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ABSTRACT

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I. ABSTRACT

This study is a little approach to determine sustainability hot spots of a cotton T-shirt through cradle to cradle analysis (including fiber farming, yarn manufacturing, fabric manufacturing, wet processing, garments manufacturing, transportation, consumption, recycle and disposal) of a white cotton t-shirt of a particular brand, made in one of the 100% compliant and green garment industry of Bangladesh and also with those obtained from the published literature about the production of cotton yarn obtained from virgin cotton produced through conventional and organic harvesting. The environmental disputes involved with consumption of textiles to examine broadly on product level in Lifecycle Assessment (LCA) studies. The social sustainability hot spots have also investigated on the Cotton T-shirt manufacturing cycle. In a word, the purpose of this case study is to address the key social and environmental issues in the lifecycle of a white cotton t-shirt which is produced in Bangladesh and selling to EU. And also identifies the legal constraints that govern the most severe hot spots found in the case study of T-shirt.

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II. INTRODUCTION

2.1 Background

Cotton is the most dominating natural fiber in textile and apparel industry, with a global textile production of 24.5 million tonnes in 2013. Usually cotton cultivated throughout the world especially in the dry areas where other crops are mostly difficult to grow. Among the main producers of cotton are China (26.4%), India (20.5%), USA (13.9%), Pakistan (8.5%), Brazil (6.3%), Uzbekistan (4.1%), Australia (3.8%), and Turkey (3.3%) [1]. In many cases, the available data on environmental impacts associated in cotton production can be hardly found in the literature. Earlier studies shown that water consumption, land occupation, emissions, and usage and management of chemicals are the most challenging aspects to be assessed during the cotton production stage [2, 3]. An extremely large volume of water is needed for Cotton cultivation, including green water, which generates from precipitation, as well as blue water, from the manual source of irrigation, and estimated as a 73% of the production. The cotton production consumes a 2.6% of global water which ultimately scaled down the freshwater inventories and resulted in drought problems in the cultivation regions and an accustomed damage of the water environment [4].

The impacts from various textile productions including spinning, weaving, cutting, and sewing are remarkably elevated, counting the required electricity amount, which ultimately escalates the emissions of CO_2 [5, 6]. Nonetheless,the

environmental impact of cotton dyeing is comparatively higher than the aforementioned steps; this is the most pollutant parts in the whole cycle of textile process. Dyeing associated with the usage of huge amounts of energy, water, steam, and various chemicals like bleaching agents, dyes, wetting agents, soap, softener, and salts, in order to obtain the required shade of colour [7, 8]. Additionally, it causes a large volume of wastewater in dyeing plants with destructive effects to the environment [8].

In the last few decades, distinct initiatives have been developed to lessen the adverseeffects of cotton production. In that case, the cultivation of organic farming practices avoids the use of fertilizers, herbicides, and insecticides [9]. The estimated total pesticide consumption in the cotton cultivation is an 11% of the world consumption, which is almost 50% in the developing countries. Hence, the practice of organic cultivation approach grants to greatly scale down the usage of chemicals and the detrimental environmental impacts [10].

Recently, a novel recovery method has been designed for the production of cotton yarns from recycled materials [11]. In this method, cotton growing is avoided, resulted to reduce the consumption of water, fertilizers, and pesticides. Furthermore, dyeing steps is avoided since the color of the raw materials is similar to the final color of cotton, such a way that the use of water, dyestuff, wetting agents, softener, and any other related chemicals is also avoided. The use of this recovery technology prevents all the environmental impacts relevant to the cotton harvesting and dyeing of yarns, while as counterpart it includes the addition of a cutting/shredding step of recycled clothes prior to the spinning step, which have resemblance with traditional ginning method. The ginning method of cotton involves the separation of lint, seeds, and other plant residues, and it can be accomplished by varioustechniques, from manual to mechanical actions which generally include high energetic steps, like drying, cleaning and pressing [12].

