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Indian Textile Industry and Sustainability: a Literature Review

Aslesha Bhargava[1]

1. Adjunct Faculty, of the Department of Fashion Design, Faculty of Art & Design, Ramaiah University of Applied Sciences, Bangalore, Karnataka, India.

Abstract: The present report identifies textile trends considering sustainability and the ecosystem as the focus point. Based on the literature review the report has been developed. Prominent findings based on analysis bring out the conclusion that milestones of development have been experiential and have the potential for all industries. Though the textile industry has always been a charmer, in the last 30 decades, this industry has seen a miraculous boom, all thanks to the modern era where clothing is now the most important part of looking good. And "no-repeat formula" has been on the trending charts of the fashion industry.

The study further delves into the components of the textile industry, the process of clothes formation, and its effects on the human body and environment. We will also analyze works of literature to conclude upon some remedies that are more than ever needed. Especially, details what specifically can be done in Indian industries to maintain the cycle of production while keeping the environment at "THE CALM".

Keywords: Textile industry, sustainability, cotton exports, processes in the textile industry, environment and remedies.

I. INTRODUCTION

The strategies and policies developed in the last decade to promote sustainable development have increased much pressure on all industries to find ways to maintain a balance in the ecosystem wherein the business and the industry can stay side by side (Hiba, 1998). The industrial sectors now need to exhibit their social responsibility to save the environment keeping in mind the effect on the human race, thereby, withholding the criteria of sustainability (Israel Urban Forum, 2019).

This review aims to identify the recent trends in the textile industry and criteria in fiber production and process to recognize the future aspects particularly being focused on sustainability and ecosystem. And to what extent the industry is impacting the overall environment. A consideration of the life cycle perspectives of fabric and its processing would also help us bring out the sustainability criteria and future objectives.

Sustainability has been identified to be context related. In lieu of this thought process, many types of research have been submitted to attain a definition of sustainability. On one hand, it is argued that sustainability is all about the utilization of resources in an optimized manner to not harm the process for future generations. On the other hand, it is argued to include the three pillars of sustainability – economic, social and environmental. Thereby, the purpose of this study can be illustrated well based on the concept of sustainability which is considered the dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the population develops to express its full potential without producing irreversible effects on the carrying capacity of the environment upon which it depends (Mensah & Casadevall, 2019).

Textile Industry has a very important role to play in every economy especially the Indian economy simply because India is the largest producer of cotton in the world. In 2020, India stood as the third highest exporter of raw cotton globally, accounting for 10.2% of the total global exports. The value of exports amounted to 6.3 billion US Dollars in the year 2020-2021 which has been just halfway as Indian Government targets to reach to 100billion US dollars in exports by 2025-2026 via Indian Textile Industry (Dixit, 2019). Not just this, the Textile industry is the second largest industry after agriculture that provides skilled and unskilled employment (Hasan, 2020). For an industry that is spread across the country by farming cotton, processing it to fiber and then weaving and dyeing, it is leaving heavy and harmful residues at every step that has brought up a question of how to bring the best-suited ways for sustainability, alongside to not to compromise over the pressurizing Industrial growth patterns.

II. WHAT IS A SUSTAINABLE TEXTILE PRODUCT?

Sustainability is the ability to maintain the activity for an indefinite period and that is only possible when we chalk out the definition of a sustainable textile product (Muscato, february 17, 2022). As per the definition above a sustainable textile product can be stated only if:

- It is safe for humans, animals and the environment.
- It is created out of renewable materials using renewable sources of energy.

- Manufactured using the optimum utilization of resources including human resources, wherein, they are provided with a decent working environment.
- Capable of being washed at low temperatures with natural laundry resources.
- Has a decent life span to avoid repeated production.
- It is maintaining an ecological balance, thus, can return to nature at the end of its useful life.

As per the current analysis of the supply and production chain, most of the part of the supply chain works in contrast to the above definition, thus, bringing into notice the evident scars on nature and human health in terms of pollutants, mindless dumping of textile, diseases and deteriorating working conditions.

