of manufacturing, this industry is an essential source of income. **India's domestic garment and textile sector makes for roughly 2.3% of the GDP, 13% of industrial production, and 12% of exports. India makes up 4% of the world market for clothing and textiles. India ranks among the world's top producers of jute and cotton.** [3]

The Indian textile sector confronts several difficulties despite its importance to the country's economy. These include a complex regulatory environment, outdated machinery, and varying quality standards. **The industry also faces environmental issues with waste management, chemical disposal, and water use.** [2]

The Indian textile sector has seen revolutionary transformations in recent years. The '**Make in India**' campaign is one example of an initiative that aims to improve domestic manufacturing and boost globally competitiveness. Furthermore, the industry landscape has changed as a result of developments in e-commerce, digital technology, and sustainable practices. India is a significant player in the world textile market, exporting a wide variety of goods, such as yarn, clothes, and fabrics. The study paper provides a deep view of the international components of the sector by delving into the major export markets, trade policies, and difficulties faced by Indian exporters.

The industry has been implementing modern technologies in order to increase competitiveness. The study would also examine technical developments and highlights how they affect productivity, quality, and environmental sustainability. Examples of these developments include Industry 4.0 applications, digital integration, and sustainable manufacturing practices. With an eye toward the future, the study conclusion discusses possible areas for expansion and approaches to deal with the problems the industry is currently facing. The focus lies on the importance of sustainable waste management, technological innovation, and policy interventions in securing the textile sector of India's growth and global competitiveness.

IMAGE (1) – SECTORS OF TEXTILE INDUSTRY IN INDIA

SOURCE- https://texmin.nic.in/

2.2 WASTE GENERATION IN TEXTILE INDUSTRIES OF INDIA

This research seeks to explain the quantitative and qualitative aspects of this environmental concern by offering an in-depth examination of waste generation in the Indian textile sector. Considering the continued significance of the textile industry to India's economic expansion, it is critical to understand and manage the environmental effects of waste production. This research aims to broaden the conversation on sustainable practices in the Indian textile sector by utilizing a mix of case studies, empirical data, and industry points of view.

This study's first component is a quantitative examination of the waste produced at various points during the textile production process. Every phase of the production process, from the extraction of raw materials to the final product, adds to the overall waste footprint. **The amount and makeup of waste streams, such as solid waste, wastewater, and emissions, will be measured on-site and through the collection of data from industry reports, environmental assessments, and on-site measurements.** The qualitative aspects are just as important as the quantitative ones, as quantitative data offers a quantifiable comprehension of waste generation. The nature of textile waste is examined in this section, with particular attention paid to the use of dangerous chemicals in dyeing and

finishing procedures, the widespread use of synthetic fibers that are not biodegradable, and the effects of ineffective production techniques. This part will be enhanced by interviews with lawmakers, environmental scientists, and industry experts who will provide insightful information about the environmental effects of present textile practices. [3]

To fully understand the environmental impact of the Indian textile sector, an examination of the present waste management strategies is essential. There will be a comparison between developing sustainable strategies like recycling, upcycling, and circular economy models and traditional approaches like landfilling and incineration. We will examine case studies of textile units that employ innovative waste management techniques to showcase effective models that can be widely implemented by the industry. This section looks into how industry-led initiatives and governmental laws have shaped waste management techniques in the textile industry. The efficacy and potential areas for improvement of the current regulations controlling pollution control and waste disposal will be reviewed.

Management of textile waste presents several barriers that must be thoroughly understood to be addressed. This thesis will discuss frequent challenges, such as lack of awareness, opposition to change, and economic limits. But these difficulties also offer chances for innovation, collaboration, and the development of sustainable methods that can spur beneficial change in the sector. The transformation of waste management in the textile sector hinges on the incorporation of cutting-edge technologies and optimal methodologies. **Modern technology, including eco-friendly production techniques, sustainable fabrics, and waterless dyeing techniques, will be examined and evaluated in this thesis.** The potential of these technologies to transform waste management procedures in the Indian textile industry will be highlighted through case studies of successful technology adoptions. [4]

2.3 TYPES OF WASTE IN TEXTILE INDUSTRIES

The textile sector, a major driver of worldwide economic growth, is also a major cause of environmental problems, especially when it comes to the production of different kinds of waste. It is crucial to understand these many waste streams to create sustainable business operations. This thesis examines the various waste streams generated by the textile industry, covering everything from the manufacturing of finished goods to the processing of raw materials.

2.3.1 RAW MATERIAL PROCESSING WASTE

The processing of raw materials marks the beginning of the waste trip in the textile production process. For instance, waste from cotton ginning is produced as cotton gin trash, which consists of lint, seeds, and other waste. Similar waste products from the silk industry include residual cocoon material and silkworm pupa. Managing these by-products effectively is essential to reducing the initial environmental impact of the textile production process. [5]

IMAGE (2)- COTTON GRIN TRASH (Raw Material Processing Waste)

SOURCE- https://www.mdpi.com/2071-1050/15/13/10500

2.3.2 FIBRE PRODUCTION WASTE

The foundation of all garments are textile fibers, and the manufacture of these fibers results in certain wastes. For example, the production of synthetic fiber produces by-products such polymer waste, which is difficult to handle because it is not biodegradable. Initiatives for upcycling and recycling are essential to addressing the environmental impact of these waste products. [5]

IMAGE (3)- NYLON FABRIC WASTE MATERIAL

SOURCE- IMAGE FROM A TEXTILE INDUSTRY AT JAIPUR

2.3.3 PRE-CONSUMER WASTE MATERIALS

Pre-consumer waste, sometimes referred to as manufacturing waste, is generated at multiple stages in the textile production process before the finished product is delivered to the customer. This comprises discarded defective parts, trims, and offcuts. **Reducing the amount of pre-consumer waste that ends up in landfills requires effective use of these materials through recycling and waste reduction techniques.** [6]

IMAGE (4)- OFFCUTS FROM TEXTILE INDUSTRY AT A LANDFILLING SITE

SOURCE- https://maake.com/blogs/news/textile-waste

2.3.4 POST CONSUMER WASTE MATERIALS

Different kinds of waste issues surface as textiles reach the consumer stage. Waste from homes and clothes is classified as post-consumer waste. Fast fashion has led to an increase in clothes disposal, which has negatively impacted landfills. The negative effects of post-consumer waste on the environment can be reduced by promoting actions like recycling, garment donation, and the development of circular fashion models.

