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INDUSTRIAL FIRES IN BANGLADESH AND PATHWAYS TO PREVENTION

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Abstract

Fire hazards have become increasingly prevalent in the industrial sector of Bangladesh due to the rapid expansion of unregulated industries, inadequate infrastructure, and poor safety standards for complex machinery and strenuous processes. Export-oriented garment industries maintain some safety standards due to buyer organizations, trade unions, and government requirements, while other sectors still face significant risk, causing substantial economic and human losses. This study investigated the causes, impacts, and gaps in the existing systems that contribute to industrial fire risks by employing a qualitative method, involving the analysis of incident reports and key informant interviews (KII) with fire safety experts and first responders. Findings revealed that inadequate fire protection systems, noncompliance with safety regulations, and a lack of effective preventive strategies are mainly responsible for fire hazards in the industrial sector. Outcomes are supported by case studies, demonstrating that these deficiencies led to significant losses of life, property, and economy. This study identified several critical prevention measures, including hazard analysis, employee training, safety drills, safety inspections, emergency action plans, infrastructure planning, and emergency evacuation plans to safeguard lives, assets, and businesses. The findings emphasise the need for a comprehensive, policy-driven strategy to mitigate fire hazard risk across diverse industries in Bangladesh.

Key words: Fire; Industrial Fire; Hazard; Fire Mitigation; Preventive Measures

Introduction

Bangladesh has recently progressed from a low-income to a middle-income country, with economic advancement largely driven by its industrial sector. The country's industrial sector, including the ready-made garments, polymers, medicinal products, and plastic industries, has developed a lot during the past few years (Wadud and Huda, 2017). This sector's contribution to the nation's GDP was 32.45 per cent in 2015-16, which increased

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to 37.65 per cent in 2022-23, as stated by the Bangladesh Bureau of Statistics (Bangladesh Economic Review, 2024). Among all sectors, the textile sector alone contributes 13% to GDP growth and 75% of foreign currency earnings in Bangladesh (Firoz, 2011). According to the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) (2022), the garment industry, as the leading export segment of Bangladesh, generated around US$27.9 billion in 2019–20 (Islam *et al.*, 2022). Despite the growing contribution of the industrial sector to the economy, its rapid development without adherence to proper construction guidelines has led to increased workplace safety concerns, particularly regarding fire hazards (Wadud and Huda, 2017; Islam *et al.*, 2022; Azad *et al.*, 2018). In 2020, of 383 industrial fires in Bangladesh, 273 occurred in the ready-made garment sector (Ekramuzzaman, 2024). However, the issue of worker safety has gained attention due to two major catastrophes, the Tazreen fire and the Rana Plaza collapse, demanding proper responses from all stakeholders. The catastrophic events in Bangladesh led to the establishment of various systems of management intended to enhance safety in the nation's textile sector during fires or other emergencies (Mizanuzzaman, 2016). While the export-oriented garment industry has a relatively good working environment, partly due to the special attention of various buyer groups, trade unions, and the government, the working environment in other industries is unsatisfactory (Alam, 2006; Ahmed and Hossain, 2009).

The human cost of these deficiencies is alarming and massive. In 2024, 758 workers died in 639 workplace accidents across the country, according to a survey conducted by the Safety and Rights Society (SRS) (Safety and Rights Society, 2024). The fire-related hazard alone constitutes a significant fraction of these fatalities. Islam *et al.* (2022) assessed over 237 incidents to determine the causes and number of casualties in industrial zones and found that 94.09% were attributable to fire incidents. Statistics from the Fire Service and Civil Defense (FSCD) indicate that 6,081 fire incidents occurred in industrial establishments over six years, from 2015 to 2020, which caused an estimated financial loss of around 372 crore BDT (Share Biz News, 2021). The lives of many workers are endangered by fire risks; many have already lost their lives. The FSCD annual statistics indicate that between 2021 and 2024, 3,561 fire incidents occurred in industrial establishments (Fig. 1(a)). These incidents resulted in 242 injuries and 249 fatalities (Fig. 2), highlighting a significant human toll. Moreover, the estimated property loss resulting from these incidents amounted to approximately 4,611 million Bangladeshi Taka (Fig. 1(b)), emphasizing the substantial economic consequences of industrial fire hazards (FSCD, 2021–2024). Moreover, these fire incidents might also lead to significant structural failures (Stochino *et al.*, 2024).

