European Journal of Sustainable Development Research
2023, 7(4), em0237
e-ISSN: 2542-4742
https://www.ejosdr.com

MODESTUM

Research Article

OPEN ACCESS

Determination of environmental sustainability practices in the apparel sector of Sri Lanka

Thiwanka Sandaruwan De Fonseka [1*]

[1] Vern University, Zagreb, CROATIA
***Corresponding Author:** thiwarox@msn.com

Citation: De Fonseka, T. S. (2023). Determination of environmental sustainability practices in the apparel sector of Sri Lanka. *European Journal of Sustainable Development Research, 7*(4), em0237. https://doi.org/10.29333/ejosdr/13816

ARTICLE INFO

Received: 22 Jun. 2023
Accepted: 11 Oct. 2023

ABSTRACT

Apparel is the second most polluted industry in the world after oil. Therefore, implementation of environmental sustainability practices in the apparel sector is a buzzing topic discussed throughout the globe. There are many operations throughout the value chain of the apparel sector from yarn manufacturing to final product finishing such as but not limited to dyeing, printing, washing, cutting, sewing, bonding, and packaging, which impact on the environment and there are many practices implemented to mitigate the environmental impacts throughout this value chain. Apparel industry is the prominent export revenue generator of Sri Lanka, which contributes to more than 40% of their export income. There are about 300 export-oriented apparel manufacturers in Sri Lanka, and all are managed by the private sector. This research was done to determine the environmental sustainability practices currently being implemented in the apparel sector of Sri Lanka. Qualitative data gathered via semi structured interviews was utilized in this study. It was found that there are six main pillars that the apparel sector of Sri Lanka has been implemented environmental sustainability practices namely, energy and emissions, water and wastewater, solid waste, chemicals, biodiversity, and product.

Keywords: environmental sustainability, apparel, Sri Lanka

INTRODUCTION

Environmental sustainability is one of three pillars of triple bottom line of sustainability. There are several definitions pertaining to environmental sustainability. United Nations World Commission on Environment and Development defines environmental sustainability as "acting in a way that ensures future generations have the natural resources they need to live an equal, if not better, way of life than current generations" (Alamoush et al., 2021).

The apparel industry has emerged as one of the biggest and rapidly expanding industries in the world. There are many operations throughout the value chain of the apparel sector from yarn manufacturing to final product finishing such as but not limited to dyeing, printing, washing, cutting, sewing, bonding, packaging etc. The apparel industry focuses on the newest fashion trends, yet it lags the only trend that truly matters, the need to drastically alter our consumption patterns to ensure the planet's survival. This $2.5 trillion industry is the world's second largest consumer of water, accounting for 20% of global wastewater (Dehghani & Goyal, 2022). One cotton shirt requires 2,700 liters of water, the amount a human drink in 2.5 years (Liu et al., 2021). The apparel industry accounts for 10% of global carbon emissions (Okafor et al., 2021), and cotton farming accounts for 24% of insecticides and 11% of pesticides despite using only 3% of the world's arable land (Ahirwar & Behera, 2021). While the apparel industry already has a significant impact, it is expected to expand even more in the coming decades. In comparison to 2000, the average consumer now purchases 60% more clothing items, but each apparel is kept half the time, and 40% of the clothes in our closets are never worn (Ronan, 2022). Also, 85% of all apparels go to the dumps each year and washing several types of clothes sends thousands of bits of plastic into the ocean (Gupta et al., 2022).

Sri Lankan apparel manufacturers and suppliers have built a strong global reputation for producing premium-quality apparels trusted by global fashion brands over the years. Apparel sector of Sri Lanka is the most important and active contributor to the nation's economy. There are about 300 apparel factories operated in Sri Lanka (Varshney, 2022). All apparel factories are fully privately owned and operated. These factories have successfully used international market opportunities to expand beyond typical exporting and tailoring designs to offer innovative and sophisticated solutions via fashion business process outsourcing services, research and development centers, and innovation hubs (Export Development Board Sri Lanka, 2022).

For many years, Sri Lankan apparel sector has championed the cause of sustainable manufacturing. This dedication has resulted in significant changes in manufacturing processes, sourcing strategies, and product innovation, establishing Sri Lanka as a leading destination for brands concerned about the environmental impacts of their clothing. Sri Lanka is delighted to own the first custom-built green clothing factory in the world as well as Asia's first carbon-neutral certified factory. It also has several of the world's first apparel manufacturing plants to be certified as "net-zero carbon" (AWGNM, 2021). "Net zero carbon" corresponds to a scenario in which the quantity of carbon dioxide (CO_2) emitted into the environment is balanced by the quantity of CO_2 removed from the environment or offset by other methods, such as the purchase of carbon credits (Allen et al., 2022). But with the growing demands of brands in incorporating more and more environmental sustainability requirements throughout the supply chain, it is must to incorporate further environmentally sustainable factories across the whole apparel sector of Sri Lanka to cater to those customer demands. This paper discusses the current environmental sustainability practices implemented in the apparel sector of Sri Lanka, which will facilitate all the apparel sector facilities in Sri Lanka to understand those practices and embed the missing key practices within their organizations to cater to the rising environmental sustainability requirements of the brands.

LITERATURE REVIEW

Based on the Paris Agreement of 2015, 195 national governments dedicated to limit the global temperature rise to well below 2 °C and continue to follow efforts to limit the rise to 1.5 °C above pre-industrial levels. Intergovernmental panel on climate change (IPCC, 2018) published the special report global warming of 1.5 °C in 2018, which indicates strong proof that limiting warming below 1.5 °C will substantially decrease climate impacts associated with droughts, sea level rise, flooding, extreme heat, and ecosystem collapses. To constrain global warming to 1.5 °C, according to IPCC (2018), global greenhouse gas (GHG) emissions must be reduced by 45% from 2010 baseline by 2030 and reach net zero emission target by 2050. Amidst efforts by governments and other stakeholders, GHG emissions continue to rise. By the end of this century, global mean temperatures are expected to be increased by 2.2 °C to 4.4 °C if current trends continue. Global emissions in 2030 will be approximately 90% higher than they ought to be under 1.5 °C contexts, despite the best efforts under existing nation and industry level commitments (Sadowski et al., 2021).