IMAGE (5)- POST CONSUMER WASTE FROM HOUSEHOLDS

SOURCE- IMAGE TAKEN AT A DUMP SITE IN JAGATPURA, JAIPUR

2.3.5 DYEING AND FINISHING WASTE

Water and a wide range of chemicals are used throughout the dyeing and finishing operations in the textile industry, producing wastewater that is full of contaminants and colorants. If not appropriately handled, the wastewater from these operations presents a major threat to the environment. Reducing the impact of dyeing and finishing waste requires investing in cutting-edge treatment technology, putting in place wastewater recycling systems, and using eco-friendly dying techniques. [7]

IMAGE (6)- DYES FROM TEXTILE FACTORY RELEASED IN WATER STREAM

SOURCE- IMAGE TAKEN AT TEXTILE INDUSTRY IN SITAPURA JAIPUR

IMAGE (7)- WASTE WATER TREATMENT PLANT AT A TEXTILE PLANT

SOURCE- https://textilelearner.net/dyeing-wastewater-treatment/

IMAGE (8)- WATER BEING USED IN DYEING LOOM

SOURCE: ON-SITE PHOTOGRAPH FROM A TEXTILE DYEING UNIT IN SITAPURA, JAIPUR

2.3.6 PACKAGING WASTE

The total amount of waste produced by the textile industry is influenced by the packing materials used in the supply chain. This covers items used for transportation and retail, such as cardboard boxes and plastic packaging. Reducing the environmental effect of packaging in the textile industry requires the adoption of sustainable packaging methods, such as the use of recyclable materials and the reduction of packaging waste. [8]

IMAGE (9)- PLASTIC PACKAGING MATERIAL IN TEXTILE INDUSTRY OF INDIA

SOURCE- https://www.fibre2fashion.com/industry-article/9005/sustainability-101-the-problems-of-packaging

2.4 FACTORS CONTRIBUTING TO WASTE GENERATION IN THE INDUSTRY

2.4.1 RAW MATERIAL PROCESSING

The processing of raw materials marks the beginning of the waste journey in the textile production process. **The ginning process produces trash including lint, seeds, and other debris in India, where cotton is a major raw material for textiles. These byproducts were traditionally ignored, which increased the total amount of garbage**. The foundational stage of textile manufacturing experiences greater waste generation in future stages because of the lack of adequate waste management strategies.

2.4.2 FAST FASHION AND OVERCONSUMPTION

Fast fashion and high consumer demand are two significant modern factors that contribute to waste generation in the Indian textile sector. **The need for less-priced clothing and the quick changes in fashion trends have resulted in shorter product lifecycles. Customers throw away apparel more frequently as a result, which raises the amount of post-consumer trash**. The need for fast-fashion, inexpensive clothing and the mindset of disposability that permeates society combined greatly increase the environmental impact of the textile business.

2.4.3 INEFFICIENT PRODUCTION PRACTICES

In the past, waste generation has been significantly influenced by inefficient production processes in the Indian textile sector. **Inadequate production methods, outdated equipment, and a lack of automation all lead to a rise in material waste**. The industry faces a dual challenge in implementing modern technologies and developing an efficient, waste-reduction, and environmentally friendly manufacturing culture.

2.4.4 CHEMICAL INTENSE PROCESSES

A lot of chemicals are used during the textile manufacturing process' dyeing and finishing phases, which significantly increases waste production. **Conventional dyeing techniques have been widely used in India, which has resulted in the release of wastewater that contains chemicals. Environmental issues are made worse by this effluent's**

inadequate treatment. Addressing the impact of chemical-intensive processes on waste creation requires adopting closed-loop chemical management systems and switching to eco-friendly dyeing techniques. [9]

2.4.5 LACK OF REGULATORY ENFORCEMENT

Even with environmental regulations in place, the Indian textile industry's inadequate waste management practices have continued because there aren't strong enforcement mechanisms in place. It is common to ignore waste disposal regulations, which results in incorrect treatment and disposal of garbage. Preventing the uncontrolled production of textile waste requires regulatory frameworks to be strengthened and implemented effectively.

2.4.6 LIMITED EDUCATION AND AWARENESS

One factor that keeps unsustainable practices going is a lack of understanding and guidance among consumers and industry players. **There may not be sufficient incentive for many textile units to adopt sustainable practices because they are not completely aware of the environmental effects of their operations**. Educating people about the environmental effects of textile production and raising awareness of these effects are essential elements of a comprehensive strategy to reduce the generation of waste.

2.4.7 LINERAR PRODUCTION MODELS

The textile industry has traditionally used linear production processes, in which raw materials are converted into finished goods that are ultimately discarded. **The linear strategy, which is marked by an absence of focus on reuse and recycling, keeps textile waste disposed of in landfills.** In order to break free from the linear production cycle and reduce waste generation, it is essential to shift to circular economy models where products are built for durability and recyclability.

2.5 QUANTIFYING THE SCALE OF THE POOR APPROACH AT WASTE MANAGEMENT IN TEXTILE INDUSTRIES OF INDIA

The raw materials are where the textile manufacturing process starts. Lint, seeds, and other waste are produced during the ginning process in India, where cotton is a major raw material for textiles. **Industry estimates indicate that between 30 and 40% of the cotton produced is wasted during the ginning process, which represents a major threat to the environment at the beginning of the manufacturing chain.** Fast fashion's growth and changing customer preferences both play a major role in the problem of textile waste. Research conducted by the *Ellen MacArthur Foundation* estimates that the **fashion industry which includes the textile industry is responsible for about 2% of the world's carbon emissions. Fast fashion contributes to this effect in India, where textile waste accounts for an estimated 5-6% of all waste generated**. The annual waste spike that results from an increase of customer turnover emphasizes the need for sustainable fashion methods. Traditionally, the Indian textile industries produced a tapestry of waste through inefficient production methods. Increased material waste is a result of antiquated equipment, labor-intensive procedures, and poor techniques**. A large portion of the 25,000 tons of textile waste produced annually by the textile sector is attributable to inefficient production methods, according to research published by the Ministry of Textiles**. This numerical realization emphasizes the observable expenses linked to inefficient manufacturing. [11]