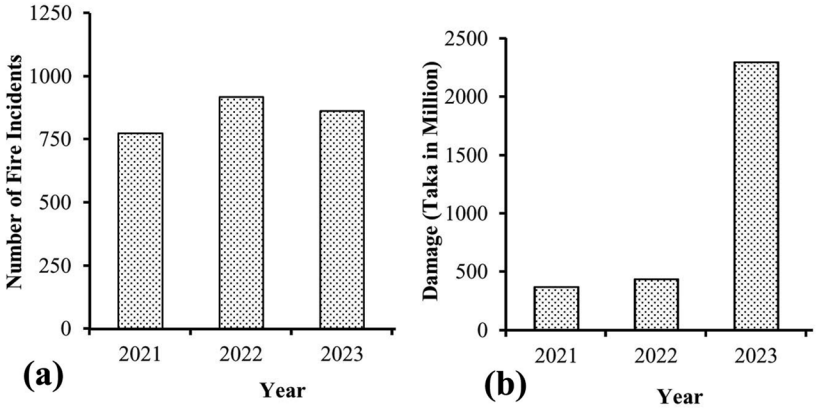

Fig. 1(a) Incident Count and (b) Damage Chart.

Even though garment factories have higher safety standards than other industries, a significant number of fire accidents still happen in this sector alone (Azad *et al.*, 2018). In 2024, BGMEA catalogued 4,149 garment factories (BGMEA, 2024), employing approximately 4.1 million people (Karim, 2020). According to the BGMEA, these factories experienced 206 fire accidents, resulting in approximately 300 fatalities between 1991 and 2011 (Mahabub, 2013).

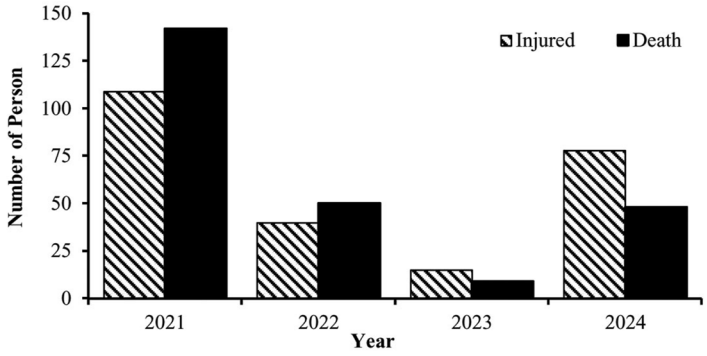

Fig. 2 Death and Injuries due to Industrial Fire Hazards.

Several researchers have identified the causes of fire occurrences in numerous studies. While electric short circuits and boiler explosions are identified as the main causes of fire hazards; insufficient emergency exit routes and staircases, suffocation due to smoke, lack

of properly marked exits, absence of underwater reservoirs, ineffective fire control systems, lack of emergency lights, and insufficient fire extinguishers further exacerbated the situation and enhanced the casualty rate (Azad *et al.*, 2018; Islam *et al.*, 2022; Chowdhury *et al.*, 2025). Over 90% of the industry lacks a fire control training system, just 5% of workers have received first aid training, and over 50% of workers are unaware of how to protect themselves from fire disasters (Azad *et al.*, 2018). Islam and Hossain (2018) reported that before fire hazards, only 34.7% remain alert, 7.9% take preparatory measures, and 1.0% attempt to learn about the fire management system, while 56.4% have no minimum fire mitigation measures. During incidents, 52.5% contact the fire service, 22.8% try to use water, 7% collaborate with the fire management team, and 15.8% are unaware of what to do.

In Bangladesh, few studies have investigated the causes, risks, losses and damages, fatalities, impacts, existing mitigation strategies, and response initiatives related to fire hazards in the industrial sector, especially in the readymade garments sector. For instance, Azad *et al.* (2018) examined the causes and effects of fire catastrophes across 20 industries in Gazipur, Dhaka, and tried to identify the best course of steps to reduce their impact. Wadud and Huda (2017) evaluated the fire risk in Dhaka's ready-made garment factory, revealing a mean Fire Risk Index (FRI) of 2.8 on a scale of 5.0, a highly alarming indicator. The findings also revealed that, among the 24 parameters assessed, locked exit doors, lack of emergency announcement system, and inadequate fire drills worsen the fire scenario. Mizanuzzaman (2016) assessed the losses and damages caused by fire hazards in selected garment factories in Bangladesh, demonstrating that fires result in substantial economic losses and damages within this industry. Ekramuzzaman (2024) evaluated the socio-economic consequences of fire incidents in ready-made garment factories, concluding that recurrent fires have resulted in fatalities, labour unrest, economic and reputational damage, job losses, and a decline in foreign investment in Bangladesh. To the best of our knowledge, no research has yet developed and proposed a specific, suitable, and actionable preventive strategy to mitigate fire hazards in the industrial environments of Bangladesh. However, certain academics are currently focusing on developing effective fire prevention measures for the industrial sector in other parts of the world (Wong and Xie, 2014). Since fire hazards are causing factories to be damaged, economies to be collapsed, and lives to be lost in Bangladesh (Figs. 1 and 2), a comprehensive investigation into the causes of fires, a timely and realistic plan, actionable occupational safety measures, and prevention strategies are required to reduce the risk of fire hazard and maintain the development trend of the industry.

