



Investigating the Demand of Various Dyes used for Cellulosic Fiber: A Survey-Based Study of Dyeing Industries in Bangladesh

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ABSTRACT

Bangladesh is one of the world's top exporters of ready-made clothing, and the country's textile dyeing industry is a vital part of its garment manufacturing sector. With an emphasis on reactive, direct, vat, sulfur, basic, and pigment dyes in the woven, knit, yarn, and jute dyeing industries, this study methodically examines the demand and consumption patterns of several dye classes used for cellulosic fiber dyeing. Ten woven dyeing companies, twenty-eight knit dyeing factories, eight yarn dyeing factories, and three jute dyeing factories were among the 49 dyeing enterprises in Bangladesh that participated in a thorough survey. To ascertain the percentage use of each dye class, quantitative data on monthly dye consumption (in metric tons) were gathered and examined. The findings clearly show that reactive dyes dominate all industry types: knit dyeing factories used only reactive dyes (100%), whereas the woven, yarn, and jute dyeing sectors recorded reactive dye shares of 61.09%, 95.86%, and 51.11%, respectively. Reactive dyes' strong performance attributes, such as their compatibility with cellulosic substrates, moderate-to-high exhaustion rates (50–95%), and outstanding wash fastness (grade 3 and beyond), were found to be the main causes of their extensive use. The results offer quantitative proof for resource planning, environmental impact evaluations, and dye market dynamics in Bangladesh's textile industry. For dye house managers, supply chain planners, and legislators involved in sustainable textile production, this report is a fundamental resource.

KEYWORDS: Cellulosic Fiber; Dyeing Industry; Dye Consumption; Textile Manufacturing; Survey Study

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1. INTRODUCTION

Plant allelochemicals are the organic compounds produced as plant secondary metabolites and play an important role in plant-plant, plant-microorganism, and plant-insect interaction, beneficially and detrimentally. The global textile industry is one of the most significant contributors to industrial production and international trade, with cellulosic fibers—primarily cotton, viscose, linen, and jute—forming the backbone of both apparel and technical textile manufacturing. Bangladesh, as the second-largest exporter of ready-made garments (RMG) globally, operates a dense network of dyeing, printing, and finishing facilities that process millions of metric tons of cellulosic substrates annually (BGMEA, 2023; World Bank, 2022). Product quality, production efficiency, water and chemical consumption, and environmental compliance are all directly impacted by the

choice of suitable dye classes for cellulosic fibers.

Cellulosic fibers are characterized by an abundance of hydroxyl (-OH) groups within the cellulose polymer chain, which confer hydrophilicity and provide reactive sites for dye fixation (Broadbent, 2001). Different dye classes exploit these hydroxyl groups in mechanistically distinct ways: reactive dyes form covalent bonds with fiber, direct dyes adhere via van der Waals and hydrogen bonding, vat dyes undergo reduction–oxidation fixation cycles, sulphur dyes utilize a comparable reduction mechanism, while basic and pigment dyes operate through ionic attraction and physical entrapment, respectively (Hunger, 2004; Shore, 2002). Reactive dyes, which form a covalent bond with cellulose hydroxyl groups, are the dominant class for cotton and viscose coloration worldwide because of their bright shades and generally good wash and rubbing fastness (Kushwaha et al.,

2025).

Despite this mechanistic diversity, dye consumption patterns in industrial settings are shaped by a complex interplay of technical performance parameters, economic constraints, environmental regulatory pressures, and end-use requirements (Zollinger, 2003). In the Bangladeshi context, where the RMG sector contributes over 84% of total export earnings, understanding dye demand across industrial sub-sectors is of immense strategic importance (Export Promotion Bureau Bangladesh, 2023). However, quantitative, survey-based studies that systematically document dye consumption patterns across multiple dyeing sub-sectors remain scarce in peer-reviewed literature.

Existing literature has focused predominantly on the technical chemistry of dye-fiber interaction (Hunger, 2004; Shore, 2002), effluent treatment (Carneiro et al., 2010; Samsami et al., 2020), and the environmental fate of textile dyes (Vikrant et al., 2018). Recent research has explored sustainable dyeing technologies including cold pad-batch (CPB) dyeing, which offers significant reductions in energy consumption, salt usage, and effluent generation (Jalil et al., 2026). Additionally, alternative water sources such as rain, river, and sea water have been investigated as dyeing media, demonstrating the potential for reducing freshwater consumption in textile processing (Valley International Journals, 2025). Research on low-salt and salt-free dyeing of cellulose fibers with reactive dyes has also gained momentum, focusing on chemical modification of cellulose and the use of non-aqueous media (Zhang et al., 2025). Comparative, industry-level consumption data, particularly for developing nations with large-scale textile manufacturing bases, are largely absent from the academic record. The present study addresses this gap by providing empirical, survey-derived quantitative data on dye demand across four major dyeing sub-sectors in Bangladesh.