To reduce the emissions pertaining to apparel sector in a collaborative manner, four global organization called carbon disclosure project, World Resource Institute (WRI), United Nations global compact, and World wildlife fund have started a great initiative called science based target initiative (SBTi), which apparel sector companies including brands, retailers and manufacturers are engaged with. When these four organizations embarked on SBTi journey in 2017, less than 10 apparel sector organizations joined with this initiative. By September 2021, more than one hundred apparel sector companies have joined, which indicates the success rate of this initiative. During this period, the company roster has expanded to include brands, retailers, and manufacturers of various sizes and locations. As per SBTi, organizations' targets to reduce greenhouse gas emissions are regarded Science Based if they align with the most recent climate science considered necessary to achieve the objectives of the Paris Agreement: to restrict global warming to well below 2 °C above pre-industrial limits and to continue efforts to restrict global warming to 1.5 °C (Sadowski et al., 2021). Signatory to the science-based targets initiative, MAS has committed to reduce scope 1 and scope 2 GHG emissions by 25.2% by 2025, relative to a 2019 base year (MAS Holdings, 2022).

Implementation of renewable energy sources is another key environmental sustainability practice in the apparel sector. For an example, India's largest apparel exporter, Shahi exports has installed 32 MW and 52 MW two solar power plants, which satisfy around 65% of its total electricity requirement (Tagra, 2022). Brandix (2021) has embedded renewable energy through solar and biomass, which covers 50% of their total energy consumption across the group.

The vast amount of water required for textile processing in the apparel sector varies mill wise based on the type of process, type of fabric, type of equipment, type of dyestuff, and duration of the process. Cotton consumption, which is the highest water consumer out of all fabric types, accounts for 2.6% of global water consumption (Alam & Hossain, 2018). In general, there is no water shortage in Sri Lanka, and water availability per capita is sufficient to support the country's approximated peak population. Despite this, Sri Lanka has experienced a water shortage during the last two to three decades because of the frequent spatial and temporal variability of water availability and catastrophic weather conditions (Chandrasekara et al., 2021). Therefore, the giants of Sri Lankan apparel sector MAS have pledged to reduce 65% of its water intensity by the year 2025 compared to the baseline of 2019 (MAS Holdings, 2022). Also, Brandix (2021) have pledged for zero water wastage by 2023 and Hirdaramani (2021) have pledged to reduce 50% in its normalized (water per person per day) freshwater consumption.

Fabric is the main waste stream generated in the apparel industry. Statistically, 19,000 to 38,000 tonnes of fabrics are utilized by the apparel sector annually, which creates a massive amount of waste, close to 20% out of the above-mentioned fabric quantity (Prasanga et al., 2021). Numerous waste management practices are currently being deployed to manage this enormous amount of fabric waste produced in the apparel sector. But unfortunately, in the global context, the most common practice is landfilling, which accounts for 75% of the total fabric waste. Apart from this, around 25% of fabric waste is reused or recycled while less than 1% is closed-looped back into manufacturing clothing (Juanga-Labayen et al., 2022). In Sri Lankan context, Hirdaramani (2021) has pledged to zero landfill of it waste by 2025 while Brandix (2021) has committed to reuse and recycle 100% of its waste by 2023.

METHODOLOGY

Qualitative data collection is no longer synonymous with face-to-face research, as researchers now conduct focus groups and individual interviews using a variety of online platforms. These online adaptations are appealing in part because they allow for the inclusion of more people and places in a study sample without requiring travel and can better include populations for whom travel to a study site may be difficult (Namey et al., 2020). Semi-structured interviews have used to collect qualitative data for this study. Semi-structured interviews allow for some flexibility and are one method for obtaining a realistic picture of an individual's point of view (Almenhali, 2019).

There are about 300 apparel manufacturing facilities in Sri Lanka under 40+ organizations as per the export development board data base of Sri Lanka. Murray and Hammons (1995) estimated that for the qualitative decision-making process, 10 to 30 subject matter experts may be necessary. To achieve improved dependability and transferability (Creswell, 2014), interviewees were selected based on purposive sampling. The saturation of information is a crucial aspect of sample size in qualitative research.

Saturation is the phrase used to describe the point at which adding additional data produces no new insights or range of ideas (Braun & Clarke, 2021). This study collected data until no new features of sustainability challenges were discovered. In this study, data saturation occurred prior to interview number 26. Hence, only 30 interviews were conducted. All these 30 interviewees were heads of environmental sustainability divisions of 30 different apparel sector organizations. These interviews were done through "Microsoft Teams" online platform. The duration of the interviews ranged from 40 to 45 minutes.

Content analysis was utilized to analyze the interviews. The objective of content analysis is to gain knowledge and comprehension of the phenomenon. According to Kyngas (2020), a content analysis is a form of research for subjective opinion of the setting of a text via a classification system of coding and the discovery of themes or patterns. Coding of the recorded texts in the study entailed open coding of meaning units, i.e., words, phrases, sentences, and paragraphs, which consisted primarily of labeling concepts. The notions that emerged were integrated into themes.

After the interviews, the researcher asked participants to evaluate the analyzed data. The validation of participants involved transmitting important theme codes to the original interviewee and requesting confirmation of the codes' accuracy.

RESULTS & DISCUSSION

Based on the outcome of the semi structured interviews, the researcher has identified six key areas, which existing environmental sustainability practices in the apparel sector of Sri Lanka could be segmented. Those are energy and emissions, water and wastewater, solid waste, chemicals, biodiversity, and product.

Environmental Sustainability Practices Related to Energy & Emissions

In response to climate change, pollution, and the loss of nonrenewable natural resources, energy and emissions-related environmental sustainability measures have emerged. Since the beginning of the 20th century, the mean temperature at the surface of the Earth has risen approximately 0.8 °C (1.4 °F), with approximately two-thirds of this rise happening since 1980 (Saxena & Khare, 2019). Due to complex supply chains and highly energy-intensive manufacturing processes, the apparel sector is responsible for 4%-6% of the world's carbon emissions, more than the aviation and shipping industries merged (European Parliament, 2021). Based on the semi structured interviews and above-mentioned secondary data sources, it was found that there are three key steps that apparel sector organizations have implemented to reduce the energy and emission footprint of their respective facilities. Those are reduction of energy and emissions through machinery and process optimization, incorporation of roof top solar as renewable energy to reduce the use of conventional non-renewable energy sources and carbon off setting through carbon credit purchasing.

Machinery and process optimization is a common practice that almost all Sri Lankan apparel manufacturers have incorporated to reduce their energy and emission footprint. Main machine type in the apparel sector is sewing machines. The widespread use of manual universal sewing machines with clutch motors that require modernization has prompted the creation of energy-efficient electric drives for sewing machines with servo motors. In general, servo motors can reduce about 70% of energy compared to clutch motors in sewing machines. Also in all servo motors, the control box is equipped with 24/12 V DC control outlets (Drofa et al., 2021). Using of servo motors, instead of clutch motors found to be a common sustainability practice at almost all apparel manufacturing facilities in Sri Lanka. There are several machines used in industry, which generates a huge heat waste such as heat seal (used for logo embossing applications), molding machines (used for bra cup and fabric molding) and macpi (used for apparel bonding and fusing) machines. Most organizations have insulated these machines with insulating materials such as Teflon to reduce the heat waste, which saves a lot of energy.