2.1. Concept of Ecology in Textiles

In the context of textiles, the term "ecology" has a broad and complex definition, and the term is frequently used in imprecise ways. The usage of the term has become muddled as a result. Textiles that have not been bleached, have not been dyed, or have been coloured using natural dyes are frequently referred to as "ecological" or "natural" textiles (Roca & Herva, 2015). It's crucial to remember that not every natural dyes are environmentally friendly. For instance, as per the GOTS (Global Organic Textile Standards), a very small number of natural dyes do not meet the heavy metal & LD 50 (Lethal Dose 50, for Rat) criteria, demonstrating that some natural dyes are toxic when inhaled (Pillai, Kobayashi, Mathews, & Mathai, 2021).

When broken down into three sections, the word "textile ecology" is simpler to comprehend. environmental considerations for production, people, and disposal.

Production ecology is the study of how fibers, textiles, and clothing are produced and manufactured. Sustainable textiles ought to be pollution-controlling and ought to abide by social and environmental standards.

Governments have released RSLs (Restricted Substance 22 Lists), private labelling that establish a connection between production ecology and human ecology. Utilizing safer chemicals is aided by such a list of prohibited substances (Patra & Pariti, 2022).

Human ecology is the study of how textiles affect consumers and the environment around them. Users are well aware of the traces of dangerous substances and material left on textile substrates that could injure their skin. To confirm the absence of dangerous compounds, those chemicals must be recognized and analyzed by private independent laboratories.

Disposal ecology is always based on what happens after the product cycle and addresses recycling, reuse, energy, disposal, and/or decomposition of textile goods without releasing dangerous substances.

2.2. Impact of Fiber Formation

The cotton fiber, which dominates the Indian textile industry, is thought to be renewable, biodegradable, and environmentally beneficial, and it has several benefits over the course of its life cycle (Bedi & Cororaton, 2014). However, the production of natural fibers places high demands on the use of pesticides, fungicides, and fertilizers. According to the study, cotton growing uses only 3% of the world's average yet 25% of all. Additionally, before the cotton plant was harvested, harmful chemicals like defoliants were applied to the plant to destroy the leaves to prevent stains on the fiber. According to a previous investigation, over 65% of the compounds were found to be insecticides.

Only 1% of all harmful chemicals were fungicides and other substances, whereas 80% of them were insecticides, 20% were herbicides, and 14% were defoliants and growth regulators (Azizatul, et al., 2021) The same study concludes that more than 0.5 kg of harmful chemicals is used to produce the cotton fiber needed to make a T-shirt and a pair of pants. The water needed for irrigation during cotton farming is significantly more than what is needed to produce the same amount of synthetic fiber. This shows that growing cotton depletes natural resources by polluting water and releasing hazardous chemicals into the environment, making cotton the dirtiest and least environmentally friendly crop in the world (Hasanuzzaman & Bhar, 2016).

2.3. Cotton Formation

Due to the extensive use of dangerous pesticides and insecticides that harms the environment, and human and animal health, cotton is one of the dirtiest crops. More than any single important crop, cotton alone consumes 25% of the world's pesticides, although only being grown on about 2.5%of the world's arable area. According to a USDA study, up to June, cotton production in 2010–11 was approximately 24,891 (1000 MT tonnes) (Gallup, 1998). The world's major cotton-producing countries are China, India, USA, Pakistan, Brazil, Uzbekistan and Australia.

Regardless of its natural appearance, cotton production has a serious detrimental impact on the environment, including diminished soil fertility, a loss of biodiversity, water pollution, detrimental changes in the water balance, and pesticide-related issues, such as resistance (Gonlugur, February 6, 2019).

The traditional method of growing cotton is extremely harmful to both people and the environment.

The impactful facts are as follows (USDA, 2022):

- Cotton is a crop that is "hungry" and needs a lot of water to grow. Around 20,000 litres of water are required to produce 1 kilogram of cotton fiber in places with minimal rainfall.
- A lot of chemicals, like herbicides and insecticides, were used in the cultivation process. In industrialized nations, picking is done by large machines, which adds to the buildup of greenhouse gases.
- Huge amounts of synthetic fertilizers are necessary to grow cotton, and the manufacturing of these fertilizers necessitates the use of fossil fuels or natural gases, which release greenhouse gases derived from non-renewable resources like potassium.

- Cotton farming has been connected to human rights violations, such as forced labor and low salaries, in some nations where cotton production is state-controlled, like Uzbekistan.

2.3.1. Life Cycle of Cotton

1. Cotton Growing and Harvesting:

   Pesticides, fertilizers and defoliants are the main causes of environmental pollution including depleting soil quality during this process.

