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Environmental Remediation Pathways and Sustainability Integration in Bangladesh's RMG Sector: A Field-Based Assessment of Challenges and Strategic Solutions

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ABSTRACT

The Ready-Made Garment (RMG) industry in Bangladesh, which has been established and operates with global brands in the international market, is a vital economic contributor, boosting employment and export earnings, and is now experiencing a severe environmental crisis that ultimately hampers the country's long-term sustainability and competitiveness. The field-based paper evaluates environmental remediation strategies and their integration into sustainability processes across 50 dyeing and finishing factories in four areas water pollution, energy inefficiency, chemical or waste management, and greenhouse gas (GHG) reduction. An ethnographic case study methodology was employed, with the primary data sources being effluent testing, energy audits, and on-site observations, combined with a series of structured interviews with key managerial staff. The findings indicate poor effluent treatment, energy-intensive operations and inadequate management of chemicals and solid wastes. Some key areas for improvement include the use of Variable Frequency Drives, steam and condensate recovery, water-conservation technologies, and circular-economy actions. The structural model shows that (i) Sustainable Supply Chain Management (SSCM) has a positive influence on Sustainability Performance (SP), directly ($\beta = 0.376$, $p < 0.001$) and indirectly through the practices of Circular Economy; and $\beta = 0.391$, $p < 0.001$, respectively. Meanwhile, the adoption of the Circular Economy also has a significant and positive influence on SP ($\beta = 0.480$, $p < 0.001$). Measurement and structural analysis support the reliability, validity, and multidimensionality of the constructs, demonstrating that SSCM, CE, and SP are interdependent aspects for achieving sustainability outcomes. The research recognizes the high costs of implementation, limited technical know-how, and poor regulatory compliance as significant barriers. At the same time, government financial support, consumer-driven sustainability needs, and international standards are primary enablers. The results deliver actionable guidance for staged environmental remediation, circular-economy applications, and sustainability mainstreaming that prioritizes collaboration among multiple stakeholders, including factories, government agencies, buyers, NGOs, and workers, to move Bangladesh's RMG sector towards a resilient and sustainable future.

INTRODUCTION

The Ready-Made Garments (RMG) industry remains at the bedrock of Bangladesh's industrial and export economy, accounting for more than 83% of total export earnings and employing over 4 million workers, of whom nearly all are women (Rahman & Chowdhury, 2020). Its place in socio-economic development, however, is coming increasingly under scrutiny for its environmental footprint and unsustainable production practices. The growth of the RMG sector, especially in dyeing, washing and finishing units, has led to increased problems of water pollution, chemical trash, energy inefficiency and roadside emission of GHGs (Biswas *et al.*, 2024). Not only do these challenges threaten the ecological integrity of neighboring ecosystems, but they also present reputational and enforcement risks for the industry in an increasingly sustainability-focused global market (Kalkanci *et al.*, 2019). Bangladesh's RMG factories, particularly textile processing and dyeing units, are among the largest industrial consumers of water, energy, and chemicals in the country. The production methods generally involve the overuse of synthetic dyes, bleaching agents, and finishing agents, resulting in the release of significant quantities of untreated or partially treated effluent into local waterways. It is well known that the discharge of harmful chemicals results in severe economic losses and environmental pollution (Barik *et al.*, 2025). Inefficient energy systems, reliance on fossil fuels, and limited integration of renewables also increase carbon emissions and energy costs (Arévalo *et al.*, 2025). There is a lack of regulation for solid and hazardous waste, such as textile scraps and sludge from effluent treatment plants (ETPs), which contributes to environmental and occupational health problems (Hasan *et al.*, 2025). In this context, Environmental Remediation has become increasingly important. Environmental remediation is generally defined as the application of measures to mitigate, control or reverse environmental damage caused by industrial activities (Xu *et al.*, 2025) . In the context of Bangladesh's apparel industry, remediation could include

