Evaluation And Mitigation of Industrial Fire Hazards in The Faisalabad Industrial Estate Development and Management Company (Fiedmc) Zones

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Industrial fire hazards are a major threat to lives, infrastructure, and economic activities, especially in growing urban areas. Although industries significantly contribute to the national industrial sector but it may easily catch fire, resulting in a brutal impact on infrastructure, workers, and the environment. This research seeks to assess the characteristics, causes, and frequency of industrial fires within FIEDMC zones, pinpoint the most frequent ignition sources, and propose effective mitigation measures. A quantitative methodology was utilized to gather fire incident data from 2014 to April 2025, drawing from official reports from rescue services and fire stations on-site. The data was analyzed using Power BI to uncover trends in incidents, injuries, and fatalities, while also identifying the most prevalent causes of industrial fires. Factors considered included overloaded wiring, HVAC malfunctions, human error, structural failures, and boiler issues. The visualizations enabled the categorization of causes and the identification of high-risk years and emerging patterns. The results indicated a notable increase in fire incidents and casualties in recent years, particularly from 2020 to 2025. Electrical and mechanical failures were identified as the primary causes, with overloaded wiring alone contributing to 30.43% of fire cases, followed by HVAC problems (18.84%) and human negligence (15.94%). The highest numbers of injuries and fatalities occurred in 2023, with 410 injuries and 80 deaths, reflecting a significant lapse in safety. The study concludes that FIEDMC zones are facing a persistent fire safety crisis influenced by ingrained weaknesses in risk management. Tackling this issue requires long-term, comprehensive solutions, which include regular inspections, worker training, infrastructure improvements, and stricter enforcement of regulations. To reduce risks related to industrial fire hazard require quarterly safety audits, load assessments of all wiring systems, mandatory fire-response training for staff, and the creation of a dedicated fire risk monitoring unit in each estate. Importantly, fire safety must be treated as a management issue, not just a technical one.

Keywords: Industrial fires, Fire hazards, FIEDMC zones, Risk management, Safety measures

Introduction:

Industries operate as commercially driven entities that manufacture large quantities of goods, playing a key role in driving the growth and expansion of industrial activities. Their productive capacity and economic output significantly contribute to the economic development of both advanced and emerging nations [1]. However, industries encounter heightened risks related to industrial fire hazards, stemming from their complex manufacturing processes, which can generate heat or serve as ignition sources themselves. According to the World Health Organization (WHO), fire-related incidents result in over 300,000 deaths worldwide each year. Disturbingly, over 95 percent of these fatalities occur in low- and middle-income countries, highlighting a significant disparity in fire safety and emergency response capabilities [2]. As a developing nation, Pakistan strives to improve the quality of life for its population. In pursuit of this goal, it has initiated numerous industrialization programs[3] and adopted the concept of industrial development from an early stage[4]. Pakistan is home to a diverse range of manufacturing sectors, including textile mills, glass manufacturing units, rice processing plants, sugar production facilities, paper and board factories, and steel production industries. Nevertheless, industrial processes, such as manufacturing, production, dyeing, distillation, cutting, and electrolysis, can all ignite fires that rapidly spread, reducing valuable assets to ashes[5]. In Pakistan, industrial zones like those managed by the Faisalabad Industrial Estate Development and Management Company (FIEDMC) have experienced swift growth in recent years. These zones have made notable advancements in sectors like textiles, pharmaceuticals, food processing, and engineering [6].

Furthermore, the presence of combustible materials, high-temperature operations, electrical machinery, and chemicals increases fire hazards in industrial settings [7]. Industrial fire hazards are considered among the most deadly and frequent types of human-made disasters[8]. Potential sources of fire in industries include electrical poles or arcing, mechanical breakdowns, and overheating of certain equipment. If oil or hazardous liquid spills are not promptly addressed, and if sparks commonly generated as byproducts of machinery operation are not properly controlled, they can lead to fire outbreaks. Moreover, if employees lack comprehensive training in fire prevention and emergency procedures, problems may easily arise. The history of industrial fire hazards in Pakistan is complex and troubling. One of the most devastating incidents was the Baldia Town factory fire in Karachi, which claimed the lives of over 259 people, making it one of the deadliest workplace disasters in history[8][9]. In September 2012, a fire at the Ali Enterprises textile mills in Baldia Township, Karachi, claimed the lives of numerous workers. Furthermore, 32 people were injured, suffering from serious wounds, as those who perished or were severely burned could not escape because of blocked windows, locked emergency exits, and a single accessible exit[9]. Such incidents underscore the urgent need for thorough fire risk assessments and the implementation of proactive prevention strategies. The high density of risky industries and the dependence on outdated or inadequately maintained electrical systems within zones managed by FIEDMC elevate the risk of catastrophic fire events. Several factors can lead to industrial fire outbreaks, including electrical faults, ignition sources, and poor housekeeping practices. Previous assessments have identified several major contributors to fire hazards, including mechanical deterioration, improperly discarded cigarettes, and static electricity [10][11]. Combustible items include fabrics, wood, paper, and fine powders such as wheat, coal dust, and sawdust. In addition, flammable materials like gasoline are extremely volatile [12]. This research intends to investigate the casualties, injuries, and causes of fire hazards within FIEDMC zones, while also assessing the effectiveness of current preventive measures. The study concentrates on uncovering structural, mechanical, electrical, and operational vulnerabilities that contribute to fire incidents. A multidisciplinary methodology is utilized in this research, integrating incident data analysis, field evaluations, and interviews with stakeholders to develop a comprehensive