The environmental effects of the finishing and dying processes, which are renowned for their high chemical content, can be measured. The release of wastewater containing chemicals is a serious risk. **The Central Pollution Control Board (CPCB) estimates that the textile sector in India is responsible for 20% of all industrial pollution, with**

dyeing and finishing facilities having a significant impact on water contamination. **[10]** The environmental cost can be starkly visualized numerically by quantifying the chemical load on water bodies. Despite established legislative frameworks, inadequate enforcement mechanisms lead to poor waste management. A study conducted by the **Centre for Science and Environment (CSE)** indicates that the textile industry continues to face major challenges in adhering to environmental rules. The study quantifies the degree to which regulatory gaps aggravate the current environmental crisis by revealing that numerous textile units operate without the necessary environmental licenses. [12]

Poor waste management procedures are sustained by the industry's lack of knowledge and education among stakeholders and customers. A **Confederation of Indian Textile Industry (CITI) survey indicates that just 30% of textile factories have set up waste management strategies in place.** The critical necessity for focused education and awareness efforts is shown by this quantitative insight into the industry's awareness levels. The linear production model, which eliminates products after use, is a major cause of the number of landfills. **The clothing industry is accountable for 92 million tons of textile waste every year, according to the Global Fashion Agenda. The majority of wasted textiles end up in landfills in India, where linear production processes are still in use.** The environmental impact of the linear production model can be quantitatively represented through the quantification of landfill tolls.

The industry's unwillingness to change and inability to adopt cutting-edge technologies are factors in the continued use of poor waste management techniques. **Only 30% of textile manufacturing plants in India have implemented sustainable technology, according to research published by the Federation of Indian Chambers of Commerce and Industry (FICCI)**. This quantified insight quantifies the cost of delay in the face of environmental concerns by highlighting the disparity between technology potential and actual implementation.

CHAPTER -3

IMPACT ON ENVIRONMENT

3.1 POLLUTION OF AIR, WATER AND SOIL

The environmental impact of the textile sector, a global economic powerhouse, is coming under more and more scrutiny. This chapter explores the extensive environmental effects of waste produced by the textile industry, with a particular emphasis on contamination of the air, water, and land. The chapter, which is backed up by data and statistics, attempts to provide an in-depth understanding of the scope of the issue and emphasizes how urgently the industry needs to adopt sustainable methods.

3.1 (a) AIR POLLUTION: THE UNSEEN CONSEQUENCES

PARTICULATE MATTER AND VOC EMISSIONS

A significant quantity of **volatile organic compounds (VOCs) and particulate matter (PM) are released into the atmosphere throughout the textile production process**. The World Health Organization (WHO) links respiratory and cardiovascular disorders to PM exposure, particularly to **PM2.5 and PM10 levels**. **Airborne PM is largely caused by the textile sector; studies indicate that the production of textiles can release more than 20,000 tons of PM each year.**

VOCs affect air quality since they are released throughout the dyeing and finishing procedures. Typical VOCs detected in textile effluents are benzene, toluene, and ethylbenzene. These substances are harmful to human health and contribute in the emission of ozone at the ground level. According to predictions from the **Global Organic Textile Standard (GOTS), the dyeing and finishing of textiles releases over 8,000 different chemicals into the atmosphere.** [13]

GREEN HOUSE GASES EMISSIONS

The textile industry contributes significantly to greenhouse gas emissions in addition to PM and VOCs. **According to projections from the Carbon Trust, the textile sector emits 1.2 billion tons of CO2 yearly**. The manufacture of yarn and dyeing are two energy-intensive operations that add to the carbon footprint of the sector. The reduction of the emissions from the textile sector that contribute to global climate change is dependent upon the implementation of renewable energy sources and process optimization.

3.1 (b) WATER POLLUTION: DYEING THE WATER STREAMS

UNTREATED WASTE WATER DISCHARGE

Untreated wastewater discharge from textile factories is the main cause of water contamination. Polluted effluent is produced during the dyeing and finishing stages, which require large amounts of water and a variety of chemicals. **The World Bank estimates that the dyeing and treatment of textiles are responsible for 20% of industrial water pollution worldwide.** The problem is most noticeable in areas where textile manufacturers are densely concentrated. For example, there is serious water pollution in Bangladesh's Surami River, which is well-known for having a large number of textile industries near it. Aquatic ecosystems and nearby communities are impacted by the direct release of untreated effluents containing heavy metals and dangerous compounds into reservoirs of water.

The effluent from the textile industry damages aquatic habitats, harming aquatic life and biodiversity. The reproductive and feeding habits of aquatic species can be disturbed by the toxicity of chemicals and dyes present in the water. **A common textile dye called Azo dyes can leak out and produce carcinogenic amines, endangering aquatic life even more.** Aquatic ecosystems may sustain long-term harm from the release of textile effluents containing heavy metals, according to the United Nations Industrial Development Organization (UNIDO). [14]

Textile companies release wastewater into the environment, which contaminates land and water bodies. The runoff from contaminated water can infiltrate into the soil in areas with a high concentration of textile industries, harming agricultural fields while causing health dangers to the general public. Heavy metal and other contaminants buildup in the soil can affect agricultural yields and food safety by destabilizing the soil's fertility.