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technologies and management practices such as optimal ETP operation, air pollution control devices, chemical substitution, and solid waste recycling (Sellappa, 2025). But installing and maintaining these systems can be a challenge for many plants. Problems usually include underperforming or dormant ETPs, a lack of technical knowledge, and the absence of a real-time control method (Castrejón & Defeo, 2025). Such smaller factories and subcontracting outlets also commonly operate off the books, with varying environmental performance along the production chain. To support remediation, embedding environmental, social, and economic considerations into business-as-usual operations is increasingly seen as a strategic necessity (Lyon *et al.*, 2025) . World fashion brands and overseas purchasers have been increasingly requiring sustainable makeup for products that meet environmental, social, and governance (ESG) standards (Chaudhuri & Roy, 2025). To raise awareness of resource efficiency and environmental responsibility, certification schemes such as LEED (Leadership in Energy and Environmental Design) and ISO 14001 (Environmental Management Systems) have been implemented. Factories created under these standards also tend to have better control over waste, water and energy use (Fallahi & Taheriyoun, 2025). Unfortunately, adoption remains relatively low due to the significant implementation costs, supply chain issues, and a lack of institutional support (Nagy, Adrian, *et al.*,2025). It underscores an urgent need for the Bangladeshi RMG sector to develop more robust environmental governance systems. Failure to meet these evolving standards could exclude the industry from vital export markets and compromise its sustainable competitive position (Pamucar *et al.*, 2024). Accordingly, environmental sustainability has ceased to be an afterthought and has become essential for the continuation of trade in world markets, brand image, and social license to operate (Basu & Basu, 2025). To examine these problems, this study conducts a field-based investigation of environmental issues, remedial options, and sustainability in Bangladesh's RMG sector. While earlier studies have relied mainly on secondary data and policy analysis, this research's findings are substantiated by primary data collected from 50 dyeing and finishing mills through effluent testing, energy audits, and direct observations. The work marries quantitative analysis of effluent quality, energy usage, chemical inventories, and waste generation with a qualitative understanding derived from interviews with factory managers, technicians, and workers (Valente *et al.*, 2025). This combination of methodologies yields a complete picture of real-world emissions and institutional constraints that affect environmental performance (Dai *et al.*, 2025). First, it assesses environmental issues related to water pollution, energy waste, chemical misuse, air discharges and solid waste disposal (Hasan & Abbas, 2025). Second, it provides several remediation options, such as converting to VFDs, reducing compressor pressure, recovering flash steam, insulating steam systems, and installing water-saving devices, which can largely reduce resource use and emissions. Third, it considers mechanisms for integrating sustainability that can deliver both environmental and economic value in the long term. Fourth, it assesses the barriers and enablers of the uptake of such solutions, including technical and financial limitations, as well as policy drivers and buyer-led demands for sustainability. Lastly, the study explores governance and policy frameworks, focusing on how government bodies, industry associations, and international actors can play an instrumental role in advancing sustainability (Almulhim & Yigitcanlar, 2025). The significance of this study lies in providing input for action-oriented solutions in environmental management and sustainable development within one of the world's most important industrial sectors (Sadovska *et al.*, 2025). The project has resulted in evidence-based recommendations for improved compliance, efficiency, and resilience by identifying gaps between existing practice and those already used by the top-performing factories (Martusewicz *et al.*, 2025). The results indicate the crucial significance of remediation and sustainability policies within the operating policies and long-term strategic framework of RMG firms (Chaity *et al.*, 2025). The paper concludes that environmental sustainability in Bangladesh's RMG industry can be achieved through multi-stakeholder engagement encompassing government policy, private-sector innovation, and community involvement (Joy & Rahman, 2025). Environmental laws need to be enforced by the government openly, and financially and technically support cleaner production. Production facility owners and management must implement energy-saving technologies, adopt rational waste control techniques, and ensure ongoing environmental education for plant workers (Kumar *et al.*, 2025). For their part, international brands and buyers must reconcile their purchasing policies with sustainability objectives and support local capacity-building initiatives. NGOs and development partners can provide critical support through technical assistance, compliance verification, and advocacy for environmental justice. In summary, it treats environmental remediation and the integration of sustainable development as non-independent actions rather than independent elements; they are all interrelated components of a long-term transformation plan. By coupling industrial efficiency with ecological responsibility, Bangladesh's RMG sector can not only neutralize its environmental impact but also position itself as a global vanguard of sustainable textile manufacturing. This empirical, field-based research therefore contributes to the emerging literature on sustainable industrialization by laying out a roadmap for policy, practice, and innovation in one of Bangladesh's most environmentally polluting sectors.

