Circular Waste Management in Synthetic Fibre Recycling for Textile Industry

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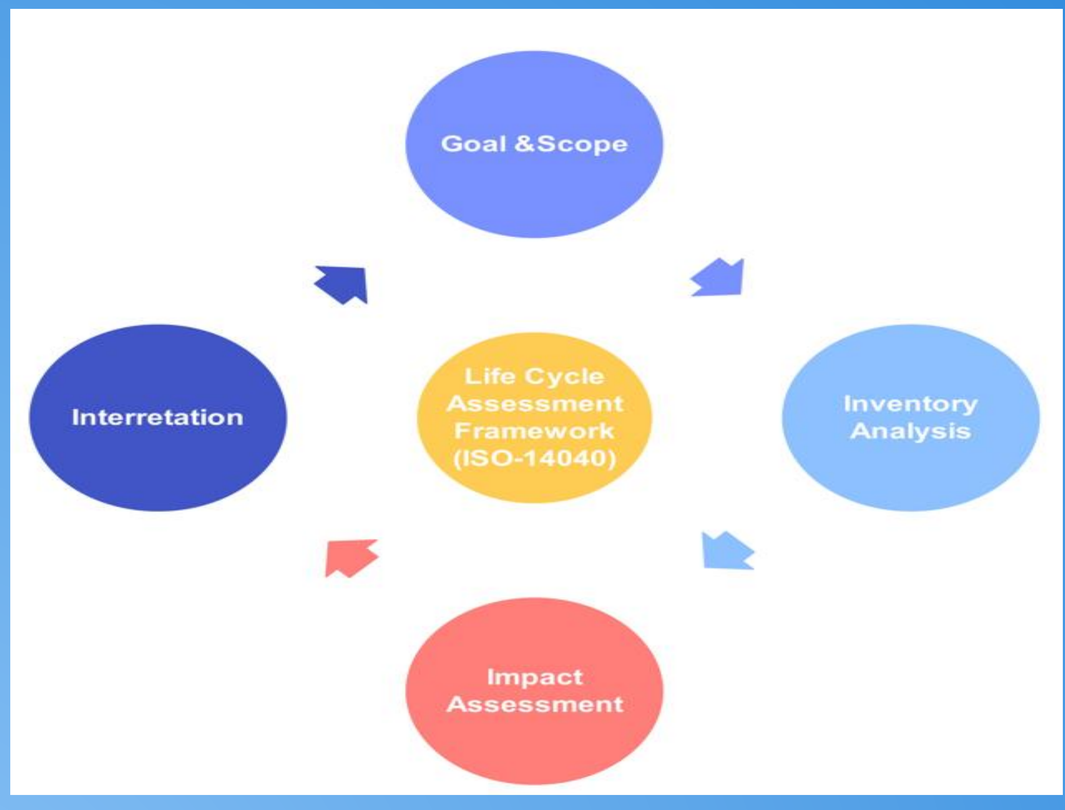
Introduction

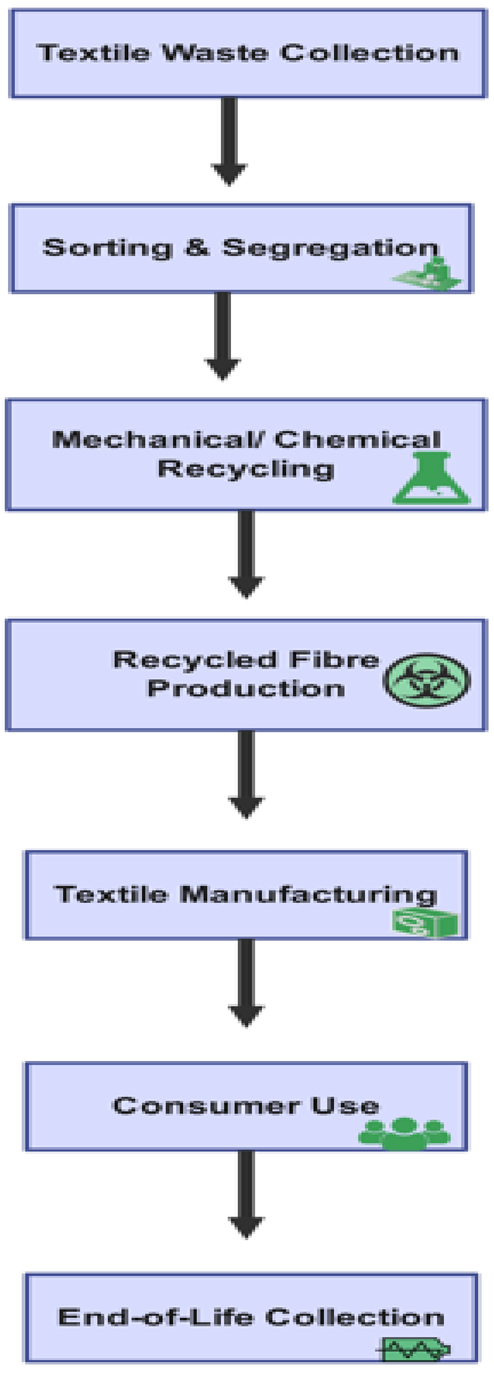
The textile industry is one of the largest contributors to global waste generation and environmental pollution. Synthetic fibres such as polyester, nylon, and acrylic account for more than 65% of global fibre production and generate substantial amounts of pre-consumer and post-consumer waste. In Pakistan, the textile sector is a major economic driver, yet large quantities of synthetic textile waste are disposed of through landfilling, incineration, or informal recycling practices. These disposal methods contribute to greenhouse gas emissions, resource depletion, and microplastic pollution.