The objectives of this investigation are: (1) to quantify the monthly dye consumption (in metric tons) across woven, knit, yarn, and jute dyeing industries; (2) to determine the relative percentage shares of reactive, direct, vat, sulphur, basic, and pigment dyes in each sub-sector; (3) to evaluate the technical performance characteristics—specifically fastness to light and exhaustion percentage—of dyes used for cellulosic substrates; and (4) to synthesize a comprehensive overview of dye market dynamics in the Bangladeshi textile sector. The findings are expected to inform procurement strategies, environmental compliance planning, and sustainable dye application research.

2. LITERATURE REVIEW

2.1 Cellulosic Fibers and Their Dyeability

Cellulosic fibers, both natural (cotton, linen, jute, ramie) and regenerated (viscose, lyocell, modal), are composed predominantly of the polysaccharide cellulose, a linear polymer of β -D-glucose units linked by 1,4-glycosidic bonds (Lewin, 2006). The main locations for dye attachment are the accessible hydroxyl groups throughout the cellulose backbone. Dye accessibility and uptake rate are determined by the crystallinity of cellulose, which differs among fiber types. To improve dye absorption in cotton, mercerization procedures that break up crystalline areas are frequently used.

The chemical affinity of various dye classes for cellulosic substrates is well-documented. Reactive dyes, introduced commercially in the 1950s through the work of Rattee and Breuer at ICI, remain the industry standard for cellulosic dyeing

owing to their ability to form stable covalent bonds with fiber hydroxyl groups under alkaline conditions (Rattee & Breuer, 1974). This covalent fixation confers superior wash fastness (ISO 105-Co6 grades 4–5) relative to non-reactive dye classes (Shore, 2002). The reactive dyes currently hold approximately 29% share of the global textile dye market, and their demand is continuously growing (Academia.edu, 2025).

2.2 Classification and Properties of Dyes for Cellulosic Substrates

Reactive dyes constitute the most commercially significant class for cellulosic dyeing, with global sales exceeding US\$1.5 billion annually (Hunger, 2004). Their chromophoric systems—primarily azo, anthraquinone, phthalocyanine, and formazan types—span the entire visible spectrum. The reactive moieties (monochlorotriazine, dichlorotriazine, vinylsulphone, etc.) determine fixation temperature and alkali concentration requirements (Zollinger, 2003). A recognized limitation is the degree of dye hydrolysis, which reduces fixation efficiency to 50–95% depending on reactive group type and dyeing conditions (Rattee & Breuer, 1974). Recent developments in low-salt and salt-free dyeing technologies have shown promise in reducing the environmental footprint of reactive dyeing (Zhang et al., 2025).

Vat dyes, particularly anthraquinonoid and indigoid types, offer the highest overall fastness performance (wash fastness: ISO grade 4–5; light fastness: ISO grade 6–8) and are preferred for specialized applications requiring extreme durability (Shore, 2002). However, the two-stage reduction–oxidation process, the use of sodium hydrosulphite as reductant, and the alkali requirements impose environmental and economic penalties that limit their use to high-value substrates (Broadbent, 2001). Direct dyes, while economically accessible and easily applicable, suffer from inferior wash fastness (ISO grade 2–4) and are increasingly restricted to applications where wash performance requirements are less demanding or where aftertreatment with fixatives is employed (Lewin, 2006).

Sulphur dyes occupy an intermediate market position, offering moderate fastness, low cost, and applicability to cellulosic fibers via a reduction mechanism similar to vat dyes; however, their limited shade range (predominantly dark browns, blacks, navy) and the environmental concerns associated with sulphide reductants restrict their scope (Shore, 2002). Basic dyes, originally developed for protein and polyacrylic fibers, find application in cellulosic systems primarily for jute coloration, where their high exhaustion rates (95–100%) and economic efficiency are advantageous, albeit with light fastness limitations (Trotman, 1984).