2.2 Life-Cycle Assessment (LCA)

Life-cycle assessment (LCA) is an effective methodology, standardized by the ISO 14040:1996 and ISO 14044:2006 (ISO, 1997, 2006). This method mainly focused on the assessment of potential environmental impacts associated with the products through the appraisal of applicable inputs and outputs during the whole life of product including the raw materials and, treatments and processing and eventual disposal. As stated earlier, there is very limited peer reviewed literature available on LCA and are usually supported by a different consultancy or research institute. Previous LCA studies conducted on textiles made by different fibers such as Polyester, Nylon, Acrylic, and Spandex, but with the cotton fibre products showed greater environmental impact [13].

Since the cotton cultivation system considered as a complex order, because the cultivation process depends on the environmental conditions in various regions and the findings may vary within a year, as well as from year to year and these may lead difficulties for right evaluation of LCA. Hence, it is too difficult to assess the impacts of cotton cultivation globally because of the variability of different cotton crops chosen. However, few studies have been conducted for the LCA of cotton from different aspects, concentrated on an individual portion of the entire process, such as: cultivation, yarn manufacturing, fabric manufacturing, dyeing, and so on.

An extensive evaluation on the impacts of cotton cultivation by LCA has conducted for both the traditional and organic harvesting system [2, 9, 14], likewise for various dyeing and finishing methods [7, 15]. Moreover that, very few LCA studies published on the reuse or recycling from the apparel waste [16, 17] and to till there is not any LCA report published specialized on the application of recovered cotton to be used for the industrial manufacturing of cotton yarn [18].

2.3 The frontier lines of producing cotton apparel product

The majorprocess and discrepancies for the cotton product manufacturing by the conventional or usual and organic cultivation, and recovery are describing in the figure 1. To focus on the differences between the methods, three critical steps have been selected as: cultivation/collection of cotton, ginning/cutting, and dyeing[18]. Transportation of raw and produced materials for each production step was also considered and discussed. All the aspects related to the spinning of the yarn, textile production, selling and usage, and final disposal were not taken into account, considering that there are not differences in the process regardless of the type of cotton fibre employed (conventional, organic or Recover).