understanding of fire risks and organizational responses. By examining fire vulnerabilities, the research provides practical recommendations that could benefit industrial stakeholders, employees, and facility owners. Industrial sector stakeholders and managers of production and manufacturing facilities will receive customized strategies to minimize fire risks, which include compliance with ISO standards, contingency plans, employee training, and emergency response procedures.

Objectives of the Study:

- To evaluate the industrial fire hazard in FIEDMC (Faisalabad Industrial Estate Development and Management Company)
- To propose mitigation measures for the Faisalabad Industrial Estate Development and Management Company.

Literature Review:

Industrial fire hazards are broadly acknowledged as significant risks to human safety, infrastructure, economic sustainability, and environmental health, particularly in densely populated and rapidly developing industrial areas like those found in Pakistan. Global studies increasingly highlight the growing concern surrounding fire risk management, emphasizing the need for stronger safety protocols and preventive strategies. For instance, [13] scrutinized more than 37,000 fire incidents in the United States, emphasizing the necessity for structured data analysis and the use of statistical tools such as Chi-square and SPSS to determine causes and prevent future occurrences. The "domino effect" of fire propagation and regional vulnerability mapping (e.g., in Istanbul and Marmara) illustrated the importance of utilizing GIS and multi-criteria decision-making methodologies, such as AHP and IDW, to evaluate and visualize risk areas. These models showcased the significance of proximity to critical infrastructure and the need for data-driven decision-making in fire management. Similarly,[14] and[15] emphasized the deficiencies in fire safety infrastructure and the weak enforcement of regulations in Pakistan. They noted that disasters like the Baldia Town factory fire were the result of poor safety compliance, a lack of adequate emergency exits, and widespread systemic mismanagement. Subsequent research revealed more profound issues, such as corruption and the absence of political commitment, with[16] revealing extortion motives behind the disaster, despite assertions of international certifications. Numerous researchers have highlighted the comprehensive Environmental Health and Safety (EHS) framework in fire risk management. [17] Asserted that risk assessments should factor in building design, spread mechanisms, and preventive measures under regulatory frameworks. [18] connected industrial fire consequences to chemical dangers and environmental contamination, while[19] documented the emission of toxic gases such as VOCs, CO, SO_2, and HCN during fires, emphasizing the necessity for real-time air quality monitoring (e.g., FTIR spectroscopy) to evaluate public health risks. These emissions frequently originate from the incomplete combustion of materials such as plastics and chemically treated wood. Studies have also highlighted the importance of passive fire prevention (PFP) materials like cement boards and fire-retardant coatings for safeguarding steel structures in high-heat environments[20]. Concurrently, recent strides in detection technologies such as IFS-DETR frameworks provide real-time fire detection through lightweight neural networks and transformer-based systems to enhance safety responses.

From a policy perspective, researchers advocate for stricter fire regulations and the institutional implementation of fire drills, audits, and awareness initiatives.[21]and [9] proposed that improving fire safety in countries like Pakistan—where regulatory frameworks are still evolving—requires a multifaceted approach. This includes educating stakeholders, formulating context-specific fire safety laws, and integrating cultural and indigenous practices into safety strategies. Simulation modelling, which incorporates weather and terrain data alongside statistical techniques such as isopleths and Wald tests, plays a crucial role in enhancing evacuation planning and predicting hazard zones[22]. These interdisciplinary

approaches highlight a growing consensus that achieving fire safety in industrial zones requires more than just technical and regulatory measures; it also demands cultural, institutional, and technological transformations to ensure effective risk mitigation.