To address research gaps and strengthen the industrial sector's resistance to fire hazards, this study used a qualitative methodology grounded in key informant interviews (KII) with fire safety experts, first responders, and policy specialists to identify the potential causes of fire hazards, evaluate the shortcomings of mitigation strategies, determine the difficulties encountered during evacuation efforts, and investigate the crucial elements of industrial fire prevention. Finally, the study outlined actionable preventive strategies to minimise the risk of industrial fires, ensure safe evacuation, and an appropriate response in the event of an emergency. The results highlight the importance of developing and implementing occupational safety programs in industrial sectors. The results will guide policymakers in improving relevant policies, strengthening safety infrastructure, protecting personnel's lives, and reducing property and economic losses.

Methodology

This study employed a qualitative research method, involving document reviews and KII to collect information on the causes of fire, existing mitigation approaches, and efficient prevention strategies to reduce fire risks in the industrial sector of Bangladesh. This work analysed the overall condition of the industrial sector in Bangladesh, focusing on fire safety across various sectors rather than a specific industrial zone. Therefore, the preventive strategies suggested in this study are suitable for all industrial sectors across the country.

Document review: The initial exploratory phase of this study involved a comprehensive investigation of incident reports, newspaper articles, governmental reports, statistics of FSCD, reports of BGMEA, and various other relevant organizational reports to determine the original problem, detect the causes, comprehend present practices and existing mitigation procedures, evaluate safety protocols, and pinpoint deficits in the existing fire hazard prevention system in the industrial sector of Bangladesh.

A crucial part of this document review involved a comprehensive study of seven official fire investigation reports from the FSCD, each describing notable industrial fire events. The selected events are based on the criteria of severity, relevance, and their accessibility, including Hashem Foods Ltd. (2022); Green Cozy Cottage, Bailey Road (2024); Tampaco Foils Ltd., Tongi, Gazipur (2016); Tazreen Fashions (2013); Zaman Jute Mill, Khulna (2024); Jahin Knitwear, Narayanganj (2022); and Square Pharmaceuticals Ltd., Gazipur (2022). All of the incidents investigated fall under different industrial sectors, as outlined in the Bangladesh Industrial Policy 2022: readymade garments, pharmaceuticals, agricultural and food processing, jute-based production (Annexe I), printing and

packaging (Annexe II), and hotels and restaurants (Annexe V) (Bangladesh Industrial Policy, 2022). Each report examined was produced by the FSCD investigative committees, formed after major fires in various sectors. These reports investigate the specific causes of the fires, evaluate the resulting damage, and propose measures to prevent similar events in the future. This method ensured the incorporation of fire safety issues and preventive recommendations from industries of all sizes and types.

The collective examination of these reports forms the basis for the next stage, KII, enabling the formation of in-depth questionnaires that captures all relevant issues.

KII: Although the assessments of prevailing literatures offered preliminary information into the existing issues and current practices, a more profound and specialized understanding was essential to meet the objectives of this study. Therefore, KII were conducted in this study to gather specialised insights from experts in this field. The key informant analysis offers access to expert knowledge, captures the unique characteristics and context of the subject, and can reveal hidden or sensitive issues that other methodologies might miss. This inclusive and detailed information provide a comprehensive understanding of the problem.

Participants comprised senior officials from the FSCD, safety officers, first responders to fire incidents, industrial zone managers, and policy experts specialising in workplace safety and disaster risk mitigation (Fig. 3). Each participant was selected based on a purposive or judgmental sampling technique, a non-probability sampling procedure employed in qualitative studies. Participants were deliberately selected by the researcher based on their knowledge, proficiency, skills, and experience in fire hazards, industrial safety management, and fire risk mitigation. Semi-structured interviews were conducted using pre-developed questionnaires that addressed the causes, risk perception, existing mitigation practices, implementation problems, and efficient preventive measures regarding fire hazards and the occupational safety of workers in the industrial sector. Interviews were conducted either in person or via digital platforms, consent was obtained from respondents prior to recording, and information was organised for thematic analysis.

Data Analysis: Finally, the findings from the document reviews and KII were systematically documented and thematically evaluated to detect potential reasons, structural susceptibilities, mitigation approaches, emergency preparedness, institutional deficits, and preventive procedures to mitigate the risks associated with industrial fire hazards and diminish the loss of life, property, and the economy in the upcoming events. Thematic analysis of relevant literature and interviews enabled the integration of insights from multiple sources, resulting in a comprehensive understanding of fire risks and the

development of appropriate preventive measures to mitigate them in the industrial sector of Bangladesh.

