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# Waste Generation and Characteristics in Sri Lankan Textile and Apparel Sector: Case Study of the Biyagama Industrial Export Processing Zone, Sri Lanka

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## ABSTRACT

The main goal of the study was to look at the properties of waste, treatment options, and disposal techniques. Furthermore, waste circulation variables in the textile and apparel sectors in Sri Lanka's Biyagama Industrial Processing Zone were calculated. The types, volumes, and per capita waste generation of ten industries were analyzed, as well as waste management activities such as trash minimization, handling, storing, recirculation, and disposal. The information was gathered using questionnaires, interviews, and field observations. According to the findings, the total industrial waste generation rate was 13792.5 tonnes per year, with 5926 tonnes per year designated as hazardous waste materials (42.9%). Furthermore, the waste generation rate per capita was 0.93 kg. The waste circulation factor was 0.38, according to the findings. The findings of the study highlight the necessity for integrated waste management methods in the textile and apparel industries.

## INTRODUCTION

The textile and apparel (T&A) industry sector is one of the most crucial for economic growth, particularly in nations where the sector is heavily reliant (Ulson de Souza et al. 2010). Sri Lanka's economy largely depends on the apparel export business, contributing 32% to the gross domestic product (GDP) and 44% to total exports in 2018 (Fibre2fashion.com 2021). It has recorded a 5.2% growth in export in 2019 (Russell 2020). The T&A sector is one of the largest industrial sectors, providing over 300000 jobs (Embuldeniya 2018). Despite the positive economic impact, this sector has negative environmental consequences because it depletes resources, generates greenhouse gases, and pollutes the environment. It is well-known for its high resource use in aggregate manufacturing methods (Kocabaş 2008) and considerable chemical use, notably in dyeing and finishing procedures (Verma 2012). The amount of resources consumed depends on the type of fiber used in the textile manufacturing process as well as the technology used (Brik et al. 2006). As a result, the textile sector faces major pollution and waste creation issues throughout the manufacturing process (Moore & Ausley 2004). As a result, it is critical to examine waste generation to develop a waste management strategy for businesses (Zaman 2013). Meanwhile, the textile and apparel sector has been identified as one of the most critical potential industries for innovative innovation and enhancement innovation (Rapsikevičienė et al. 2019). Furthermore, previous research has shown that waste in the textile industry has the potential to be recyclable and can become raw material for one or different sectors (Villanueva et al. 2010).

In this regard, the current research seeks to determine the characteristics, waste generation, waste management, and waste circulation potential in the textile and apparel industries in Biyagama Export Processing Zone (BEPZ), Sri Lanka. The study's findings will enable the development of new suitable waste management and sustainable activities for these materials, based on the knowledge and characteristics of waste ingredients. Aside from that, it has the potential to contribute to further research in finding solutions to increase their reuse or recovery potential.

## MATERIALS AND METHODS

### Study Area

BEPZ is located in the Gampaha District and is one of the three districts in Western Province. It is about 24 km from Colombo city. It is 1km away and is close to the Bandaranaike International Airport. For this study, ten textile factories were selected from the BEPZ region, which is not disclosed due to their research ethics. Factories were labeled with a pseudo-code such as T1, T2. etc. Selected factories are divided into three groups based on their processes: 1) fabric

manufacturing, 2) garment washing and dyeing, and 3) clothing manufacturing.

Fabric producers utilize imported yarn and automated knitting technology to manufacture fabric. Fabric manufacturers and Garment washing and dyeing conduct wet processing, including pre-treatment, dyeing, and finishing. De-sizing, scouring, bleaching, and mercerizing are all part of the pre-treatment process, necessitating a considerable volume of pure water for washing, rinsing, and steam generation. The apparel manufacturing sector produces finished garment products that are ready for use.

### Data Collection Procedure

Obtaining data required an examination of industrial waste generation and waste management procedures, as shown in Fig. 1. Waste generating points, types, and waste volumes, as well as disposal methods, were identified. The characteristics of each industry category that produces waste items were determined during the analysis. Questionnaires, interviews, and field observations were used to gather the information needed to evaluate the waste composition and management status.