The concept of a circular economy promotes resource recovery and waste minimization by recycling materials back into the production cycle. Therefore, synthetic fibre recycling offers a promising strategy for reducing environmental burdens while creating economic value. This study evaluates the techno-economic feasibility and environmental performance of synthetic fibre recycling pathways in the textile industry using Life Cycle Assessment (LCA) and Techno-Economic Assessment (TEA).

Methodological Framework



System Boundary

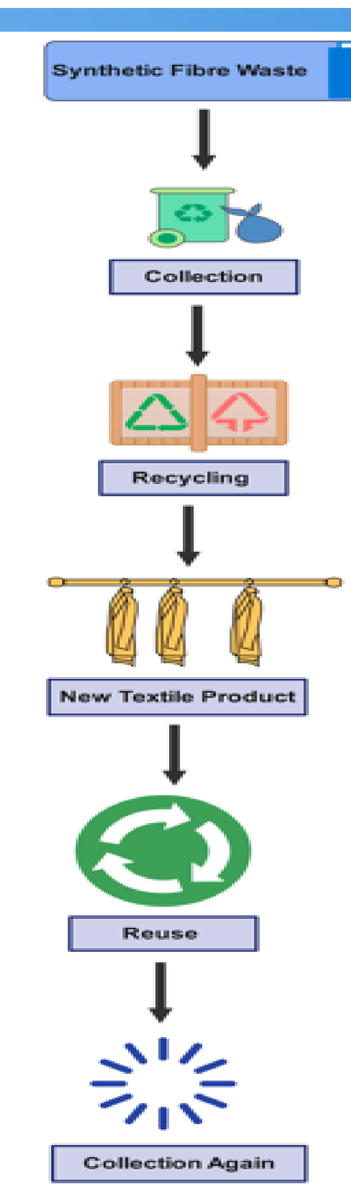


The system boundary includes textile waste collection, sorting, recycling, fibre production, and textile manufacturing. Inputs such as energy and water, and outputs including emissions and waste, are considered to evaluate environmental performance throughout the recycling process.

The higher impacts of recycled polyester are linked to its greater production volume and processing requirements. However, recycling synthetic fibres supports circular economy goals by reducing waste generation and dependence on virgin materials.

Circular Economy Framework

The circular economy approach aims to minimize waste generation and maximize resource recovery within the textile sector. Synthetic textile waste is collected, sorted, and recycled into secondary raw materials that can be reintroduced into the production cycle. This closed-loop system reduces dependence on virgin synthetic fibres, lowers environmental burdens, conserves resources, and promotes sustainable textile manufacturing. The adoption of circular waste management practices supports both environmental sustainability and economic value creation in the textile industry.



Results & Discussion

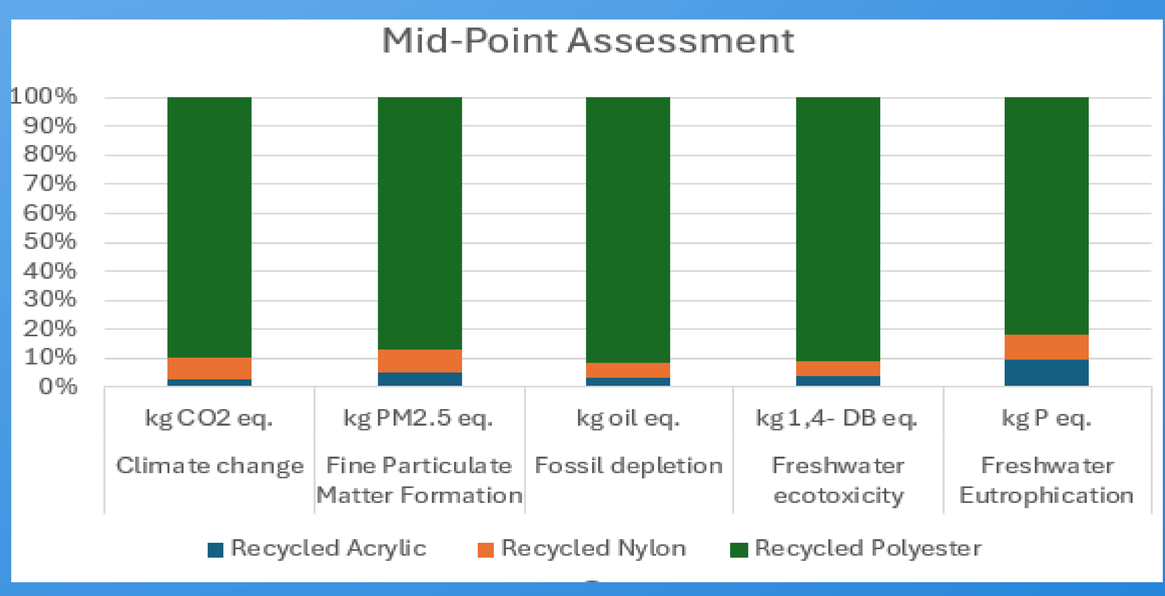


Figure: Relative contribution of recycled polyester, recycled nylon, and recycled acrylic to selected environmental impact categories

The results indicate that recycled polyester contributed the highest share (80–90%) across all environmental impact categories, including climate change, fossil depletion, freshwater ecotoxicity, and particulate matter formation. Recycled nylon showed moderate contributions, while recycled acrylic exhibited the lowest environmental burden. Freshwater eutrophication displayed comparatively higher contributions from nylon and acrylic than other impact categories.

Conclusion

Synthetic fibre recycling offers a sustainable solution for circular waste management in Pakistan's textile sector. The integration of environmental and techno-economic assessments can identify efficient recycling pathways that reduce waste generation, lower carbon emissions, and improve resource utilization. The adoption of circular recycling systems can support the development of a low-carbon, resource-efficient, and sustainable textile industry.

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