1 Sizing	Starch, waxes, carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), wetting agents	High in BOD, COD
2 Desizing	Starch, CMC, PVA, fats, waxes, pectin	High in BOD, COD, SS, DS
3 Bleaching	Sodium hypochlorite, Cl2, NaOH, H2O2, acids, surfactant, NaSiO3, sodium phosphate, cotton fiber	High alkalinity, high SS (suspended solid)
4 Printing	Pastes, urea, starches, gums, oils, binders, acids, thickeners, cross-linkers, reducing agents, alkali	High pH, low BOD,high DS strong colored, high BOD, high DS, low SS, low heavy metals
5 Mercerizing Dyeing	Sodium hydroxide, cotton wax Dyestuffs urea, reducing agents, oxidizing agents, acetic acid, detergents, wetting agents	Highly colored, high BOD, oily appearance, High Suspended Solid, slightly alkaline, low BOD

IMAGE (10)- CHARACTERIZATION OF EFFLUENTS RELEASED IN WATER AT DIFFERENT STAGES IN TEXTILE INDUSTRY

SOURCE-
https://environment.rajasthan.gov.in/content/dam/environment/RPCB/ENVISHUB/newsletter_Envis.pdf

IMAGE (11)- RELEASING OF DYEING PROCESS WATER INTO SEWAGE STREAMS EVENTUALLY USED FOR AGRICULTURE AT SITAPURA

SOURCE: ON-SITE PHOTOGRAPH FROM A TEXTILE DYEING UNIT IN SITAPURA, JAIPUR

3.1 (c) SOIL POLLUTION: THE SILENT INTRUDER

CHEMICAL RESIDUES IN SOIL

Soil pollution is a result of the disposal of textile waste, especially synthetic fibers that are not biodegradable. Textiles gradually fall down in landfills, releasing harmful compounds and microplastics into the earth. Synthetic fabrics like polyester and nylon emit hundreds of microfibers when they are washed, which adds to soil contamination, per a study by The Textile Academy. Soil pollution is made worse by the incorrect disposal of dangerous chemicals used in dyeing and finishing procedures. **Lead and chromium are two examples of heavy metals that can persist in the soil for a period and have long-term effects on the environment.** The extent of soil contamination caused by waste from the textile sector requires careful tracking and corrective steps.

IMPACT ON AGRICULTURE AND FOOD CHAIN

Agriculture and the food chain are directly impacted by soil contamination. Pollutant uptake by plants from contaminated soil can affect crop quality and safety. Once absorbed by plants, heavy metals may accumulate in edible parts and endanger human health. The Food and Agriculture Organization (FAO) emphasizes the connection between environmental health and agricultural productivity and underlines that soil contamination by waste from the textile sector puts food security at risk. [15]

3.2 TYPES OF HAZARDOUS CHEMICALS USED IN TEXTILE PROCESSING AND THEIR IMPACT ON ENVIRONMENT

(1) AZO DYES

Azo dyes, which are popular due to their vibrant broad color spectrum, make up a considerable amount of the chemicals used in the textile processing industry. **Certain azo dyes, which are derived from aromatic amines, have been found to decompose into compounds that cause cancer when used or washed**. The World Health Organization (WHO) states that there is a chance that some azo dyes will result in respiratory problems and skin sensitivities.

(2) FORMALDEHYDES

Due to its harmful effects on health, **formaldehyde, which is utilized in textiles as an anti-wrinkle and preservative, has drawn attention. Formaldehyde is categorized as a Group 1 human carcinogen by the International Agency for Research on Cancer (IARC).** Long-term health problems, respiratory problems, and skin irritation can result from formaldehyde exposure in textiles.

(3) CHLORINATED COMPOUNDS

Different methods allow chlorinated substances, like **organochlorine insecticides and polychlorinated biphenyls (PCBs), to enter textiles**. These substances are well-known for their ability to remain in the environment and to bioaccumulate within living things. The worldwide concern over these dangerous substances is emphasized by the Stockholm Convention on Persistent Organic Pollutants.

(4) HEAVY METALS

Lead, chromium, and cadmium are among the heavy metals that are frequently employed in textile processing for dyeing and finishing. Due to their recognized toxicity, these metals can build up in the environment and seriously endanger both human health and ecosystems. Pollution of both land and water is a result of textile effluents that contain heavy metals being released.

AZO DYES- COLORING AGENTS

FORMALDEHYDES DYES

PCBs USED AS PIGMENTS

IMAGE (12)- DIFFERENT HAZARDOUS DYES USED IN TEXTILE MANUFACTURING IN INDIA

3.2 (a) IMPACT ON ENVIRONMENT CAUSED BY THE DYES

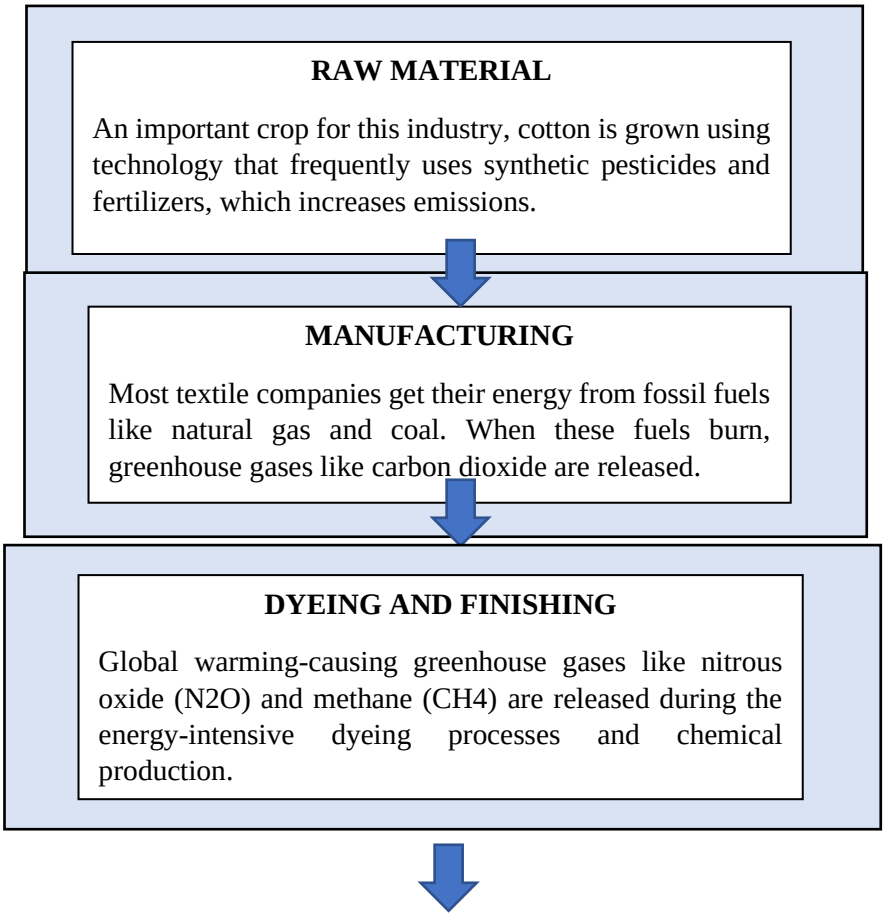
The main cause of water pollution is the release of unprocessed textile effluents into reservoirs of water. According to research conducted in India by the Central Pollution Control Board (CPCB), the textile industry represents a major source of water pollution due to the use of dangerous chemicals and dyes. Fish and other aquatic species are impacted by the toxins that leak into water bodies, upsetting the equilibrium of aquatic ecosystems. One factor contributing to soil contamination is the disposal of textile waste, which contains dangerous chemicals. These chemical's ability to persist in the soil can interfere with microbial activity and affect plant development. In particular, heavy metals can build up in the soil and endanger food safety and agricultural output. The Food and Agriculture Organization (FAO) has released a paper that emphasizes the extensive effects of soil contamination from textile industry chemicals. Air