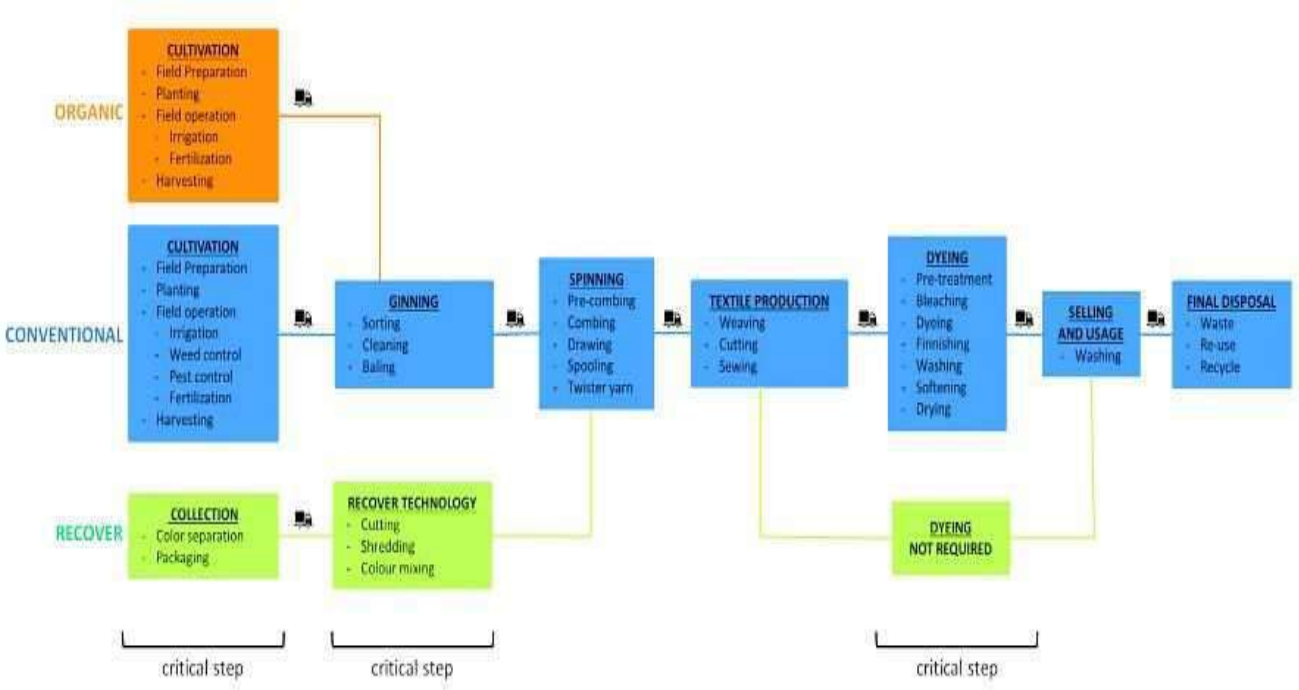

Figure 1: Summary of the main steps involved in the production of textile clothes using conventional, organic, and Recover cotton [18].

The growing concern in "sustainable development" has driven many organizations to analyses the approaches in which they practice with environmental affairs [19]. To meet the goals, distinctive mechanism, approach and notions have been introduced over the last 20-30 years [10]. In this study, a Life Cycle Assessment (LCA) method (cradle-to-cradle analysis) applied to assess the environmental impact associated to produce a cotton T-shirt.

Lastly, the analysis of sustainability hot spots may recommend relevant actions such as: the unified data or information from current research may facilitate the accuracy of directions for new cotton LCAs by upgraded methodology, evidence and systems understanding, the universal guidelines of cotton LCA studies, the environmental impact analysis may publish through communication strategies and moreover to make the commitment among the major stakeholders (4).

2.4 Objective

The main aim of this study is the determination of sustainability hot spots of a cotton T-shirt through the cradle to cradle analysis with those obtained from the published literature about the production of cotton yarn obtained from virgin cotton produced through conventional and organic harvesting. The environmental disputes involved with consumption of textiles to examine broadly on product level in Lifecycle Assessment (LCA) studies. The social sustainability hot spots

are also intended to investigate on the Cotton T-shirt manufacturing cycle. In a word, the purpose of this case study is to address the key social and environmental issues in the lifecycle of a white cotton t-shirt which is produced in Bangladesh and selling to EU. And secondly to identify the legal constraints that govern the most severe hot spots found in the case study of T-shirt.

III. METHODOLOGY

This case study has been carried out based on the information about the practices of social and environmental issues on every phases of manufacturing like- fiber farming, yarn manufacturing, fabric manufacturing, wet processing, garments manufacturing, transportation, use, recycle and disposal of a white cotton t-shirt of a particular brand, made in one of the 100% compliant and green garment industry of Bangladesh and selling to EU. The overall manufacturing stages and their analysis strategy can be classified in two major headings as given below-

