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*Article*

# Environmental Life Cycle Assessment of Recycled Coarse Aggregate and Textile Waste Fibers

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**Abstract**

The use of textile waste and recycled concrete as alternative construction materials is important for advancing sustainability and encouraging a circular economy. In developing countries such as Pakistan, improper disposal of concrete and textile waste significantly adds toward environmental degradation. This study quantifies the Global Warming Potential (GWP) and Cumulative Energy Demand (CED) associated with the production of Recycled Coarse Aggregates (RCA) and recycled textile fibers. A cradle-to-gate Life Cycle Assessment (LCA) was conducted using the OpenLCA framework, incorporating Ecoinvent and NEEDS databases, and tailored to the Pakistani context with the 2025 energy mix. The results indicate that producing 1 ton of RCA results in a GWP of 8.86 kg CO2e, while 1 kg of recycled textile fiber emits 0.212 kg CO2e. Transportation is the primary energy consumer in the textile fiber sector, accounting for 76% of total demand, whereas processing machinery is the main contributor to RCA-related emissions. Recycled textile fibers exhibit a substantially lower carbon footprint compared to conventional synthetic fibers such as PET, basalt, and macro-synthetic fibers. This study sets an important environmental benchmark, demonstrating that RCA and recycled textile fibers are viable low-carbon, circular material strategies for the local construction sector.

**Keywords:** Life Cycle Assessment; Recycled Concrete Aggregate; Textile Waste Fiber; Circular Economy; Sustainability; Construction Materials.

## 1. Introduction

Pakistan faces a critical dual challenge of rapid urbanization and unmanaged industrial waste. The country generates approximately 49.6 million tons of solid waste annually, with the construction sector contributing significantly to landfill saturation [1] . Simultaneously, as a major global textile hub, Pakistan produces an estimated 887 kilotons of pre-consumer textile waste per year. A large proportion of this waste is incinerated or openly dumped, exacerbating hazardous smog and air pollution in the region [2]. Advancing a circular economy requires the construction industry to utilize these waste streams as alternative building materials.

Recycled Concrete Aggregates (RCA) offer a sustainable alternative to virgin Natural Aggregates (NA). While studies indicate that RCA can exhibit a 10–25% reduction in compressive strength compared to natural aggregates, it remains highly effective for non-structural applications, such as road sub-bases, pavements, and low-load bearing walls [3]. To address potential performance limitations, the use of recovered textile fibers has emerged as an innovative reinforcement strategy. Research indicates that incorporating textile fibers can enhance the tensile strength and ductility of concrete by 11–38%, effectively bridging micro-cracks and improving strain resistance [4].

Although the mechanical potential of these materials is well established, there is a significant gap in quantifying their environmental impacts within the Pakistani context. Reliable localized data is scarce, with nearly no studies specifically addressing the environmental footprint of RCA and recycled textile fibers in the region [5][6]. Furthermore, most existing Life Cycle Assessments (LCA) rely on generic global datasets that fail to reflect the specific energy intensity of South Asian waste transportation and processing [5]. This paper addresses this deficiency by performing a focused LCA of RCA and recovered textile fibers. The study utilizes the OpenLCA computational framework, grating background inventory data from the Ecoinvent and NEEDS databases to ensure methodological rigor. By quantifying the Global Warming Potential (GWP) and energy demand of the" cradle-to-gate" processing phases, this work establishes a foundational environmental baseline. These results show the need to close the regional data gap and will inform future experimental efforts to optimize the mechanical performance of fiber-reinforced composites for the local construction sector.

## 2. Materials and Methods

*2.1 Materials*

2.1.1 Textile Waste Fibers

Recycled textile fibers were procured from specialized recycling facilities located in Faisalabad, Pakistan's primary textile processing hub [2]. This region serves as a central aggregation point where pre-consumer textile waste—consisting predominantly of off-cuts from knitting and woven fabric production—is transported. At the facility, the collected waste underwent a multi-stage mechanical recycling process, including industrial shredding and opening, to convert fabric scraps into a loose fibrous mass. The properties of this recycled fiber are detailed in Table 1.

The material used in this study was the final processed fiber, prepared for concrete reinforcement applications. The physical appearance of the fibers is shown in Figure 1.