2.3 Jute Dyeing: Distinctive Characteristics

Jute dyeing presents distinctive challenges compared to cotton dyeing. Jute, being a lignocellulosic material with significant lignin and hemicellulose content, exhibits dyeability by multiple dye classes (International Jute Study Group, 2026; Chakraborty & Pal, 2024). Studies have shown that direct dyes are particularly well-suited to jute's multi-component fiber structure, offering acceptable fastness at modest cost (Trotman, 1984; Ganguly & Datta, 2000). The effect of pH on direct dyeing of jute has been investigated, revealing that dye uptake is significantly influenced by the acidic or alkaline nature of the dye bath (Mondal & Saha, 2018). Compatibility of binary mixtures of direct dyes for jute dyeing has also been studied to optimize color matching and cost-effectiveness (Samanta & Agarwal, 2013).

Research on sulphur dyeing of jute has demonstrated that jute fabrics can be economically dyed with sulphur dyes using optimized processes developed by the Bangladesh Jute Research Institute (Kabir et al., 2008). Reactive dyes, despite their dominance in cotton dyeing, show limited uptake on jute due to its high lignin content and crystallinity. Pretreatment strategies including chitosan treatment and surface modification with polyethylene polyamine or quaternary ammonium reagents have been investigated to improve reactive dye uptake on jute (Haque & Rahman, 2020; Jabbar et al., 2021). Comparative studies on dyeing of jute and cotton with reactive dyes have shown that jute requires different dyeing conditions and exhibits lower color yield compared to cotton (Sinha & Roy Maulik, 2012; Ahmed & Hossain, 2016). Comparative studies on jute dyeing with basic and reactive dyes have also been conducted to evaluate the relative performance of these dye classes (Alam & Rahman, 2018).

2.4 Sustainable Dyeing Technologies

Recent advancements in sustainable dyeing technologies have gained significant attention. Cold pad-batch (CPB) dyeing using reactive dyes has emerged as an energy-efficient alternative to conventional exhaust dyeing, offering savings in water, energy, and chemicals (Jalil et al., 2026). The characterization and dyeing performance of the CPB method have been extensively studied, demonstrating its potential for large-scale industrial application. Research on low-salt and salt-free dyeing of cellulose fibers with reactive dyes has focused on chemical modification of cellulose, development of new reactive dye structures, and the use of non-aqueous media (Zhang et al., 2025).

The use of alternative water sources—rain, river, and sea water—has been investigated as a sustainable approach to reduce freshwater consumption in textile dyeing (Valley International Journals, 2025). Studies have shown that with proper pre-treatment and process optimization, alternative water sources can be effectively utilized for dyeing operations. Garment dyeing technology has also evolved significantly, with recent advances in mechanisms, process variables, and coloration technology expanding the range of achievable effects and improving process efficiency (Rahaman et al., 2026).

2.5 Dye Industry in Bangladesh

Bangladesh's textile and garment manufacturing sector employs over 4 million workers and has been the primary driver of national export growth over the past three decades (BGMEA, 2023). The sector processes predominantly cotton and cotton-blend cellulosic fabrics, establishing reactive dye chemistry as the dominant technology. Several studies have documented the effluent treatment challenges arising from unfixed reactive dye in mill wastewaters (Carneiro et al., 2010; Samsami et al., 2020), but industry-level quantitative demand data remain unreported in peer-reviewed sources. The present study addresses this deficiency through direct primary industry surveying.

Recent sustainability initiatives by BGMEA have set ambitious targets, including reducing carbon emissions by 30%, incorporating sustainable raw materials in 50% of production, and cutting groundwater usage by 50% by 2030 (BGMEA, 2023). These commitments underscore the urgency of understanding current dye consumption patterns to inform environmental compliance planning. As of 2023, Bangladesh has 200 LEED-certified green garment factories, with 73 achieving the highest platinum category, reflecting the industry's growing commitment to sustainability (BGMEA, 2023).

Research on water and chemical consumption in the textile processing industry of Bangladesh has revealed significant variability in resource utilization across factories, highlighting opportunities for efficiency improvements (Uddin et al., 2023). Water vulnerability assessments in Dhaka, Narayanganj, and Gazipur districts have underscored the critical role of textile dye production in regional water stress (Rasmussen et al., 2025). Water reduction strategies in black shade dyeing processes for 100% cotton using pH-neutral non-ionic surfactants and acidic anionic soaping agents have demonstrated that significant water savings can be achieved through optimized processing parameters (Rashed et al., 2025).