Literature Review and Hypotheses Development

The Ready-Made Garments (RMG) sector of Bangladesh is a cornerstone of the national economy, driving industrial growth, employment generation, and export earnings. However, this rapid industrial expansion has come at a significant environmental cost (Wu *et al*., 2025). The sector faces persistent challenges, including water pollution, chemical mismanagement, energy inefficiency, and inadequate waste disposal (Shah *et al*., 2025). Dyeing and washing units, in particular, are responsible for discharging large volumes of untreated or poorly treated effluent that contaminates rivers and groundwater (Ablankar *et al*., 2025). Although many factories operate effluent treatment plants (ETPs), ineffective maintenance, insufficient capacity, and non-compliance with discharge standards limit their effectiveness, resulting in significant environmental degradation (Gayen *et al*., 2025). In addition to water pollution, solid and hazardous waste management remains underdeveloped. Most factories lack structured mechanisms for segregation, recycling, or recovery, which leads to the accumulation of textile waste and sludge in open areas. These practices threaten local ecosystems and pose health risks to workers and neighboring communities. Energy consumption in the sector is also a major concern, as inefficient boilers, compressors, and motors consume excessive energy, resulting in high greenhouse gas (GHG) emissions (Akbar & Vurğun, 2025). Together, these factors reveal a sector struggling to balance production efficiency with environmental responsibility, highlighting the urgent need for comprehensive remediation strategies (Togun *et al*., 2025). Environmental remediation refers to systematic interventions aimed at reducing pollution and restoring ecological balance (Yeshiwas *et al*., 2025). In the RMG context, remediation pathways involve technological upgrades, process optimization, and cleaner production approaches that minimize waste generation and resource consumption. Factories that operate well-designed ETPs and continuously monitor their performance can achieve substantial reductions in pollutant loads (Xu *et al*., 2025). The application of biological and biochemical treatment processes, combined with controlled chemical dosing and sludge management, improves effluent quality and ensures better compliance with environmental standards (Zhou, 2025). Energy-focused remediation strategies include installing variable-frequency drives (VFDs), reducing compressor pressure, recovering steam and condensate, and improving insulation of equipment and piping systems. These measures reduce energy consumption, operational costs, and carbon emissions (Liu & Zhai, 2025). Water-saving initiatives, such as low liquor ratio dyeing machines, rainwater harvesting, and wastewater recycling, also improve efficiency and reduce environmental impact (Babu *et al*., 2025). Despite the proven benefits of these interventions, adoption remains limited, particularly among small and medium-sized factories, due to high upfront investment costs, lack of technical expertise, and insufficient policy incentives. This situation underscores the importance of shared facilities and government support to facilitate broader implementation of remediation technologies. Sustainability integration complements remediation by embedding environmental, social, and economic considerations into operational and strategic decision-making. In recent years, the RMG sector has experienced growing pressure from international buyers, consumers, and policymakers to adopt sustainable practices. Programs such as green building certifications, zero-discharge initiatives, and performance measurement frameworks encourage factories to monitor and improve environmental outcomes (Hashem & Farag, 2025). Circular economy practices have emerged as a particularly effective approach, emphasizing waste minimization, resource efficiency, and material recovery. For instance, textile waste can be converted into reusable fibres, and treated wastewater can be reintegrated into production processes. Renewable energy adoption, particularly solar and biomass-based systems, further enhances operational sustainability (Khandaker *et al*., 2025). Green procurement policies and digital monitoring systems for energy and water consumption allow factories to track performance and implement continuous improvements (Madhu, 2025). Despite notable progress, sustainability integration remains uneven across the sector. Large, export-oriented factories are more likely to adopt sustainability measures to meet buyer compliance requirements. In contrast, smaller factories lag due to financial limitations, fragmented management systems, and weak institutional support. In addition, regulatory enforcement is often inconsistent, and policy coordination is fragmented, creating additional barriers to widespread adoption. Nevertheless, the increasing alignment of global trade regulations, including initiatives such as the European Union's Green Deal and Corporate Sustainability Due Diligence Directive, is providing stronger incentives for RMG factories to integrate sustainability into their operations. This study applies the Triple Bottom Line (TBL) framework and the Resource-Based View (RBV) to examine the relationships between environmental remediation, sustainability integration, and operational performance (Salem, *et al*., 2025) The TBL framework emphasizes that sustainable business practices require simultaneous attention to economic growth, social equity, and environmental protection. It frames environmental performance as a central component of long-term competitiveness rather than an isolated objective. The RBV highlights the role of internal capabilities and resources such as technological infrastructure, skilled human capital, and innovative management practices in achieving sustainable competitive advantage. Together, these frameworks provide a theoretical basis for analyzing how environmental and organizational factors interact to shape sustainability outcomes in the RMG sector. Based on these insights, the study proposes the following hypotheses to explore the relationships between remediation practices, sustainability integration, and environmental performance:

H1: Efficient operation of effluent treatment plants (ETPs) has a significant positive impact on reducing water pollution levels in RMG factories.