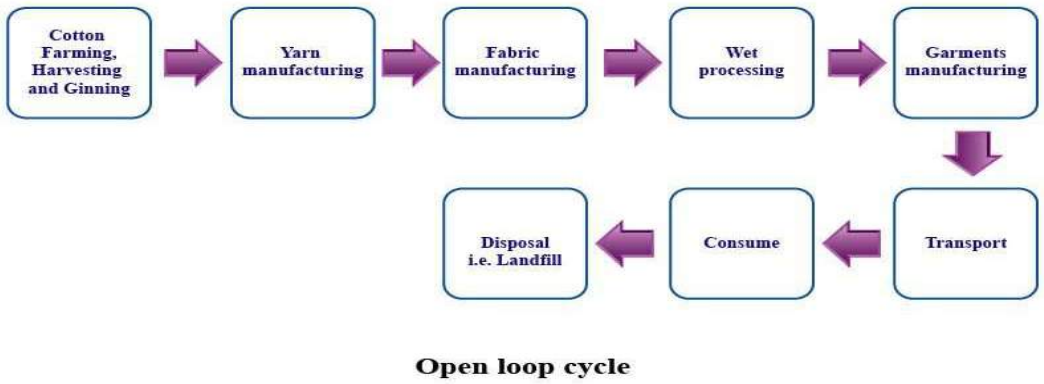

Figure 2: Cradle to grave analysis

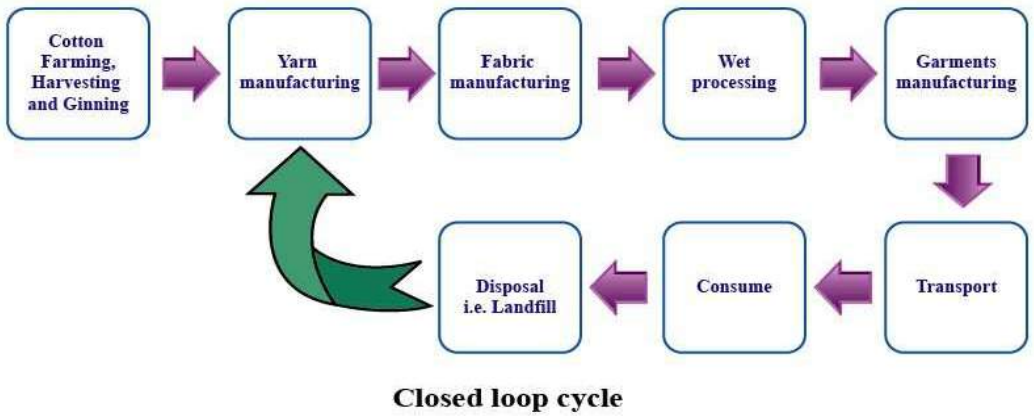

Figure 3: Cradle to cradle analysis

3.1 Social and environmental hot spot analysis

The sustainability hot spot analysis (SHSA) [20] will be applied to this case study as because it can identify key issues on analyzed categories such as resource use, ecological and social challenges along the whole value chain, in a quick, reliable and lifecycle-phase-specific way. The results highlight so called 'hot spots' in the product chain and can be seen as a starting point for the detailed elaboration of efficient actions for improvement. In these cases, a hot spot is defined as a harm or risk at a particular point in the product lifecycle. The results of the SHSA will contribute to the development of the sustainability Assessment guidelines for subsequent work package.

3.2 Qualitative case study methodology:

A case study is a qualitative inquiry in a contemporary phenomenon within its real-life context, and it is especially relevant when the boundaries between phenomenon and context are not clearly evident [21]. It will help to achieve comprehensive understanding as well as play a supportive role in the facilitative understanding of the overall project case i.e., the identification of environmental and social externalities in global value chains that undermine social and economic development and the policies and laws that make them possible.

IV. RESULTS AND DISCUSSION

According to methodology, the outcomes of analyzing the lifecycle of a white cotton t-shirt have been fragmented in two phases i.e.phase-A is about the finding of social and environmental risks and phase-B is about the findings of the most severe social and environmental hot spots in the lifecycle of this garment. The social and environmental issues are summarized in the table1 as given below-

Table 1: Social and environmental issues involved in the lifecycle of t-shirt

Social issues	Environmental Issues
• Employment • labor/management relations, OHS (Occupational health and safety) • Equal opportunity • Equal remuneration • Child labor • Freedom • of association • Security practices • Anti-corruption etc.	• Materials ❖ fertilizers ❖ pesticides ❖ fungicides ❖ auxiliaries ❖ raw materials ❖ packaging materials • Energy • Water • Biodiversity • Emissions • Effluent and waste • Transport • Supplier environmental assessment etc

4.1 Environmental Hot Spots

4.1.1 Use of chemicals

The following chemicals with the given quantity are used in the pre-treatment section of wet processing to make the garments white from grey fabric stage.