International Jute Study Group (IJS) technical bulletins provide reference data for jute dyeing practice (International Jute Study Group, 2026), while peer-reviewed textile chemistry literature (Zollinger, 2003; Shore, 2002) provides the performance benchmarks against which survey results are contextualized in the present work.

3. MATERIALS AND METHODS

3.1 Survey Design and Sampling

A structured survey was conducted among actively operating dyeing facilities in Bangladesh. Industry participants were selected through stratified random sampling across four sub-sector categories: woven fabric dyeing, knit fabric dyeing, yarn dyeing, and jute dyeing. The sampling frame was constructed from the registered membership databases of the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and the Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA), supplemented by the IJS directory for jute processors. Ethical clearance and informed consent were obtained from all participating facilities prior to data collection.

The final sample comprised 49 dyeing facilities: 10 woven dyeing factories, 28 knit dyeing factories, 8 yarn dyeing factories, and 3 jute dyeing factories. This sample size was determined to achieve a 95% confidence level with a $\pm 5\%$ margin of error for the dominant dye category (reactive dyes), consistent with established survey methodology for industrial studies (Cochran, 1977).

3.2 Data Collection Instrument

A structured questionnaire was developed and validated through a pilot study involving five dyeing facilities (not included in the main analysis). The instrument captured: (1) facility type and scale; (2) monthly total dye consumption in metric tons; (3) quantity of each dye class consumed per month, including reactive, direct, vat, sulphur, basic, and pigment/azoic/acid dyes; and (4) primary substrates processed. Data were collected through direct facility visits and cross-checked against purchase records and production logs to minimize reporting bias.

3.3 Data Analysis

Quantitative data were entered into a spreadsheet database and verified for accuracy. Dye demand percentages were calculated as the ratio of mass of each dye class consumed to total dye consumption within each sub-sector, expressed as a percentage. Descriptive statistics (mean, total, percentage share) were computed for each dye class and each industry sub-sector. Summary tables and bar chart representations were generated to visualize comparative consumption patterns across sub-sectors.

4. RESULTS AND DISCUSSION

4.1 Technical Performance of Dyes Used for Cellulosic Substrates

Before discussing consumption patterns, it is instructive to

examine the technical performance characteristics of the principal dye classes applied to cellulosic fibers. Table 1 presents fastness to light and exhaustion rates for the five main dye classes based on published reference data.

Table 1. Fastness and Exhaustion Characteristics of Different Dyes Used for Cellulosic Substrates

Dye Class	% of Dye Used	Fastness to Light (ISO Grade)	Exhaustion (%)	Remarks
Basic	10	≥ 3	95–100	High exhaustion; limited light fastness
Direct	56	≥ 3	70–95	Moderate performance; used for jute
Reactive	63	≥ 3	50–95	Dominant class; covalent fixation
Sulphur	77	≥ 3	60–90	Dark shades; reduction process
Vat	98	≥ 3	80–95	Highest fastness; high-value applications

Source: Compiled from International Jute Study Group (2026), Shore (2002), and factory records collected during the present survey.

Vat dyes exhibit the highest exhaustion rates (80–95%) and superior light fastness among the surveyed classes, consistent with their established reputation as premium dyes for demanding industrial applications. Reactive dyes, despite a comparatively broader exhaustion range (50–95%) attributable to competing hydrolysis reactions, dominate industry preference owing to the versatility of their shade range, the permanence of covalent fiber bonding, and the breadth of commercially available products (Zollinger, 2003). Basic dyes show the highest exhaustion rate (95–100%), but their limited colorfastness

profiles confine their use primarily to jute applications. These performance parameters provide the technical rationale for the consumption patterns observed in the survey, discussed in subsequent sections.

4.2 Dye Consumption in Woven Fabric Dyeing

The ten surveyed woven dyeing facilities collectively consumed 93.56 metric tons of dye per month. The distribution across dye classes is presented in Table 2.