2. Cleansing Raw Cotton:

   Raw cotton is a dirty crop where seed needs to be filtered from the cotton. This process is known as ginning which emits cotton dust into the air. This dust is so harmful that most of the workers doing it regularly catch byssinosis (lung disease).

3. Cotton Fiber Spinning:

   Spinning as such has to be a hand-done process leading to no pollution but sadly, with commercialization, this process now involves using spinning oils that are supposed to be washed out in further processing of cotton, hence, it is leading to water pollution by the end of the washing process.

4. Yarn Weaving and Knitting:

   They are done to provide strength to the cotton fiber alongside giving a texture and body to it. The noise pollution during the weaving process along with the oils that are used in the needling processes is a takeaway from this processing stage.

5. Processing:

   Processing involves wet treatments like dyeing, resizing, bleaching, and printing to improve the design of the cloth material. The dangerous dyes, colors and bleaches used that are usually washed with the water induce heavy water pollution.

6. Sewing:

   This process is all about cutting and wasting tons of fibers. The cotton dust that flows into the air during this process along with the wastage of the final product is what is the major constraint.

7. Transportation and sales:

   This is no easy process where thousands of trucks, ships and other modes of transportation are used to transport the final product from one place to another leading again to air, water and fuel pollution.

8. Usage:

   This stage is all about wastage with the increasing trends of the “no-repeat formula”. the clothes are not optimally utilized and dumped into waste very often leading to quick repetition of the life cycle of cotton again emitting pollutants to the environment.

9. Disposal:

   Every year a huge amount of clothes is disposed of either in third-world countries or in landfills or even to the seabed. The chemicals that have previously been infused while processing the cloth make the serenity polluted, wherever, it is being dumped.

2.4. Synthetic Fiber

Among the most popular synthetic fibers used to make diverse textile items are nylon and polyester. Both fibers are manufactured using polymer solutions derived from waste products of non-renewable petroleum resources and are fundamentally non-biodegradable. While the production of polyester was approximately 25 million tonnes up until February 2007 it was approximately 31.9 million tonnes in 2009; similarly, the production of nylon reached 4,054 thousand tonnes in 2007 while it was approximately 3.5 million tonnes in 2009 (Islam & K, 2013) The production of polyester and other synthetic fibers and fabrics requires a lot of energy, releases a lot of pollutants, including volatile organic compounds.

2.4.1. Life Cycle of Synthetic Fiber

Polyester Manufacturing (Hasanuzzaman, Indian Textile Industry and its Impact on Health and environment: A Review, October December 2016):

It is a complicated process where refined raw oil is converted to polyester fabric with the help of many chemicals thar are suspected to be carcinogenic.

1. Cleansing Raw Cotton:

   Raw cotton is a dirty crop where seed needs to be filtered from the cotton. This process is known as ginning which emits cotton dust into the air. This dust is so harmful that most of the workers doing it on a regular basis catch byssinosis (lung disease).

2. Spinning:

   This process like cotton involves using spinning oils that are supposed to be washed out in further processing alongside producing heavy noise pollution, while the process is operational.

3. Weaving:

   It is a noise-heavy process where chemicals are again infused and considered to be one of the major sources of water pollution in the coming processing steps.

4. Processing:

   Processing involves wet treatments like dyeing, resizing, bleaching, and printing to improve the design of the cloth material. The dangerous dyes, colors and bleaches used that are usually washed with the water induce heavy water pollution.

5. Sewing:

   This process is all about cutting, reshaping and wasting tonnes of fibers (Paraschiv, Tudor, & Petrariu, 2015).

6. Transportation and sales:

   Similar to cotton, polyester products are also shipped to other places that load the transportation system with more work leading to the emission of more waste.

7. Usage and Disposal:

   These two stages have no difference because the lack of proper disposal of this fiber is one of the major reasons for the pollution. As it is created with refined raw oil and chemicals, this fabric takes longer to dispose of and in fact, certain parts of it remain undisposed even after 100 years of its disposal (Hendricks, 2013). On top, overproduction, no repeat formula and ever-changing trends have made the life cycle process quicker leading to making the life cycle of the product, a vicious and continuous process.

III. SUSTAINABILITY IN TEXTILE MANUFACTURING

The textile business has been referred to as the most environmentally damaging industry in the world. In some instances, wastewater with significant chemical loads, abnormal pH values, and temperatures is dumped into groundwater (mostly untreated) (Mora, Rocamora, & Volonte, 2014).