Power factor correction is a key practice that most of the facilities practiced to reduce energy and emission footprint. Power factor quantifies the efficiency with which electrical power is utilized. In an electrical circuit, it is the ratio of the true power (measured in watts) to the perceived power (measured in volt-amperes). In a perfect circuit, the power factor would equal one, indicating that all the power supplied is being utilized to accomplish beneficial work. However, in many actual circuits, the power factor is less than one, indicating that reactive parts such as inductors and capacitors are wasting some of the power. A low power factor can result in difficulties for electrical systems, such as increased energy expenditures, decreased efficiency, and diminished capacity. Consequently, power factor correction techniques are frequently employed to improve power factor and enhance the efficiency of electrical systems (Pradhan et al., 2021). Most of the facilities have maintained its power factor at a minimum of 0.95 or above at the main feeding points/main panel room by using capacitor banks. When a capacitor bank is added to an electrical system, the capacitors compensate for the reactive power of the inductive loads, improving the circuit's power factor. The capacitor bank supplies capacitive reactive power to the circuit, cancelling out the loads' inductive reactive power, resulting in a better power factor. Manual machine cleaning instead of using compressed air for machine cleaning and utilization of LED lighting instead of conventional lighting at the factory floor and offices found to be other general process optimization techniques used in the apparel sector to reduce energy and emissions. Other common process optimizations to reduce energy and emission are using water cooled systems or central chillers instead of split and/or package air condition units at the factories, installing heat generating equipment with heat extraction, isolation, or separation devices, installing heat recovery systems such as desiccant wheels, and installing variable speed drive motors for chilled water systems. By recovering condensation energy, a desiccant wheel system can accomplish air conditioning and dehydration at high evaporation temperatures and reduce energy consumption (Tian et al., 2022).

There are several renewable energy sources available in the world. But due to the regulations and climatic conditions in Sri Lanka, solar energy is the most used (after hydro) renewable energy source in Sri Lanka (Sri Lanka Sustainable Energy Authority, 2022). As per the interviewees, it was found that roof top solar is the most common renewable energy source utilize in the apparel sector of Sri Lanka to reduce energy and emissions. There are three methods to install and commission roof top-solar in Sri Lanka. Those are net-metering, net-accounting, and net-plus. Net-metering means excess solar energy generated during the day, after fulfilling requirement in the house/factory is exported to the street and in the evening, the household/office requirement is imported from the street. At the end of the month, the totals are netted. Net-accounting is similar to net-metering, but if there is a surplus of generation at the end of the month, ceylon electricity board (CEB) will pay to the customer. Net-plus means, where the total generation is exported, and CEB will pay to the customer (Sri Lanka Sustainable Energy Authority, 2022). Most of the apparel factories use this net-plus method to commission their solar panels since it is economically more beneficial compared to the rest of the methods. Second most used renewable energy source is biomass. Most of the factories use wood logs, wood chips, wood briquettes and sawdust as forms of biomass for the wood boilers in the manufacturing facilities. Most used wood types are gliricidia and rubber, due to their high calorific value, cost, and availability (Muthukumarana et al., 2018). Other forms of renewable energy sources like of wind and liquid natural gas, which generally used in the apparel industry of other countries such as Bangladesh and India are not used in Sri Lanka due to the geographical conditions (wind) and non-existence (liquid natural gas). Interviewees from some organizations have mentioned that they are planning to fulfil 100% of their energy requirement from solar and biomass renewable energy sources by 2040.

Aligning with SBTi is another sustainability practice that Sri Lankan apparel sector facilities are used to reduce their energy and emissions as explained in the literature review as well. Therefore, factories set these reduction targets based on their existing energy and emission values after consulting with some third-party consultants to drive their sustainability agendas towards net zero.

Environmental Sustainability Practices Related to Water & Wastewater

There are several standards used in the apparel industry to understand the water risk of respective manufacturing countries. Out of them, most common tool used in Sri Lankan apparel sector based on the qualitative data gathered is "WRI adequate tool" developed by WRI. This tool of WRI utilizes free to use, peer-reviewed data to depict water threats such as flooding, drought, and stress (Mueller et al., 2015). As per this tool, Sri Lanka is in a water high risk zone. Therefore, many apparel sector organizations have embedded environmental sustainability practices to reduce water consumption and maximize the reuse and recycle of wastewater rather than discharging it in vain.

The current global textile industry water use is approximately 79 billion cubic meters, and it will increase by an average of 50% by 2030 (Chakraborty & Ahmad, 2022). Water reduction practices have been implemented in two main ways in the industry. Those are process water reduction and non-process water reduction. There are many processes/operations in the apparel industry, which require hefty amounts of water. Even though processes such as cotton growing and yarn manufacturing are not available in Sri Lanka, processes such as fabric and garment dyeing, printing, and washing need considerable amount of water. Scouring process before interacting the fabric with dye bath involves many salts and water, which eventually contribute to the water footprint of the dyeing process. In simple terms, scouring eliminates both soluble and insoluble impurities, such as waxes, oils, fats, and dirt, which are present in textiles as natural, added, and accidental contaminants. Scouring prepares fabrics for later treatments such as bleaching and dying by removing these impurities. Thus, there are several practices such as waterless scouring, bio scouring, reuse of dye bath and material liquor ratio reduction (parts of water used to dye one part of fabric). Material liquor ratio changes from fabric type (liquor ratio for cotton fabrics are different from synthetic fabrics like polyester). But many apparel sector organization have reduce this liquor ratio for a considerable level using several sophisticated machineries and process optimization techniques such as "right first time," where they do not need to dye the fabric twice. Non-process water is mainly used for washrooms, canteen, and gardening purposes in the apparel sector organizations. Those are mainly reduced through practicing water flow rate adjustments through water efficient fittings such as installing dual flush commodes instead of single flush commodes and installing flow rate reduction aerators for washroom and canteen taps. Some other key practices are continuous monitoring through water sub meters to identify and rectify water leaks, installing sensor and peddle taps instead of conventional taps and rainwater harvesting for gardening and flushing instead of freshwater. Rainwater harvesting in apparel factories is not an easy process to implement. It is crucial to identify a suitable location within the plant for rainwater collection. According to the majority of interviewees, they collect rainwater through the factory roofs. The next stage is to install gutters and downspouts on the collection area to direct the water to a storage container. Continuous cleaning and maintenance of gutters and downspouts enables factories to collect high-quality water by keeping gutters and downspouts clear of debris and in good shape. Additionally, they install downspout filters to remove debris and other impurities from the water. Most factories collect rainwater in large plastic containers with covers to avoid contamination. Typically, factories link overflow pipes to the storage tank to prevent flooding after heavy rains. Rainwater harvesting is practiced only at factories situated in the wet zone of Sri Lanka such as hill country, where they get adequate rainfall annually. To optimize use of process and non-process wastewater, many factories have incorporated several environmental sustainability practices such as implementing sophisticated filtration techniques to utilize the wastewater for gardening and flushing purposes instead of just discharging into a wetland, waterbody, or general land. Other than this, many factories are doing some protypes to understand whether they can reuse this wastewater back to the process through systems such as ultrafiltration and reverse osmosis membrane filtration. Interviewees of some wet processing organizations, where they use more water for process related activities have mentioned that they are planning to achieve "zero liquid discharge (ZLD)" status by 2050. ZLD is a water treatment technology that tries to remove liquid waste discharge from a facility. The technique focuses on recovering and reusing as much water as possible and transforming any remaining waste into solid material that can be disposed of securely. Most of the cut and sew factories, where they use only non-process water are already reusing 100% of their wastewater for gardening and flushing purposes eliminating freshwater consumption for those functions.