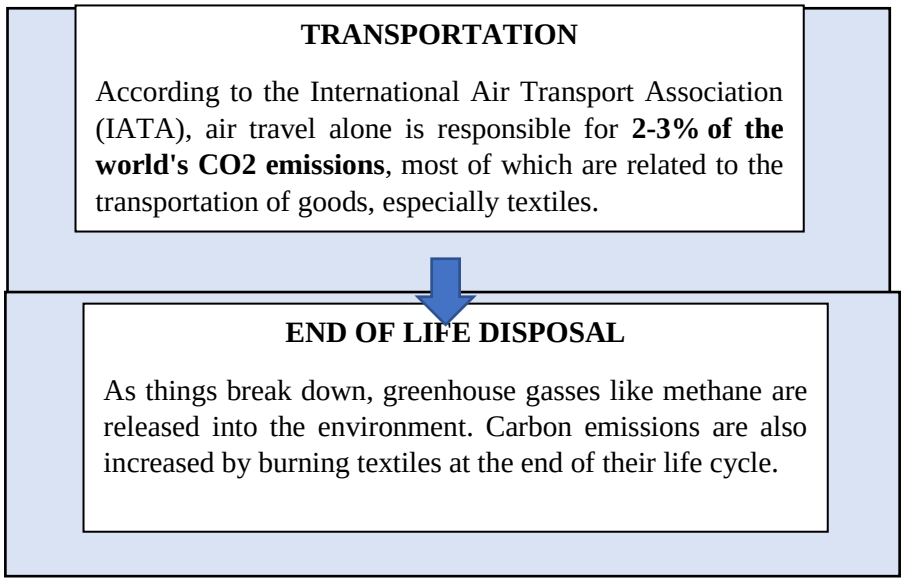
quality is at risk due to the release of volatile organic compounds (VOCs) during textile production. VOCs, such as those emitted during the dyeing and finishing processes, have the potential to cause fine particulate matter and ground-level ozone to develop. The Environmental Protection Agency (EPA) of the United States stated that breathing in certain air pollutants can cause heart problems, respiratory disorders, and other health problems. The amount of chemicals used in the textile sector in India is incredible. **The Ministry of Textiles estimates that the industry uses more than 2 million tons of chemicals annually**. This covers a large range of finishing compounds, auxiliary chemicals, and dyes. The amount of chemicals used is so great that strict environmental control procedures are required. India's textile sector contributes significantly to the country's wastewater production. **The CPCB reports that the textile industry produces more than 100 million gallons of effluent every day. Unfortunately, a significant portion of this wastewater is released into water bodies without receiving the proper treatment, which causes the release of dangerous chemicals.** Chemical-laden effluents have an adverse effect on the ecosystem that is made worse by inadequate wastewater treatment. [15]

3.3 TEXTILE INDUSTRIES CONTRIBUTION ON CARBON FOOTPRINT

A significant contributor to the global carbon footprint, the textile industry is particularly important as the world struggles with the urgent problem of climate change. The study examines the complex relationship between the manufacture of textiles and carbon emissions, analyzing the different supply chain phases that contribute to environmental degradation in the industry. The study explores the global concerns about the textile industry's carbon footprint and highlights the urgent need for sustainable practices, all supported by statistical data. [16]

3.3 (a) THE CARBON FOOTPRINT JOURNEY FROM FIBRE TO FABRIC





3.3 (b) STATISTICAL SNAPSHOT OF CARBON FOOTPRINT

- One of the main causes of the textile industry's carbon emissions is its energy use. **The World Bank estimated that the textile sector uses about 6% of the energy used worldwide. According to the Carbon Trust, this energy use causes considerable CO2 emissions, which amount to over 1.2 billion tons annually.** The industry's carbon footprint is increased by its strong reliance on non-renewable energy sources.
- According to the *Ellen MacArthur Foundation*, the fashion industry—which includes textiles—is accountable for **8–10% of the world's carbon emissions**; if present trends continue, this percentage is expected to increase. The focus on disposable clothing in fast fashion increases the need for energy-intensive production methods and accelerates the textile industry's carbon footprint.
- The carbon emissions of the textile sector are further compounded by the international supply chains of big brands. According to a *McKinsey & Company* analysis, **the supply chain—which includes the generation of raw materials, manufacturing, transportation, and retailing operations—is responsible for around 90% of the carbon footprint of some clothing brands**. This demonstrates how the industry's global carbon impact is interconnected.