*Figure 1: Textile fiber obtained from manufacturer (left) and prepared for use (right)*

*Table 1: Engineering properties of recycled textile fiber*

| Property | Value/Description |
|---|---|
| Composition | 95% Polyester & 5% Elastane |
| Density | 150 kg/m³ |
| Modulus @ 40% – Warp | 0.55 N |
| Modulus @ 40% – Weft | 0.45 N |
| Melting point | 240 °C |
| Reaction with water | Hydrophobic |

2.1.2 Recycled Concrete Aggregates (RCA)

The RCA used in this study was sourced from laboratory waste, specifically tested concrete cylinders from prior compressive strength experiments. This ensures a known parent concrete quality (typically 30–40 MPa). The waste cylinders were collected and processed to produce coarse aggregates.

The concrete cylinders (Figure 2) were manually comminuted and screened to obtain a coarse aggregate fraction consistent with ASTM C33 standards [7]. The aggregates were washed to remove excessive adhered mortar dust before use.

*Figure 2: Recycled aggregates obtained from cylinders.*

### *2.2 Life Cycle Assessment (LCA) Framework*

Life cycle assessment is conducted in accordance with the International Standards Organization's 14040 and 14044 instructional guidelines in four phases. These four phases are explained below.

- Goal and Scope
- Life Cycle Inventory Analysis
- Life Cycle Impact Assessment
- Interpretation

### *2.3 Goal and Scope Definition*

The primary goal of this assessment is to quantify the Cumulative Energy Demand (CED) and Global Warming Potential (GWP) of processing waste streams into usable construction materials. The assessment strictly follows the **ISO 14040** environmental management framework [8].

- **Scale-Up Assumption:** Although laboratory samples were prepared manually, this LCA models an industrial-scale scenario using standard heavy machinery (Jaw

Crushers, Vibrating Screens) rather than manual labor. This approach assures the results are relevant to the construction industry and correctly reflect the fuel and electricity consumption of real-world implementation.

- **Functional Unit**: 1 ton of Recycled Concrete Aggregate (RCA) and 1 kg of Recycled Textile Waste Fiber, processed and ready for mixing in concrete.
- **System Boundary**: The study adopts a" cradle-to-gate" approach. The boundary encompasses raw material extraction (waste collection), transportation to the recycling facility, and all subsequent mechanical processing steps (crushing, shredding, washing), which are listed in Figure 3.