### Calculation of Waste Circulation Factor

The principles of circular economics are utilized in this study to estimate the circular waste factor. A circular economy is a type of economic system that attempts to eliminate waste and continuously recreate resources (Fig. 2). Progress toward a circular economy should include the ethical use of natural resources as well as the ability to reuse, repurpose, recycle, and retrieve the value stored in previously discarded items. Waste incineration or landfilling, which have been identified as potential disposal processes, are not viewed as high-priority strategies for achieving a circular economy. In a circular economy, resource sinks such as cremation and landfilling operate as resource sinks, whereas resource circulation occurs in balanced resource flows.

The waste circulation factor for this study was computed using formula (1) and the principles of a circular economy as outlined below.

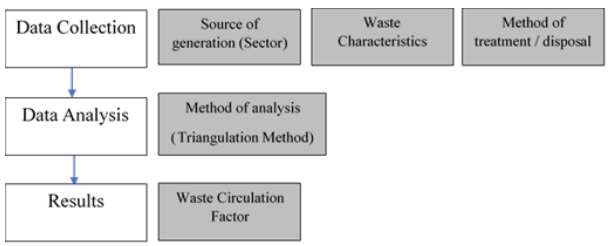


Fig. 1: Methodological Framework.

$$\frac{\sum_{i=1}^{i} w_{re}^{i} + \sum_{i=1}^{i} w_{ru}^{i}}{\sum_{i=1}^{i} w_{Total}^{i}} = \text{Waste Circulation Factor-(1)}$$

$w_{re}^{i}$ = Recyclable waste fraction of waste type i
$w_{ru}^{i}$ = Reused waste fraction of waste type i
$w_{Total}^{i}$ = Total waste generation of waste type i

## RESULTS AND DISCUSSION

### Primary Waste Streams

In the results of the study presented in Table 1, each waste category in the selected 10 T&A industries was prioritized by arranging them in descending order of magnitude. Pareto chart is used for preliminary identification of the most significant waste stream and to discover the "vital" streams that accounted for 80% of waste generation. The outcome of the analysis is given in Table 1 presenting the results following the application of the Pareto principle. Fig. 3 shows the

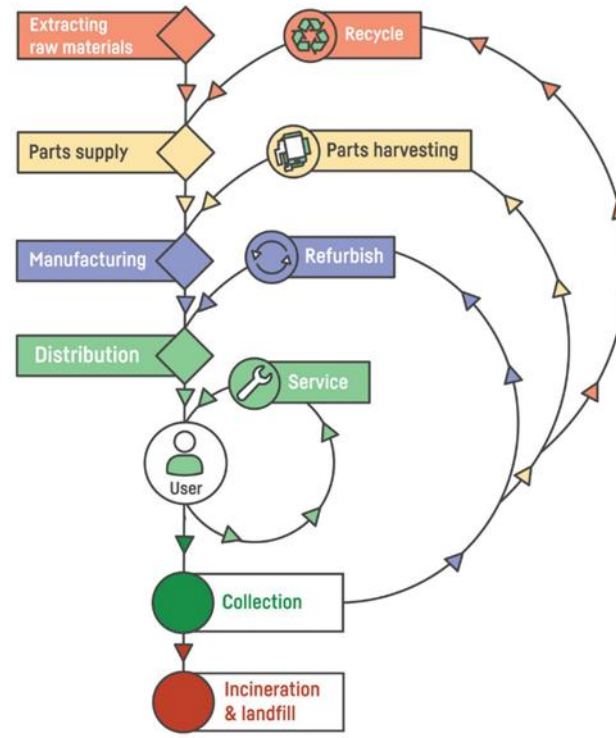


Fig. 2: Resource circulation through the circular economy (TCO certified 2021).

waste generation in each selected T&A industry sector. The total waste generation accounted for 13792.5t per year, of which 5926t per year belonged to hazardous waste materials (42.9%). The results also indicate the per capita waste generation based on the number of workers in the industry sector. The total number of personnel surveyed was 15421 and the waste per capita accounted for 0.93 kg.day$^{-1}$ per worker.