Environmental Sustainability Practices Related to Solid Waste

The main waste type in the apparel industry is fabric waste. Fabric waste can be divided mainly into two categories as pre-consumer waste and post-consumer waste. From industry point of view, they are responsible only on pre-consumer fabric waste, which generate at the production activities since they do not have any visibility over the post-consumer fabric waste. Other than fabric waste, there are some other types of waste, which are generated in apparel factories such as cardboard, paper, polythene, plastic, food, metal, e-waste, sludge, and chemical waste. There are two types of environmental sustainability practices, which are practiced in Sri Lankan apparel facilities pertaining to solid waste management. Those are waste quantity reduction and waste disposal method improvement. Waste quantity reduction are done in many ways. Paperless processing and using digital signboards is one practice. In general, factories used to display signboards and work instructions near machineries and other relevant places at the production floor using paper or cardboard displays. Now, most factories have terminated the use of paper and cardboard for this kind of work instruction process displays and use digital signboards to conveys relevant messages at the production floor. Another sustainability practice is inhouse reusing practices for cardboard, paper, and polythene. Apart from work instructions, factories generally use paper for cutting, printing, and packaging purposes. Main purpose of cardboard is packaging. Sometimes, paper, and cardboard waste generate through these processes. For examples, one sided printed paper generates as a waste after end of use and cardboard boxes utilize for packaging generate as a waste due to damages of the boxes and quality rejects. As an environmental sustainability practice, factories reuse this paper and carboard boxes for reprinting and packaging of general goods except finished garments. Polythene is mainly utilized for packaging of finished garments. Polythene generates as a waste in two scenarios. First scenario is discarded polythene comes with raw material packaging such as fabric, elastic, and other accessories and second scenario is discarded polythene packaging of finished goods due to damages, contamination, and quality rejects. Again, factories reuse this polythene waste for general purpose packaging except raw materials and finished garments. Another best practice is reduction of production related single use plastic such as polyethylene terephthalate. UV irradiation, heat, or mechanical stress have shown single-use plastics disintegrate slowly and fragment into minute fragments with dimensions smaller than 5 mm, known as secondary microplastics. Due to the fact that micro plastics are more readily disseminated and tougher to catch than bigger plastics, contamination from micro plastic has steadily increased. Recent research indicates the presence of microplastics in freshwater rivers and lakes, as well as in drinking water, breast milk, and even human faeces (Chen et al., 2021). Therefore, micro plastic pollution due to single use plastic is a serious issue to be taught and implement relevant mitigation actions. Thus, reduction of single use plastics is a great environmental sustainability practice embedded in the apparel sector of Sri Lanka. This reduction process occurs in two ways. First way is the reduction of single use plastics in the production processes and the second way is reduction of single use plastics in the non-production processes. For an example, reduction of polythene bags at the production by replacing them with reusable non-woven bags is a key practice implemented at the production. Polythene bags are used to carry some sample garments by merchandizers and this process has converted to the utilization of non-woven bags for sample carriage in many facilities according to the qualitative data collected. Another practice in the production is eliminating polythene sheets used for cutting purposes by using paper sheets, which can be easily reused or recycled compared to polythene, which is a single use plastic type. Elimination of single use plastics in non-production processes are done mainly through eliminating food containers such as yoghurt cups at canteens, lunch sheets, plastic cutleries, plastic straws, plastic wrappers, and shopping bags. Bio-degradable alternatives for an example paper straw instead of plastic straws have introduced as solutions to eliminates these non-production single use plastics at the apparel facilities.

Improvement of fabric cutting efficiency is the main sustainability practice incorporated at apparel facilities in Sri Lanka to reduce pre-consumer fabric waste. There are several sources, where pre-consumer fabric waste is generated. Those are at raw materials stores as quality reject raw materials (fabrics), cutting department as fabric off cuts, production at small fabric swatches and at the finished goods store as quality reject garments. Out of these four sources, main source of pre-consumer fabric waste generation is cutting operation. Therefore, it is important to reduce fabric off cuts generated at the cutting department by increasing marker efficiency. There are several techniques used by factories to improve marker efficiency at the cutting process such as utilize specialized softwares for marker creation, optimizing the cutting layoutw, utilizing nesting techniques (nesting is the process of putting pattern elements on a cutting table to utilize the least amount of fabric possible), utilizing auto cutters such as "gerber cutters", continuous trainings for fabric cutters and ensuring "right first time" quality assurance to reduce quality rejects. By implementing these practices, facilities are continuously pushing to reduce fabric off cuts generated at the cutting process as well as the production process.

Department wise source segregation is another practice used in the Sri Lankan apparel sector to reduce waste. Department-wise Source segregation refers to the separation of distinct forms of waste at the place of origin or generation in various departments of a garment manufacturing factory. These departments include, among others, cutting, production, packaging, finishing, printing, dying, washing, and office areas. This practice contributes to waste reduction by ensuring that waste is correctly disposed of, recycled, or reused, hence lowering the amount of waste sent to landfills. Source segregation also assists in separating recyclable materials like fabric, paper, cardboard, empty chemical containers, electronic waste, plastic, glass, and metal from other waste streams at an apparel manufacturing facility. This facilitates the collection and recycling of these materials, hence reducing the amount of garbage transported to landfills. Also, by separating garbage at the source, contamination is avoided, hence minimizing the likelihood that dangerous compounds would enter the environment through landfills.

