

Environmental sustainability practices in effluent management of fashion manufacturing in developing country: Insights from Bangladesh

Md Shamsuzzaman^a, Mazed Islam^{b,*}

^a Department of Textile Engineering, World University of Bangladesh, Dhaka, Bangladesh

^b Department of Fashion and Textiles, University of Southampton, Southampton, UK

ARTICLE INFO

Keywords:

Environmental sustainability
LEED certification
Wastewater treatment
Factory performance

ABSTRACT

This study examines the environmental sustainability of three textile factories in Bangladesh with varying levels of LEED certification: Platinum LEED-certified (Factory A), Gold LEED-certified (Factory B), and non-LEED-certified (Factory C). Following LEED standards for water usage and pollution control, both untreated and treated effluents were collected from these factories and subjected to chemical analysis. The findings were assessed against established limits for parameters including Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, and color. Effluent samples were collected three times a month, and average values were used in the analysis. The results indicated that LEED-certified factories possess greater capacity for effective water use and treatment system design compared to non-certified factories. Significant increases in key metrics such as BOD, TSS, turbidity, and pH are recorded across all factories after ETP treatment, demonstrating the efficacy of wastewater treatment techniques. Although initial (untreated) effluent samples from all factories exceeded acceptable standards, post-treatment results for Factories A and B achieved compliance with standard parameters, while Factory C was found to require a comprehensive overhaul to meet environmental sustainability requirements. The research shows that LEED certification greatly inspires factory managers to adopt and execute sustainable practices in manufacturing, water management, and effluent treatment. It highlights the necessity of effective wastewater treatment techniques in reducing environmental impact and meeting compliance with regulations in fashion manufacturing. It also emphasizes the technical constraints faced by non-LEED-certified facilities in Bangladesh. Findings will inspire a wide range of stakeholders, including academics, researchers, and industry practitioners, to emphasize reducing the environmental effect of knit textile production. Furthermore, findings will assist industry practitioners in making viable strategic decisions to improve the environmental sustainability of fashion manufacturing.

1. Introduction

Every year, between 80 to 150 billion clothes are produced globally, with over 300 million people actively engaged in this industry (One Planet, 2021; Karpova et al., 2021). This is due to the increase in fast fashion manufacturing and product diversification. This trend has fueled demand for frequent updates to fashion collections, driving manufacturers to increase output to meet client expectations for novelty and diversity (Rasel et al., 2020). Along with socioeconomic progress, it poses questions regarding environmental sustainability. The fashion business is regarded as the second most polluting industry after the oil industry, responsible for more than 10 % of global CO₂ emissions and

nearly 20 % of waste output (Khan and Islam, 2015). Around 92 million tons of fashion and textile waste are created annually, greatly contributing to environmental degradation (Akter et al., 2022; Shamsuzzaman et al., 2025).

Sustainable textile production become a top priority in response to rising demand for apparel due to the concept of non-hazardous, non-polluting, energy and natural resource efficient, economically viable, and safe for workers, communities, and customers (Shamsuzzaman et al., 2025; Saha et al., 2022). The United Nations and the European Union (EU) have provided a complete map of sustainability, recommending to development sustainable garment value chain at the bilateral, regional, and global levels through collaboration (Shamsuzzaman

* Corresponding author.

E-mail addresses: shamsuzzaman@textiles.wub.edu.bd (M. Shamsuzzaman), m.m.islam@soton.ac.uk (M. Islam).

<https://doi.org/10.1016/j.clwat.2025.100085>

Received 11 February 2025; Received in revised form 14 May 2025; Accepted 14 May 2025

Available online 15 May 2025

2950-2632/© 2025 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

et al., 2023, 2025). This can mitigate potential risk factors associated with fashion manufacturing (United Nations, 2023; European Parliament, 2023). To monitor these activities several regulatory bodies like Sustainable Apparel Coalition (SAC), Leadership in Energy and Environmental Design (LEED) certification, SANE Standard, Better Cotton Initiative – BCI, Bluesign, Cradle to Cradle – C2C, OEKO-TEX, MADE SAFE® etc. has been established (Das and Das, 2024; bluesign, 2023; Business intelligence, 2020). Using certification criteria, brands, sustainability efforts in production and supply chain including raw materials, finished goods, and/or procedures can be measured and assessed (Islam et al., 2025). Any fashion sector focusing on fibre standards, chemical control, worker rights, circular standards, and fair trade is eligible for eco-label certification that may help to maintain transparency and negotiate a complicated business market (Mousavi et al., 2024; Zhu, 2024).

The LEED certification provides a standardized framework for evaluating and benchmarking sustainability practices in various categories such as energy efficiency, water conservation, material selection, indoor environmental quality, and design innovation (Brem et al., 2020; Li et al., 2020). This certification is acknowledged as a symbol of environmental stewardship and sustainability, with implications for customer perceptions, market competitiveness, and regulatory compliance (Hallas, 2024; Fahim et al., 2024). Globally, although precise statistics on the total number of LEED-certified textile facilities are not easily accessible, Bangladesh's significance is apparent. As of January The Daily Star (2025), Bangladesh has obtained LEED certification for 233 factories, of which 93 have achieved Platinum status and 126 have secured Gold certification. Besides, the nation hosts 62 of the top 100 highest-rated LEED-certified facilities globally, underscoring its prominence in sustainable manufacturing efforts and solidifying its commitment to environmental stewardship. This certification is awarded based on distinct compliance requirements and specific core threshold (Dhaka Tribune, 2023; The Business Standard, 2023; Tayyab et al., 2020).

This study aims to investigate insights into the environmental sustainability landscape of knitted garment production by comparing and contrasting the practices and outcomes of LEED and non-LEED certified facilities. In this study, researchers investigated the performance of three knitted facilities in Bangladesh through wastewater characterization namely: (i) platinum LEED certified, (ii) gold LEED certified, and (iii) non-LEED certified, considering LEED components including water quality management and waste reduction. The specific water quality parameters like Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Biochemical/biological Oxygen Demand (BOD), Total Dissolved Solid (TDS), Total Suspended Solid (TSS), turbidity, and pH values from both untreated and after-treated wastewater were quantified and compared with government prescribed levels (Gomes et al., 2024; Nahar et al., 2024; Shamsuzzaman et al., 2021). These tests will be conducted, encompassing critical LEED environmental metrics such as water efficiency, energy consumption, and Indoor Environmental Quality, thereby positioning LEED-certified companies as the focus of this study. LEED-certified facilities were chosen for their dedication to environmental sustainability and compliance with rules, even though our research focused on wastewater treatment. Organizations certified by LEED need to adopt sophisticated environmental measures, including wastewater treatment, to demonstrate their commitment to sustainable industrial operations (USGBC, 2022). The research examines the influence of certification on wastewater management practices by focusing on certified companies. This method provides a practical standard for assessing certified and non-certified factories. Furthermore, LEED certification has shown an improvement in cleanliness and environmental standards in industrial facilities, particularly in resource-intensive industries like textiles (Kwan et al., 2024; Rashid and Haque, 2024). This will help us to address critical wastewater management challenges by conducting a comparative evaluation between globally certified factories (LEED) and non-certified textile manufacturing facilities. This approach allowed us to assess their respective performances in

wastewater treatment and highlighted the actual industry scenario.

The uniqueness of this study is its systematic evaluation of wastewater management practices covering a wide range of indicators for LEED-certified and non-LEED-certified factories, which provides an empirical assessment of whether LEED certification improves environmental performance in industrial effluent treatment. By doing so, we can provide empirical evidence on the effectiveness of LEED certification in enhancing wastewater management practices (Sagnak et al., 2024; Tolentino-Zondervan and DiVito, 2024). Unlike previous research, which mostly focused on LEED certification as a framework for sustainable building design and energy efficiency, this study examines its real-world implications for wastewater management in the textile industry. This study fills critical research gaps by examining the actual execution of effluent treatment plant (ETP) operations, thereby offering concrete insights into the environmental benefits of sustainability certificates. Besides, it will provide momentum to knit producers to solve environmental issues, improve brand reputation, and satisfy changing customer expectations for sustainable products (Fahim et al., 2024; Ali et al., 2024). Furthermore, this study advances our understanding of policy effectiveness by shedding light on whether businesses with LEED certification adhere more strictly to water quality regulation (Bungau et al., 2022). By adopting these changes, we hope to provide a more exact and academically rigorous picture of the role of LEED certification in the textile sector, emphasizing its importance in environmental stewardship and sustainable production methods. Two specific research objectives (RO) have been set:

RO1: To analyze, and assess environmental sustainability performance of fashion manufacturing, focusing on wastewater management strategies

RO2: To compare LEED and non-LEED certified fashion manufacturing factories, identifying risks, poor practices, and opportunities for improving wastewater management

The remainder of the research involves in reviewing important literature and theoretical background in the knitted LEED and non-LEED textile industries, and their environmental sustainability problems. The methodology section outlines a multi-case study's data collection and analysis approach. Finally, the results, discussions, and research implications (both theoretical and practical) are presented, followed by conclusions and recommendations.