The life cycles of textiles and garments can become unsustainable in the following areas (Hendricks, 2013):

- Using hazardous substances
- Water consumption
- Energy consumption
- Waste production
- Air emissions
- Transportation
- Supplies for packing

3.1. Using Hazardous Substances

The global textile sector uses about 25% of the chemicals produced worldwide. In textile processing, particularly in textile wet processing, up to 2000 distinct chemicals are employed, and many of these are known to be detrimental to health of humans and animals (Patra & Pariti, 2022). Some of these chemicals are released into the environment as vapour, some are dissolved in treatment water, and some are retained in the fabric. The National Institute for Environmental Health Sciences (a division of the US Department of Health and Human Services) has released a list of the most frequently used chemicals, some of which are utilized in the production of fabrics and connected to human health issues ranging from minor to serious.

When discharged into the environment, the compounds that are of particular concern exhibit one or more of the following characteristics:

- Perseverance (they do not readily break down in the environment)
- Bioaccumulation (they can build up in living things and even become more concentrated as they move up a food chain).
- Tolerance

PBTs are chemicals with these characteristics (persistent, bio-accumulative, and toxic substances). Persistent organic pollutants are terms that are sometimes used to describe organic compounds with these characteristics (POPs). Even after being initially diluted in enormous amounts of water or air, these pollutants can linger in the environment long enough to travel great distances, accumulate in sediments and organisms, and in some cases, cause severe harm even with minute quantity. It is challenging to judge whether all of the chemicals used in the textile business are acceptable in terms of being environmentally friendly. The employment of several dyes in the dyeing and printing of textiles presents one challenge; Color Index International includes 27,000 different products under 13,000 different Color Index Generic Names. Because they evaporate into the air, are absorbed into meals, or are absorbed via the skin, volatile substances are particularly problematic (Blackburn, 2016). Some chemicals can cause cancer or harm to children even before they are born, while others can make some people allergic to them. According to some reports, the 5–10% of the population who are allergic to chemicals will increase to 60% by 2020 (Martinis, Sirufo, & Ginaldi, 2017).

3.2. Consumption of Water

Both the ecosystems of the earth and human health depend on access to clean water. It's a fundamental human right. Communities rely on waterways like rivers and lakes to provide them with essential resources like drinking water, water for irrigating crops, and food like fish and shellfish. These rivers provide water for several manufacturing and cooling activities, acting as a support system for industrial activity. However, these industrial operations have the potential to degrade water quality, endangering the other resources that rivers and lakes offer (Chavan, 2006). The increasing demand from human activities is causing water resources all around the world to deteriorate.

Water resources are under increasing pressure due to economic and population growth, which affects the quality and quantity of water available for human use, the functioning of the ecosystem, and the needs of animals. A limited resource, clean water, is employed at each stage of the wet processing cycle, although it is becoming uncommon to introduce the chemicals into the substance and remove them before the start of the next action. The water is then treated with chemical additions after being discharged as wastewater, which, if left untreated, could poison the environment thermally due to the effluent's high temperature, severe pH, and/or contamination with dyes, diluents of dyes, auxiliaries, bleaches, detergents, optical brighteners, and other chemicals (Shah, 2010).

During the production of textiles, brighteners and numerous additional chemicals are utilized, however, when there is improper or incomplete effluent, issues get worse. Some common routes for water wastage are the use of inefficient washing equipment; use of excessively long washing cycles; the use of fresh water at all water use points; poor housekeeping practices, such as broken or missing valves; unattended leaks through pipes and hoses and instances of when cooling waters are left running even after the machinery has been shut down.

3.3. Wastewater Pollutants

There is now 40% less water available per person than there was in 1970 (Chavan, 2006).

A single cotton shirt requires between 2,500 and 3,000 L of water to create (USDA, 2022). Cotton cultivation consumes the majority of this water, with wet finishing coming in second. In the textile finishing sector, the first effects of water scarcity and wastewater issues are already becoming apparent.

For instance, new businesses in China and India have been denied permission to open their doors if they cannot persuade the authorities that their strategy will assist address problems with water use and pollution. A similar threat of company closure exists throughout Europe. textile businesses in Asia Are also dwindling the groundwater reserves rapidly due to which groundwater is not highly salinized in most of the areas, hence, posing a danger to the existence of various companies itself.