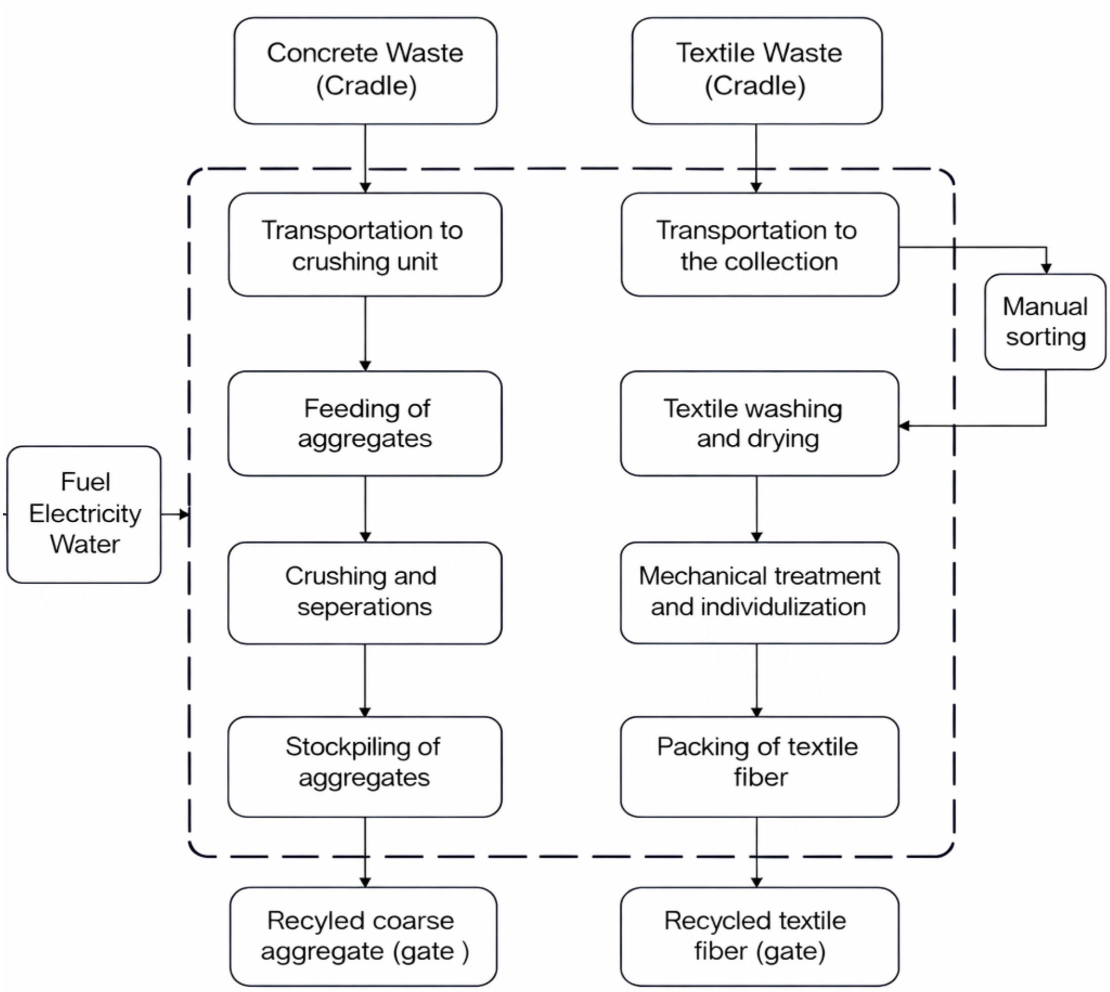


*Figure 3: System boundary flowchart to produce Recycled Coarse Aggregates (RCA) and Recycled Textile Fibers.*

The system boundary is defined using a cradle-to-gate approach, encompassing raw material procurement, transportation, and primary recycling stages for both RCA and textile fibers. To ensure a focused comparative examination, auxiliary processes for recovering non-fiber or non-aggregate co-products—such as sand, garment accessories, and decorative wood chips—are excluded. Furthermore, given the consistency of raw materials such as cement and admixtures, as well as the uniformity of construction and maintenance across fiber-reinforced concrete types, these factors are deemed outside the scope.

Consistent with Lei et al. [9], a material recovery rate of 65% was applied for RCA production. Consequently, to deliver the functional unit of 1 ton of RCA, the system accounts for the processing of 1.54 tons of raw waste, treating the non-aggregate fraction as system loss.

### *2.4 Life Cycle Inventory (LCI)*

Life Cycle Inventory modeling was performed using the OpenLCA software framework [13]. Primary data on machinery energy consumption and throughput were obtained from manufacturer specifications and local industrial surveys to ensure representativeness under Pakistani operating conditions. Background data, including regional electricity generation mixes, diesel combustion profiles, and emission factors, were sourced from Ecoinvent v3.8 and Needs database and national energy sector reports[10] - [12].

- **Transportation:** Transportation logistics were modeled using 32-ton heavy-duty trucks for both material streams. For Recycled Coarse Aggregates (RCA), a transport distance of 70 km was assumed from a waste recovery site in Haripur (KPK). In contrast, the textile fibers were modeled with a 400 km haul from the recycling facility in Faisalabad (Punjab). Although the vehicle class remained consistent, distinct LCI datasets were used to accurately calculate the Global Warming Potential (GWP) for each supply chain.
- **Energy Mix:** A country-specific Pakistan electricity grid model was developed. A conservative" pessimistic" grid factor was applied, accounting for 18% transmission and distribution losses [14].The grid composition for the year 2025 is detailed in Table 2.

*Table 2: Electricity Grid Data of Pakistan (2025 Projection)[12][14].*

| Parameter / Energy Source | Share (%) |
|---|---|
| Thermal (Gas, Coal, Oil) | 46.3% [12] |
| Hydel (Hydroelectric) | 30.4% [12] |
| Nuclear | 19.1% [12] |
| Renewables (Wind/Solar) | 4.2% [12] |
| T&D Losses (Grid Inefficiency) | 17.55% [14] |

#### 2.4.1 Inventory of Recycled Coarse Aggregate (RCA)

Transportation and excavation impacts were modeled in OpenLCA using validated Ecoinvent v3.8 datasets for heavy-duty road transport. Electricity-related impacts were evaluated using a country-specific Pakistan electricity grid model developed within

OpenLCA. To ensure model durability, software results were cross-verified through independent manual calculations.