2. Literature review

2.1. Environmental sustainability issues of knitted facilities in Bangladesh

The textile industry in Bangladesh, comprising over 3000 knitting facilities and employing approximately one million individuals, has faced increasing scrutiny for its considerable environmental footprint. This sector is criticized for excessive consumption of water and energy, substantial chemical pollution, and waste generation (Masud Sumaiya, 2022; Rahman and Chowdhury, 2020). Textile production processes predominantly generate two types of waste: solid waste, including fiber, fabric, and garment remnants, and liquid waste, particularly effluent or wastewater. The dyeing and finishing stages alone release approximately 280,000 tons of chemicals into the environment each year through effluent discharge. Additionally, the fashion manufacturing facilities in Bangladesh are estimated to produce 350 million cubic meters of wastewater annually, a figure projected to increase to 450 million cubic meters by 2030 (Rafiq et al., 2024). Textile effluent contains oil, grease, caustic soda, Glauber salt, ammonia, sulfide, lead, heavy metals, and other substances that affect parameters like COD, DO, BOD, TDS, TSS, and pH. These are liable for environmental and health risks, sewage line corrosion, groundwater contamination, and significant capital expenditure in reducing multifaceted negative repercussions (Shamsuzzaman et al., 2023; 2023; Uddin et al., 2015). Untreated effluent may contain a variety of contaminants, including heavy metals, toxic chemicals, organic pollutants, and pathogens, all of

which are detrimental to aquatic ecosystems and people.

Therefore, standard ETP treatment plant is strongly recommended to lessen the environmental impact of discharged wastewater (Maity et al., 2021). It will assist in the removal of dangerous chemicals from industrial wastewater before it is discharged into natural water sources. Industries that handle wastewater may significantly reduce the levels of these hazardous substances, lowering water pollution and protecting biodiversity (Sachidhanandham and Periyasamy, 2021). Effective effluent treatment processes, such as filtration, chemical treatment, and biological treatment, ensure that discharged water meets environmental standards (Saravanan et al., 2021). This not only ensures the quality of water supplies, but it also helps local communities remain viable by supplying cleaner drinking, agricultural, and recreational water. Furthermore, cleansing wastewater lowers the likelihood of legal fines and boosts the reputation of firms committed to environmental responsibility (Maity et al., 2021).

2.2. Standard wastewater parameters and their impact

Since the effluent contains organic and inorganic materials, it requires successive treatment processes. The effluent treatment plant (ETP) in a knitted textile facility has standard criteria for the treatment, and even after the treatment, it needs to follow the prescribed parameters of effluent (Table 1).

The effluent was generally found to discolor and affect the above-mentioned effluent parameters. The chemical oxygen demand (COD) represents the quantity of oxygen required to break down organic matter. Higher COD values result in hazardous and anaerobic water conditions (Rafiq et al., 2024). The amount of oxygen found in water as dissolved condition is known as dissolved oxygen (DO). A healthy DO level maintains a balanced ecosystem, allowing fish, invertebrates, bacteria, and underwater plants to thrive. The usual concentration is 9 mg/L or more; below 4 mg/L, aquatic species struggle to live. Furthermore, DO levels range from 1 to 20 mg/L during diffusion, aeration, photosynthesis, respiration, and decomposition (Wang et al., 2022). The biological oxygen demand (BOD) measures the oxygen degradation after a certain period. The maximum allowable BOD concentration for direct discharge into the environment is 10 mg/L. It is mostly governed by Dissolved Organic Carbon (DOC), Particulate Organic Carbon (POC), and Total Organic Carbon (TOC) concentrations (Han et al., 2024). When the organic (carbonates, nitrates, bicarbonates, chlorides, and sulfates) and inorganic (calcium, potassium, magnesium, and sodium) particles are found in a dissolved state, known as total dissolved solids (TDS). This mostly increases the toxicity of water by increasing salinity and modifying ion composition. If these particles are found in a suspended solids state, known as total suspended solids (TSS). These large particles absorb a lot of light, decreasing oxygen levels while raising water temperature and turbidity. Because of the high TDS and TSS levels in the water, the effluents were opaque, foggy, or muddy, inhibiting light from reaching deeper depths and affecting

photosynthesis, free movement, and aquatic life diseases (World Health Organization, 2017). Larger particles hinder light from passing through water. The standard turbidity for drinking water is < 1 NTU, whereas wastewater is < 10 NTU. However, water becomes murky around 100 NTU and completely opaque at 2000 NTU. The potential of hydrogen (pH) presence in water may vary due to temperature, water movement, and chemical mixture. Extreme alkalinity clogs metal pipelines, corrodes water-carrying equipment and produces unpleasant odors or tastes in effluents. However, the acidity of water degrades its nutritional value, making it dangerous to drink and making the land unproductive (World Health Organization, 2011; Panhwar et al., 2024).

2.3. Overview of certifications in textile factories and impact in wastewater management

Certification promotes industrial innovation and collaboration by establishing standards and encouraging continual development. The popular certification including GOTS (Global Organic Textile Standard), OEKO-TEX Standard 100, Fair Trade, Cradle to Cradle, LEED etc. focuses on distinct areas of sustainability (Sagnak et al., 2024; Tolentino-Zondervan and DiVito, 2024). Their provided framework significantly improves sustainability practices in the fashion and textile industries by encouraging openness, accountability, and beneficial environmental and social results (Wu et al., 2017). The following Table 2 displays the key contributions of certifications in wastewater management in the textile industry.

2.4. LEED certification in textile industry: links to wastewater management and environmental performance

The U.S. Green Building Council (USGBC) promotes LEED certification for manufacturing industries by transforming the built environment. In the textile sector, gaining LEED certification entails incorporating sustainable practices throughout the manufacturing process. Although textile factories in Bangladesh have started getting their LEED-certifications from 2011, it has seen a rapid increase from 2017, indicating an increasing dedication to sustainable practices within Bangladesh's textile industry. This trend corresponds with worldwide market demands for environmentally sustainable production and underscores the sector's continuous transition toward internationally acknowledged green building standards. LEED accreditation in the textile sector emphasizes sustainable practices across every step of the production chain, from raw material procurement to manufacture and distribution (Di Gaetano et al., 2023). Textile companies may get LEED certification by using ecologically responsible techniques to reduce energy use, water usage, water quality, and waste disposal. This not only indicates a dedication to environmental stewardship, but it also brings concrete benefits such as cost savings, improved brand recognition, and access to new markets (Islam et al., 2021; Pushkar, 2023). The following Fig. 1 displays the year-wise certifications by Bangladeshi factories, emphasizing the importance of LEED certification for sustainability.

LEED certification is given to facilities in four categories: (i) LEED Basic, (ii) LEED Silver, (iii) LEED Gold, and (iv) LEED Platinum (Fig. 2). The LEED Platinum level accreditation is the highest accolade, while the LEED Certified level indicates fundamental, essential performance. To achieve this accreditation, a manufacturer must fulfill several criteria and receive standard ratings. Out of 100 points, 40–49 gain basic LEED certification, 50–59 earn silver-level certification, 60–79 earn gold-level certification, and 80 or more receive platinum certification (Hafez et al., 2023; Mosaddeque, 2022).

In LEED certification, performance is evaluated in five components shown in Fig. 3.

Fig. 3 displays key features of LEED certification for sustainable textile manufacturing methods, including energy efficiency, water management, and environmental impact. Manufacturers should prefer organic fibers like cotton and wool, recycled fibers, and low-impact dyes

Table 1
Parameters of standard effluent (Von Sperling et al., 2020; Qasim, 2017).

Parameters	Accepted and Approved by Government of Bangladesh	Grading		
		Excellent Range	Good Range	Poor Range
COD (mg/L)	200	< 100	100–200	> 200
DO (mg/L)	9	≥ 9	5–9	≤ 4
BOD (mg/L)	50	≤ 10	10–20	≥ 40
TDS (mg/L)	300	< 300	300–600	> 600
TSS (mg/L)	100	< 100	100–200	> 200
Turbidity (NTU's)	10	≤ 10	10–20	≥ 100
pH	6–9	7	6–8	< 4 & > 9
Colour	Light Brownish/watery			

Table 2

Key certifications and their attributes in textile industry towards sustainability.

Certification	Wastewater management focus	Key requirements	Key contribution
LEED (Leadership in Energy and Environmental Design)	Indirect but includes WE Credit 2: Innovative Wastewater Technologies and water use credits	Reduction of potable water use, on-site wastewater treatment, efficient systems	Promotes holistic resource efficiency, encourages advanced wastewater treatment, and water reuse strategies
OEKO-TEX® STeP	Direct focus on chemical and wastewater management	Implement proper wastewater treatment systems and conduct regular monitoring	Ensures safe discharge of water, promotes closed-loop water systems, and minimizes harmful chemical release
bluesign®	Strong emphasis on input stream management and effluent control	Mandates responsible chemical usage, advanced ETPs (Effluent Treatment Plants), and wastewater tracking	Prevents water pollution at the source, supports clean production and safe working conditions
ZDHC (Zero Discharge of Hazardous Chemicals)	Exclusive focus on eliminating hazardous chemicals and managing wastewater discharge	Adherence to wastewater guidelines, MRSL (Manufacturing Restricted Substances List), and regular auditing	Enhances transparency, ensures zero discharge of hazardous chemicals, and elevates global effluent standards
(ISO, 2019) 14001 (Environmental Management System)	General emphasis on compliance with environmental legislation, including wastewater	Identify environmental aspects and impacts, including water discharge	Provides a systematic framework for continual improvement in wastewater and resource management
GOTS (Global Organic Textile Standard)	Moderate focus; mandates wastewater treatment in wet processing units	Requires functional ETPs, monitoring of discharge quality, and environmental compliance	Supports organic production integrity while controlling water pollution in processing stages
SA8000	No direct requirements; focuses on social accountability	Emphasizes worker safety and rights, which may indirectly encourage better environmental practices	Encourages ethical operations, which can align with sustainable wastewater practices in responsible factories

and chemicals to promote sustainable sourcing. Energy-saving technologies like LED lighting, solar electricity, and efficient machinery all help to reduce carbon emissions. Water conservation technology, such as closed-loop recycling and low-flow fixtures, reduces water use and waste, wastewater management, thereby improving local ecosystems. The waste reduction component emphasizes recycling and waste-to-energy initiatives. Finally, the Indoor Environmental Quality Index focuses on improving indoor air quality by reducing volatile organic compounds, enhancing ventilation, and creating ergonomic work circumstances.