The wastes stream quantities in the surveyed factories were evaluated during the study. Effluent treatment plant (ETP) sludge accounted for 39.4 % of the total wastes, followed by fabric and yarn (29.6%), metal (5.6%), Paper and cardboard (5.4%), plastic (5.2%), food (4.3%), mixed waste (4.0%), chemical containers (2.4%). The remaining wastes constituted less than 5% of the total waste. The accuracy of results could be affected due to challenges with collecting complex waste regeneration data. The data in this instance is associated with a range of production processes, raw materials, and multiple data points.

T1, T3, T8: represent Fabric Mills

T2, T6, T7, T9: represent Garment washing & Dyeing plant

T4, T5, T10: represent Apparel Manufacturing companies

## Waste Treatment Mechanisms

The following options are identified as the most common waste disposal methods used by the factories in BEPZ. The proportions of primary waste disposal methods were calculated and are shown in Fig.4.

Table 1: Types of waste generation in the T&A sector in the BEPZ, Sri Lanka.

| Waste Types | Total waste generation in T&A sector industries(t/year) |
|---|---|
| Boiler ash | 311.6 |
| Chemical Containers | 331.0 |
| Contaminated Fabric | 38.9 |
| ETP Sludge | 5434.2 |
| E-Waste | 2.9 |
| Expired chemicals | 6.9 |
| Fabric and yarn waste | 4082.6 |
| Food Waste | 593.0 |
| Metal | 772.3 |
| Paper & Cardboard | 744.7 |
| Polythene | 110.3 |
| Plastic (including tread cone) | 717.2 |
| Waste Oil | 1.8 |
| Wood and Wood Pallet (0.55) | 87.8 |
| Mixed waste | 557.3 |

- Option 1: Reuse within the facility
- Option 2: Reuse for other industries
- Option 3: Returned to supplier
- Option 4: Co-processing in cement kiln
- Option 5: Energy recovery within the facility
- Option 6: Sold to licensed recycling company
- Option 7: Landfilling
- Option 8: Collected by scavengers
- Option 9: Collected by the third party and exported for recycling
- Option 10: Open dumping at Zone dump yard
- Option 11: Storing

## Non-hazardous Waste Treatment Disposal

The study revealed that all selected industries generate some common types of waste, although their quantities were different. The common types of waste (non-hazardous) include fabric, paper, polyethylene, metal, plastic, food, and wood waste. Those wastes are typically stored in a dry place within the factory premises ensuring protection from the climate hazards. This waste is separately handled and the main portion of non-hazardous waste contains fabric which accounts for 51% of the total amount.

## Waste Storage

The study also looked at how waste is stored in temporary storage. The results revealed that closed space (52.5%) and open space (50%) were the most commonly used temporary storage options (28.5%). Polyethylene bags (12.8%), boxes (4.5%), and barrels (1.7%) were the other commonly used solutions for the temporary storage of industrial wastes in BEPZ.

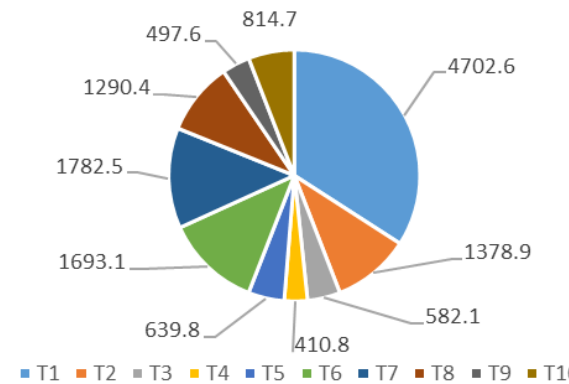


Fig. 3: Waste generation (t per annum) of T&A industries in BEPZ, Sri Lanka.

According to the information in this study, 62.1% of industrial wastes were disposed of on weekly basis, 30.9% on monthly basis and 4% on daily basis, and 3% on annual basis.