Fig. 3. Key Informant Interview (KII) with Fire Service and Civil Defense officials.

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The aforementioned technique has been instrumental in efficiently understanding fire safety concerns, with satisfactory results in other studies (Owusu-Sekyere *et al.,* 2017). Hence, this technique was utilised in this study to identify root causes and develop preventive strategies to mitigate the risks of fire hazards and the associated loss of life, property, and the economy.

Results and Discussion

The main objective of this study was to develop effective prevention strategies to impede or mitigate industrial fire risks. Before developing preventive measures, it is essential to identify the underlying causes of fire accidents in industrial sectors. For this purpose, the study reviewed relevant documents, newspapers, and reports from relevant governmental organisations on fire incidents, and conducted KII with industrial zone managers, fire safety officials, policy specialists, and first responders to fire incidents. Through this

process, the causes, current mitigation measures and systems, implementation difficulties, emergency response, and recommended prevention practices were identified. The findings are briefly described below.

Causes of Fire Hazards in Industries

Fire prevention practices have improved in export-oriented garment factories; however, significant fire hazards persist in other industrial facilities. Industrial fires will continue if they're not addressed properly. The first step toward effective fire prevention is a comprehensive understanding of the specific hazards within a facility and the dominant causes of fire risks in industrial settings. A successful fire prevention program involves more than merely identifying risks; it requires an integrated strategy to address these hazards on multiple levels. The main causes of fire hazards are outlined below:

Non-compliant Industries: At present, buildings are not being constructed in compliance with the country's fire safety codes. Additionally, the owners are constructing buildings by violating rules and norms to maximise profits, without protecting the occupational safety and health environment of the industrial facility. Moreover, it is alleged that most developed industries lack regulations. All these issues are exacerbating fire risks in the industry, potentially resulting in significant damage to property, economy, and human life (Hideki, 2015; Azad *et al.*, 2018).

Unplanned Infrastructure: The materials utilized in constructing buildings and the products generated within the structure significantly influence the spread and intensity of fire. Unfortunately, in Bangladesh, construction codes are violated, and structures are often used for unintended purposes. This leads to an increase in fire incidents, which in turn increases the number of casualties. For example, in July 2021, a fire at the Hasem Food factory in Narayanganj resulted in the deaths of 52 individuals (Prothom Alo, 2021). Investigation revealed that the factory was built without permission. Furthermore, sufficient and appropriate fire safety measures were absent, which exacerbated the impact of the incident.

Lack of Necessary fire Protection Systems and Equipment: Fire safety measures are inadequate across industries outside Bangladesh's sole garment industry. In most cases, the structure lacks a sufficient and necessary firefighting system. This finding was also demonstrated in an earlier study conducted by Ahmad and Kamruzzaman (2015). However, in several locations, firefighting equipment was discovered, but it was predominantly outdated. This is corroborated by a study of Tabassum *et al.* (2014), demonstrating that while most of the industry had some firefighting apparatus, it was not

properly maintained. The lack of appropriate, sufficient, and modern firefighting systems exacerbates fire hazards in Bangladesh's industrial sector.

Storage of Dangerous Goods, Flammable and Combustible Materials: Factories utilize various combustible materials, including chemicals, liquids, solids, and gases that are easily ignitable. Fire may occur if these flammable materials are not stored properly. Sometimes combustible materials are stored in the factory with permission to operate as a warehouse, which may cause a fire if not stored properly. For example, the devastating fire at the BM depot in 2022 (Fig. 4(a)) resulted in more than 40 fatalities and 200 injuries (Chowdhury, 2023). The investigation disclosed that the presence of hydrogen peroxide in the depot and the failure to comply with appropriate safety protocols resulted in the incident.

Smoking Precautions: According to the FSCD's 2023 annual statistics, there were 4906 fire incidents in the country caused by burning bits of cigarettes. This was also the second-highest leading cause of fire in 2023 (FSCD, 2023). Therefore, precautions should be taken when smoking to prevent factory fires. If necessary, smoking should be completely prohibited in the critical establishment, or separate rooms should be arranged for smoking.

Chemicals and Fuels: Chemicals and fuels are utilized in industrial plants. However, industries lack skilled and experienced manpower when using them, which causes accidents such as fires. Therefore, experienced personnel must be engaged in the management and use of chemicals and fuels to reduce fire hazards. Moreover, appropriate regulations must be followed in storing chemicals and fuels. Chemicals must be stored in a designated room at a specific temperature to mitigate fire hazards. Improper management of chemicals and fuels may lead to significant fire incidents. For example, 71 people lost their lives in a terrible fire event at the chemical warehouse (categorized as industry according to Annex V of the Bangladesh Industrial Policy 2022) at Churihatta intersection in Chawkbazar on 20 February 2019 (Fig. 4(b)) (Prothom Alo, 2022; Bangladesh Industrial Policy, 2022). The investigation revealed noncompliance with proper chemical storage regulations at that site, which caused the fire.