Moreover, effluent analysis, which involves the assessment of wastewater or discharge from industrial activities, has a strong

relationship to LEED certification, notably in terms of environmental performance and sustainability, water recycling, and waste reduction. LEED certification is primarily concerned with green building design and sustainable operations, where environmental performance is specific to wastewater management is one of the prerequisites to get certification and achieve environmental sustainability. Effluent analysis is critical for analyzing and mitigating the environmental impact of wastewater discharge, aligning with LEED's goals of reducing environmental pollution and fostering sustainability (Lee and Skorski, 2019; Debnath et al., 2023). To achieve environmental sustainability, effluent management is an important requirement for LEED certification. The results can help influence strategies for minimizing water pollution, increasing water management efficiency, and assuring environmental compliance, which are critical components of attaining LEED certification. As a result, sustainable practices in effluents management fosters certification process by improving environmental performance and responsible resource management in building projects (Bungau et al., 2022).

3. Materials and methodology

3.1. Case factory information

Three knitted production factories were considered for the research such as (i) Factory A (Platinum LEED Certified), (iii) Factory B (Gold LEED certified), and (iii) Factory C (Non-LEED Certified). The analyzed LEED-certified factories in this study received their certifications from 2017 to United Nations (2023), indicating an increasing dedication to sustainable practices within Bangladesh's textile industry. This trend corresponds with worldwide market demands for environmentally sustainable production and underscores the sector's continuous transition toward internationally acknowledged green building standards. The particulars of these factories are shown in Table 3.

3.2. Sampling and testing

To measure the environmental sustainability performance among case factories, LEED components such as water conservation, waste reduction, and recycling were considered. Both untreated and treated effluents were collected in glass containers and coded from the case factory according to the plan. The untreated effluents were collected from the equalization tank of the ETP plant, and treated effluents were collected at the releasing point of the plant after treatment. The collected effluent samples were preserved in a refrigerator at 4-degree Celsius temperature and conducted relevant environmentally friendly tests within 24–48 hours of collection. The collected effluents were tested 3–5 times for a day and average values were considered for that day. Similarly, effluents from each factory were tested thrice in a month and average calculated values with counted for final analysis and discussion. The whole collection process is shown in Fig. 4 and Fig. 6.

3.3. Methods: effluent treatment and research plan

To measure the performance of water quality, such as COD, DO, BOD, TDS, TSS, turbidity, and pH value among case factories, appropriate chemical and physical methods were conducted according to standard methods (Table 4) (Azanaw et al., 2022). Later, test values were analyzed and compared with the prescribed standards of effluents released to the environment by the Government. Fig. 5 displaying the pictorial view of testing.

Fig. 6 depicts the study's research design and procedures. Specifically, effluent samples were collected on three distinct days each month, and the average value for each sample was determined. Each collection day, at least five different measurements were taken to establish a strong and representative average result for effluent quality that day. This method seeks to identify any deviations and provide a

LEED certification scenario, yearly distribution

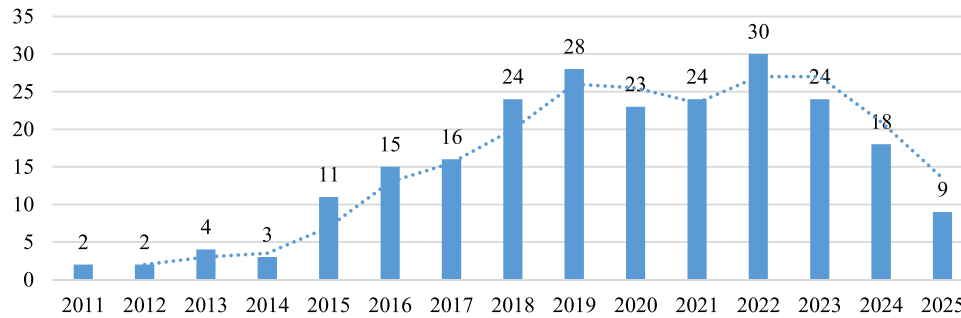


Fig. 1. Yearly distribution of LEED certification by Bangladeshi factory.

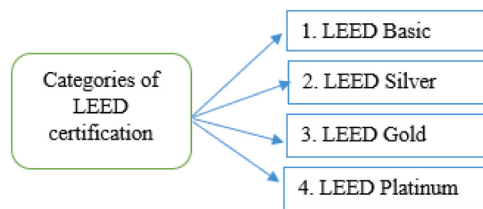


Fig. 2. Categorize of LEED certification.



Fig. 3. Components of LEED certification.

more accurate and reliable assessment of effluent qualities. The option to collect effluent data on three distinct days on a month was deliberated to avoid potential biases and account for changes in wastewater qualities over time. This methodology helps to optimize effluent data by ensuring that the results are indicative of typical operational settings and are not

influenced by outliers or irregular sampling. We thought that by combining many measurements collected on different days, we could increase the data's validity and representativeness, resulting in a more thorough and scientifically sound analysis of the wastewater treatment processes utilized by the industries under investigation.

4. Results and discussion

The analysis compared the environmental sustainability performance among three case factories in terms of water quality management. Several important water quality parameters, such as COD, DO, BOD, TDS, TSS, pH, and turbidity were assessed to ascertain between LEED and non-LEED certified facilities. The comparison was made according to the prescribed standard by the Bangladeshi government (shown in Table 1). Results show a gradual underscoring in performance from factory A to factory C. The details of the outcomes are discussed in Sections 4.1 to 4.8.

4.1. Impact of chemical oxygen demand (COD)

The COD value represents the amount of oxygen required to break down the organic matter in the effluent. The following Table 5 shows the calculation of COD values for three different days from the case factory, and Fig. 7 shows environmental sustainability performance in terms of COD value.

Fig. 7, showed a gradual decrease in COD values after ETP treatment indicating the successful elimination of organic pollutants from wastewater. LEED-certified factories A (platinum) and B (Gold) satisfied the standard limits and achieved values 53.15 mg/L and 99.29 mg/L, respectively. This refers to the sophisticated and large decrease of organic components from the wastewater following treatment. Although factory C (non-LEED) had shown greater potential after treatment, unable to meet the basic requirements even after treatment, indicating

Table 3

The particulars of the tested knit factories.

Site's Name	Site's main operations	Factory Capacity (pcs/day)	Types of operation	Virgin, certified organic content %	Chemical impact reduction	Green chemistry third-party verification	Wastewater Management
Factory A (Platinum LEED Certified)	Knit composite	80,000	Knit fabric production, dyeing, printing, finishing, garment manufacturing	0 %	Yes, used environmental friendly chemicals	Yes, OEKO Tex standard 100, LEED-certified	Chemical ETP, Capacity lies from 5 to 1000 Kiloliters/day
Factory B (Gold LEED Certified)	Knit composite	80,000	Knit fabric production, dyeing, printing, finishing, garment manufacturing	0 %	Yes, used environmental friendly chemicals	Yes, OEKO Tex standard 100, LEED-certified	Chemical ETP, Capacity lies from 5 to 1000 Kiloliters/day
Factory C (Non-LEED certified)	Knit composite	60,000	Knit fabric production, dyeing, printing, finishing, garment manufacturing	0 %	Not defined	Yes, OEKO Tex standard 100, Non-LEED certified	Chemical ETP, Capacity lies from 5 to 1000 Kiloliters/day

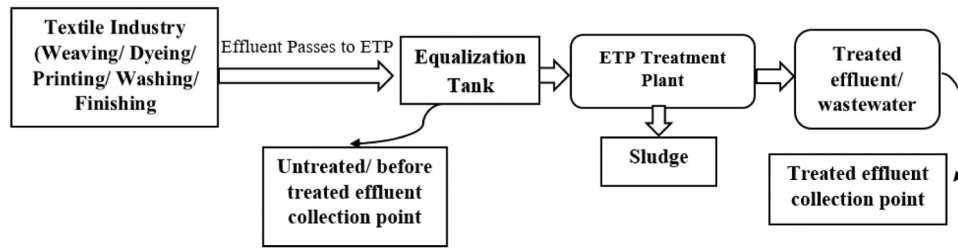


Fig. 4. Effluent collection process.