### Waste Segregation and Recycling

According to the findings, 70% of industries segregate and separate their trash at the point of generation. It's telling evidence that there's a high level of waste management awareness and procedures, as well as great management by industrial managers. Except for fabric offcuts, the most common recyclable materials generated in the sector are paper, polythene, cardboard, and metal. In the BEPZ's textile industry supply chain, 91% of paper and cardboard, 79% of polythene, 76% of metal, and 43% of plastic and chemical containers waste were recycled. As a result, over 80% of the factories decided to sell these materials to licensed recycling companies. The remaining materials were collected by unauthorized small-scale entrepreneurs for resale, and their whereabouts are unknown.

### Fabric Waste Management

Fabric waste accounted for the highest generation among all types of waste. The most common fabric waste types generated in the BEPZ were cotton, polyester, nylon, and mixed material. There is a significant demand for cotton and nylon fabric waste for recycling, however, treatment of polyester or a mix of material off-cut waste has become a significant challenge in this sector due to the unavailability of textile recycling facilities in the country. Therefore, a significant amount of fabric waste is disposed of through co-processing in cement kilns due to the unavailability of collectors. Two industries in BEPZ burn the fabric waste in their boilers and recover energy. However, the boiler ash disposal is a problem due to it contains heavy metal which comes through the fabric and this remains unaddressed.

Fig. 5 Shows the fabric waste flow in the BEPZ. These are the current management practices for fabric waste in the BEPZ. Fig. 6 shows the waste disposal methods of fabric waste.

Method 1- Energy Recovery

Method 2- Co-processing at Cement Kiln

Method 3: Sold to licensed recycling company

Method 4: Reuse

Method 5: Export for recycling through collectors

Method 6: Landfilling through collectors

### Hazardous Waste Disposal

Due to the lack of technologies and the facilities for hazardous waste treatment and disposal in the country, most of the surveyed industries dispose of the hazardous waste through co-processing in cement kilns. A total amount of 6847.4t of hazardous waste (95%) per year was co-processed at the cement kiln, including 100% of ETP sludge. The rest of the hazardous waste is accumulated in the factories due to the unavailability of treatment options.

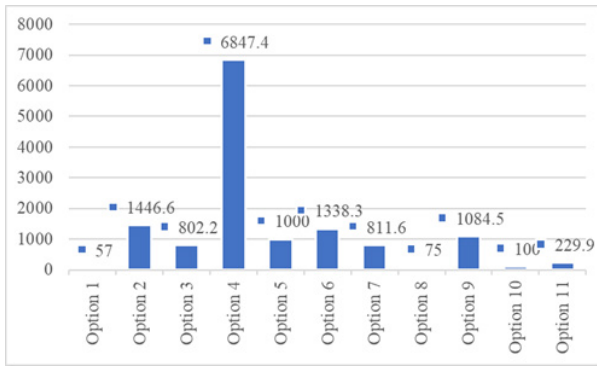


Fig. 4: The treatment methods of the primary waste streams (t per year).

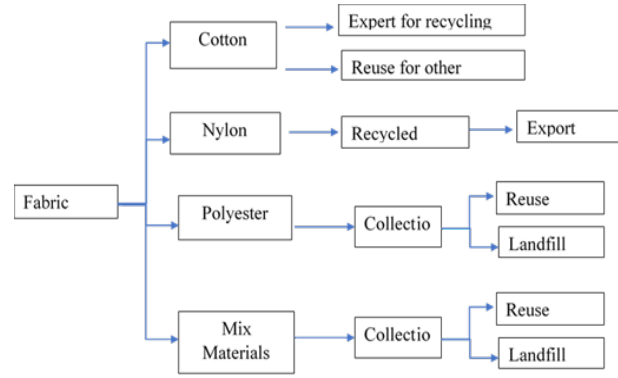


Fig. 5: Fabric waste flow in the BEPZ.

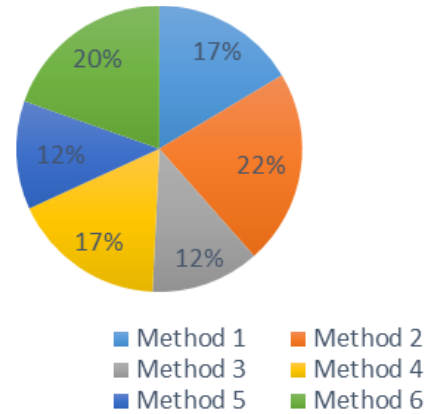


Fig. 6: Management practices of fabric waste (%) in T&A industries in the BEPZ.