Table-2: Chemicals used during pre-treatment (Scouring, bleaching, neutralizing)

Chemical	Quantity in %
DEPICOL TLK LIQ	0.300
HASULYN NOF	1.000
OPTAVON MAX LIQ	0.700
SEQUION 48 98	0.300
RON LUBE PLUS C	0.500
KAPPAZON H 53 250	1.000
CAUSTIC SODA	2.000
HYDROZEN PEROXIDE	10.000
ACETIC ACID	1.000
TERMINOX ULTRA 50L	0.150
JQ-600	0.250
SYNO WHITE 4BK	0.315

Without this, in the Effluent Treatment Plant (ETP) the following chemicals are used based on

the type of the plant i.e., Biological ETP or Membrane Bioreactor Plant (MBR)

Table-3: Chemicals used for Biological Plant

Name of Chemicals	Type	Use
Sulfuric Acid	Hazardous	Continue
Water Decolorant	Non-Hazardous	Discontinuous
Polyelectrolyte/Polymer	Non-Hazardous	If Needed
Anti foam	Non-Hazardous	If Needed
Nutrient	Non-Hazardous	If Needed

Table-4: Chemicals used for MBR Plant

Name of Chemicals	Type	Use
Sulfuric Acid	Hazardous	Continue
Water Decolorant	Non-Hazardous	Discontinuous
Citric Acid	Hazardous	MBR Filter Maintenance
Sodium Hypochlorite	Hazardous	MBR Filter Maintenance
Polyelectrolyte/Polymer	Non-Hazardous	If Needed
Anti-foaming agent	Non-Hazardous	If Needed
Nutrient	Non-Hazardous	If Needed

4.1.2 Treatment of effluents

The Textile Division of this particular industry has two effective Effluent Treatment Plants (ETP), known as biological ETP and membrane bioreactor ETP by which wastewater discharged from wet processing section is treated before it is released to the environment so that environmental pollution is reduced. The undermentioned tables reveal the characteristics of untreated and treated wastewater for both types of plants-

Table-5 (A): Test result of Biological ETP treated wastewater of the 1st week of August' 2017

Biological ETP														
Date	Inlet							Outlet						
	pH	Temp°C	DO	TDS	TSS	COD	BOD_5	pH	Temp°C	DO	TDS	TSS	COD	BOD
1-Aug-2017	9.6	31.8	12.9	1314	-	-	-	7.8	33	6	1575	-	-	-
2-Aug-2017	9	36.2	0.6	1100	55	420	420	7.7	34.1	5.8	1478	8.1	100.0	6.2
3-Aug-2017	9.9	34.5	5.8	3020	-	-	-	7.8	33.3	5.9	1353	-	-	-
4-Aug-2017	10.2	38.3	0.8	1585	-	-	-	7.7	32.8	5.5	1354	-	-	-
5-Aug-2017	10.2	36.8	0.9	2128	-	-	-	7.7	33.6	5.7	1537	-	-	-
6-Aug-2017	8.7	34.7	6.2	334	-	-	-	7.8	34.6	6.2	334	-	-	-
7-Aug-2017	10	38.1	7.7	889	-	-	-	7.8	34.1	6.1	1621	-	-	-

Table-5 (B): Test result of Membrane Bioreactor ETP of the 1st week of August' 2017