Grid-related impacts were validated using the following formulations, accounting for the regional electricity generation mix and transmission and distribution losses ($L$):

$$CI = \frac{\sum_i S_i \ EF_i}{1 - L}$$

$$PEF = \frac{\sum_i S_i \ PEF_i}{1 - L}$$

where $\boldsymbol{CI}$ is the grid carbon intensity emission factor, $\boldsymbol{PEF}$ is the grid primary energy factor, $\boldsymbol{S_i}$ represents the share of electricity generation from source $\boldsymbol{i}$, $\boldsymbol{EF_i}$ and $\boldsymbol{PEF_i}$ are the source-specific life-cycle emission and primary energy factors, respectively, and $\boldsymbol{L}$ denotes the transmission and distribution loss factor.

Consistency between these formulations and OpenLCA outputs confirms that the model accurately represents the regional environmental profile of recycled concrete aggregate (RCA) production.

The operational characteristics of the machinery used in RCA production are summarized in Table 3. On-site material-handling operations, including aggregate feeding and stockpiling, were modeled based on the fuel consumption of **Komatsu PC200-8** hydraulic excavators, assuming a realistic load factor of **0.45**, representative of continuous industrial material-handling operations. As excavators do not have a fixed rated throughput, an effective handling capacity of approximately **125 t/h** was estimated based on manufacturer specifications and observed operating conditions.

The RCA production operation was modeled as a mobile crushing and screening system. Primary crushing was performed using an **HX938HD86** mobile impact crusher, while screening, magnetic separation, and dust suppression constituted secondary electrical loads. Dust suppression was facilitated by an **IRG 40-200-4** inline centrifugal pump with a rated power of **4.0 kW**. Internal material transport was handled by three **B800-series** belt conveyors, serving crusher discharge, RCA stockpiling, and fines separation. For inventory simplification, the conveyors were modeled as a single functional unit with a total installed power of **19 kW** (two 7.5 kW units and one 4 kW unit). Energy consumption was calculated under the assumption of steady-state operation at the rated plant throughput.

*Table 3: Operational characteristics of the RCA crushing and screening circuit.*

| Process Stage | Manufacturer | Machine Unit | Model | Capacity (t/h) | Power (kW) |
|---|---|---|---|---|---|
| Feeding | Komatsu Ltd. | Hydraulic Excavator | PC200-8 | 125 | 110 (Diesel) [15] |
| Crushing | Henan Liming | Mobile Impact Station | HX938HD86 | 125 | 300 (Elec) [16] |
| Dust Suppression | Shanghai Kaiquan | Inline Pump | IRG 40-200-4 | 125 | 4.0 (Elec) [17] |
| Separation | Henan Hongxing | Vibrating Screen | 3YK-1548 | 150 | 15.0 (Elec) [18] |
| Separation (Aux) | Fushun Ejet | Magnetic Separator | RCYD-8 | 125 | 2.2 (Elec) [19] |
| Conveying | Henan Hongxing | Belt Conveyors | B800 | 125 | 19.0 (Elec) [20] |
| Stockpiling | Komatsu Ltd. | Hydraulic Excavator | PC200-8 | 125 | 110 (Diesel) [15] |

2.4.2 Inventory of Textile Waste

Transportation impact here was modeled in OpenLCA using validated NEEDS datasets for heavy-duty road transport. The Rest Global Warming Potential (GWP) assessment methodology, including electricity grid carbon intensity calculation, and transmission loss correction, was identical to that applied for recycled concrete aggregate (RCA) production. The same OpenLCA framework and characterization approach were used, with differences limited to the foreground inventory.

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The operational characteristics of the Machinery used in the textile waste recycling line are summarized in Table 4. The system boundary includes auxiliary equipment and support loads typically excluded from nominal vendor ratings.