Materials And Methods:

Data Collection:

The numerical data was collected from the rescue departments of FIEDMC, hazard reports from FIEDMC, and information from Rescue 1122, and subsequently organized concerning incidents of industrial fire hazards linked to the Faisalabad Industrial Estate Development and Management Company. This region represents a significant portion of Faisalabad's industrial operations, making it a crucial site for assessing fire hazard risks. The information encompasses the tally of fire incidents recorded over the previous year, categorized by their underlying causes. Additionally, data on the human impact of industrial fires—such as statistics on fatalities and injuries—was collected to assess the severity and consequences of these incidents on individuals. The data was sourced from official entities such as the Rescue department of the Faisalabad Industrial Estate Development and Management Company, fire station records, and safety audit reports. This quantitative information serves as a vital foundation for evaluating fire hazards and observing trends in the frequency and intensity of industrial fires. Furthermore, specific details regarding the causes of each fire incident were collected to shed light on the inherent risk factors associated with these hazards. The causes were categorized into various groups, including electrical short circuits, chemical reactions, mishandling of flammable substances, boiler issues, wire overloading, and heat-related factors. In many instances, multiple contributing factors were noted for each case, allowing for a more nuanced analysis of fire risk dynamics. This data not only facilitates statistical analyses of the severity and frequency of industrial fire incidents but also helps uncover underlying systemic issues that may contribute to their recurrence. By correlating the number of incidents with probable causes and effects, the research aims to evaluate industrial fire risks and propose effective fire prevention strategies. This thorough data collection effort is essential for establishing a basis for hazard mapping, vulnerability assessment, and the creation of targeted risk reduction initiatives.

Description of the Study area:

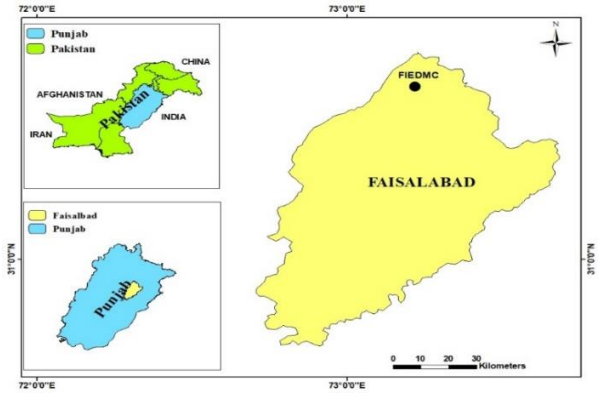

Figure 1: Study area map of Faisalabad

Faisalabad, commonly known as the "Manchester of Pakistan," ranks as the third-largest city in the nation and serves as a crucial industrial center in Punjab[23]. Its strategic location offers road and rail connections to major urban areas such as Lahore, Multan, and Islamabad. The city is famous for its textile sector, which plays a vital role in bolstering Pakistan's economy through the export of yarn, fabrics, garments, and home textiles[24]. In addition to textiles, Faisalabad is home to industries including chemicals, fertilizers, pharmaceuticals, food processing, and steel. The establishment of the Faisalabad Industrial Estate Development & Management Company (FIEDMC) and special economic zones has

further propelled industrial expansion, drawing both local and international investment. While these industrial activities are essential for economic advancement, they also pose challenges related to environmental pollution, occupational health, and disaster risks, highlighting the necessity for research focused on both industrial and environmental issues[25].

Methodology:

This study employs a quantitative research approach, focusing on the analysis of data related to fire incidents to identify patterns, trends, and contributing factors. The data was examined using statistical software (Power BI) to identify fire hazards within the Faisalabad Industrial Estate Development and Management Company. The dataset included the frequency of fire reports per year, the number of fatalities and injuries resulting from these events, and the identified causes of the fires, including electrical failures, chemical spills, equipment issues, or negligence in safety protocols. Once collected, the data underwent pre-processing and analysis. Numerical data was refined and organized with Power BI to remove inconsistencies, duplicates, and formatting errors. This process allowed for systematic categorization and insightful analysis of incident trends through attractive graphs. The cleaned and organized datasets were then evaluated to uncover patterns and trends in fire occurrences, causes, and associated impacts. Additionally, these findings were visualized using comprehensive maps, providing a graphical representation of high-risk zones, prevalent causes, and time-related patterns

Results and Discussion:

Number of Incidents/Year:

Figure 2 presents an analysis of the "Total Number of Incidents by Year" at the Faisalabad Industrial Estate Development and Management Company (FIEDMC) from 2014 to April 2025. The data reveals a concerning upward trend in reported fire incidents over the years, indicating a growing need for improved safety measures and risk mitigation strategies. The data indicates that the highest number of incidents occurred in the most recent years, 2023, 2024, and 2025, each recording 10 incidents, implying a continuing and unresolved safety concern. Previous years exhibited lower incident counts, with the minimum recorded in 2019 at only 2, which might be attributed to enhanced safety practices or underreporting. Between 2016 and 2020, incident numbers were relatively low, ranging from 2 to 4, while 2014 had 8 incidents and both 2015 and 2021 had 7, suggesting fluctuations linked to temporary safety improvements or changes in industrial activity. The steady increase in incidents from 2020 to 2023 suggests that existing safety measures may be losing effectiveness, or that emerging risks are arising as a result of rapid industrial expansion, inadequate regulatory enforcement, or shortcomings in hygiene and maintenance practices. The consistent figure of 10 incidents per year over the past three years points to persistent systemic issues that demand urgent and targeted intervention.

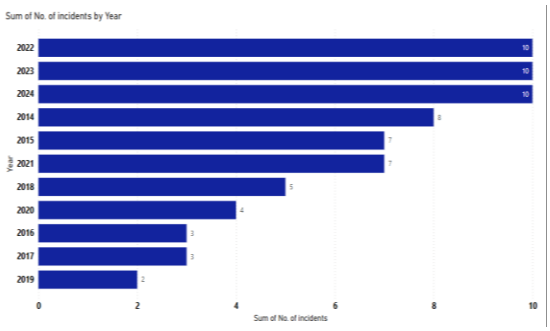

Figure 2: Number of Incidents/years from (2014-2025)

Causes of Fires:

The results provide a detailed analysis of the contributing factors behind fire incidents at the Faisalabad Industrial Estate Development and Management Company (FIEDMC),

revealing that electrical and mechanical failures are the leading causes of these occurrences. The primary cause was overloaded wiring, responsible for 30.43% of fires, which highlights inadequate electrical systems and poor load management practices. The influence of air conditioning units was at 18.84%, likely due to malfunctioning devices or insufficient maintenance. Human error made up 15.94%, emphasizing the need for rigorous safety compliance and training. Issues such as roof collapse (13.04%) and heat-related problems (11.59%) pointed to weaknesses in structural integrity and thermal management, while boiler failures (7.25%) and loose wiring (2.9%) further revealed deficiencies in equipment upkeep and regular inspections.

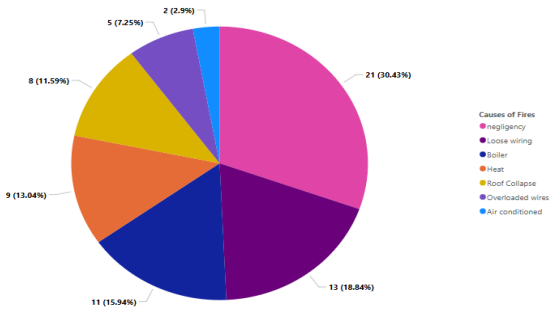

Figure 3: Causes of fire incidents/year from (2014-2025)

Number of Injuries/Year:

Figure 4 illustrates a troubling and unstable trend related to injuries at FIEDMC (Faisalabad Industrial Estate Development and Management Company) over a span of ten years. Between 2014 and 2017, the number of injuries remained consistently high, fluctuating between 176 and 187 cases each year. However, in 2018, there was a notable drop to 100 injuries, followed by an unusually low number of nearly zero in 2019—this figure raises suspicions of underreporting or a change in data management rather than a real improvement. The situation deteriorated significantly starting in 2020, with injuries surging to 167 that year, and nearly doubling to 319 in 2021. While there was a slight reduction to 200 in 2022, the figure soared again to an all-time high of 410 in 2023. Preliminary data for 2024 already reports 324 injuries, suggesting that the final tally could surpass the total recorded in the previous year. This concerning trend reveals that FIEDMC is undergoing a persistent safety crisis rather than experiencing a random fluctuation.