MBR ETP Plant														
Date	Inlet							Outlet						
	pH	Temp°C	DO	TDS	TSS	COD	BOD	pH	Temp°C	DO	TDS	TSS	COD	BOD
1-Aug-2017	9.9	40.4	1.4	2210	-	-	-	8.2	35.7	6.4	2082	-	-	-
2-Aug-2017	9.7	36.1	0.6	1848	76	770	344	8.2	36	6.8	2072	2.9	105.6	6.2
3-Aug-2017	10.2	39.2	6	1868	-	-	-	8.2	34.8	6.5	2090	-	-	-
4-Aug-2017	9.8	40.5	6.2	2098	-	-	-	8.2	35.4	6.4	2087	-	-	-
5-Aug-2017	9.2	37.9	6.3	1282	-	-	-	6	36.3	6.6	2012	-	-	-
6-Aug-2017	9.9	34.5	5.9	2710	-	-	-	8.2	36.1	6.5	2030	-	-	-
7-Aug-2017	9	37.6	6.3	605	-	-	-	8.2	36.1	6.8	2040	-	-	-

4.1.3 Consumption of energy and fresh water:

The general consumption of fresh water and energy in producing a cotton t-shirt has been reported by Steinberger et al and van der Veldenet al [22, 23] as given in the table-

Table-6: Consumption of energy and fresh water

Processing steps	Quantity	Yarn count (Ne)	Electricity (kWh)	Steam, natural gas, LPG, Diesel, LFO (MJ)	Water (L)
Conventional cotton production	1 kg	n/a	0.41	8.71	7103
Organic cotton production	1 kg	n/a	0.41	8.71	7103
Spinning (Combed yarn, Rieter ring spinning system including winding)	1 kg	30	3.34	-	-
Knitting (Mayer & Cie, circular knitting machines, 30-in. diameter, 24 gg, 96 Feeders)	1 kg	30	0.19	0.19	
Wet processing (pretreatment, dyeing and finishing)	1 kg	30	2.42	2.4	80
Garment manufacturing	1 T-shirt		0.67		

Around 35-40 L freshwater is consumed in the pre-treatment section of wet processing which was 50-60 L before and this improvement has been achieved by process modification. Besides through the rain water harvesting system, the ground water consumption has been reduced. Energy consumption has been reduced by using a transparent sheet in the production floor. Around 0.05 Kw is consumed in the scouring and bleaching section to treat 1 kg fabric. Besides energy efficient equipments like- T5 type tube light, direct drive servo Motors , motion Sensors to avoid unnecessary usage of light, digital energy meters, good quality steam traps to minimize the steam loss, digital Flow-Meters, VFD (Variable Frequency Drive) driven mechanical ventilation,

VFD (Variable Frequency Drive) driven Air-Conditioning system, solar street lamps, solar water heating system to promote Green Energy, waste collection channel (Duct) to collect operational wastes and meters to monitor the inside temperature and CO_2 level in different areas have been installed to reduce energy consumption.

4.2 Social Hot Spots

4.2.1 Occupational Health & Safety

The participant apparel industry ensures a healthy working environment for all and provides a safe and healthy workplace setting to prevent accidents and injury to health arising out of linked with or occurring in course of work or as a result of the operation of employers' facilities. It has adopted responsible measures to mitigate the negative impacts that the workplace has on the environment. Besides, there is a good ventilation system which makes the working environment comfortable. Without it, the infrastructure of the factory facilitated the use of day light instead of electric bulbs. And a female doctor has been assigned for the treatments of female workers in the year of 2016 based on the request of workers.

4.2.2 Working Hours

Normal working hours is 8 and the average overtime is 2 hours. Overtime is usually seasonal especially when work load becomes extreme as well as urgency is needed. There are several reasons behind the overtime issues like reprocessing of the work or longer processing time, distortion in the supply chain and longer approval period. Besides, there is a shifting system for maintenance workers, embroidery workers and security guard and Friday is the general holiday for all personnel.