**The Tunnel Washer (SDX60-13)** power demand includes the rated drum drive as well as an additional **5.0 kW** for hydraulic circulation and auxiliary pumping systems. Drying operations were carried out using a **TYD-7** continuous belt dryer, selected to match upstream material throughput.

Shredding and opening stages were modeled to include both feed motors and pneumatic transport fans. Packing operations were performed using an **FPS-1 semi-automatic baler**, with total power demand reflecting the baler drive, external air compressor, and integrated heat-sealing unit.

*Table 4: Operational characteristics of textile waste recycling machine.*

| Process Stage | Manufacturer | Machine Unit | Model | Throughput (kg/h) | Power |
|---|---|---|---|---|---|
| Washing | Jiangsu Sea-Lion | Tunnel Washer | SDX60-13 | 1200 | 29.2 [21] |
| Drying | Qingdao Huarui | Belt Dryer | TYD-7 | 1000 | 44.0 [22] |
| Shredding | Qingzhou Xinhang | Fibre Cutter | SBJ800 | 500 | 8.5 [23] |
| Opening | Qingdao Seanoel | Textile Opener | SN-OP350 | 300 | 12.0 [24] |
| Packing | Taizhou Bitop | Semi-Auto Baler | FPS-1 | 250 | 2.8 [25] |

## 3. Results

### *3.1 Life Cycle Impact Assessment (LCIA)*

Life Cycle Impact Assessment (LCIA) was conducted to translate the compiled life cycle inventory flows into environmental impact indicators using the OpenLCA software framework. LCIA quantifies indicators of environmental pressure—such as climate change, natural resource depletion, and human health effects—associated with interventions occurring across the life cycle of a product, based on established characterization factors.

In this study, the impact assessment primarily focuses on **Global Warming Potential (GWP)**, as **greenhouse gas (GHG)** emissions represent the most relevant indicator for evaluating recycling-based material production systems. Emissions are expressed as carbon dioxide equivalents **(kg $CO_2$e)**, allowing aggregation of contributions from different energy carriers. Fossil energy demand includes both direct fuel consumption (e.g., diesel use in transportation and material handling) and indirect energy associated with electricity consumption.

### *3.2 Interpretation*

#### 3.1.1 Recycled Coarse Aggregate (RCA)

The Auxiliary processes like Dust Suppression and the magnetic separators contribute the least in the total GWP. Overall, the hybrid modeling approach, combining fuel-based calculations for mobile equipment and electricity-based modeling for stationary processes, enhances lucidity and strengthens the robustness of environmental assessment. The Auxiliary processes like Dust Suppression and the magnetic separators contribute the least in the total GWP. Overall, the hybrid modeling approach, combining fuel-based calculations for mobile equipment and electricity-based modeling for stationary processes, enhances lucidity and strengthens the robustness of environmental assessment.

Table 5 shows the total GWP and the CED to produce 1 ton of recycled coarse aggregate. For the RCA production system, LCIA results indicate that **transportation and diesel-based material handling** are the dominant contributors to GWP, while **electricity-driven crushing and separation processes** represent a secondary but non-negligible share of emissions. The use of a

**65% recovery rate** provides a realistic representation of industrial RCA production and ensures consistency between material flows, energy demand, and emissions.
The Auxiliary processes like Dust Suppression and the magnetic separators contribute the least in the total GWP. Overall, the hybrid modeling approach, combining fuel-based calculations for mobile equipment and electricity-based modeling for stationary processes, enhances lucidity and strengthens the robustness of environmental assessment. The Auxiliary processes like Dust Suppression and the magnetic separators contribute the least in the total GWP. Overall, the hybrid modeling approach, combining fuel-based calculations for mobile equipment and electricity-based modeling for stationary processes, enhances lucidity and strengthens the robustness of environmental assessment.