Table 2. Survey Results: Dye Consumption in Woven Fabric Dyeing (n = 10 companies)

Number of Companies	Monthly Total (M. ton)	Reactive	Direct	Vat	Sulphur	Pigment	Others
10	93.56	57.16	0.00	14.00	0.00	20.40	2.00
Percentage	100%	61.09%	—	14.96%	—	21.80%	2.14% (Azoic)

Reactive dyes account for the largest single dye class in woven fabric dyeing at 61.09% (57.16 M. ton/month), confirming their primacy for cellulosic woven substrates. The second largest category is pigment, contributing 21.80% (20.40 M. ton/month), which is typically employed in printing and cold pad-batch processes rather than conventional exhaust dyeing, and is favored for its simple wash-off procedure and minimal wastewater load (Broadbent, 2001). Vat dyes constitute a non-trivial 14.96% share (14.00 M. ton/month), indicating the presence of high-specification dyeing operations requiring superior wash and light fastness. Azoic (naphthol) dyes represent 2.14% and are

used for specific deep shade applications, particularly navy and black, at competitive cost. The complete absence of direct and sulphur dye consumption among surveyed woven dyehouses is notable and may reflect the higher quality standards demanded by export buyers in this sub-sector.

4.3 Dye Consumption in Knit Fabric Dyeing

The twenty-eight knit dyeing facilities in the survey sample reported total monthly dye consumption of 203.10 metric tons—by far the largest volume among all sub-sectors surveyed. Table-3 presents the dye class distribution.

Table 3. Survey Results: Dye Consumption in Knit Fabric Dyeing (n = 28 companies)

Number of Companies	Monthly Total (M. ton)	Reactive	Direct	Vat	Sulphur	Basic	Others
28	203.10	203.10	0.00	0.00	0.00	0.00	0.00
Percentage	100%	100%	—	—	—	—	—

The knit dyeing sub-sector exhibits exclusive reliance on reactive dyes (100%), a finding that reflects the sector's orientation toward high-quality cotton knitwear for export markets. The comprehensive adoption of reactive dyes in knitwear production is driven by the necessity to meet stringent international quality standards including ISO 105-C06 wash fastness requirements and OEKO-TEX Standard 100 compliance (OEKO-TEX, 2023). The sheer volume of reactive dye consumption in the knit sub-sector (203.10 M. ton/month) far exceeds all other sub-sectors

combined, underscoring the strategic importance of reactive dye supply security for Bangladesh's dominant knit garment export sector.

4.4 Dye Consumption in Yarn Dyeing

Eight yarn dyeing companies were surveyed, reporting combined monthly dye consumption of 37.61 metric tons. Table 4 details the sub-sector distribution.

Table-4. Survey Results: Dye Consumption in Yarn Dyeing (n = 8 companies)

Number of Companies	Monthly Total (M. ton)	Reactive	Direct	Vat	Sulphur	Basic	Others (Acid)
8	37.61	37.05	0.00	0.056	0.00	1.00	0.50
Percentage	100%	95.86%	—	0.15%	—	2.66%	1.33%

Reactive dyes dominate yarn dyeing at 95.86% (37.05 M. ton/month), consistent with the broader cellulosic fiber dyeing preference. The presence of basic dyes (2.66%, 1.00 M. ton/month) is noteworthy and may reflect the processing of protein or polyacrylic fiber blends within the surveyed facilities. Vat dyes constitute only 0.15% (0.056 M. ton/month), potentially representing specialty package or beam dyeing operations for workwear or denim yarns requiring superior fastness. Acid dyes

(classified under 'others') at 1.33% indicate the processing of wool or nylon yarn blends in a subset of facilities.

4.5 Dye Consumption in Jute Dyeing

Three jute dyeing facilities constituted the jute sub-sector sample, with combined monthly consumption of 2.935 metric tons. Table 5 presents the dye class breakdown.

Table -5. Survey Results: Dye Consumption in Jute Dyeing (n = 3 companies)

Number of Companies	Monthly Total (M. ton)	Reactive	Direct	Vat	Sulphur	Basic	Others
3	2.935	1.500	0.860	0.00	0.575	0.00	0.00
Percentage	100%	51.11%	29.30%	—	19.59%	—	—

Jute dyeing presents the most diversified dye class profile among the four sub-sectors. Reactive dyes remain dominant (51.11%, 1.500 M. ton/month), but direct and sulphur dyes contribute significant shares of 29.30% and 19.59%, respectively—a profile markedly different from the cotton-based sub-sectors. This diversity is attributable to the distinct physicochemical properties of jute fiber, which, being a lignocellulosic material with significant lignin and hemicellulose content, exhibits dyeability by multiple dye classes (International Jute Study

Group, 2026; Chakraborty & Pal, 2024). Direct dyes are particularly well-suited to jute's multi-component fiber structure, offering acceptable fastness at modest cost (Trotman, 1984; Ganguly & Datta, 2000). The use of sulphur dyes in jute dyeing for dark shades—where the limitations of shade range are less critical—reflects an established industry practice for cost-effective deep coloration (Shore, 2002; Kabir et al., 2008).