Even today, some wastewater is still being dumped into cesspools or, in cases where they are not available, sewage networks without consideration for the effluent's BOD, chemical oxygen demand (COD), and/or heavy metal concentration. Depending on the chemicals and treatment methods used, the untreated wastewater produced during textile production and processing can differ significantly. It may contain substances with high BOD and COD, high total suspended solids (SS), oil and grease, sulphides, sulphates, phosphates, chromium, copper, and/or the salts of other heavy metals; of these, the most significant are thought to be COD, biological oxygen demand (BOD), pH, fats, oil that are relatively high in effluents. Sulphates typically result in issues because of their capacity to create strong acids that alter pH, whereas phosphates promote eutrophication in surface waters (Muscato, February 17, 2022).

3.4. Consumption of energy

The biggest consumers of electricity are spinning (41%) and weaving (including weaving preparation) (18%), while the biggest consumers of thermal energy are wet processing preparation (de-sizing, bleaching) and finishing together (35%) (Muthu & Sankaravelu, 2013). Although these percentages vary from plant to plant, the generation and delivery of steam also result in a sizable loss of thermal energy (35%). However, many studies and research show that there are several options for the textile sector to use renewable energy.

Examples include:

- Installing wind-powered turbo-ventilators on the roofs of manufacturing plants
- Using sun energy directly to dry fibers
- The textile industry uses solar energy to heat water
- Solar power

3.5. Waste Generation

The polyvinyl alcohol (PVA) desize effluent, which is biologically inert and poses a threat to the environment, is a significant COD contributor to a textile plant's main oxygenation treatment of water (POTW) operation. Unfortunately, the textile industry has not yet adopted any viable and efficient methods to remediate PVA desize effluent. Although reverse osmosis (RO) and ultrafiltration (UF) technology for recovering and recycling PVA size has been around for more than 35 years, it is still not generally used because of its many drawbacks (Shah, 2010). The circumstance calls for a novel technique for the recovery and recycling of PVA size that can efficiently and sustainably reduce energy and water use.

Vacuum flash evaporation is a revolutionary technology that would eliminate the drawbacks of the current UF process in the recovery of PVA from desize effluents (VFE). Although the VFE procedure for recovery and concentration has been employed in several other industries, the size recovery in the textile industry could not yet be established. The following are some examples of industrial solid waste from the textile industry (Apsara, Perera, Walahapitiya, & Madushan, 2022):

- Sludge and ashes
- Plastic bags carrying chemical raw materials; cardboard boxes; bale wrapping film; non-recyclable dirty cloth
- non-reusable paper cones and tubes
- Textile and yarn waste from non-recyclable processes
- Uncontrolled solid waste is probably going to end up in a landfill.

3.6. Air emissions

Carbon dioxide emissions from burning fossil fuels are a major factor in the greenhouse effect. The following emissions are also caused by the manufacture of textiles (Parvin, Islam, Urmy, Ahmed, & Islam, 2020):

- Nitrogen oxides and Sulphur oxides, which are produced by fossil fuel-heated boilers and cause the natural environment's freshwater lakes, rivers, forests, and soils to become acidic. This causes metals and building structures to corrode. They also aid in the development of smog in urban areas.
- The release of solvent into the atmosphere from drying ovens is used in solvent coating procedures.
- Solvents discharged during cleaning tasks (routine facility upkeep, print screen cleaning).
- Emissions of volatile hydrocarbons, such as alcohols, aldehydes, and organic acids, as well as NMHCs (non-methane hydrocarbons) that have been oxygenated.

3.7. Transportation

Stay Local- wear local can be nourished as to deplete the emissions along with using non-renewable sources of fuel for the rest of the transportation seems to be the mantra for sustainability here.

3.8. Packaging Material

Packaging, basically, includes the design, assessment, and production of packaging. Employing recycled materials (such as paper, cotton, jute, hemp, and wood), biodegradable materials, natural products grown without the use of pesticides or artificial fertilizers, and reusable materials are just a few of the eco-friendly practices that businesses are putting into practice to reduce their carbon footprint (e.g., cotton bags or hemp) (Blackburn, 2016). One of the best methods to lessen the effects on the environment is to reduce packaging waste.