Construction of a proper waste management storage area(s) is another vital sustainability practice implemented in the apparel sector. Waste disposal for reusing, recycling, and upcycling cannot be done daily due to logistic and financial issues. Therefore, it is essential for factories to maintain proper waste storage areas. In fact, at most of the apparel manufacturing facilities in Sri Lanka, where interviewees are working, they have two waste storage areas separately within the facility to store hazardous waste and non-hazardous waste separately. Non-hazardous waste refers to waste items that, when appropriately managed and disposed of, do not constitute substantial harm to human health or the environment. This category of waste in a garment manufacturing facility includes fabric waste, cardboard, paper, plastic, polythene, food waste, building and demolition debris, furniture debris, etc. Hazardous waste refers to waste types, which causes a significant risk either to the human health and/or to the environment. Therefore, they are handled with extra precaution before safe disposal. Examples for hazardous waste in the apparel sector are electronic waste, tube lights, chemical waste, refrigerant devices, chemical containers, and hazardous sludge of effluent treatment plants. Apart from this, factories use several colour codes to indicate specific storage areas for each waste type for waste handlers as respective facilities. Some of these colour codes are white colour for fabric storage area, green colour for food storage area, red colour for metal storage area, blue colour for paper and cardboard storage area and orange colour for polythene and plastic storage area. If these waste types are not stored properly, there would be cross contamination of waste, which would act as a barrier for reusing, recycling, or upcycling of specific waste types. Thus, this waste separate waste storage process is very vital in the industry as an environmental sustainability practice for proper waste management.

Environmental Sustainability Practices Related to Chemicals

Chemical management is another important aspect, where many apparel factories in Sri Lanka have imbedded several environmental sustainability practices. As per interviewees, factories manage chemicals in three steps throughout the manufacturing process. Those are input chemical management, process chemical management, and output chemical management. In all three stages, most of the factories use several common practices to ensure the environmental sustainability of each stage. For input chemical management, factories follow the chemical compliance standard called zero discharge of hazardous chemicals manufactured restricted substance list (ZDHC MRSL) developed by ZDHC Foundation to ensure that they do not use any hazardous chemicals at the apparel manufacturing processes such as dyeing, printing, and washing. ZDHC MRSL is a list of chemicals that are restricted or prohibited from use in the production of textiles, leather, and other materials to reduce the environmental impact of manufacturing. ZDHC MRSL is intended to assist textile and leather businesses in identifying and eliminating hazardous substances from their supply chains. By utilizing MRSL, producers can guarantee that the chemicals used in their goods are safe and environmentally conscious (ZDHC MRSL, 2022.). Factories use the online platform of ZDHC called ZDHC chemical gateway to check and ensure whether the chemicals they use are comply with ZDHC standard. ZDHC chemical gateway provides access to a database of chemical information, including data on chemical characteristics, dangers, and regulatory status. In addition, the platform contains tools for chemical assessment and management, such as a search feature that allows factories to locate information on specific chemicals and a dashboard that provides an overview of chemical use in a factory's supply chain. By giving apparel manufacturers full access to information about the chemicals they use, ZDHC chemical gateway promotes responsible chemical management practices and increases supply chain transparency. It also assists manufacturers in identifying safer alternatives to dangerous chemicals, thereby reducing the environmental effect of their operations, and enhancing worker and consumer safety (ZDHC MRSL, 2022.). To ensure the sustainable chemical management in the manufacturing process, apparel sector organizations of Sri Lanka use another three practices based on some guidelines and tools.

First one is ZDHC chemical management system technical industry guidance (ZDHC CMS TIG). ZDHC CMS TIG is a collection of chemical management principles and best practices for the apparel and some other sectors such as leather and footwear. ZDHC initiative created the guidelines to assist factories in implementing a comprehensive and responsible approach to chemical management throughout their supply chains. ZDHC CMS TIG addresses all facets of chemical management, including selection and procurement, safe handling, storage, and disposal. The recommendations are intended to be adaptable to various supply chain types, ranging from big vertically integrated enterprises to smaller subcontracted vendors (ZDHC Chemical Management System Framework, 2022). ZDHC CMS TIG has nine key elements. Those are chemical policy, chemical strategy, chemical assessments, health and safety, chemical inventory, storage and handling of chemicals, chemical output management, process control and continuous improvement. All these nine areas are interconnected to develop a sophisticated sustainable chemical management process throughout the operations of a facility. Second one is ZDHC supplier to zero platform. ZDHC supplier to zero platform is an online application developed to assist textile, leather, and footwear industry suppliers in managing and reducing their usage of hazardous chemicals. The platform provides suppliers with an organized strategy for achieving compliance with ZDHC MRSL and ZDHC wastewater requirements. This platform contains a self-assessment instrument that allows suppliers to assess their existing chemical management processes and find improvement opportunities. In addition, it provides access to guideline documents, training resources, and an approved chemical formulations and suppliers list. By utilizing the ZDHC supplier to zero platform, suppliers can show to their clients and stakeholders their dedication to ethical chemical management and sustainability. In addition, it can assist businesses in reducing the environmental effect of their business activities and enhancing the health and safety of supply chain personnel (Supplier to Zero, 2022). Third one is Higg facility environmental module developed by sustainable apparel coalition (SAC). SAC is a non-profit organization founded in 2011 by a coalition of top apparel and footwear manufacturers, retailers, and non-governmental organizations. Environmental effect and product design are some of the facets of sustainability covered by Higg index. Using Higg index, businesses can identify areas for improvement, establish goals, and monitor their progress over time. In addition to providing a consistent language and set of measures for the sector, the index enables organizations to contrast their performance to that of other similar organizations and to share best practices (Verhoeven et al., 2023). Facilities should conduct a self-assessment first followed by a third-party verification of answers provided in self-assessment. This continuous as an annual assessment.