### Waste Flow Analysis

Fig. 7 shows the overall waste flow in the selected T&A industries in the BEPZ. In the zone, four different waste treatment methods were applied. Reuse (2805.8t), energy recovery (7847.4t), recycle (2497.8t), landfill (411.7t), and export for recycling where the waste treatment options (229.9t). Recycling and reusing accounted for 38.45% of the total. Incineration (56.8%) was the most commonly employed waste treatment technology for energy recovery.

### Analysis of Waste Circulation Factor

The waste circulation factor of the waste was calculated using Equation 1. The results show the overall waste circulation factor of the textile and apparel industries in the Biyagama Export Processing zone was 0.38.

### Waste Management Practices

According to the findings, all organizations strive to reduce waste generation, and they also underline that waste management should be the responsibility of all departments. Furthermore, most firms adopted separate organizational rules under the ISO 14001 Environment Management System to minimize or regulate waste. There was a clear indication of how to manage waste in the policy. In general, four of the industries surveyed use cleaner production methods.

## CONCLUSION

The textile industry has a huge opportunity to divert waste from landfills and into recycling and reuse. However, a review of the scientific literature reveals that incineration and landfills account for the majority of industrial textile waste disposal. The research discussed in this article uses the data triangulation method to look at T&A sector industries in BEPZ for 2019. Furthermore, the waste circulation factor for the industry is calculated using an equation established utilizing circular economy principles. The study's findings reveal a high potential for circulation of waste within inter and intra-industry sectors.

According to the findings, overall waste production was 13792.5t per year, with hazardous waste items accounting for 5926t per year (42.9%). The findings also illustrate the per capita trash generation based on the number of persons employed in the industry. The total number of people polled was 15421, with each worker producing 0.93kg of garbage per day. Co-processing in a cement kiln is the most common waste disposal strategy used by businesses in BEPZ, followed by reuse for other industries and sale to an authorized recycling business. The study discovered that all of the businesses studied produce certain similar forms of waste but varied proportions. According to the findings, 70% of manufacturers segregate and separate their waste at their production point. It is an excellent indicator of solid waste management, knowledge and procedures, and outstanding management by industrial managers. Among all forms of waste, fabric waste accounted for most production. The most prevalent waste management options are co-processing at cement kilns (22%), landfilling through collectors (20%), reuse (17%), and energy recovery (17%). The majority of industries examined use cement kilns to co-process hazardous waste. The cement kiln co-processed a total of 6847.4t of hazardous waste (95%) each year, including 100% ETP sludge. According to the findings, the overall waste circulation factor of the textile and apparel businesses in the BEPZ was 0.38.

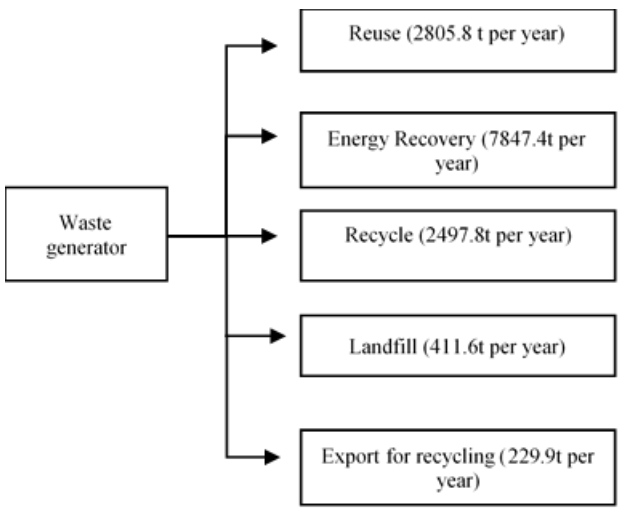


Fig. 7: Waste flow in the selected T&A industries in BEPZ.

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