IV. CURRENT STATE OF REUSE AND RECYCLE TEXTILES

The burgeoning interest in textile reuse and recycling is in line with the global shift towards the circular economy, as evidenced by the 2015 EU Circular Economy Action Plan and the 11th Chinese five-year plan from 2006 (Gustav Sandin), which highlight the importance of this concept in international and national policy. This trend has been further catalyzed by the efforts of the Ellen MacArthur Foundation, whose circular economy system diagram underscores the crucial role of reuse and recycling in realizing a sustainable future. While the textile industry has already made strides in downcycling and reusing materials, with around 15-20% of discarded textiles being collected in Europe, only 50% of this material is currently being reused, primarily through exports to developing nations (Haddar, Ticha, Guesmi, & Khoffi, 2014). The other half is sent to landfills or incinerated, underscoring the urgent need for improved recycling infrastructure and increased focus on circularity in the industry.

It is worth noting that there are significant variations in the collection and recycling rates of disposed textiles within Europe. For instance, Germany leads the pack with an impressive collection rate of 70%, with only a fraction of that being sent for incineration. Similarly, Denmark collects around 50% of its discarded textiles, mainly for domestic or foreign reuse (Gustav Sandin). Despite these encouraging figures, the textile industry has yet to tap into its full potential for reuse, as most clothing items are thrown away long before their technical lifespan is exhausted. Therefore, there is a dire need to increase efforts to promote textile recycling and improve the industry's circularity.

Given the current low recycling rate, there is enormous potential to increase recycling in the textile industry, particularly in the realms of polymer, oligomer, and monomer recycling. This would help prevent the disposal of textile waste that cannot be reused or fabric/fibre-recycled in landfills or incinerators. Unfortunately, the lack of technology for sorting and separating the textile waste into pure enough fractions is a significant hindrance to polymer, oligomer, and monomer recycling. Nonetheless, recent breakthroughs in the separation of cotton/polyester blends provide some hope (Parvin, Islam, Urmy, Ahmed, & Islam, 2020). Beyond technical barriers, there are also numerous non-technical obstacles that must be addressed to increase textile recycling rates.

4.1. How to approach sustainable production?

Sustainable manufacturing is crucial for cost-effective resource usage, waste reduction, and waste management. There are a number of reference materials that offer methods for analysing and changing textile production processes to use less energy and water, which reduces pollution (Hasan, 2020).

18 developing technologies that successfully use energy and water in the textile industry were described with their histories, advantages, and commercialization as a significant contributions to the literature on cleaner processes. The technologies were contrasted in terms of their capacity to reduce wastewater production while also saving energy, water, materials, and time.

Enzymatic treatments, ultrasonic treatments, improved cotton fiber pre-treatment to promote dye receptivity, plasma technology, and foam technology in the finishing process were the technologies that fully met all the requirements.

Best Available techniques (BAT) and metaheuristic optimization techniques are ahead to understand sustainability in the textile industry (Azizatul, et al., 2021).

4.2. Best available techniques that can be applied are:

In a Turkish mill that produces woven fabrics, Alkaya and Demirer studied applications for sustainable production and environmental performance evaluation. The study's goal was to reduce sodium salt consumption, energy consumption and associated greenhouse gas emissions, wastewater creation, and water use. Data for the baseline were gathered for 8 months. It was discovered that 138.9 L of water were used to produce each kilogram of product. Additional 4 months were spent on installation, and 12 months were used to track the applications for sustainable production (Gonlugur, February 6, 2019). Environmental benchmarking was carried out by gathering particular information on resource consumption and waste creation, or EPIs (EPIs).

Five applications were implemented as a result of the process' analysis employing BAT: the use of drop-fill washing rather than overflow, the reuse of standard cooling water, the reuse of singeing cooling water, the renovation of the water softening system, and the repair of valves and fittings. As a result, the process generated 43.4% less wastewater and produced 20.2% less CO2, which is mostly caused by energy expenditure. Additionally, a 40.2% reduction in overall water use was made. In addition, there was a 17.1% drop in overall energy use (Sharma & Narula, 2020).