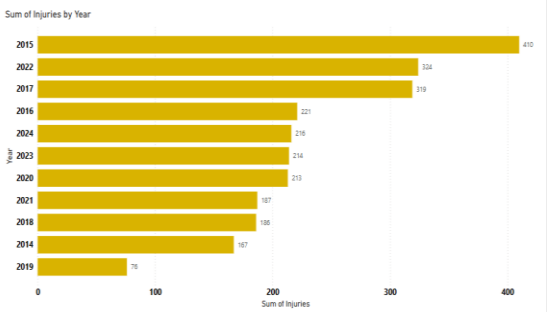

Figure 4: Number of Injuries/years from (2014-2025)

Number of Deaths/Year:

Figure 5 presents a longitudinal examination of death counts at FIEDMC (Faisalabad Industrial Estate Development and Management Company) spanning from 2014 to April 2025, highlighting ongoing and concerning variations in industrial fatalities. It reveals a pronounced peak in 2015 with 120 deaths, which was double that of the previous year, followed by a notable decline in 2016, indicating the possibility of an extraordinary incident or temporary safety interventions. Between 2017 and 2019, the number of fatalities remained

stable at elevated levels, before increasing again in 2020 (65 deaths) and 2021 (76 deaths), pointing to recurring failures in safety protocols. Despite a decrease to 60 deaths in 2022, the second-highest total was again registered in 2023 with 80 deaths, and the partial data for 2024 (42 deaths by midyear) suggests a possible increase in upcoming fatalities. The erratic annual trends, with no consistent decline in death counts and no year recording fewer than 41 fatalities, indicated that fire and safety measures at the estate were largely reactive. These measures were typically enacted briefly in response to emergencies, rather than being integrated into a comprehensive, long-term safety strategy. These trends suggested underlying problems such as inconsistent enforcement of safety regulations, operational pressures, and likely neglect from management, resulting in a persistent baseline risk that continues to jeopardize workers every year.

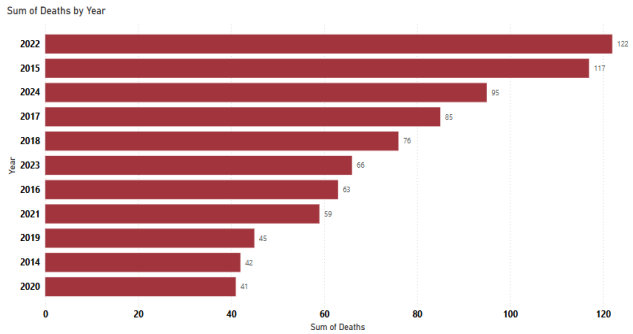

Figure 5: Number of deaths/years from (2014-2025)

Discussion:

The analysis reveals a steady rise in fire incidents at FIEDMC from 2014 to 2025, with peak occurrences in 2023–2025, indicating persistent safety deficiencies. The decline in incidents between 2016–2020 suggests temporary interventions or reduced activity, but the subsequent surge highlights diminishing effectiveness of safety measures or emerging risks linked to industrial expansion and aging infrastructure.

Overloaded wiring was the primary cause of fires (30.43%), followed by air conditioning failures (18.84%) and human error (15.94%), underscoring both technical and operational shortcomings. Structural issues like roof collapses and boiler failures, though less frequent, point to gaps in preventive maintenance. These findings align with global evidence emphasizing the dominance of electrical faults and poor safety compliance in industrial fire risks.

Injuries and fatalities show erratic yet rising trends, with record highs in 2023, reflecting reactive rather than sustained safety practices. Temporary declines, such as in 2019, are likely to result from underreporting or short-term interventions rather than lasting improvements.

Overall, the results demand a shift toward integrated risk management, combining infrastructure upgrades, strict regulatory enforcement, routine safety training, and real-time incident monitoring to ensure long-term safety resilience at FIEDMC.

Conclusion:

The examination of fire-related statistics from 2014 to 2025 within the FIEDMC (Faisalabad Industrial Estate Development and Management Company) zones shows a concerning and ongoing rise in incidents, injuries, and fatalities. Particularly worrisome is the steady increase in fire occurrences since 2020, with the highest levels recorded in 2023 for both injuries and deaths. Despite identifying causes such as overloaded wiring, HVAC malfunctions, human carelessness, and inadequate maintenance, there has been no significant decrease in risk. Instead, safety measures often seem temporary and reactive, frequently enacted post-incident rather than as part of a proactive and strategic fire risk management

approach. The continuous high rates of injuries and fatalities underscore significant deficiencies in infrastructure, regulatory enforcement, and organizational commitment to safety in the workplace. To change this trajectory, an all-encompassing and forward-thinking strategy is critically required. Fire safety should not be regarded as a sporadic issue, but rather integrated into the operational processes of every industrial unit. This entails consistent equipment inspections, upgraded electrical systems, compulsory fire drills, employee safety education, and real-time monitoring of high-risk operations. It is equally important to enhance the enforcement of safety regulations and to invest in contemporary firefighting capabilities. If these long-term systemic changes are not implemented, the FIEDMC zones will continue to experience avoidable disasters, jeopardizing worker safety, industrial efficiency, and the broader aim of sustainable economic progress in Pakistan.

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