Table 4
Test name and standards.

Sl. No.	Name of the effluent test	Methods/standards of test (References)
1	Determination of COD value of effluent	Winkler titration (ISO 6060, 1989)
2	Determination of Dissolved Oxygen (DO) value of effluent	ASTM, D888–18 (2018)
3	Determination of BOD Value of effluent	Chemical test (titration)
4	Determination of Total Dissolved Solids (TDS) of effluent	ASTM D(5907), (2018)
5	Determination of Total Suspended Solid (TSS) of effluent	ASTM D(5907), (2018)
6	Determination of Turbidity of effluents	ISO, (7027)–1, (2016)
7	Determination of pH of effluents	ASTM D(1293)–18 (2018)

possible inefficiencies in the treatment process. Factory-wise COD differs focusing on individual factory responsibilities on actioning and managing effluent treatment plant, emphasizing the importance of LEED certification and management.

4.2. Impact of dissolved oxygen (DO)

The DO value represents the amount of oxygen dissolved in the effluent. The following Table 6 shows the calculation of DO values for three different days from the case factory and Fig. 8 shows environmental sustainability performance in terms of DO value.

The DO level increased substantially following ETP treatment, showing the increase of oxygen, and promoting an adaptable environment to aerobic organisms in the water (Fig. 8). The DO level after post-treatment varied across all factories, with platinum-certified factory A and gold-certified factory B falling somewhere between good and poor. This suggested a greater improvement in water quality after treatment, and microorganisms can be sustained there. Interestingly, factory C

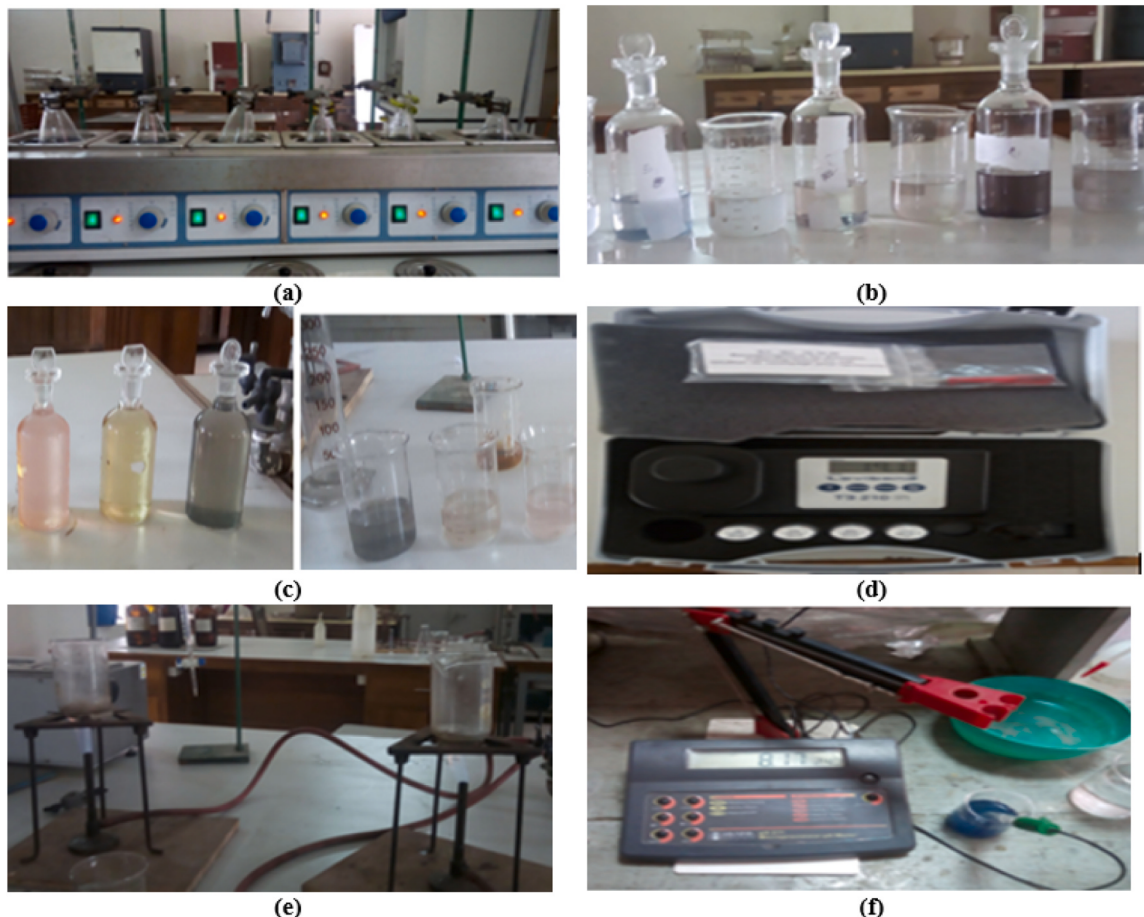


Fig. 5. Testing of effluents: Determination of (a) COD, (b) BOD, (c), DO, (d) Turbidity, (e) TDS, (f) pH value.

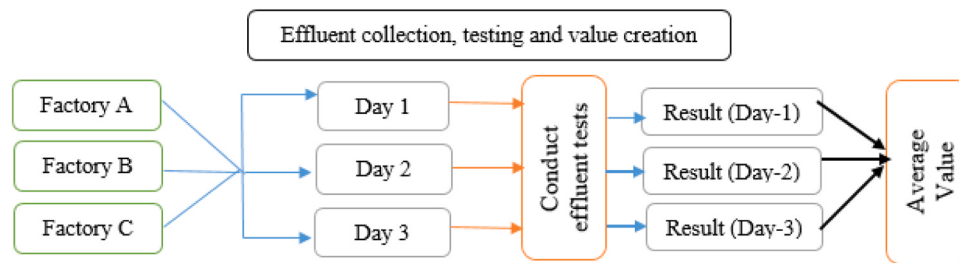


Fig. 6. Research plan.

Table 5

Data table of the COD value test result of effluents.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before	After	Before	After	Before	After
	ETP	ETP	ETP	ETP	ETP	ETP
	Treated	Treated	Treated	Treated	Treated	Treated
Day 1	114.62	39.44	256.62	68.16	565.26	286.61
Day 2	156.35	52.63	291.35	109.92	551.53	284.29
Day 3	144.51	67.39	384.51	119.78	448.15	219.87
Average	138.49	53.15	310.83	99.29	521.65	263.59

showed the greatest rise afterwards treatment, reaching 2.7 from 1.3, however, no animals can survive in this water. This showed excellent performance involving modern aeration technologies or biological treatments among case factories, though LEED-certified factories performed over non-LEED-certified factories.

4.3. Impact of biological/biochemical oxygen demand (BOD)

The differentiation of initial DOi and final DO_f expresses the BOD value of effluent. Table 7 shows the final DO_f which is measured similarly to the initial DOi. Then Table 8 is calculated for the determination of BOD. By considering the average value Fig. 8 is for the final DO_f and Fig. 9 is for BOD.

After five days, water quality both treated and untreated has fallen down considerably, demonstrating a drop in dissolved oxygen levels in the effluent even after ETP treatment (Fig. 9). That is why DO_f (final dissolved oxygen) is always less than DOi (initial dissolved oxygen). This indicates that the water is becoming poisonous and turning into dead zones for aquatic plants, algal photosynthesis, and diffusion with time.

Since the oxygen-consuming organisms reduced DO levels over time, a lowered BOD value is seen and remained below acceptable limits (<10 mg/L) (Fig. 10). This indicates a lack of supplementary airflow and wave motion during the ETP treatment, hampering photosynthesis and creating dead zones for aquatic and algal life. Furthermore, lowered BOD values could affect Dissolved Organic Carbon (DOC), Particulate Organic Carbon (POC), and Total Organic Carbon (TOC) levels in water.

4.4. Impact of total dissolved solids (TDS) values

The TDS value represents the amount of organic and inorganic compounds present in dissolved form in the effluent. The following Table 9 shows the calculation of TDS values for three different days from the case factories, and Fig. 11 shows environmental sustainability performance in terms of TDS value.

Untreated effluents contained more organic and inorganic substances in dissolved form, however, no factories have met the standard parameters of TDS even after treatment (Fig. 11). Factory A (Platinum) is very close to standard parameters whereas factory B (Gold) needs a few more actions and factory C (non-LEED) is out of standard though dissolved organic and inorganic substances were removed after the treatment significantly. This indicates inefficiencies/improper treatment action taken by the case factories.

4.5. Impact of total suspended solids (TSS) value

The TSS value represents the amount of organic and inorganic solid matter found in the effluent. The following Table 10 shows the calculation of DO values for three different days from the case factory, and Fig. 12 shows environmental sustainability performance in terms of TSS value.