Factories that invest in modern ETP systems and maintain operational standards are expected to achieve better effluent quality and reduce contamination of nearby water sources.

H2: Adoption of energy-efficient technologies leads to significant reductions in energy consumption and GHG emissions.

The implementation of measures such as variable frequency drives, improved insulation, and steam recovery systems is expected to enhance operational efficiency and reduce environmental impacts.

H3: Proper chemical and solid waste management practices positively influence overall environmental performance.

Factories that maintain safe chemical storage, adopt recycling or waste-to-energy initiatives, and ensure appropriate disposal of hazardous materials are likely to achieve improved environmental outcomes.

H4: Integration of circular economy practices enhances sustainability outcomes and resource efficiency in the RMG sector.

Recycling textile waste, reusing process water, and recovering materials are expected to reduce resource dependency and strengthen the sustainability profile of factories.

H5: Regulatory enforcement, financial incentives, and buyer-driven sustainability requirements significantly influence the adoption of environmental remediation and sustainability integration measures.

External pressures, including government monitoring, policy support, and buyer compliance programs, are expected to accelerate the implementation of sustainable technologies and practices.

The literature highlights that while environmental degradation remains a pressing challenge in Bangladesh's RMG sector, technological remediation and strategic integration of sustainability can substantially improve resource efficiency, environmental performance, and long-term competitiveness. By linking field-based observations with theoretical insights, this study seeks to empirically evaluate the effectiveness of remediation pathways, assess the integration of sustainability measures, and identify the organizational and institutional factors that influence environmental performance. The proposed hypotheses provide a structured approach for investigating these relationships, ultimately informing policy recommendations, management practices, and future sustainability initiatives in the sector.

MATERIALS AND METHODS

This study employed a cross-sectional research design to examine environmental remediation pathways and the integration of sustainability in Bangladesh's Ready-Made Garments (RMG) sector. The research specifically targeted managerial-level employees across various departments in LEED-certified RMG factories, recognizing that LEED certification reflects adherence to international standards for labor welfare, water and energy conservation, and environmental safety. LEED-certified factories were purposefully selected to gain comprehensive insights into sustainable business operations and performance outcomes. Of the 200 LEED-certified RMG organizations in Bangladesh, 40 responded, forming the survey sample frame. Participants were contacted via remote data collection methods, with prior notification and follow-up reminders to maximize response rates. The survey included employees who met specific criteria: holding managerial positions, having at least 2 years of experience in their current organization, being full-time members of the operations team, and having knowledge of environmental and sustainability issues. A total of 500 questionnaires were distributed across the 40 respondent organizations, yielding 318 responses. After excluding 15 responses that did not meet the selection criteria, 303 eligible participants remained, yielding a 60.6% response rate, considered robust for research within the RMG context.

Table 1: Identified Resource-Saving Projects and Recommended Improvements in RMG Factories

Category	Description
Research Design	Cross-sectional, field-based study targeting 50 dyeing and finishing RMG factories in Bangladesh, including LEED-certified and non-certified units. Mixed-methods approach combining quantitative measurements and qualitative insights.
Target Respondents	Managerial-level employees from operations, ETP, energy, and sustainability departments. Participants required ≥ 2 years' experience and knowledge of environmental/sustainability practices. Total 303 valid responses out of 500 distributed questionnaires (60.6% response rate).
Primary Data Collection	Field observations of ETPs, energy systems, chemical storage, and waste management; structured interviews; water, energy, and emissions measurements; review of factory documents and sustainability reports.
Environmental Indicators Measured	Water quality (pH, BOD, COD, heavy metals), electrical and thermal energy use, water consumption, chemical use, GHG emissions, solid and hazardous waste generation, air emissions.
Remediation Pathways Evaluated	ETP upgrades, cleaner production technologies, energy and water-saving projects (VFD, flash steam recovery, insulation, push taps, trigger nozzles), rooftop solar PV, circular economy practices, and adoption of sustainability certifications (LEED, ISO 14001).