Electrical Faults: Overloaded circuits, defective wiring, substandard electrical appliances, and improper use of electrical equipment can all cause sparks and ignite adjacent materials. Numerous studies corroborate these conclusions, showing that electrical short circuits are the primary source of fire hazards in Bangladesh's industrial sector (Firoz, 2011).

Fig. 4. (a) Fire Accident in BM Depot Chittagong and (b) Churihatta Chemical Fire Disaster

Spontaneous Combustion: Certain substances, such as oil-soaked rags or improperly stored organic materials, can undergo a heat fermentation process and ignite spontaneously, without external ignition sources.

Welding and Cutting Operations: Welding and cutting operations involve the use of intense heat sources, sometimes referred to as hot work, which generate significant heat that can ignite surrounding combustibles or flammables.

Dust Explosions: Fine, ignitable dust particles suspended in the air can form explosive mixtures when ignited by a spark, causing a fire.

Gas Explosions: Fires are also caused by gas explosions resulting from gas leaks in pipelines or cylinders, insufficient ventilation, malfunctioning equipment, inadequate maintenance, or igniting sources such as sparks, flames, or overheated instruments.

Case Study

A thorough case study of a few industrial fire incidents has been carried out following the identification of the causes of fire in the industrial sector of Bangladesh, including Hashem Foods Ltd, Rupganj, Narayanganj (2021); Green Cozy Cottage, Bailey Road, Dhaka (2024); Tampaco Foils Ltd., Tongi, Gazipur (2016); and Square Pharmaceuticals Ltd., Kaliakair, Gazipur (2022). This study outlines the causes of fire occurrences, identifies shortcomings in fire hazard prevention within the industry, emphasises the need for robust fire protection measures, and provides recommendations to improve the existing system to manage similar events more effectively in the future.

Case Study-1: Hashem Foods Ltd, Rupganj, Narayanganj (2021)

Causes and consequences: On 9 July 2021, at approximately 5 PM, a fire broke out at the multi-story building of Shezan Juice Factory, a part of Hashem Foods Ltd in Rupganj,

Narayanganj (Fig. 5(a)). The incident caused over 52 fatalities, missing of many workers, and more than 50 injuries, as many people jumped from the building (Prothom Alo, 2021; Dhaka Tribune, 2021a). The existence of combustible chemicals, plastics, foil, paper, resin, cardboard, and cooking oil intensified the fire. Casualties were enhanced due to deficient fire protection systems and insufficient exit routes. The factory facility, measuring 35,000 square feet, required four to five emergency exits but had only two, both of which were rendered dysfunctional during the fire. The front gate, the sole entry and exit point, was also closed after the fire began, hindering escape and contributing to fatalities (Dhaka Tribune, 2021a). Furthermore, the building was built without governmental permission (Anam, 2022).

After the event, the FSCD developed a five-member investigative committee on 11 July 2021. The inquiry revealed that the fire originated from an electrical malfunction, resulting in property damage equivalent to BDT 2,47,73,25,253 (FSCD, 2022a). The examination carried out by the Narayanganj district administration inquiry committee found that an electrical short circuit in the ground-floor compressor room originated the fire, which spread swiftly due to the presence of excessive amounts of chemicals and foil sheets. The committee revealed insufficient emergency exits and violations of the building code in the facility (Dhaka Tribune, 2021b). Despite the intensity of the fire, the FSCD's quick response and effective firefighting tactics successfully controlled it and prevented its spread to connecting facilities.

Lessons learned: This fire incident highlighted the necessity for automated smoke detection and fire sprinkler systems in industrial buildings. The factory fire underscored the need for fire-resistant materials and effective compartmentalization in large structures. This incident demonstrated the critical need for rapid response, fire safety protocols, adequate fire protection, and effective firefighting equipment in managing fire events and related emergencies. This case study also underscores the necessity for careful storage and maintenance of combustible goods and materials to prevent similar fire threats in the future.

Case Study-2: Fire Incident at Green Cozy Cottage, Bailey Road, Dhaka (2024)

Causes and consequences: The Green Cozy Cottage, a prominent multi-story restaurant located on Bailey Road in Dhaka, experienced a fire on 29 February 2024, resulting in significant casualties and property damage (Fig. 5(b)). After the fire, the FSCD's five-member investigative team reported that the fire originated from an electric kettle at the 'Cha Chumuk' coffee shop adjacent to the ground-floor stairway. Flammable materials

near the kettle, the ignition of adjacent items, and a gas leak enhanced the fire's spread, which was further exacerbated by an explosion of the refrigerator compressor. Smoke, heat, and flames rapidly engulfed the stairwell, hindering residents' evacuation through the only staircase (FSCD, 2024). The FSCD study concluded that the building was deficient in essential firefighting systems, lacked an alternate fire escape, contained a narrow, non-compliant stairway, and did not have an appropriate fire safety plan.