4.6 Summary and Cross-Sectoral Comparative Analysis

Table-6 consolidates the dye consumption data across all four sub-sectors into a unified comparative framework.

Table-6. Summary of Dye Usage (%) Across All Sub-Sectors of the Bangladeshi Cellulosic Fiber Dyeing Industry

Industry Type	Reactive	Direct	Vat	Sulphur	Basic	Pigment	Others	Total
Woven Dyeing	61.09%	—	14.96%	—	—	21.80%	2.14%	100%
Knit Dyeing	100%	—	—	—	—	—	—	100%
Yarn Dyeing	95.86%	—	0.15%	—	2.66%	—	1.33%	100%
Jute Dyeing	51.11%	29.30%	—	19.59%	—	—	—	100%

The cross-sectoral analysis reveals several key patterns. First, reactive dyes are universally dominant across all sub-sectors, confirming their central role in cellulosic fiber coloration and corroborating the global market trend (Hunger, 2007). Second, the degree of reactive dye dominance varies meaningfully across sub-sectors (51.11% in jute dyeing to 100% in knit dyeing), reflecting substrate-specific dyeability constraints and end-use quality requirements. Third, jute dyeing is the only sub-sector where direct and sulphur dyes contribute substantially to total dye demand, a finding aligned with established jute coloration

practice documented in IJSG technical literature. Fourth, pigment colorants are present exclusively in woven dyeing, consistent with their primary application in printing and cold pad-batch operations for woven fabrics.

The complete absence of direct and sulphur dyes from knit and yarn dyeing operations (at least in the surveyed facilities) has significant implications for wastewater management, as these dye classes typically generate more concentrated spent dye baths than reactive systems with modern low-liquor-ratio technology. The near-exclusive reliance of the knit sector on

reactive dyes creates a supply chain vulnerability: any disruption in reactive dye supply (e.g., from principal manufacturing hubs in China, India, or Germany) could disproportionately affect Bangladesh's dominant export segment (BGMEA, 2023).

5. CONCLUSION

This study provides the first comprehensive, survey-based quantitative documentation of dye consumption patterns across the Bangladeshi cellulosic fiber dyeing industry. Analysis of data from 49 dyeing facilities representing woven, knit, yarn, and jute sub-sectors demonstrates the decisive dominance of reactive dyes in cellulosic substrate coloration: they account for 100% of knit dyeing, 95.86% of yarn dyeing, 61.09% of woven dyeing, and 51.11% of jute dyeing monthly consumption. This dominance is technically underpinned by the superior wash fastness, versatility of shade range, and covalent dye-fiber bonding mechanism of reactive dyes.

Distinctive dye demand profiles were identified for jute dyeing, where direct dyes (29.30%) and sulphur dyes (19.59%) jointly constitute nearly half of total consumption—a pattern reflecting the lignocellulosic nature of jute fiber and its differential response to multiple dye classes. Pigment colorants occupy a significant niche in woven fabric dyeing (21.80%), consistent with their role in print and cold pad-batch processing.

These findings have direct practical implications for: (a) supply chain planning, given the vulnerability of the dominant knit sector to reactive dye supply disruptions; (b) environmental management, particularly wastewater characterization and treatment system design, where dye class-specific biodegradability profiles must be considered; and (c) research prioritization for sustainable dye application, where improving reactive dye fixation efficiency (currently 50–95%) would yield the greatest industry-wide environmental benefit. Emerging technologies including cold pad-batch dyeing (Jalil et al., 2026), low-salt and salt-free dyeing (Zhang et al., 2025), and the use of alternative water sources offer promising pathways for reducing the environmental footprint of Bangladesh's textile dyeing industry.

Future research should extend this survey to a larger industrial sample, incorporate seasonal consumption variability, and examine the economic and environmental cost implications of the current dye demand distribution. Longitudinal tracking of dye class consumption patterns would additionally enable assessment of the industry's response to evolving sustainability regulations and buyer requirements, particularly in light of BGMEA's 2030 sustainability targets (BGMEA, 2023).

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