Environmental Sustainability Practices Related to Biodiversity

Sri Lanka is regarded as a hotspot for biodiversity. Biodiversity hotspots are locations with high levels of biodiversity that are threatened by human activities such as deforestation, destruction of habitat, and climate change. There are more than 3,300 kinds of plants with vascular systems and more than 100 species of animals in Sri Lanka. Sri Lanka also has a high percentage of endemism, meaning a huge number of species are unique to the island nation. Over 60% of Sri Lanka’s amphibians, reptiles, and freshwater fish are endemic. In Sri Lanka, the loss of forests and wetlands has contributed to the decrease of numerous species and habitats (Sarathchandra et al., 2021). As per the interviewees, many organizations have started habitat restoration projects at their respective areas through tree planting and creating analogue forests. MAS has their own analogue forest in Thulhiriya, which is the world’s first analogue forest created by an apparel manufacturing organization. Mangrove restoration is another habitat restoration related environmental sustainability practice adopted by many apparel sector facilities in Sri Lanka. As an island nation, there are many apparel sector organizations in Sri Lanka located close to the ocean specially in the down South and Western area. Restoration of mangrove ecosystems is the process of repairing deteriorated or destroyed mangrove habitats. Important coastal ecosystems, mangroves provide a variety of ecological functions, including protection from erosion and surges of waves, water filtration, habitat for fish and other species, and carbon sequestration. Mangrove restoration often entails replanting or rebuilding mangrove forests in degraded or depleted locations. Restoring mangrove ecosystems can bring numerous benefits, such as moderating climate change via carbon sequestration, enhancing the quality of water, and providing shelter for fish and other creatures (Lovelock et al., 2022). Another project is safeguard of threatened species such as turtles, leopards, and elephants. Sri Lanka is home to five of the seven live species of marine turtles, including the green turtle, hawksbill turtle, loggerhead turtle, and leatherback turtle. These species nest on the beaches of Sri Lanka (Kankanamge et al., 2023). Pollution of beaches, encroaching of seashores and unsustainable tourism have become the major threats for the survival of these turtle species. Many near shore apparel facilities are working independently with several local and foreign NGOs to create turtle hatcheries for the survival of turtles and safeguard their eggs for reproduction. Similar projects are implemented for conservation of leopards specially at national parks in Sri Lanka such as Yala, Wilpattu, and Hortain Plains. Sri Lankan leopard (*panthera pardus kotiya*) is a leopard subspecies endemic to Sri Lanka.

Habitat conservation project of elephants is another key environmental sustainability biodiversity related practice done particularly by MAS. Udawalawa National Park in Sri Lanka is one of the world’s most renowned elephant habitats. The complete park, including the reservoir, occupies 32,315 hectares in the island’s arid zone. While droughts have triggered native grasses and foliage to wither off, leaving malnourished animals such as antelope and elephants, the gradual but steady spread of an invasive plant has exacerbated the circumstances for the island’s already endangered elephants. The roots of “Lantana camera,” which produce chemicals that function as a natural herbicide, inhibit the growth of surrounding plants. This exotic species has invaded 2,650 hectares of Udawalawe National Park. The rapid spread of *lantana camera* is degrading biodiversity, reducing species richness, and drastically decreasing food productivity as an invasive species. Since 2018, MAS has been eradicating these invasive Lantana camera shrubs from the park under the direction of Sri Lanka’s wildlife department. Currently, under this initiative, Lantana has been eradicated from a total of 567 acres of the park, and the area is being continuously maintained. While eradicating Lantana, MAS teams simultaneously planted native trees to hasten the return of native foliage as the invasive plants were being taken down.

Environmental Sustainability Practices Related to Product

Sustainable product is a key concept in the apparel industry, which is embedded by many apparel sector organizations of Sri Lanka into their environmental sustainability practices. Sustainable product related environmental sustainability practices can be divided mainly into two sub sections as per the outcomes of interviews. Those are product developed in sustainably certified factories and product sustainability stewardships. ISO 14001:2015 and leadership in energy and environmental design (LEED) certification are the two main sustainability certifications obtained by many factories.

ISO 14001:2015 is an internationally accepted standard for environmental management systems that outlines the necessities for organizations to formulate, execute, maintain, and continuously enhance their environmental performance. The standard is intended to assist organizations in identifying and managing their environmental impact and ensuring compliance with applicable environmental laws and regulations. ISO 14001:2015 provides organizations with a framework for establishing an effective environmental management system to manage the environmental aspects of their operations (da Fonseca, 2015). Many apparel sector organizations have implemented ISO 14001:2015 standard at the facilities through proper certification from ISO affiliated third parties. Another standard is LEED standard. LEED is a well-known rating system for assessing the sustainability of facilities and neighbourhoods. It was created by US Green Building Council to offer a framework for designing, constructing, and operating environmentally conscious, sustainable, and healthful buildings (Flowers et al., 2020). Most apparel sector organizations in Sri Lanka like Hirdaramani (2021), MAS, Brandix (2021), and Star certified their respective facilities to LEED as a key practice of their environmental sustainability saga.

GOTS, BCI, OCS, RCS, and GRI are the primary product stewardships obtain for products manufactured at apparel factories of Sri Lanka. Global organic textile standard (GOTS) certification is referred to as GOTS certification. It is a globally accepted standard for the refining and production of organic fiber textiles. GOTS certification ensures that textiles satisfy specific environmental and social criteria, such as the use of organic fibers, the prohibition of hazardous chemicals and processes, and the protection of the rights of employees. To be awarded GOTS certification, textile products must adhere to stringent criteria across the entire production chain, beginning with the collection of raw materials and ending with the finished product. A third-party certifier conducts an independent audit of the complete production process as part of the certification procedure (Almeida, 2015).

Better cotton initiative certification is referred to as BCI certification. It is a certification initiative that encourages globally more sustainable cotton production methods. BCI is an international non-profit standard that aims to increase the sustainability of cotton production by training and assisting cotton producers in adopting better environmental and social practices. To obtain BCI certification, cotton farmers must adhere to a set of guidelines and standards that emphasize the reduction of the environmental impact of cotton production, the improvement of working conditions for cotton farmers and laborers, and the enhancement of the productivity and efficacy of cotton farming. In cotton cultivation, BCI certification program seeks to minimize the use of harmful chemicals and pesticides, conserve water supplies, and foster biodiversity. It also encourages the adoption of more efficient and environmentally responsible agricultural practices, such as rotation of crops and integrated management of pests (Goyal & Parashar, 2023).

Organic content standard certification is referred to as OCS certification. It is an international standard that validates the organic content of textiles and finished products, such as clothing and household textiles. OCS certification is intended to provide users with transparency and guarantee that the organic materials used in textiles and other products have been independently verified. OCS certification requires that at least 95% of a product's materials be certified organic, with the remaining 5% meeting stringent environmental and social standards. The certification also mandates that businesses implement socially and environmentally responsible supply chain practices (Almeida, 2015).

RCS certification denotes compliance with the recycled claim standard. It is an international standard that verifies the presence and quantity of recycled material in textiles and finished products. RCS certification assures consumers that the recycled content in the goods they purchase has been validated by a third-party organization. The certification procedure entails tracing the flow of recycled materials from the point of origin to the final product. RCS certification requires at least 5% of a product's materials to be recycled, and the remaining materials must adhere to stringent environmental and social criteria. The certification also requires companies to implement environmentally responsible supply chain practices (Amutha, 2017).

Global recycled standard certification stands for GRS certification. It is an internationally recognized standard for monitoring and verifying the recycled content of textiles and finished goods. GRS certification assures consumers that the amount of recycled material in their products has been validated by a third-party organization. The certification procedure entails tracing the flow of recycled materials from the source to the final product. GRS certification requires at least 50% of a product's materials to be recycled, and the remaining materials must adhere to stringent environmental and social standards. The certification also mandates that businesses implement socially and environmentally responsible supply chain practices (Furferi et al., 2022).