Fig. 5. (a) Fire Accident in Shezan Juice Factory, (b) Fire Accident in Green Cozy Cottage, (c) Fire Accident in Tampaco Foils Ltd. Factory, and (d) Fire Accident in Square Pharmaceuticals Ltd. Factory.

The consequences were catastrophic; over 46 people lost their lives due to smoke inhalation and entrapment, while more than 75 experienced injuries (Prothom Alo, 2024). The building experienced significant structural damage, rendering many floors inoperable, and the restaurant was forced to shut down indefinitely. The incident sparked public outrage, led to protests, extensive media coverage, and further demands for stricter enforcement of fire safety standards in commercial establishments across Dhaka.

Lessons learned: The tragic event highlighted significant deficiencies in urban fire safety, especially in densely populated commercial zones. Regulatory deficiencies, including inadequate gas system maintenance, unsafe construction modifications, missing inspections, and a lack of fire escapes, intensified the risk. There was widespread panic

because neither staff nor customers were trained in emergency evacuation procedures. Despite the availability of fire extinguishers, they remained mostly unutilized due to inaccessibility and inadequate preparedness. The tragedy emphasizes the necessity of retrofitting older buildings, installing sprinklers, enforcing occupancy restrictions, ensuring accessible exits, and improving coordinated emergency response, which was hindered by traffic congestion, narrow roadways, and poor communication with fire services.

The Green Cozy Cottage fire is an evident reminder that in high-density urban areas, primarily where restaurants and entertainment venues operate, proactive fire safety measures are essential. It calls for comprehensive regulatory reforms, regular audits, improved public awareness, and stronger collaboration between private businesses and public safety agencies.

Case Study-3: Fire Incident at Tampaco Foils Ltd., Tongi, Gazipur (2016)

Causes and consequences: On the early morning of 10 September 2016, a massive explosion followed by a devastating fire broke out at the Tampaco Foils Ltd. factory located in the BSCIC industrial zone of Tongi, Gazipur (Fig. 5(c)). The explosion occurred at about 6:00 AM when the morning shift started. The explosion was so powerful that it caused portions of the five-story building to collapse instantly, trapping numerous workers under the debris (The Daily Star, 2016). The FSCD reported that the fire was finally extinguished on 11 October 2016, following over a month of relentless firefighting efforts.

Primary inquiries suggested that the explosion resulted from a gas leak originating from either the boiler or the gas pipeline system. Significant amounts of combustible chemicals and packaging materials, such as aluminium foil and plastic laminates, exacerbated the fire. The building collapsed due to its inadequate structural integrity, lack of adequate safety engineering, and negligence of prior safety warnings.

A seven-member investigation committee formed by the FSCD submitted a detailed report on the incident. The report stated, "Most of the individuals who gave testimony acknowledged the presence of a gas leak, and it was revealed that Line Supervisor Mr. Subhash went to repair the leak just as the explosion occurred. Based on this, the investigation committee concluded that the explosion was likely triggered by either the pressure of accumulated leaked gas or a spark from an unidentified source igniting the gas. Furthermore, the presence of highly flammable and volatile chemicals stored inside the building contributed to the rapid spread of the fire and caused a secondary explosion

throughout the factory (National Human Rights Commission, 2016)." The results indicated both operational negligence and insufficient safety measures as the contributing factors to the disaster.

The human and economic costs of the fire were substantial. At least 40 people were confirmed dead, and 44 people were injured (DIFE, 2016). A significant number of victims were laborers, including adolescents and contract workers, leading in several families losing their sole breadwinners. The facility was completely destroyed, adjacent structures sustained damage, and industrial operations in the vicinity were interrupted, revealing substantial deficiencies in labour protection and industrial safety regulations in Bangladesh.

Lessons learned: This accident exposed significant shortcomings in industrial safety standards, including insufficient emergency training, poor gas pipeline maintenance, blocked or inadequate exits, and a lack of operational fire detection and suppression systems. It also underscored the urgent need for stronger building code enforcement, regular safety audits, and greater accountability for factory owners who disregard their compliance obligations. Moreover, the incident highlighted the importance of strengthening coordination among regulatory bodies, local administration, and emergency services to ensure swift and effective response during industrial accidents.