4.2.3 Discrimination

First of all, personnel operation in the production and management for gender depends on the basis of the quality (whether personnel may be male or female). For example – a welfare officer could be male or female. But for some exceptional area like loading and unloading, only male workers are preferable. This particular industry provides a workplace environment which is free of any sexual and/or other form of harassment, abuse and any corporal punishment. It rewards employees according to their individual performance' and maintain the equal opportunity policy in recruitment, training and development, promotion, transfer, compensation and benefits etc. without any form of discrimination such as race, caste, color, religion, sex (including pregnancy), marital status, family status, sexual orientation, regional origin, age, disability and veteran status.

4.2.4 Fair Salary

Employees are hired basically on the basis of their skill. Average payment is determined as per the "gazette of Bangladesh 2013".Workers salary is paid monthly basis and overtime is paid to double of basic salary. Payment amount may be like per hour 40-50 taka.

4.2.5 Employment Facilities

This industry is a heaven for its employees and workers because of the enormous facilities providing by this organization to all. There are 20 flats (per flat is 3000 square feet) available for management and non-management employees and 75 dormitories for individual employees. Usually, personnel live close to the factory. It provides leave with pay as per the followings-

Table-7: Leave types with respective values

Item of Leave	Days
Casual leave	10 days
Sick leave	14 days
Festival leave	12 days
Maternity leave	112 days

A project known as 'Renu' (fair price shop) has been established and successfully operated from January 2017 to provide basic commodities (43 items till date and will be raised upto 400) at 20% less price in comparison with local market maintaining a good quality of the product. A field

study was carried out during the whole period of 2016 to evaluate the feasibility of the project. All the personnel can buy the product from this shop based on their respective income level. Besides employees as well as workers in the factory are being provided snacks (bakery) by factory owned confectionary items. And some exceptional employment facilities are Gifts for New Born, Scholarship program, KHEA and turning the disability to the ability of the workers. Management of this industry organizes view exchange meeting or social dialogue with workers regularly. Workers have this unique opportunity to seat and discuss issues with the Managing Director. Such social dialogues motivate the workers as they get a chance to talk to the Managing Director directly to share their views and feelings and even grievance without any hesitation. A special HR team spends 2 hr/month for every worker to discuss about different issues. Without this, workers can meet with the Managing Director at once per 3 months. Besides, the company has implemented a concept of "Help Desk" in its production floor to provide official assistance, query and grievance. All employees receive this service in a native voice within a short span of time. This concept serves the workers within their work floor and within their comfort level.

4.2.6 Freedom of Association

This organization appreciates forming and joining any registered association, trade unions, and participation committee. It has a platform for the workers in the name of Worker's Participation Committee (WPC) which is a unique team building initiative that helps to achieve objectives by creating a direct bridge between the top management and workers. Worker's Participation Committee (WPC) leaders regularly meet together to engage in open discussion to discuss about any problematic issues as well as claim. The union leaders are not authorized to determine the salary because the Government of Bangladesh has already determined the standard salary structure for the worker and factory authority is maintaining that.

4.2.7 Risks Assessment

Phases Risks	Raw Materials	Yarn production	Fabric Production	Garment Production	Transportation	Consumer Use	Waste/ recycling
Child labour	-	-	No	No	-	-	-
Forced labour/ Migrant labour	-	-	No	No	-	-	-
Excessive working hours	-	-	If needed	If needed	-	-	-
Low wage	-	-	No	No	-	-	-
Health and safety risk	-	-	No	No	-	-	-
Gender- and other discrimination	-	-	No	No	-	-	-
(lack of) Freedom of association	-	-	No	No	-	-	-
(lack of) Collective Bargaining	-	-	-	No	-	-	-
Corruption	-	-	No	No	-	-	-
Violation of land rights	-	-	No	No	-	-	-

Conclusion and follow-up activities: The social and environmental issues during the manufacturing of a white cotton t-shirt in Bangladesh has been discussed in this case study in order to identify the footprints of Textile and RMG sector. Information's on the social and environmental issues of Cotton farming in India and the uses, disposal, and recycling scenario of a white cotton t-shirt can also be discussed in a further study.

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