*Table 5: LCI and GHG emissions for producing 1 ton of RCA.*

| Process Stage | Energy Source | CED (MJ) | GHG (kg $CO_2$e) |
|---|---|---|---|
| Transportation (Lorry) | Diesel | 72.48 | 5.366 |
| Feeding (Excavator) | Diesel | 4.83 | 0.355 |
| Crushing (Impact Crusher) | Electricity | 16.20 | 2.470 |
| *Aux: Dust Suppression* | Electricity | 0.22 | 0.030 |
| Separation (Vibrating Screen) | Electricity | 0.68 | 0.100 |
| *Aux: Magnetic Separator* | Electricity | 0.12 | 0.020 |
| Conveying | Electricity | 1.03 | 0.160 |
| Stockpiling (Excavator) | Diesel | 4.83 | 0.355 |
| **TOTAL (per 1 ton)** | | **100.4** | **8.86** |

### 3.1.2 Recycled Textile Fiber

Table 6 shows the total GWP and the CED to produce I kg of recycled textile fiber. The LCIA results indicate that transportation dominates the energy demand of textile waste fiber recycling, accounting for approximately 76% of total energy consumption). This dominance is attributed to the low bulk density of textile fibers, which leads to inefficient payload utilization and increased transport energy per unit mass.
In contrast, electricity-driven processing stages contribute the majority of on-site GHG emissions, with drying and opening operations being the most energy-intensive among the mechanical processes. The combined results show the sensitivity of textile recycling systems to transport distance and material density, suggesting that logistical optimization and densification strategies might significantly reduce overall environmental impacts.
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*Table 6: LCI and Impact Results for producing 1 kg of Textile Fiber.*

| Process Stage | Energy Source | Energy (MJ/kg) | GHG (kg $CO_2$e/kg) |
|---|---|---|---|
| Transportation | Diesel | 1.96 | 0.120 |
| Washing | Electricity | 0.107 | 0.016 |
| Drying | Electricity | 0.193 | 0.030 |
| Shredding | Electricity | 0.075 | 0.011 |
| Opening | Electricity | 0.176 | 0.027 |
| Packing | Electricity | 0.049 | 0.008 |
| **TOTAL (per 1 kg)** | | **2.56** | **0.212** |

# 4. Discussion

*4.1 Recycled Coarse Aggregate (RCA)*

The environmental assessment of 1 ton of recycled coarse aggregate (RCA) resulted in a Global Warming Potential (GWP) of **8.86 kg $CO_2$-eq** and a cumulative energy demand of **100.4 MJ**. In contrast, published life-cycle assessment (LCA) studies report average GWP values of approximately **28.6 kg $CO_2$-eq/t** and non-renewable energy demand of around **401 MJ/t** for natural aggregates (NA). This comparison indicates an approximate 69% reduction in GWP when RCA is used as a substitute for virgin aggregates [26], [27]. Such reductions are consistent with previous studies that identify recycled aggregates as a lower-impact alternative to conventional aggregate production.

A direct, site-specific comparison between RCA and NA production, however, is inherently difficult due to substantial variability in aggregate properties, extraction techniques, crushing technologies, and operating conditions across several regions and production sites. This variation is especially marked in the context of Pakistan, where standardized and spatially representative inventory data for natural aggregate production and end-of-life landfilling practices are limited or inadequately reported. As a result, a direct comparison between RCA production and landfilling scenarios could not be robustly established within the local context.

Given these constraints, benchmarking RCA against representative average values from literature provides a more defensible and transparent basis for environmental comparison. Despite uncertainties related to regional variability and data availability, the results reliably demonstrate that RCA shows markedly lower environmental burdens than natural aggregates. This advantage is especially evident when transport distances are comparable, a factor widely recognized as a dominant contributor to the environmental impacts associated with aggregate production and supply chains[27].

*4.2 Recycled Textile Fiber*

The environmental assessment of 1 kg of recycled textile fiber conducted in this study resulted in a Global Warming Potential (GWP) of **2.12 kg $CO_2$-eq** and a cumulative energy demand (CED) of **2.56 MJ**. In comparison, a recently published life-cycle assessment reports a GWP of **0.338 kg $CO_2$-eq/kg** and a **CED of 3.610 MJ/kg** for recycled textile fiber production under a different system configuration [28].Although both studies employ comparable functional units and broadly similar system boundaries, the variation in results can be attributed to differences in process modeling and underlying assumptions.