Total suspended solids in effluents decreased considerably after the treatment, however, no factories achieved satisfactory levels except factory A which is close enough to meet standard parameters (Fig. 12). Factory B's TSS levels are nearly double those of the required criteria,

Table 6

Initial dissolved oxygen values (DOi) values of wastewater samples.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before	After	Before	After	Before	After
	ETP	ETP	ETP	ETP	ETP	ETP
	Treated	Treated	Treated	Treated	Treated	Treated
Day 1	3.2	5.1	2.9	4.7	1.2	2.8
Day 2	4.1	5.8	3.8	5.6	1.6	2.6
Day 3	3.9	4.8	3.2	5.4	1.1	2.6
Average	3.7	5.3	3.3	5.2	1.3	2.7

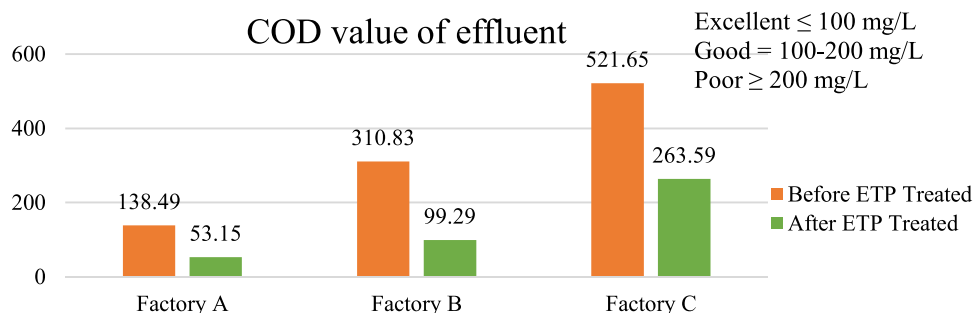


Fig. 7. COD value of effluent.

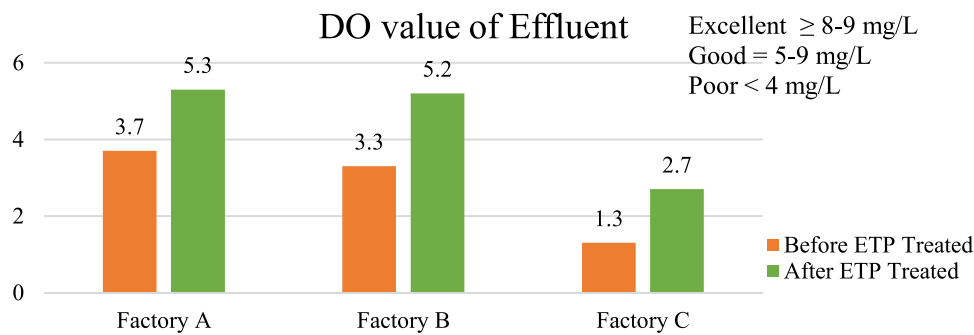


Fig. 8. DO value of effluent.

Table 7

5 days later DO value of effluent.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated
	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated
Day 1	2.8	4.1	2.6	3.2	2.2	2.9
Day 2	2.4	3.6	2.2	2.9	1.8	2.1
Day 3	2.2	2.9	1.8	2.6	1.8	2.3
Average	2.5	3.5	2.2	2.9	1.9	2.4

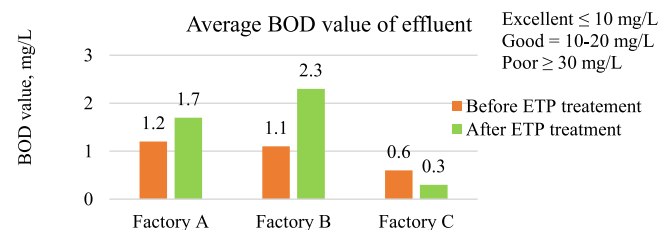


Fig. 10. BOD value of effluent.

Table 8

BOD value of effluent.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated
	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated
Day 1	0.4	1	0.3	1.5	1	0.1
Day 2	1.7	2.2	1.6	2.7	0.2	0.5
Day 3	1.7	1.9	1.4	2.8	0.7	0.1
Average	1.2	1.7	1.1	2.3	0.6	0.3

Table 9

TDS value of effluent.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated
	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated	Before ETP Treated	After ETP Treated
Day 1	1228	418	1886	669	2612	1268
Day 2	1544	686	1650	841	2832	1455
Day 3	1722	754	2156	957	3260	1662
Average	1498	619	1897	822	2901	1462

whereas factory C's are three times as high. Although it indicates robust treatment processes by stringent environmental requirements, its value is out of the standard by many metrics. This indicates that the entire concentration of particles suspended in water, including organic and inorganic matter, fibers, and other solid components, was not adequately eliminated. These findings illustrate the effectiveness of treatment procedures used by LEED and non-LEED-certified factories to reduce the concentration of suspended particles in textile wastewater, which is insufficient.

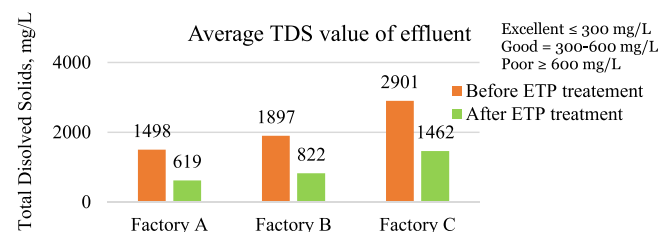


Fig. 11. TDS value of effluent.

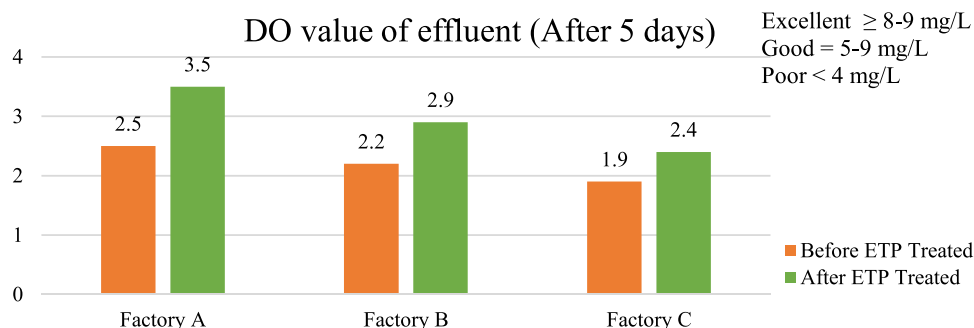


Fig. 9. Final DO value of effluent.

Table 10

TSS value of effluent.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before ETP	After ETP	Before ETP	After ETP	Before ETP	After ETP
	Treated	Treated	Treated	Treated	Treated	Treated
Day 1	682	228	921	446	1057	568
Day 2	766	245	883	398	1126	642
Day 3	565	182	745	341	1148	699
Average	667	214	849	390	1110	636

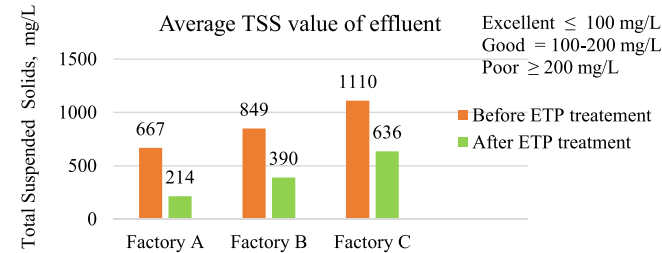


Fig. 12. TSS value of effluent.

4.6. Impact of turbidity values

The turbidity value represents the number of light resists to pass inside the effluent. The following Table 11 shows the calculation of turbidity values for three different days from the case factory and Fig. 13 shown environmental sustainability performance in terms of COD value.

After the ETP treatment, the turbidity value improved; factory A showed comparatively better scores than other factories (Fig. 13). Factory B and C had the highest initial turbidity values (374.7 and 581.8), which decreased after subsequent treatment whereas factory C showed the greatest potential. However, unable to meet the standard value, indicating a large amount of suspended and dissolved solid particles even after the treatment. The decreased turbidity tendency on post-treatment across all factories demonstrates their dedication to environmental sustainability and regulatory compliance, which is consistent with the LEED certification requirements. These findings highlight the efficacy of the treatment techniques used by LEED-certified manufacturers in improving water clarity and reducing the visual impact of suspended particles in textile effluent, hence contributing to environmental and resource conservation.

4.7. Impact of pH value

The pH value measures the potential of hydrogen found in the effluent. The following Table 12 shows the obtained pH values for three different days from the case factory and Fig. 14 shows environmental sustainability performance in terms of COD value.

The wastewater samples were slightly alkaline before treatment and showed a tendency to turn neutral after the treatment (Fig. 14). The

Table 11

Turbidity value of effluent.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before ETP	After ETP	Before ETP	After ETP	Before ETP	After ETP
	Treated	Treated	Treated	Treated	Treated	Treated
Day 1	87.1	5.5	508	60.4	628.5	112.7
Day 2	177	18.2	248	25.5	545.6	63.2
Day 3	21.5	6.98	368	40.2	571.2	84.4
Average	95.2	10.3	374.7	42.1	581.8	86.8

Average Turbidity value of effluent

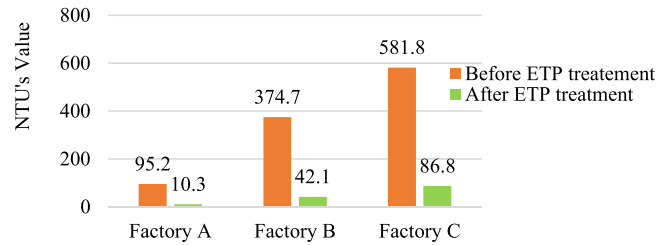


Fig. 13. Turbidity value of effluent.

closer alignment of pH readings to neutral levels by factories A and B following treatment demonstrates their dedication to environmental sustainability and regulatory compliance. Maintaining pH levels below safe limits is critical for sustaining aquatic habitats, preventing infrastructure corrosion, and assuring the efficacy of biological treatment methods. However, for non-LEED certified factories C, the effluent contained alkalinity both before and after treatment. These findings highlight the necessity of robust wastewater treatment in reducing environmental impact while achieving severe regulatory standards.