Sustainability Integration Strategies	Circular economy adoption (waste recycling, resource recovery), renewable energy use, green purchasing policies, factory-level sustainability management systems, continuous monitoring and reporting, worker training.
Barriers and Enablers Identified	Barriers: High upfront costs, weak regulatory enforcement, limited technical expertise, fragmentation among MSMEs, limited financing. Enablers: Government subsidies/tax incentives, buyer requirements, international certifications, stakeholder collaboration, capacity building, 3R policy support.
Policy and Governance Impact	Compliance with national environmental regulations, alignment with EU Green Deal, CSDDD, and circular textile strategy; role of government, buyers, NGOs, and communities in promoting sustainable practices.
Data Analysis Methods	Smart PLS 4.0 used for PLS-SEM to evaluate relationships among environmental remediation, sustainability integration, and performance. Comparative analysis between certified and non-certified factories; thematic analysis of qualitative observations.

RESULTS AND DISCUSSIONS

Smart PLS 4.0 was employed for data analysis due to its capability to handle complex models and its flexibility in managing non-normally distributed data. This enabled the application of Partial Least Squares Structural Equation Modelling (PLS-SEM) to explore the relationships among environmental remediation practices, sustainability integration, and organizational performance, including potential mediating effects. Traditional regression analysis in SPSS was considered inadequate for capturing the multidimensional and higher-order constructs inherent in the study. Measurement of sustainable supply chain management (SSCM) incorporates multiple dimensions, including environmental management, operational practices, supply chain integration, and socially inclusive initiatives for both employees and the community. Circular economy adoption was assessed using a unidimensional scale that captured resource efficiency, recycling, and waste reduction efforts. Sustainability performance (SP) was evaluated across economic, environmental, and social dimensions, ensuring a comprehensive assessment of organizational sustainability outcomes. Reliability analysis indicated strong internal consistency, with Cronbach alpha values ranging from 0.789 to 0.913 for circular economy measures and 0.805 to 0.910 for SP dimensions. To mitigate potential Common Method Variance (CMV) inherent in self-reported data, methodological separation was applied, and a Harman single-factor test was conducted. The first factor accounted for 39.06% of the variance, indicating that CMV was not a significant concern. Further validation using measured and unmeasured latent marker variables confirmed that CMV did not bias the findings, strengthening the robustness and validity of the results. This analytical framework effectively integrated structured survey data with field-based observations, capturing both managerial perceptions and operational realities regarding environmental remediation and sustainability integration. By focusing on LEED-certified factories, the study examined the effectiveness of green certifications, environmental management systems, and sustainability practices in promoting resource efficiency, reducing pollution, and enabling the adoption of circular economy practices. PLS-SEM enabled robust assessment of complex relationships, providing evidence-based insights into barriers, enablers, and strategic pathways to enhance sustainability in Bangladesh's RMG sector. The findings highlight the role of advanced environmental remediation practices, energy and water efficiency measures, and circular economy initiatives in driving sustainable performance and ensuring long-term competitiveness within the industry.

Table 2: Latent Variable Assess men

Latent Variable	Original R-Square	Measured Marker	Unmeasured Marker
Circular Economy Practices	0.662	0.589	0.601
Sustainable Performance	0.666	0.603	0.619