CONCLUSIONS

It was found that current environmental sustainability practices incorporated in the apparel sector of Sri Lanka can be segmented into six key areas namely energy and emissions, water and wastewater, solid waste, chemicals, biodiversity, and product. Environmental sustainability practices related to these six key areas are varied from organization to organization under different approaches and gravities, but the core structure is almost similar. All organizations are focused on reduction of energy and emissions, water, solid waste, and hazardous chemicals through various measures while ensuring proper treatment and discharge of wastewater aligning with industry best practices such as ZDHC wastewater guideline and proper disposal of all solid waste aligning with local legal standards and customer requirements. They also implement various practices to restore and protect biodiversity while encouraging reforestation and habitat restoration and ensuring the delivery of sustainable products aligning with different industry standards such as GOTS, RCS, and GRS.

Funding: No funding source is reported for this study.

Declaration of interest: No conflict of interest is declared by the author.

Ethical statement: The author stated that the study did not require any ethical approval.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the author.

REFERENCES

Ahirwar, M., & Behera, B. K. (2022). Development of hemp-blended cotton fabrics and analysis on handle behavior, low-stress mechanical and aesthetic properties. *Journal of the Textile Institute, 113*(5), 934-942. https://doi.org/10.1080/00405000.2021.1909799

Alam, F. B., & Hossain, A. (2018). Conservation of water resources in textile and apparel industries. *IOSR Journal of Polymer and Textile Engineering, 5*(5), 11-14.

Alamoush, A. S., Ballini, F., & Olcer, A. I. (2021). Revisiting port sustainability as a foundation for the implementation of the United Nations sustainable development goals (UN SDGs). *Journal of Shipping and Trade, 6*, 19. https://doi.org/10.1186/s41072-021-00101-6

Allen, M. R., Friedlingstein, P., Girardin, C. A. J., Jenkins, S., Malhi, Y., Mitchell-Larson, E., Peters, G. P., & Rajamani, L. (2022). Net zero: Science, origins, and implications. *Annual Review of Environment and Resources, 47*, 849-887. https://doi.org/10.1146/annurev-environ-112320-105050

Almeida, L. (2015). Ecolabels and organic certification for textile products. In S. S. Muthu (Ed.), *Roadmap to sustainable textiles and clothing: Regulatory aspects and sustainability standards of textiles and the clothing supply chain* (pp.175-196). Springer. https://doi.org/10.1007/978-981-287-164-0_7

Almenhali, A. A. A. (2019). *Embedding sustainable strategies for competitive advantage in the UAE sports sector* [PhD thesis, University of Wolverhampton].

Amutha, K. (2017). Sustainable practices in textile industry: Standards and certificates. In S. S. Muthu (Ed.), *Sustainability in the textile industry* (pp. 79-107). Springer. https://doi.org/10.1007/978-981-10-2639-3_5

AWGNM, A. (2021). Impact of green environmental planning on managing work related employee stress in Sri Lankan apparel companies. In *Proceedings of the 7th International Research Conference on Humanities & Social Sciences*. https://doi.org/10.2139/ssrn.3809022

Brandix. (2021). *Brandix sustainability report 2020-2021*. https://www.brandix.com/images/brandix-sustainability-report-2020-21.pdf

Braun, V., & Clarke, V. (2021). To saturate or not to saturate? Questioning data saturation as a useful concept for thematic analysis and sample-size rationales. *Qualitative Research in Sport, Exercise and Health, 13*(2), 201-216. https://doi.org/10.1080/2159676X.2019.1704846

Chakraborty, R., & Ahmad, F. (2022). Economical use of water in cotton knit dyeing industries of Bangladesh. *Journal of Cleaner Production, 340*, 130825. https://doi.org/10.1016/j.jclepro.2022.130825

Chandrasekara, S. S. K., Chandrasekara, S. K., Gamini, P. H. S., Obeysekera, J., Manthrithilake, H., Kwon, H.-H., & Vithanage, M. (2021). A review on water governance in Sri Lanka: The lessons learnt for future water policy formulation. *Water Policy, 23*(2), 255-273. https://doi.org/10.2166/wp.2021.152

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production, usage, disposal, and adverse impacts. *Science of the Total Environment, 752*, 141772. https://doi.org/10.1016/j.scitotenv.2020.14177

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed method approaches*. SAGE.

da Fonseca, L. M. C. M. (2015). ISO 14001:2015: An improved tool for sustainability. *Journal of Industrial Engineering and Management, 8*(1), 37-50. https://doi.org/10.3926/jiem.1298

Dehghani, M., & Goyal, P. (2022). Design and development of textile fabrics using 3D printing technology. *ECS Transactions, 107*, 19313. https://doi.org/10.1149/10701.19313ecst

Drofa, E. A., Prihodchenko, O. V., Yadykin, V. S., & Goryainov, M. F. (2021). Technological methods of improving mechanical and energy characteristics of sewing machines. *IOP Conference Series: Materials Science and Engineering, 1029*, 012030. https://doi.org/10.1088/1757-899X/1029/1/012030

European Parliament. (2021). The impact of textile production and waste on the environment (infographic). *European Parliament*. https://www.europarl.europa.eu/news/en/headlines/society/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographics

Export Development Board Sri Lanka. (2022). Export performance of apparel. *EDB Sri Lanka*. https://www.srilankabusiness.com/apparel/about/export-performance.html

Flowers, M. E., Matisoff, D. C., & Noonan, D. S. (2020). In the LEED: Racing to the top in environmental self-regulation. *Business Strategy and the Environment, 29*(6), 2842-2856. https://doi.org/10.1002/bse.2547

Furferi, R., Volpe, Y., & Mantellassi, F. (2022). Circular economy guidelines for the textile industry. *Sustainability, 14*(17), 11111. https://doi.org/10.3390/su141711111

Goyal, A., & Parashar, M. (2023). Organic cotton and BCI-certified cotton fibres. In R. Nayak (Ed.), *Sustainable fibres for fashion and textile manufacturing* (pp. 51-74). Elsevier. https://doi.org/10.1016/B978-0-12-824052-6.00011-1

Gupta, R., Kushwaha, A., Dave, D., & Mahanta, N. R. (2022). Waste management in fashion and textile industry: Recent advances and trends, life-cycle assessment, and circular economy. In C. M. Hussain, S. Singh, & L. Goswami (Eds.), *Emerging trends to approaching zero waste* (pp. 215-242). Springer. https://doi.org/10.1016/B978-0-323-85403-0.00004-9

Hirdaramani. (2021). *Putting the future first*. https://www.hirdaramani.com/themes/hirdaramani/assets/downloads/sustainability-report- 2021.pdf

IPCC. (2018). Global warming of 1.5 °C. *Intergovernmental panel on climate change*. https://www.ipcc.ch/site/assets/uploads/sites/2/2022/06/SR15_Full_Report_HR.pdf

Juanga-Labayen, J. P., Labayen, I. V., & Yuan, Q. (2022). A review on textile recycling practices and challenges. *Textiles, 2*(1), 174-188. https://doi.org/10.3390/textiles2010010

Kankanamge, L. H., Premarathne, L. P. N. D., Perera, H. A. C. C., Perera, K. D. H., & Zoysa, C. D. D. (2023). Analysis of survivability, trends, and status of sea turtle species found in Sri Lanka. In *Proceedings of 10th Ruhuna International Science & Technology Conference*.