4.8. Summary of the key findings

The summary provides an in-depth assessment of several water quality indicators in textile effluent before and after treatment in three facilities, identified as A, B, and C (Table 13). Significant increases in key metrics such as BOD, TSS, TDS, turbidity, and pH are recorded across all factories subsequent ETP treatment, demonstrating the efficacy of wastewater treatment techniques executed following ETP and LEED certification standards (Habib et al., 2022; Panhwar et al., 2024). Non-LEED certified factory C routinely showed a significant decrease in pollutant levels after treatment, indicating lack of effective treatment mechanisms in place. This includes significant decreases in indicators such as BOD, TSS, TDS, turbidity, and pH, demonstrating a dedication to environmental sustainability and regulatory compliance. However, even after treatment, the effluent quality remains below standard. Similarly, though varied degrees, LEED-certified factory A and factory B demonstrate improvements in water quality metrics following treatment (Shamsuzzaman et al., 2021).

The constant improvement in water quality measures after treatment demonstrates the commitment of LEED-certified factories A and B to responsible environmental conservation and sustainability. These findings demonstrate the successful removal of contaminants from textile wastewater and illustrate the benefits of implementing strong ecological regulations in industrial processes. Conversely, non-LEED certified factory C consistently obtains a significant reduction in pollutants across multiple criteria, indicating strong treatment techniques; yet insufficient to meet the required standards (Ali et al., 2024).

The overall finding suggests that LEED-certified factories A and B performed better than non-LEED-certified factory C based on measurable parameters and their potential impact on the environment.

Table 12

pH value of effluent.

Day	Factory A (Platinum LEED certified)		Factory B (Gold LEED certified)		Factory C (Non-LEED certified)	
	Before ETP	After ETP	Before ETP	After ETP	Before ETP	After ETP
	Treated	Treated	Treated	Treated	Treated	Treated
Day 1	8.35	7.54	8.22	7.76	10.69	9.24
Day 2	7.87	7.35	7.66	6.5	11.92	10.38
Day 3	8.13	7.91	8.9	8.1	9.68	7.56
Average	8.12	7.6	8.26	7.45	10.76	9.06

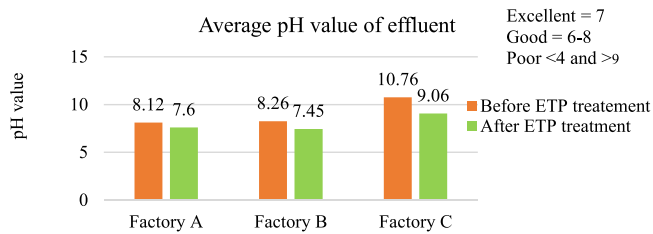


Fig. 14. pH value of effluent.

Although all knitted textile facilities embrace an effective effluent treatment plant (ETP), we have identified gaps in existing operations such as filtration, purification, sedimentation, clarifiers, and coagulations, which cannot efficiently remove solids from water, particularly in non-LEED certified factories. Also, inadequate diffusion, aeration, and decomposition prevent light from reaching lower depths of water, resulting in lower DO and BOD readings even after effluent treatment. Furthermore, the water remains opaque due to inefficient grit chamber operation. The findings are aligned with the existing body of knowledge (Shamsuzzaman et al., 2021) but differ from a LEED and Non-LEED certification factory contexts. This analysis showed insufficient neutralization treatment in the ETP plant for factory C, which resulted in unacceptable water pH values. Therefore, we highlight the necessity of effective wastewater treatment techniques in reducing environmental impact and guaranteeing compliance with regulations in the textile industry. Furthermore, they emphasize the benefits of implementing severe environmental standards, such as LEED certification, on industrial operations, resulting in a more sustainable and ecologically responsible manufacturing industry. The key findings are recommended below-

✓ **Resource efficient practices in effluents treatment reduce environmental impact**, for example, LEED-certified factory performance overweigh non-LEED-certified ones; factories A and B have shown greater potential than factory C

✓ **Identified environmental standards** of water quality management i.e. filtration, purification, sedimentation, clarifiers, and coagulation for case factories A and B.

✓ **Empowering workers and stakeholders** in the supply chain through education, training, workshops, and technical upskilling can enhance sustainability efforts.

✓ **Incentives for green technologies and regulations** on waste management can encourage businesses to adopt more sustainable operations

5. Research implications and future directions

This research highlights the critical role of wastewater management in advancing environmental sustainability within textile manufacturing. It highlights the practical importance of LEED certification, especially the acquisition of specific credits like sustainable practices in improving wastewater management through a range of aspects in the textile sector. By emphasizing these specific credits, LEED-certified factories are incentivized to adopt sophisticated wastewater treatment systems that diminish potable water consumption and facilitate the on-site reuse and recycling of treated water. These practices correspond with sustainable industrial operations, resulting in enhanced environmental performance and adherence to regulatory standards. The incorporation of these particular LEED credits into manufacturing processes provides a targeted guidance for producers seeking to implement sustainable practices, thus advancing the overarching objectives of environmental stewardship and resource conservation. This research elucidates the impact of environmental certifications, specifically LEED, on sustainable operational practices within resource-intensive sectors such as textiles. This study enhances environmental management theories by demonstrating how voluntary standards can affect organizational behavior and promote ecological innovation through specific credits. It indicates that both regulatory and non-regulatory mechanisms, such as green building certifications, adopt diverse strategic approaches to implement more sustainable practices. This research empirically validates the connection between certification status and enhanced wastewater management outcomes, thereby advancing the discourse on certification-driven environmental performance. These findings illustrate that certifications serve as strategic instruments for environmental compliance, performance benchmarking, and corporate legitimacy within global supply chains, thereby enriching environmental sustainability theory. By examining LEED-certified facilities, it underscores the potential of green certifications to drive improved effluent treatment and water quality practices. Future research should explore scalable, cost-effective wastewater technologies and assess their adoption across diverse manufacturing contexts. Comparative studies between certified and non-certified factories can further clarify best practices. Additionally, integrating digital monitoring tools and circular water systems presents promising directions. Strengthening policy frameworks and industry incentives will be essential to align wastewater management with broader Sustainable Development Goals (SDGs).

6. Conclusion

According to the investigation of parameters associated with water quality in textile effluent treatment across LEED-certified facilities, various recommendations may be made for the future application and

Table 13
Summary of the key findings.

Parameters	Factory A (Platinum LEED)		Factory B (Gold LEED)		Factory C (Non LEED)		Key Findings
	Before ETP treated (mg/L)	After ETP treated (mg/L)	Before ETP treated (mg/L)	After ETP treated (mg/L)	Before ETP treated (mg/L)	After ETP treated (mg/L)	
COD	138.49	53.15	310.83	99.29	521.65	263.59	Organic materials can be completely oxidized to CO ₂ chemically for factories A, B Aquatic species can survive in Factory A, B whereas hardly sustain and grow in Factory C Aquatic species can rarely survive and grow over there.
DOi	3.7	5.3	3.3	5.2	1.3	2.7	
DOf	2.5	3.5	2.2	2.9	1.9	2.4	
BOD	1.2	1.7	1.1	2.3	0.6	0.3	Poor BOD value due to lower DO _f , degraded the water quality
TDS	1498	619	1897	822	2901	1462	Water turns turbid due to dissolved solids Restricts aquatic animal mobility and harms soil nourishment.
TSS	667	214	849	390	1110	636	
Turbidity	95.2	10.3	374.7	42.1	581.8	86.8	Water becomes hazy and none can sustain there
pH	8.12	7.6	8.26	7.45	10.76	9.06	Disrupt soil fertility and drainage systems

enhancement of wastewater treatment in the textile industry. Leveraging best practices from factories A and B can serve as a model for other companies, particularly those that are not LEED-certified. Implementing sophisticated treatment methods, such as biological treatment and improved oxidation processes, may enhance organic matter removal while also increasing overall treatment efficiency. Furthermore, regular monitoring and refinement of treatment procedures are required to maintain consistent compliance with environmental legislation and sustainability objectives. Special consideration should be given to those who are not LEED-certified for real-time monitoring systems. This could allow firms to discover areas for improvement and optimize treatment processes for optimal efficiency and efficacy. Furthermore, investing in R&D activities to persuade the majority of textile factories to obtain certification from a globally recognized agency could build a culture of sustainability practices. This can foster a shared commitment to decreasing the environmental footprint and encouraging good industrial practices. This study highlighted several limitations to environmental sustainability, particularly for non-LEED certified enterprises. This is due to few key sustainability requirements imposed by LEED-certified manufacturers, which have a substantial influence on areas such as energy efficiency, water conservation, waste reduction, and interior environmental quality. Non-LEED certified firms lack strong sustainability requirements and may use old, inefficient methods that lead to increased pollution, waste, and resource depletion. These are the major reasons why non-LEED certified enterprises should implement extensive sustainability measures to maintain long-term environmental and economic viability.