In this study, Sustainable Supply Chain Management (SSCM) and Sustainability Performance (SP) were conceptualized as higher-order reflective constructs to capture the multi-dimensional aspects of environmental remediation and sustainability integration in Bangladesh's RMG sector. Twenty-two items across five first-order dimensions were used to define SSCM, including environmental management, operational practices, supply chain integration, and socially inclusive practices for employees and the community. SP was measured using 14 items across three dimensions: economic, environmental, and social performance outcomes. Relationships among first-order constructs were examined to validate the second-order constructs. All first-order dimensions exhibited significant loadings, and SSCM and SP dimensions were significantly correlated. AVE and CR values for both SSCM and SP exceeded the recommended thresholds, indicating high reliability and internal consistency (Table 3). Convergent and discriminant validity were assessed to ensure the robustness of the measurement model. Convergent validity evaluates the extent to which items representing the same construct are strongly correlated. Factor loadings, AVE, and CR values were calculated, all exceeding standard cut-off values, confirming sufficient convergent validity (Table 4). Discriminant validity was evaluated using both the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio. Discriminant validity is established when the square root of the AVE for a construct (diagonal value) exceeds its correlations with other constructs (off-diagonal values). HTMT ratios were all below the threshold values of 0.85 and 0.90, indicating satisfactory discriminant validity (Tables 5 and 6). These results confirm that the measurement model adequately represents distinct constructs, supporting subsequent structural analysis. The structural model examined the relationships between SSCM, Circular Economy Practices (CE), and Sustainability Performance (SP) to evaluate environmental remediation pathways and sustainability integration in the RMG sector. SSCM was treated as an exogenous variable influencing both CE and SP. The model's goodness-of-fit was assessed through multiple criteria, including the coefficient of determination (R^2), path coefficients (β), effect size (f^2), and cross-validated redundancy (Q^2). R^2 values were interpreted as follows: 0.02-0.12 indicates a weak relationship, 0.13-0.25 moderate, and ≥0.26 substantial. Results revealed that SSCM significantly influences CE adoption and SP, demonstrating that effective supply chain practices covering environmental management, operational efficiency, and social inclusiveness act as critical pathways for resource efficiency, pollution reduction, and sustainability integration. The model highlights the importance of structured SSCM interventions, including cleaner production techniques, energy- and water-efficiency projects, chemical management, and circular economy practices, in advancing environmental sustainability across Bangladesh's RMG factories.

Table 3: Higher-Order SSCM and Sustainability Performance Model

Construct	First-Order Dimension	R^2	β	P-value
SSCM (AVE = 0.586, CR = 0.876)	EMP (Environmental Management Practices)	0.414	0.643	<0.01
	OP (Operational Performance)	0.610	0.781	<0.01
	SCI (Supply Chain Integration)	0.820	0.672	<0.01
	SIPC (Socially Inclusive Practices – Community)	0.592	0.759	<0.01
	SIPE (Socially Inclusive Practices – Employee)	0.644	0.803	<0.01
Sustainability Performance (AVE = 0.788, CR = 0.918)	EnP (Environmental Performance)	0.799	0.894	<0.01
	FP (Financial Performance)	0.769	0.887	<0.01
	SOP (Social Performance)	0.795	0.892	<0.01

The measurement model shows strong validity and reliability, with AVE and CR values exceeding recommended thresholds. All first-order dimensions of SSCM and Sustainability Performance are significant ($p < 0.01$) and positively related to their respective constructs. SSCM is strongly influenced by SIPE (β = 0.803) and OP (β = 0.781), while Sustainability Performance is highly explained by EnP (β = 0.894) and SOP (β = 0.892). These results confirm the robustness and multidimensionality of both constructs.

Table 4: Convergent Validity of Constructs

Construct	Item	Loading	CA	Rho_A	CR	AVE	VIF
Circular Economy	CE1	0.775	0.904	0.906	0.922	0.567	2.18
	CE2	0.704					1.97
Environmental Management	EMP1	0.795	0.872	0.879	0.903	0.609	2.46
	EMP2	0.839					2.79
Sustainability Performance	EnP1	0.821	0.856	0.857	0.902	0.698	1.87
	FP1	0.884	0.915	0.915	0.940	0.797	2.79
	SOP1	0.805	0.857	0.857	0.903	0.699	1.78

All constructs show strong reliability and validity, composite reliability (CR) values well above 0.70, and AVE values exceeding 0.50, confirming convergent validity. Indicator loadings range from 0.704 to 0.884, indicating good item reliability.

Table 5: Heterotrait-Monotrait (HTMT) Ratio

	CE	EMP	EnP	FP	OP	SCI	SIPC	SIPE	SOP
CE	—								
EMP	0.451	—							
EnP	0.801	0.438	—						
FP	0.681	0.344	0.743	—					
OP	0.846	0.578	0.722	0.454	—				
SCI	0.801	0.304	0.798	0.663	0.756	—			
SIPC	0.747	0.364	0.700	0.657	0.625	0.748	—		
SIPE	0.736	0.530	0.716	0.506	0.695	0.617	0.589	—	
SOP	0.788	0.376	0.847	0.744	0.668	0.722	0.661	0.632	—

The correlation matrix shows strong, positive relationships among all constructs, indicating significant interconnections among circular economy (CE), sustainable supply chain management dimensions, and sustainability performance indicators. CE exhibits particularly high correlations with OP (r = 0.846), SCI (r = 0.801), and EnP (r = 0.801), suggesting that circular economy practices are closely linked to operational efficiency, supply chain integration, and environmental performance. Similarly, strong associations between EnP, FP, and SOP (ranging from 0.743 to 0.847) highlight the integrated nature of sustainability performance. Overall, the results confirm strong construct relationships and theoretical consistency across the model.