Case Study-4: Fire Incident at Square Pharmaceuticals Ltd., Kaliakair, Gazipur (2022)

Causes and consequences: On 23 May 2022, a significant fire broke out at the Square Pharmaceuticals Ltd. facility in Kaliakair, Gazipur (Fig. 5(d)). The fire led to an extensive emergency response, with 19 units of the Fire Service working relentlessly for seven hours to bring the flames under control (bdnews24.com, 2022). Following the incident, on 2 July 2022, the FSCD formed a five-member committee to inspect the event. The committee reported that the fire resulted from an electrical malfunction (FSCD, 2022b) and found no evidence of inappropriate conduct. The inquiry revealed significant fire safety deficiencies: the facility lacked an FSCD-approved fire safety plan, sufficient trained personnel for emergency response, and a functioning fire hydrant system. The fire damaged saline, tablet raw materials, and chemicals stored in the affected unit, resulting in significant production losses. The company disclosed to the stock exchange and in its audited financial statements that the incident resulted in an estimated revenue impact of about Tk 50 crore (BDT 500 million) and a profit impact of Tk 8 crore (BDT 80 million) (The Business Standard, 2022; The Financial Express, 2022).

Lessons learned: The committee strongly recommended the fast development and implementation of a comprehensive fire safety plan, along with regular staff training and maintenance of fire suppression systems to prevent similar occurrences in the future. In addition, the event highlights the necessity of routine inspection, repair, and renovation of electrical systems in medical facilities to prevent sources of ignition.

Recommended Practices

This study identified several preventive strategies and practices to mitigate fire hazards in industrial environments, based on case studies, documents, and news articles on fire incidents, as well as KII with fire safety officials, industry managers, and first responders. These strategies and practices will work as actionable guidelines for policymakers, safety managers, and stakeholders. The following outlines recommended strategies and practices for effectively mitigating or controlling industrial fires.

Hazard Identification and Risk Analysis: Industries must regularly conduct routine inspections to identify potential fire risks within the facility and evaluate fire risks across all operational areas. This includes the identification of combustible materials, equipment used, procedures, material storage practices, faulty electrical systems, and improper waste disposal. Such examinations must be carried out in accordance with the National Fire Protection Association (NFPA) and the Department of Inspection for Factories and Establishments (DIFE) guidelines to ensure compliance with standards (NFPA, 2021; DIFE, 2023).

Safe Work Practices and Housekeeping: It is essential to develop, implement, and enforce safe work practices to reduce the use of ignitable materials, guarantee proper handling and storing of combustibles, and maintain a clean and orderly work environment. This must also include separate smoking zones, suitable signage, and appropriate waste-disposal procedures. Strong housekeeping practices are crucial in mitigating or preventing workplace fire incidents.

Employee Training and Drills: It is crucial to develop and implement a training program to provide staff with the information and skills necessary for fire prevention. Training must incorporate fire safety protocols, the effective use of fire extinguishers, the operation of fire alarms, and safe evacuation techniques. Routine evacuation drills must be conducted to ensure personnel are familiar with emergency protocols and can respond effectively and evacuate the workplace safely in the event of a fire emergency. This practice was also recommended in a previous study conducted by Azad *et al*. (2018).

The DIFE mandates the Safety Committee to conduct training for a diverse group of employees, including managers, supervisors, maintenance personnel, emergency managers, first aid responders, evacuation teams, firefighting teams, security guards, and workers. It recommends a yearly training plan and states that this training must be free of charge, conducted regularly, and participation should be regarded as working hours (DIFE, 2023). The Occupational Safety and Health Administration (OSHA) also mandates that all industry personnel must be familiar with fire extinguishers and undergo this training annually. This training also seeks to familiarise workers with the PASS system (Pull, Aim, Squeeze, Sweep) for initial firefighting efforts with fire extinguishers. Local fire departments can assist with this training (OSHA, 2020a).

Fire Protection Systems: It is crucial to install and maintain appropriate fire protection systems. Industrial facilities must install smoke detectors, heat detectors, and fire alarm systems throughout the premises to ensure early detection of fire events. Previous investigations support this suggestion as well (Bukowski *et al.*, 2003; Ko *et al.*, 2009). The facility must be equipped with appropriate fire suppression apparatus, including automatic sprinkler systems, portable fire extinguishers, and fire blankets, ensuring they are easily accessible, regularly maintained, and available for employee use. The fire protection system installed must be tailored to the specific hazards present in the facility and comply with NFPA and OSHA standards (NFPA, 2021; OSHA, 2020b).

Equipment Maintenance: Industrial facilities should regularly examine and service their electrical systems, heating units, machinery, and other potentially fire-prone equipment to prevent malfunctions. Furthermore, fire safety equipment should be inspected regularly to ensure proper working order and preparedness for emergencies. Regular inspection and monitoring of equipment are also critical to ensure that firefighting apparatus are functioning and accessible for emergency response. These inspections should be documented properly for accountability.