In the referenced study, the recycling process is based on **GM 600** and **GM 250** machines, which primarily perform opening and cleaning functions and do not represent dedicated washing or sorting operations. By contrast, the present study explicitly models separate washing and sorting stages, including manual sorting, to better reflect industrial recycling practice. Transportation was also modeled differently, with this study adopting **32-ton heavy-duty trucks** from the Ecoinvent database, whereas the referenced study assumes trucks with a **2,000 kg** carrying capacity, resulting in higher transport intensity per functional unit. In addition, conservative (pessimistic) assumptions were intentionally applied to energy use and transport to avoid underestimation of impacts. As a result, although the calculated GWP is higher than that reported in the literature, the findings provide a robust and transparent estimate of the environmental performance of recycled textile fiber production under realistic industrial conditions.

Textile waste fiber, like several alternative fiber reinforcements, is primarily utilized in concrete to enhance **toughness, ductility, and crack control**, rather than to significantly increase compressive strength. Previous studies have demonstrated that fibers such as **recycled PET, basalt, jute, and kenaf** provide comparable post-cracking and deformation-related benefits when incorporated into cementitious composites.

To place the environmental performance of textile waste fiber in a broader sustainability context, its life-cycle greenhouse gas (GHG) emissions are compared with those of other fibers commonly investigated for concrete applications, as presented in Table 7. All comparative values are reported in the literature as cradle-to-gate GWP expressed per unit mass of fiber.

*Table 7: Comparison of GWP of fibers used in concrete.*

| Fiber Type | GWP (kg $CO_2$e / kg) | Reference |
|---|---|---|
| **Textile waste fiber** | **0.212** | **This study** |
| Recycled PET fiber | ~0.45 | [29] |
| Basalt fiber | ~1.90 | [30] |
| Jute fiber | ~0.57 | [31] |
| Kenaf fiber | 0.45–0.52 | [32] |

The comparison shows that textile waste fiber exhibits a lower GHG emission intensity than all other fibers considered, including recycled PET, basalt, jute, and kenaf fibers. While these alternative fibers have been shown to improve cracking resistance and post-peak behavior in concrete, their higher life-cycle emissions highlight the environmental advantage of textile waste fiber. The results therefore underline the strong potential of textile waste fiber as a low-carbon, circular reinforcement material for sustainable concrete applications.

## 5. Conclusions

This study presented a cradle-to-gate life cycle assessment of Recycled Coarse Aggregate (RCA) and recycled textile waste fiber intended for concrete applications, providing a regionally relevant environmental benchmark for waste-derived construction materials. The results confirm that RCA production exhibits a substantially lower environmental burden than representative values reported for natural aggregate production and landfilling, with transportation and diesel-based material handling identified as the dominant contributors. For recycled textile fiber, transportation governs cumulative energy demand, while electricity-intensive processing stages primarily drive greenhouse gas emissions. The conservative modeling approach adopted assures that the reported results are representative of realistic industrial conditions.

A comparative assessment with fibers commonly used in concrete indicates that recycled textile waste fiber exhibits a lower greenhouse gas emission intensity than recycled PET, basalt, jute, and kenaf fibers, while offering comparable improvements in toughness, ductility, and crack control. These conclusions highlight the possibility of combining RCA and textile waste fiber as a low-carbon, circular material strategy for non-structural and low-to-moderate performance concrete applications.

Future research needs to priorities the development of region-specific environmental and cost data for natural aggregate production and construction and demolition waste landfilling to allow robust local comparisons. A full life cycle assessment of concrete incorporating RCA and recycled textile fibers is also required, extending beyond material production to include construction, service life, and end-of-life stages. In parallel, further studies must focus on mechanical optimization and durability performance of fiber-reinforced RCA concrete, as well as comparative evaluation of textile fibers in both RCA- and natural aggregate-based concrete systems, to support the development of low-carbon concrete solutions.

## Abbreviations

1. ASTM – ASTM International
2. CED – Cumulative Energy Demand
3. CSCE – Conference on Sustainable Civil Engineering
4. GHG – Greenhouse Gas
5. GWP – Global Warming Potential
6. ISO – International Organization for Standardization
7. LCA – Life Cycle Assessment
8. LCI – Life Cycle Inventory
9. LCIA – Life Cycle Impact Assessment
10. NA – Natural Aggregates
11. NEEDS – New Energy Externalities Developments for Sustainability
12. NEPRA – National Electric Power Regulatory Authority
13. RCA – Recycled Coarse Aggregates / Recycled Concrete Aggregates

14. T&D – Transmission and Distribution

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