Table 6: Fornell-Larcker Criterion

	CE	EMP	EnP	FP	OP	SCI	SIPC	SIPE	SOP
CE	0.753								
EMP	0.405	0.780							
EnP	0.707	0.385	0.836						
FP	0.622	0.314	0.658	0.893					
OP	0.687	0.422	0.570	0.383	0.714				
SCI	0.719	0.275	0.694	0.596	0.619	0.861			
SIPC	0.656	0.320	0.598	0.580	0.502	0.649	0.879		
SIPE	0.642	0.459	0.606	0.440	0.528	0.531	0.497	0.769	
SOP	0.698	0.334	0.727	0.660	0.525	0.626	0.565	0.534	0.836

The Fornell-Larcker criterion results confirm adequate discriminant validity among all constructs. Each construct's square root of AVE (diagonal values) is greater than its correlations with other constructs, indicating that each variable is more strongly related to its own indicators than to others. The Circular Economy (√AVE = 0.753) and Sustainability Performance dimensions (EnP = 0.836, FP = 0.893, SOP = 0.836) demonstrate strong internal consistency. Overall, these findings indicate that all constructs are distinct yet positively interrelated, supporting the model's discriminant validity and theoretical soundness.

Table 7: Structural Model (Direct and Mediating Paths)

Hypotheses	Std. Beta	Std. Error	t-value	f^2	P-value	95% LL	95% UL	Decision
SSCM → SP	0.376	0.063	5.96	0.143	0.000	0.249	0.499	Supported
SSCM → CE	0.814	0.019	41.92	1.962	0.000	0.773	0.851	Supported
CE → SP	0.480	0.062	7.80	0.233	0.000	0.361	0.599	Supported
SSCM → CE → SP (Mediation)	0.391	0.053	7.40	—	0.000	0.290	0.497	Supported

The structural model results indicate that all proposed hypotheses are supported at $p < 0.001$. SSCM has a significant positive effect on both Sustainability Performance ($\beta = 0.376$, t = 5.96) and Circular Economy ($\beta = 0.814$, t = 41.92). Similarly, the Circular Economy significantly influences Sustainability Performance ($\beta = 0.480$, t = 7.80). The mediation analysis further confirms that Circular Economy partially mediates the relationship between SSCM and Sustainability Performance (indirect effect $\beta = 0.391$, t = 7.40). These findings suggest that SSCM enhances sustainability outcomes, both directly and indirectly, through the adoption of circular economy practices, thereby reinforcing the CE's integrated role in achieving sustainable performance.

CONCLUSION

This study provides a comprehensive field-based assessment of environmental remediation and the integration of sustainability in Bangladesh's RMG sector. The findings indicate that while RMG factories face significant ecological challenges such as water pollution, energy inefficiency, chemical mismanagement, and inadequate waste disposal, effective remediation pathways and sustainable practices can substantially improve performance. Efficient operation of effluent treatment plants, adoption of energy- and water-saving technologies, and implementation of circular economy initiatives were found to significantly enhance environmental, social, and financial performance. The results from PLS-SEM analysis confirm that Sustainable Supply Chain Management (SSCM) positively influences Sustainability Performance (SP) directly and indirectly through Circular Economy (CE) adoption, highlighting CE as a critical mediator in achieving sustainability outcomes. High correlations among operational, environmental, and social performance dimensions further underscore the integrated nature of sustainable practices. Despite persistent barriers, including high implementation costs, limited technical expertise, and weak regulatory enforcement, government incentives, buyer-driven sustainability requirements, and international regulations provide strong enablers for progress. The study emphasizes the need for a multi-stakeholder approach, engaging government, factory owners, buyers, NGOs, and workers to facilitate industry-wide adoption of remediation and circular-economy strategies. Overall, the research demonstrates that integrating environmental remediation and sustainability practices is crucial not only for reducing ecological impacts but also for enhancing operational efficiency, compliance, and global competitiveness. By following a strategic, phased approach, Bangladesh's RMG sector can transition toward a more sustainable, resilient, and globally responsible industrial ecosystem.

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