CRediT authorship contribution statement

Shamsuzzaman Md.: Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mazed Islam:** Writing – review & editing, Visualization, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

- Akter, M.M.K., Haq, U.N., Islam, M.M., Uddin, M.A., 2022. Textile-apparel manufacturing and material waste management in the circular economy: a conceptual model to achieve sustainable development goal (SDG) 12 for Bangladesh. *Clean. Environ. Syst.* 4, 100070. <https://doi.org/10.1016/j.cesys.2022.100070>.
- Ali, S.R., Hossain, M.A., Islam, K.Z., Alam, S.S., 2024. Weaving a greener future: The impact of green human resources management and green supply chain management on sustainable performance in Bangladesh's textile industry. *Clean. Logist. Supply Chain* 10, 100143. <https://doi.org/10.1016/j.clscn.2024.100143>.
- ASTM D1293-18, 2018. Standard Test Methods for pH of Water. ASTM International, West Conshohocken, PA. Accessed 15 May 2024. (<https://www.astm.org/Standards/D1293.html>).
- ASTM D5907, 2018. Standard Test Methods for Filterable Matter (Total Dissolved Solids) and Nonfilterable Matter (Total Suspended Solids) in Water. ASTM International, West Conshohocken, PA. Accessed 15 May 2024. (<https://www.astm.org/Standards/D5907>).
- ASTM D888-18, 2018. Standard Test Methods for Dissolved Oxygen in Water. ASTM International, West Conshohocken, PA. Accessed 15 May 2024. (<https://www.astm.org/Standards/D888.html>).
- Azanaw, A., Birlie, B., Teshome, B., Jemberie, M., 2022. Textile effluent treatment methods and eco-friendly resolution of textile wastewater. *Case Stud. Chem. Environ. Eng.* 6, 100230. <https://doi.org/10.1016/j.cesce.2022.100230>.
- bluesign, 2023. Sustainable textile solutions for a safer, cleaner industry. (<https://www.bluesign.com/en/>) (accessed on May 10, 2025).
- Brem, A., Cusack, D.Ó., Adrita, M.M., O'Sullivan, D.T., Bruton, K., 2020. How do companies certified to ISO 50001 and ISO 14001 perform in LEED and BREEAM assessments? *Energy Effic.* 13, 751–766. <https://doi.org/10.1007/s12053-020-09864-6>.
- Bungau, C.C., Bungau, T., Prada, I.F., Prada, M.F., 2022. Green buildings as a necessity for sustainable environment development: dilemmas and challenges. *Sustainability* 14 (20), 13121. <https://doi.org/10.3390/su142013121>.
- Business intelligence. 2020. Sustainability Certification Organizations in the Fashion Industry. (<https://fashionunited.com/i/sustainability-certification-organizations-in-fashion#environmental-certifications>) (Accessed on 20 Mar 2024).
- Das, S., Das, D., 2024. Assessing the relationship between firm resources and factory certifications: a quantitative content analysis of the Bangladeshi fashion industry. In: *International Textile and Apparel Association Annual Conference Proceedings*, 80. Iowa State University Digital Press. <https://doi.org/10.31274/ita.17432>.
- Debnath, B., Siraj, M.T., Rashid, K.H.O., Bari, A.M., Karmaker, C.L., Al Aziz, R., 2023. Analyzing the critical success factors to implement green supply chain management in the apparel manufacturing industry: implications for sustainable development goals in the emerging economies. *Sustain. Manuf. Serv. Econ.* 2, 100013. <https://doi.org/10.1016/j.smse.2023.100013>.
- Dhaka Tribune, 2023. A Bangladeshi RMG factory is now world's highest-rated green factory. (<https://www.dhakatribune.com/business/333795/a-bangladeshi-rmg-factory-is-now-world-s>) (Accessed on June 15 2024).
- Di Gaetano, F., Cascone, S., Caponetto, R., 2023. Integrating BIM processes with LEED certification: a comprehensive framework for sustainable building design. *Buildings* 13 (10), 2642. <https://doi.org/10.3390/buildings13102642>.
- European Parliament, 2023. Global value Chain. ([https://www.europarl.europa.eu/RegData/etudes/STUD/2023/702582/EXPO_STU\(2023\)702582_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2023/702582/EXPO_STU(2023)702582_EN.pdf)) (Accessed on June 20 2024).
- Fahim, M.F.H., Hossen, M.L., Sakib, N.A., Shakil, M.S., Haque, M., 2024. Transforming Bangladesh's traditional textile and apparel industry: a sustainable future with green supply chain management. *Supply Chain Inside | ISSN (1), 14, 2617-7420 (Print), 2617-7420 (Online)*.
- Gomes, K., Caucci, S., Morris, J., Guenther, E., Miggelbrink, J., 2024. Sustainability transformation in the textile industry—The case of wastewater management. *Bus. Strategy Dev.* 7 (1), 324. <https://doi.org/10.1002/bsd2.324>.
- Habib, M.A., Balasubramanian, S., Shukla, V., Chitakunye, D., Chanchaichujit, J., 2022. Practices and performance outcomes of green supply chain management initiatives in the garment industry. *Manag. Environ. Qual.* 33 (4), 882–912. <https://doi.org/10.1108/MEQ-08-2021-0189>.
- Hafez, F.S., Sa'di, B., Safa-Gamal, M., Taufiq-Yap, Y.H., Alrifay, M., Seyedmahmoudian, M., Stojcevski, A., Horan, B., Mekhilef, S., 2023. Energy efficiency in sustainable buildings: a systematic review with taxonomy, challenges, motivations, methodological aspects, recommendations, and pathways for future research. *Energy Strategy Rev.* 45, 101013. <https://doi.org/10.1016/j.esr.2022.101013>.
- Hallas, N.E., 2024. LEED certification and sustainable building practices: a comprehensive guide to efficient and sustainable facilities. *Design Strategies for Efficient and Sustainable Building Facilities*. IGI Global, pp. 124–161. <https://doi.org/10.4018/979-8-3693-3200-9.ch006>.
- Han, B., Cao, D. and Yu, Z., 2024. Optimal Control of Influent Water Quality Disturbance in Wastewater Treatment Aeration Process. In *2024 China Automation Congress (CAC)* (pp. 1001–1006). IEEE. <https://doi.org/10.1109/CAC63892.2024.10864642>.
- Islam, M.M., Perry, P., Gill, S., 2021. Mapping environmentally sustainable practices in textiles, apparel and fashion industries: a systematic literature review. *J. Fash. Mark. Manag.* 25 (2), 331–353.
- Islam, M., Shamsuzzaman, M., Hasan, H.M., Atik, M.A.R., 2025. Environmental sustainability of fashion product made from post-consumer waste: impact across the life cycle. *Sustainability* 17 (5), 1917. <https://doi.org/10.3390/su17051917>.
- ISO, 2019. ISO 14000 family, environmental management. (<https://www.iso.org/standards/popular/iso-14000-family>) (accessed on May 10, 2025).
- ISO 6060, 1989. Water quality determination of the chemical oxygen demand. (<https://www.iso.org/obp/ui/#iso:std:iso:6060:ed-2:v1:en>). (Accessed 15 July 2024).
- ISO 7027-1, 2016. Water quality-Determination of turbidity-part 1: quantitative methods. (<https://www.iso.org/standard/62801.html>). (Accessed 15 July 2024).
- Karpova, E., Kunz, G.I., Garner, M.B., 2021. Going global: the textile and apparel industry. *Bloombsbury Publ. USA*. <https://doi.org/10.5040/9781501338700>.
- Khan, M.M.R., Islam, M.M., 2015. Materials and manufacturing environmental sustainability evaluation of apparel product: knitted T-shirt case study. *Text. Cloth. Sustain.* 1, 1–12.
- Kwan, Y.Y., Ngo, D., Shi, T., 2024. Sustainable operations management practices in the textiles, apparel, and footwear industry. *J. Supply Chain Oper. Manag.* 22 (2), 63.
- Lee, S.E., Skorski, S., 2019. Green stores: an analysis of LEED-Certified fashion stores. *Fash. Pract.* 11 (2), 244–268. <https://doi.org/10.1080/17569370.2019.1607227>.
- Li, Q., Long, R., Chen, H., Chen, F., Wang, J., 2020. Visualized analysis of global green buildings: development, barriers and future directions. *J. Clean. Prod.* 245, 118775. <https://doi.org/10.1016/j.jclepro.2019.118775>.
- Maity, S., Singha, K., Pandit, P., 2021. Textile wastewater management. In *Green Chemistry for Sustainable Textiles*. Woodhead Publishing, pp. 417–427. <https://doi.org/10.1016/B978-0-323-85204-3.00026-9>.
- Masud Sumaiya, K., 2022. RMG Ind. Bangladesh Financ. Statement Anal. *Consum. Knitex Ltd.* (<http://dspace.uiu.ac.bd/handle/52243/2370>) (Accessed on 10 November 2024).
- Mosaddeque, I.A., 2022. Envoy Text. Ltd.: A drive Green. *Transit.* (<http://hdl.handle.net/10361/17600>).
- Mousavi, K., Kowsari, E., Ramakrishna, S., Chinnappan, A., Gheibi, M., 2024. A comprehensive review of greenwashing in the textile industry (life cycle