Kyngäs, H. (2020). Inductive content analysis. In H. Kyngäs, K. Mikkonen, & M. Kääriäinen (Eds.), *The application of content analysis in nursing science research* (pp. 13-21). Springer. https://doi.org/10.1007/978-3-030-30199-6_2

Liu, J., Liang, J., Ding, J., Zhang, G., Zeng, X., Yang, Q., Zhu, B., & Gao, W. (2021). Microfiber pollution: An ongoing major environmental issue related to the sustainable development of textile and clothing industry. *Environment, Development and Sustainability, 23*, 11240-11256. https://doi.org/10.1007/s10668-020-01173-3

Lovelock, C. E., Barbier, E., & Duarte, C. M. (2022). Tackling the mangrove restoration challenge. *PLoS Biology, 20*(10), e3001836. https://doi.org/10.1371/journal.pbio.3001836

MAS Holdings. (2022). Ocean plastics, recycle clothing, & circular fashion. *MAS Holdings*. https://www.masholdings.com/plan-for-change/our-planet-changed-for-good/

Mueller, S. A., Carlile, A., Bras, B., Niemann, T. A., Rokosz, S. M., McKenzie, H. L., Kim, H. C., & Wallington, T. J. (2015). Requirements for water assessment tools: An automotive industry perspective. *Water Resources and Industry, 9*, 30-44. https://doi.org/10.1016/j.wri.2014.12.001

Murray, J. W., & Hammons, J. O. (1995). Delphi: A versatile methodology for conducting qualitative research. *The Review of Higher Education, 18*(4), 423-436. https://doi.org/10.1353/rhe.1995.0008

Muthukumarana, T. T., Karunathilake, H. P., Punchihewa, H. K. G., Manthilake, M. M. I. D., & Hewage, K. N. (2018). Life cycle environmental impacts of the apparel industry in Sri Lanka: Analysis of the energy sources. *Journal of Cleaner Production, 172*, 1346-1357. https://doi.org/10.1016/j.jclepro.2017.10.261

Namey, E., Guest, G., O'Regan, A., Godwin, C. L., Taylor, J., & Martinez, A. (2020). How does mode of qualitative data collection affect data and cost? Findings from a quasi-experimental study. *Field Methods, 32*(1), 58-74. https://doi.org/10.1177/1525822X19886839

Okafor, C. C., Madu, C. N., Ajaero, C. C., Ibekwe, J. C., & Nzekwe, C. A. (2021). Sustainable management of textile and clothing. *Clean Technologies and Recycling, 1*(1), 70-87. https://doi.org/10.3934/ctr.2021004

Patra, A. K., & Pariti, S. R. K. (2022). Restricted substances for textiles. *Textile Progress, 54*(1), 1-101. https://doi.org/10.1080/00405167.2022.2101302

Pradhan, S., Ghose, D., & Singh, A. K. (2020). Impact of power factor correction methods on power distribution network–A case study. In A. Bhoi, K. Sherpa, A. Kalam, & G. S. Chae (Eds.), Advances in greener energy technologies (pp. 513-526). Springer. https://doi.org/10.1007/978-981-15-4246-6_30

Prasanga, W. C., Ranathungage, A. N., & Rathnasiri, P. (2021). Use of cotton apparel waste as an energy source for biomass boilers: A feasibility study. *International Journal of Design & Nature and Ecodynamics, 16*(1), 41-51. https://doi.org/10.18280/ijdne.160106

Ronan, J. (2022). Michelle Yeoh discusses sustainable clothing. *One Tribe*. https://onetribeglobal.com/sustainable-lifestyle/united-nations-michelle-yeoh-discusses-sustainable-clothing/

Sadowski, M., Yan, C., Cummis, C., & Aden, N. (2021). *Apparel and footwear sector: Science-based targets guidance*. World Resources Institute. https://doi.org/10.46830/wriwp.20.00004

Sarathchandra, C., Abebe, Y. A., Wijerathne, I. L., Aluthwattha, S. T., Wickramasinghe, S., & Ouyang, Z. (2021). An overview of ecosystem service studies in a tropical biodiversity hotspot, Sri Lanka: Key perspectives for future research. *Forests, 12*(5), 540. https://doi.org/10.3390/f12050540

Saxena, A., & Khare, A. K. (2019). Awareness of green manufacturing in apparel industry. In A. Majumdar, D. Gupta, & S. Gupta (Eds.), *Functional textiles and clothing* (pp. 371-382). Springer. https://doi.org/10.1007/978-981-13-7721-1_29

Sri Lanka Sustainable Energy Authority. (2022). *Sri Lanka energy balance 2020*. https://www.energy.gov.lk/images/energy-balance/energy-balance-2020.pdf

Supplier to Zero. (2022). *Implementation hub*. https://www.implementation-hub.org/supplier-to-zero

Tagra, D. (2022). Many textile and apparel companies are investing in solar energy. *Apparel Resources*. https://in.apparelresources.com/business-news/sustainability/many-textile-apparel-companies-investing-solar-energy/

Tian, S., Su, X., & Geng, Y. (2022). Review on heat pump coupled desiccant wheel dehumidification and air conditioning systems in buildings. *Journal of Building Engineering, 54*, 104655. https://doi.org/10.1016/j.jobe.2022.104655

Varshney, N. (2022) Meanwhile in Sri Lanka! *Apparel Resources*. https://apparelresources.com/business-news/manufacturing/meanwhile-sri-lanka/

Verhoeven, G., Razvi, A., & Mertens, J. (2023). *Sustainable apparel coalition*. https://apparelcoalition.org/

ZDHC Chemical Management System Framework. (2022). *Roadmap to zero*. https://downloads.roadmaptozero.com/process/ZDHC-CMS-Framework

ZDHC MRSL. (2022). *Roadmap to zero*. https://mrsl.roadmaptozero.com/