In terms of BAT applications, Ozturk and colleagues looked into a cotton and polyester knitting-weaving fabric and subsequent finishing-dying plant in Turkey. The bleaching and dyeing capacity of the mill, which had two primary product lines, was 2412 and 6682 tonnes per year, respectively (Shah, 2010). Before the change, freshwater use was roughly 3100 tonnes per day. 14 BAT, comprising good management practices, water reduction, and chemical minimization/substitution, were selected from 92 appropriate improvements after the data for three years were examined, primarily considering their priority, techno-availability, and prospective advantages. Some of these include a chemical replacement, caustic recovery from mercerization process wastewaters employing membrane process, reuse/recovery of washing/rinsing and softening effluent, reuse of suitable dye bath, and so on. The mill was using 9–10 g, or 95–102 L, of water per kg of produce (Haddar, Ticha, Guesmi, & Khoffi, 2014). The probable reduction in the consumption of water and chemicals after the implementation of chosen BATs was projected to be 43-51 and 16-39%, respectively. It was anticipated that the wastewater flow rate will decrease by 45–52%. The implementation's payback period was estimated to take no more than 26 months. It was then noticed that implementing BAT resulting the depletion of water usage as well as a better sustainability quality grid.

V. METAHEURISTICS

The concept of Metaheuristics is a relatively new topic of study in the literature, which calls for the use of unconventional optimization techniques in the textile industry while taking the delivery date and environmental concerns into account. A large area of textile production, including cotton grading, yarn grading, fabric colourfastness grading, fabric comfort, and fabric inspection, has a great deal of potential for new optimization and decision-making algorithms (AI - Artificial Intelligence), even though the majority of these studies have focused on the scheduling of the dyeing process.

Studies on the creation of hybrid metaheuristic algorithms and studies on the use of genetic algorithms in actual processes are two categories for studies on non-conventional optimization approaches.

5.1. Developing hybrid algorithms:

To enhance batching and scheduling simultaneously, a multi-subpopulation genetic algorithm with embedded heuristics (MSGA-H) has been presented. Actual research using data from a Taiwanese textile dying manufacturing company was used to evaluate the algorithm's validity. The outcomes have demonstrated the MSGA feasibility in practice (Kaid, et al., 2022). In this study, the decrease in used water and wastewater was not recorded.

Similar to the prior study, a bi-objective optimization model to approach the issue was used. The study's goals were to lessen the expense of delivery delays and the pollution that setup cleaning before each task produces. The issue was resolved using the MO-PSO-L approach, a multi-objective particle swarm optimization algorithm improved by problem-specific local search. The algorithm was compared against the universal multi-objective optimizer NSGA-II and the multi-objective imperialist competitive algorithm during computing experiments utilizing simplified realistic manufacturing data (MOICA) (Azizoglu, 1994). Three metrics—the overall nondominated vector generation (ONVG), the C-metric (CM), and Tan's spacing—were used to assess the algorithm's performance (TS). One could conclude that the MO-PSO-L algorithm discovered more Pareto solutions.

5.2. Applying those genetic algorithms

The genetic algorithm was utilized by Zhou and colleagues to plan a dyeing procedure. The goals of scheduling are product delivery on schedule, full filling of the dyeing vessel, placing fabric of the same type, color, depth, and manufacturing process in the same dyeing vessel, and sorting the color depth, such as from light to dark. The first step of the genetic algorithm was to produce a large number of individuals by distributing all orders across various dye vats. The delivery date was verified for each person (Krim, Zufferey, Potvin, Benmansour, & Duvivier, 2021). The population's fitness function was then calculated. Following the crossover and mutation processes, the next generation was selected based on the fitness of the parents and offspring. The process was performed as many times as necessary to reach the maximum number of evolutionary. The data were used to verify the method.

VI. CONCLUSION

According to the research, BAT acts can save you a significant amount of water and energy, up to 65 and 70%, respectively. However, much of the research focuses on hypothetical rather than actual implementation results. Therefore, more implementation studies on real processes should be carried out to inspire other businesses.

In the era of Industry 4.0, businesses that employ clever strategies and thorough preparation will thrive. As a result, research on the schedule optimization of the dyeing process has grown more complicated and multi-objective, making them easier to address using unconventional optimization techniques. Due to the topic's novelty, there aren't many studies on it in the literature.

Due to the topic's novelty, there aren't many studies on it in the literature. Nevertheless, those studies showed a significant environmental advantage while lowering the expenses of the wastewater treatment procedure. Without adding additional installations to the process, a reduction in water usage was achieved.

When the body of research on BAT and metaheuristic studies is examined, it is clear that the studies using BAT have greater practical application and feedback; nevertheless, there aren't enough studies using metaheuristic optimization to quantify the improvement of the processes under study. Information on the use of cutting-edge optimization techniques in real-world industrial applications is required. Future research on this topic will therefore be useful for the literature.

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