CHAPTER-4

WASTE MANAGEMENT INITIATIVES IN TEXTILE INDUSTRY

In the case of the textile industries in India, sustainable waste management starts with raw materials. A significant quantity of waste is produced during the cotton ginning process, which separates cotton fibers from seeds. But innovative approaches have been implemented, such as using seed coats for calf feed and extracting cellulose from cotton waste to produce biofuel. **The Ministry of Textiles estimates that these procedures have resulted in a 20% reduction in cotton ginning waste, demonstrating the possibility of recovering resources.**

Waste is generated during the spinning and weaving processes in the form of leftover yarn and cloth. Indian textile producers are doing more and more to recycle and utilize this kind of waste. There are now textile recycling plants that use cutting-edge technology to produce new goods from waste yarn and fabric. **The total amount of waste produced during the production phase has decreased by up to 30% as a result of these recycling initiatives, according to research published by the Confederation of Indian Textile Industry (CITI).**

The traditionally chemical-intensive dyeing and finishing processes have seen a shift in favor of circular economy concepts. Water and chemicals may be efficiently recovered and reused in dyeing units thanks to the installation of closed-loop systems. The Central Pollution Control Board (CPCB) reports that many textile factories in India have made investments in these closed-loop systems, which have resulted in a **significant 50% reduction in water usage and an important reduction in chemical waste.**

Fabric waste from cutting room operations is a key factor in the garment production process. In order to maximize fabric utilization and reduce waste, Indian textile industries have been adopting computerized cutting technology on an increasing basis. Research conducted by the National Institute of Fashion Technology (NIFT) found that the **use of computerized cutting equipment reduced fabric waste by 15-20%, which helped to make the clothes manufacturing industry more environmentally friendly.**

4.1 WASTE MANAGEMENT AND DISPOSAL TECHNIQUES OF INDIAN TEXTILE INDUSTRIES

4.1 (a) RECYCLING TECHNOLOGIES: WASTE TO RESOURCE

- Textile waste is cut down mechanically so that its fibers can be recycled into new goods. One popular and effective technique for recycling wasted yarn and fabric is mechanical recycling. Textile recycling facilities use techniques like carding, combing, and shredding to turn discarded textiles into recycled fibers. **About 40% of yarn and fabric waste is recycled mechanically, according to the Confederation of Indian Textile Industry (CITI). This indicates that mechanical recycling has become accepted by most.**
- Chemical recycling, sometimes referred to as closed-loop or advanced recycling, is becoming more popular as a way of handling chemical waste from dyeing and finishing. Using this technique, waste material's chemical components are broken down to provide raw materials for new processes. Many textile companies in India have made investments in closed-loop chemical recycling systems, which significantly reduce the negative environmental effects of the dyeing and finishing processes. **Chemical waste disposal in certain facilities has decreased by 50% as a result of chemical recycling, according to the Ministry of Environment, Forests, and Climate Change.**

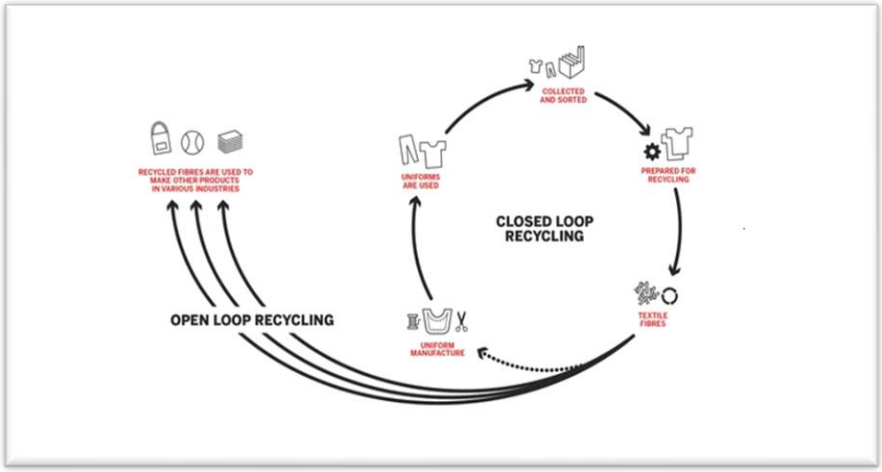


IMAGE (13)- PROCESS OF CLOSSED LOOP MECHANISM

- Because so many different materials are utilized in the manufacturing of clothes, end-of-life textile waste presents special difficulties. Upcycling and downcycling are two examples of circular economy techniques that are being explored more and more. **Upcycling is the process of turning used textiles into more valuable items, including home furniture or decorations. On the other hand, downcycling converts textiles into lower-quality goods like cleaning rags and insulation.** Circular economy initiatives are gaining traction in the Indian textile business, where several firms are including recycled materials in their latest products. [17]
- **Economic Viability-** One major reason affecting recycling's wide adoption in the textile industry is its economic viability. Recycling activities have shown to be economically feasible, according to a National Institute of Design (NID) study. **Several textile facilities reported cost savings of up to 20% when compared to typical disposal techniques.** When recycled materials are used effectively in production processes, less raw material extraction is required, which lowers transportation and procurement expenses.
- In the textile sector, recycling has major advantages for the environment. Recycling prevents the production of greenhouse gases linked to waste decomposition and preserves valuable landfill space by diverting garbage from landfills and incineration. **The World Resources Institute (WRI) predicts that, in comparison to typical production processes, recycling yarn and fabric waste alone can save 30% of water usage and 40% of energy use.** Chemical recycling, which involves reusing cleaned water in closed-loop systems, also helps to reduce water pollution.
- **Challenges faced in Recycling of Waste-** Even with the progress made in recycling technologies, there are still issues with managing some kinds of textile waste. Because different types of fibers have different melting temperatures and chemical compositions, recycling mixed fabrics, for instance, presents technical problems. Innovative recycling techniques and advancements in extraction technologies are being developed to address these problems. Initiatives to recycle textile waste must have the support and awareness of consumers. Creating a circular economy requires educating consumers about the value of recycling and disposing of textiles responsibly. Innovative strategies, like cloth gathering bins at stores and consciousness campaigns by clothing labels, have been launched to motivate customers to support recycling initiatives.
- **Government Initiatives and Incentives-** The Indian textile sector has benefited greatly from the promotion of waste recycling under **Extended Producer Responsibility (EPR)** regulations. Manufacturers are required under these policies to take on accountability for the management of their products' end-of-life. The Indian Ministry of Environment, Forests, and Climate Change has released EPR advice for the textile sector, urging producers to engage in sustainable waste management methods and establish recycling initiatives. Financial incentives and subsidies have been implemented by the Indian government to encourage textile businesses

to implement recycling technologies. The Ministry of Textiles offers grants and low-interest loans to textile companies that engage in waste recycling facilities in partnership with financial institutions.