- assessment, life cycle cost, and eco-labeling). *Environ., Dev. Sustain.* 1–41. <https://doi.org/10.1007/s10668-024-04508-6>.
- Nahar, N., Haque, M.S., Haque, S.E., 2024. Groundwater conservation, and recycling and reuse of textile wastewater in a denim industry of Bangladesh. *Water Resour. Ind.* 31, 100249. <https://doi.org/10.1016/j.wri.2024.100249>.
- One Planet, 2021. A New Textiles Economy: Redesigning fashion's future. (<https://www.oneplanetnetwork.org/knowledge-centre/resources/new-textiles-economy-redesigning-fashions-future>). Accessed on 10 July 2024.
- Panhwar, A., Jatoi, A.S., Mazari, S.A., Kandhro, A., Rashid, U., Qaisar, S., 2024. Water resources contamination and health hazards by textile industry effluent and glance at treatment techniques: A review. *Waste Manag. Bull.* 1 (4), 158–163. <https://doi.org/10.1016/j.wmb.2023.09.002>.
- Pushkar, S., 2023. LEED-NC platinum-certified industrial manufacturing space projects in Bangladesh and their environmental assessment. *Heliyon* 9 (11). <https://doi.org/10.1016/j.heliyon.2023.e21277>.
- Qasim, S.R., 2017. Wastewater treatment plants: planning, design, and operation. Routledge. <https://doi.org/10.1201/9780203734209>.
- Rafiq, M.S., Apurba, M.S.H., Khandaker, 2024. Implement. *Sustain. Pract. Wastewater Treat. Mater. Waste Manag. Text. Appar. Sect. Bangladesh*. In: (http://www.iccesd.com/proc_2024/papers/47.pdf).
- Rahman, K.M., Chowdhury, E.H., 2020. Growth trajectory and developmental impact of ready-made garments industry in Bangladesh. *Bangladesh's Econ. Soc. Prog.: a Basket Case a Dev. Model* 267–297. https://doi.org/10.1007/978-981-15-1683-2_9.
- Rasel, Md. Shamsuzzaman, Das, Dip, Khan, Malaz Rahman, 2020. Current scenario of textile sector in Bangladesh (2019); A comprehensive review. *Int. J. Innov. Stud. Sci. Eng. Technol.* 6 (1). (https://www.researchgate.net/publication/338750654_Current_Scenario_of_Textile_Sector_in_Bangladesh_2019_A_Comprehensive_Review).
- Rashid, S., Haque, N., 2024. Regulatory or market pressures: What promotes environmental grandstanding in Bangladesh? *J. Clean. Prod.* 457, 142444. <https://doi.org/10.1016/j.jclepro.2024.142444>.
- Sachidhanandham, A., Periyasamy, A.P., 2021. Environmentally friendly wastewater treatment methods for the textile industry. In *Handbook of nanomaterials and nanocomposites for energy and environmental applications*. Springer International Publishing, Cham, pp. 2269–2307. https://doi.org/10.1007/978-3-030-36268-3_54.
- Sagnak, M., Berberoglu, Y., Kazancoglu, Y., 2024. Sustainable Performance Assessment of Textile and Apparel Industry in a Circular Context. *Sustainable Manufacturing Practices in the Textiles and Fashion Sector*. Springer Nature Switzerland, Cham, pp. 199–228. https://doi.org/10.1007/978-3-031-51362-6_9.
- Saha, T., Uddin, Z., Islam, M.N., Shamsuzzaman, M., Tahsin, A.A., Islam, M.D., 2022. Assessing the effectiveness and environmental sustainability of Reactive dyes for their structural diversity. *Tex. Leath. Rev.* 5, 103–119. <https://doi.org/10.31881/TLR.2022.02>, 2022.
- Saravanan, A., Kumar, P.S., Jeevanantham, S., Karishma, S., Tajsabreen, B., Yaashikaa, P. R., Reshma, B., 2021. Effective water/wastewater treatment methodologies for toxic pollutants removal: Processes and applications towards sustainable development. *Chemosphere* 280, 130595. <https://doi.org/10.1016/j.chemosphere.2021.130595>.
- Shamsuzzaman, M., et al., 2023. Waste Management in Textile Industry. In: Rahman, M. M., Mashud, M., Rahman, M.M. (Eds.), *Advanced Technology in Textiles. Textile Science and Clothing Technology*. Springer, Singapore. https://doi.org/10.1007/978-981-99-2142-3_10.
- Shamsuzzaman, M., Al. Mamun, M.A., Hasan, H.R.U., Hassan, R., Zulkernine, A., Atik, M. A.R., Islam, M., 2025. Fashion Circularity: Potential of Reusing and Recycling Remnant Fabric to Create Sustainable Products. *Sustainability* 17 (5), 2010. <https://doi.org/10.3390/su17052010>.
- Shamsuzzaman, M., Islam, M., Mamun, M.A.A., Rayyaan, R., Sowrov, K., Islam, S., Sayem, A.S.M., 2025. Fashion and Textile Waste Management in the Circular Economy: A Systematic Review. *Clean. Waste Syst.*, 100268 <https://doi.org/10.1016/j.clwas.2025.100268>.
- Shamsuzzaman, M., Islam, M.M., Rakib Ul Hasan, H.M., Khan, A.M., Sayem, A.S.M., 2023. Mapping environmental sustainability of knitted textile production facilities. ISSN 0959-6526 *J. Clean. Prod.* 405, 136900. <https://doi.org/10.1016/j.jclepro.2023.136900>.
- Shamsuzzaman, M., Kashem, M.A., Sayem, A.S.M., Khan, A.M., Shamsuddin, S.M., Islam, M.M., 2021. Quantifying environmental sustainability of denim garments washing factories through effluent analysis: A case study in Bangladesh, 1-13. ISSN 0959-6526 *J. Clean. Prod.* 290, 125740. <https://doi.org/10.1016/j.jclepro.2020.125740>.
- Tayyab, M., Jemai, J., Lim, H., Sarkar, B., 2020. A sustainable development framework for a cleaner multi-item multi-stage textile production system with a process improvement initiative. *J. Clean. Prod.* 246, 119055. <https://doi.org/10.1016/j.jclepro.2019.119055>.
- The Business Standard, 2023. Bangladesh's SM Sourcing tops global LEED Green Factory ranking. (<https://www.tbsnews.net/economy/rmg/bangladeshi-garment-factory-claims-no1-spot-global-leed-green-factories-rankings-756822>) (Accessed on 10 June 2024).
- The Daily Star, 2025. Bangladesh leads with 233 LEED-certified green garment factories. (<https://www.thedailystar.net/business/news/bangladesh-leads-233-leed-certified-green-garment-factories-3793911?>) (Accessed on 10 January 2025).
- Tolentino-Zondervan, F., DiVito, L., 2024. Sustainability performance of Dutch firms and the role of digitalization: The case of textile and apparel industry. *J. Clean. Prod.* 459, 142573. <https://doi.org/10.1016/j.jclepro.2024.142573>.
- Uddin, M.G., Islam, M.M., Islam, M.R., 2015. Effects of reductive stripping of reactive dyes on the quality of cotton fabric. *Fash. Text.* 2, 1–12.
- United Nations, 2023. Circular Textile Value Chains Through a Comprehensive Policy Approach under a UNIDO-led project in Bangladesh. (<https://bangladesh.un.org/en/254808-circular-textile-value-chains-through-comprehensive-policy-approach-un-der-unido-led-project>). Accessed on 10 June 2024.
- USGBC, 2022. Wastewater management. (<https://www.usgbc.org/credits/we4>). May 10, 2025.
- Von Sperling, M., Verbyla, M.E., Oliveira, S.M., 2020. *Assessment of treatment plant performance and water quality data: a guide for students, researchers and practitioners*. IWA publishing.
- Wang, X., Jiang, J., Gao, W., 2022. Reviewing textile wastewater produced by industries: characteristics, environmental impacts, and treatment strategies. *Water Sci. Technol.* 85 (7), 2076–2096. <https://doi.org/10.2166/wst.2022.088>.
- World Health Organization, 2011. Guidelines for Drinking-Water Quality, fourthed. WHO Library Cataloguing-in-Publication Data, pp. 1e564. (Accessed 20 March 2024).
- World Health Organization, 2017. Water quality and health - review of turbidity: information for regulators and water suppliers. *Who/Fwc/Wsh/17.01*, p. 10. (Accessed 20 March 2024).
- Wu, P., Song, Y., Shou, W., Chi, H., Chong, H.Y., Sutrisna, M., 2017. A comprehensive analysis of the credits obtained by LEED 2009 certified green buildings. *Renew. Sustain. Energy Rev.* 68, 370–379. <https://doi.org/10.1016/j.rser.2016.10.007>.
- Zhu, W., 2024. Reducing Fashion MNEs' Potential Litigation Risk Arising From Environmental Sustainability Marketing Messages From A Signalling Theory Perspective (Doctoral dissertation).