Designate Proper Evacuation Routes: Develop and mark all emergency exits, and ensure they are not blocked in any way. Previous research by Nagai *et al.* (2004) and Soomaroo and Murray (2012) has recommended this method to reduce fire risk. Regular drills should be conducted to acquaint employees with evacuation routes and procedures. This can be done efficiently by working in partnership with local fire departments. Earlier research has also supported this finding (Smith and Trenholme, 2009; Azad *et al.*, 2018).

Formulate an Emergency Action Plan (EAP): The EAP outlines the actions for employees those need to follow during emergencies. An effective EAP guides industries in establishing a reporting mechanism for fires or other crises and in developing clearly

demarcated evacuation processes and escape routes, each designated with proper signage. It delineates the precise roles and responsibilities of emergency personnel. An EAP also provides clear instructions on what to do after the evacuation process is complete. Furthermore, the EAP specifies the rescue and medical assistance of workers, if necessary. Finally, an EAP assembles a list of personnel assigned with specific responsibilities, representing whom to contact for further information or clarification of duties. OSHA provides detailed instructions for developing an EAP that industrial establishments should follow (OSHA, 2020c).

Formulate an Emergency Response Plan: Develop and periodically assess a plan that outlines protocols for fire reporting, emergency exit procedures, personnel evacuation, and collaboration with local fire departments.

Infrastructure Planning and Regulatory Measures: The materials utilized in building construction and the products produced within the building significantly influence the spread and intensity of fire. Therefore, industrial infrastructures must be built in accordance with the national building code. Regulatory bodies, such as the DIFE, must ensure that all industrial structures adhere to the Bangladesh National Building Code (BNBC) and fire safety regulations. Penalties should be imposed on unapproved constructions, and regular inspections must be performed to ensure compliance with regulations (BNBC, 2020; DIFE, 2023). Furthermore, fire-resistant materials must be used in construction, whereas combustible and substandard materials should be strictly prohibited. Before granting operational permission, all industrial structures must obtain a fire safety certificate from the FSCD confirming that all structural and operational fire safety measures are in place (FSCD, 2023).

Optimisation Problem: In most cases, it is found that industries have many deficiencies in their safety management systems. Industry owners must prioritise compliance requirements to implement fire prevention, fire safety, and emergency response management systems that protect their businesses, reputations, and ensure sustainability.

Policy Update: Fire safety policies must be routinely reviewed and updated to reflect any changes to the facility or regulations, ensuring ongoing improvement in fire safety practices. By adhering to these recommendations, industrial facilities can significantly enhance their fire safety protocols and establish safer working environments for all personnel.

Ensuring Stiff Punishment of Offenders: To reduce the recurrence of fire hazards in industries, it is essential to ensure strict, consistent punishment for those responsible. As highlighted by Ekramuzzaman (2024), factory owners who have previously violated fire

safety regulations face very little consequence or minimal accountability, which, in turn, indirectly encourages other factory owners to neglect compulsory fire protection measures. Implementing strict legal action against offenders not only serves justice but also motivates factory owners to invest in effective fire safety systems, ultimately protecting both workers and assets from the risk of fire disasters.

Conclusion

Industrial fire hazards in Bangladesh are a major concern, posing significant risks to worker safety, industrial assets, environmental integrity, and national economic growth. Despite advancements in export-oriented garment factories, many other industrial sectors continue to face devastating fire risks due to widespread noncompliance with fire safety regulations, inadequate firefighting equipment and safety systems, improper storage and handling of hazardous chemicals and goods, insufficient training and experience among workers, and inadequate fire exits. Hence, effective fire prevention strategies are necessary to mitigate this hazard risk. This study, supported by KII and document reviews, emphasises that effective fire prevention is not simply a technical exercise; it requires a strong safety culture embedded within organisational practices and a shift towards proactive safety management. Fire prevention must be a comprehensive, multifaceted approach that incorporates hazard identification, safe work practices, regular equipment maintenance, employee training, the installation of effective fire protection systems, and the formulation and implementation of both an emergency action plan and an emergency response plan. Establishing and maintaining such a system requires significant effort and commitment from management, as well as support from employees. Fire safety procedures and practices must be regularly reviewed and updated to reflect operational changes, technological advancements, and lessons learned from incidents. Fire prevention is an ongoing process that requires persistent observation, adaptability, and institutional support to ensure a secure working environment for all personnel. As industrial activity increases across the country, safety protocols must adapt accordingly. By adopting a comprehensive fire risk management strategy and strengthening intersectoral collaboration, Bangladesh's industrial sector can evidently reduce the frequency and severity of fire-related incidents. Stricter regulatory enforcement and a shift from reactive to proactive fire safety practices are imperative to safeguard workers, preserve assets, and protect surrounding communities and the environment.

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Author contributions

Mohammad Tajul Islam Chowdhury: Conceptualization; Data curation; Formal analysis; Investigation; Resources; Visualization; Roles/Writing - original draft

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