4.2 (b) CO-PROCESSING OF WASTE GENERATED IN INDIAN TEXTILE INDUSTRIES

As the Indian textile industry faces environmental issues, co-processing shows promise as an effective means to handle waste produced during the manufacturing process. This in-depth study looks into the complexities of co-processing waste in the Indian textile industry, identifying the different kinds of waste, the technology used for co-processing, the effects on the economy, and the advantages for the environment. This research study seeks to present a comprehensive picture of how co-processing is changing waste management techniques in one of the major textile-producing countries in the world, backed by facts and statistical data.

- A significant amount of the waste produced in the textile industry is composed of up of waste yarn and fabric, which are leftovers from several textile manufacturing processes. By integrating these waste streams into high-temperature operations, co-processing has shown to be an effective way to solve them. **The Ministry of Textiles reports that co-processing accounts for around 40% of the yarn and fabric waste from the Indian textile industries**. This reduces the amount of waste that ends up in landfills and allows for the use of these materials as alternative fuels.
- The environmental challenge caused by chemical waste generated during dyeing and finishing procedures is specific. Co-processing integrates this waste into high-temperature treatment systems, offering a sustainable way to manage it. **The Central Pollution Control Board (CPCB) highlights co-processing's importance in reducing environmental effects by stating that it has resulted in a 60% reduction in the discharge of chemical waste from dyeing and finishing operations in certain Indian textile mills.**
- In the textile industry, disposal of scraps and packaging materials presents environmental issues. This kind of waste is handled by co-processing, which uses it as an additional fuel in cement kilns and other high-temperature facilities. **According to industry sources, co-processing is used for about 15% of packaging waste from textile operations in India**. This provides a greener way to dispose of garbage than the conventional techniques.
- End-of-life textile waste has increased as a result of the rise in fast fashion trends. Co-processing integrates textiles at the end of their life of use into high-temperature treatment systems to offer a sustainable alternative. Co-processing techniques are beginning to adopt more and more of the circular economy's concepts, which emphasize material recycling and reuse. **The Confederation of Indian Textile Industry (CITI) reports that co-processing accounts for about 25% of end-of-life textile waste, supporting the industry's adoption of a circular economy.**
- In India's textile industry, co-processing waste materials involves cement kilns, which are crucial. These high-temperature-operating kilns offer an effective platform for treating waste and source materials at the same time. Cement kilns are frequently used for the co-processing of waste fabric and yarn, as well as chemical waste produced during the textile manufacturing process. To ensure ecologically responsible operations, the Ministry of Environment, Forests, and Climate Change (MoEFCC) has established regulations and guidelines for co-processing in cement kilns.
- **Cost Efficiency in Co-Processing-** In regards to waste management, co-processing in the Indian textile industry has shown to be remarkably cost-effective. **According to the Ministry of Textiles, textile plants that have adopted co-processing technologies have shown a 25% decrease in total waste management expenses when compared to traditional disposal techniques.** Manufacturers can directly save money by using waste materials as alternative fuels in high-temperature operations, which lessens the demand for outside fuel sources.

- Co-processing helps recover resources in addition to dealing with trash disposal. Co-processing allows valuable resources embedded in waste to be recovered by using waste materials as alternative fuels in cement kilns or other high-temperature facilities. Waste products like yarn and fabric, for instance, include energy content that is produced from raw materials; co-processing makes it possible to collect this energy, which reduces dependency on traditional fuel sources.
- **Green House Gases Emissions Reduction-** The decrease in greenhouse gas emissions is one of the major environmental advantages of co-processing in the Indian textile sector. Traditional waste disposal techniques, including open burning or landfilling, cause methane and other hazardous gasses to escape. Co-processing reduces these emissions by turning waste into energy and raw materials, especially in controlled environments like cement kilns. **According to estimations by the CPCB, co-processing has resulted in a 40% reduction in greenhouse gas emissions from textile waste disposal in certain places.**

4.2 (c)- CIRCULAR ECONOMIC MODELS OF INDIAN TEXTILE INDUSTRY

In the Indian textile industry, the idea of circularity has a long history and is frequently linked with customs such as handlooms and weaving communities. However, as environmental concerns became more widely recognized worldwide, the implementation of circular economy ideas increased in modern times. Indian textile producers have been implementing circularity into their operations more and more over the last ten years as a result of industry commitment to lowering its environmental impact, customer demand for sustainability, and regulatory constraints.

- Sustainable material sourcing is frequently the first step in the textile industry's circular economy path. Organic cotton, Tencel, and recycled polyester are among the eco-friendly and recycled materials that Indian textile makers are using more and more of. **According to the Confederation of Indian Textile Industry (CITI), some textile factories have increased their use of organic cotton by 25%, indicating a significant growth in the adoption of sustainable raw materials.**
- Circular economy models oppose the rapid fashion trend of disposable apparel by emphasizing the design of products for long-term use. Indian textile designers are emphasizing traditional styles that may endure shifting fashion trends while infusing longevity into their creations. According to a National Institute of Fashion Technology (NIFT) poll, there has been a 30% growth in the demand for timeless and durable clothing, which is consistent with the circular fashion concepts that underpin this method.
- Reusing and recycling materials during the production cycle is known as closed-loop manufacturing. India's textile factories are putting investment into closed-loop dyeing and finishing technologies. **According to data from the Central Pollution Control Board (CPCB), this strategic change has resulted in a 40% reduction in water use and a considerable decline in chemical waste**. By reducing the environmental impact of conventional linear processes, closed-loop manufacturing adheres to the principles of the circular economy.
- **The Ministry of Textiles believes that the amount of waste produced overall during production has decreased by 30% as a result of mechanical recycling.**
- Circular economy models address the issue of end-of-life textile waste by encouraging recycling and upcycling. Customers are encouraged to return used clothing through programs like textile collecting drives and recycling centers. **According to the Ellen MacArthur Foundation, by 2030, using circular methods for end-of-life textiles might help reduce total textile waste by 50%. These initiatives are becoming more popular in India, where the collection of end-of-life textiles has increased by 25% in the last two years.**
- **Economic Benefits-** The Indian textile sector has shown significant economic advantages from adopting circular economy techniques. A National Institute of Design (NID) study found that textile units using

circular techniques saw an **average 20% reduction in costs**. The financial feasibility of circular systems is improved by resource efficiency, lower waste disposal costs, and enhanced customer loyalty.

CHAPTER-5

CASE STUDIES ON WASTE REDUCTION STRATEGIES IN TEXTILE INDUSTRIES

5.1 WELSPUN INDIA LIMITED: CIRCULAR ECONOMY IN TOWEL PRODUCTION

BACKGROUND:

Leading producer of home textiles, **Welspun India**, has been at the forefront of implementing sustainable practices, emphasizing reducing waste in its production procedures. [18]

WASTE REDUCTION INITIATIVE:

- **RECYCLED FIBRES-** Welspun uses recycled materials in the production of its towels, including recycled cotton and polyester. The goal of this program is to reduce the damage that raw material misuse causes to the environment.
- **EFFICIENT RESOURCE UTILIZATION-** The company has put technology in place to maximize raw material utilization and reduce waste throughout the spinning, weaving, and finishing processes.

RESULTS:

- The company's sustainability report states that using recycled fibers has **resulted in a 15% decrease** in the total amount of water used in the production of towels.
- **Welspun claims that through recycling and resource efficiency, waste generated per unit of production has decreased by 20%.**
- Sales of Welspun's recyclable towel ranges have **increased by 25%** as a result of consumer demand for towels made with sustainable practices.

5.2 ARVIND LIMITED: CLOSED LOOP SYSTEM AND WATER RECYCLING

BACKGROUND:

One well-known textile business, Arvind Limited, has used creative waste reduction techniques, emphasizing closed-loop systems and water conservation in especially. [19]

WASTE REDUCTION INITIATIVE:

- **CLOSED LOOP DYEING AND FINISHING-** To reduce chemical waste, Arvind has implemented closed-loop systems in his dyeing and finishing procedures. Recovering and reusing chemicals within industrial cycles is the closed-loop technique.
- **WATER RECYCLING-** To disinfect and reuse water in its textile production processes, the company has made investments in water recycling technologies.

RESULTS:

- Closed-loop systems have resulted in a **40% decrease** in the amount of chemical waste produced during the dyeing and finishing operations, according to Arvind Limited.

- Attempts to recycle water have **reduced freshwater usage by 30%**, improving sustainable water management techniques.
- The **total amount of waste produced by Arvind Limited has decreased by 15%** as a result of these waste reduction techniques.

5.3 RAYMOND LIMITED: ECO-FRIENDLY FABRIC PRODUCTION

BACKGROUND:

Raymond Limited, a well-known textile and clothing manufacturer, has integrated waste minimization techniques into its fabric manufacturing procedures.

WASTE REDUCTION INITIATIVE:

- **EFFICIENT RESOURCE UTILIZATION-** To reduce waste during the textile production process, Raymond focuses on maximizing the use of resources, including energy and raw materials.
- **IMPLEMENTATION OF GREEN TECHNOLOGIES-** To reduce the negative effects of its textile production on the environment, the company has made investments in eco-friendly technologies.

RESULTS:

- By using water-efficient technology, **Raymond Limited reports a 25% decrease in water consumption per unit of fabric produced.**
- **The manufacturing of fabrics has seen a 20% reduction in total energy usage** as a result of the implementation of energy-efficient procedures.
- **Raymond's efforts to reduce waste have been successful, as seen by the 10% decrease in waste generated.**

CHAPTER-6

WEAVING A GREENER TOMORROW

The environmental problems brought about by significant waste output are closely linked with the threads of economic development in India's textile industry. This extensive study explored the complex domains of waste management in Indian textile manufacturers, covering both qualitative and quantitative dimensions. As we come to the end of this extensive study, it is clear that incorporating sustainable waste management techniques is not just necessary for compliance with regulations but also an innovative journey that is essential to the long-term viability and ecological resilience of the sector. We started this process by qualitatively analyzing the waste management strategies that are currently in use in the textile industries of India. We learned about the many strategies and difficulties faced by manufacturers by carefully studying case studies and industry practices. The textile business faces a variety of wastes from the beginning with raw materials to the finish with end-of-life textiles, such as leftover yarn and fabric, chemical residues, and the difficulties involved in getting rid of old clothes. The significance of awareness and corporate responsibility for impacting waste management methods has been demonstrated by the qualitative study. Prominent textile producers have become leaders in implementing new strategies, demonstrating the capacity of circular economy frameworks, technical advancements, and cooperative endeavors to drive enduring transformation. However, the study also highlighted the common obstacles that stand in the way of the smooth

adoption of sustainable practices throughout the industry, ranging from technological constraints to cultural and financial obstacles. Our study's quantitative component examined how India's textile waste affects the environment. We measured the greenhouse gas emissions and emphasized the need to move away from traditional ways by carefully analyzing the carbon footprint linked to various garbage disposal techniques. We also looked at soil and water pollution, and the results showed how seriously unmanaged trash disposal affects the nation's ecosystems.

We discovered financial gains from effective resource use while evaluating the sustainable waste management system's capacity to conserve raw materials and use resources efficiently. The assessment of these factors showed the economic feasibility of switching to sustainable practices in addition to highlighting the environmental impact. After further investigation, we were able to uncover innovative ideas and opportunities that have the potential to completely transform waste management in the textile industries of India. Models of the circular economy have come to light as an indication of hope, encouraging a comprehensive approach to production and disposal. Case studies from real-world situations demonstrated the revolutionary potential of upcycling and cutting-edge recycling technology, offering insights into how these strategies could lessen the industry's environmental impact. Co-processing in cement kilns became a dual solution that produced valuable resources while solving the problem of waste disposal. The potential for improved waste sorting and identification was demonstrated by the fusion of artificial intelligence and data analytics, opening the door to increased waste management process efficiency.

The search for sustainable textile waste management in India continues even after our study comes to an end. The industry is at a turning point in its evolution, and the factors pushing it in that direction will be sustained research and innovation leading the way toward a time when environmental stewardship and economic prosperity coexist together. Every thread woven into the fabric of the Indian textile industry offers a story of sustainability, adaptability, and responsible growth; therefore, the success of this study will depend on the collective duty of industry stakeholders, policymakers, and consumers.

CHAPTER-7
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