



Preventing Fire Risks in Pulp and Paper Mills

Abstract:

The pulp and paper industry faces significant fire risks due to the presence of combustible materials, high-temperature machinery, and chemical processes. This document highlights the critical fire hazards and emphasizes the importance of integrated mitigation strategies. These include engineering controls, administrative measures, and compliance with regulations such as the Factory Act and Environment Protection Act. By adopting best practices in fire detection, emergency preparedness, and employee training, mills can significantly reduce the likelihood of fire incidents. Embracing modern technologies and green chemistry can enhance both safety and sustainability in industry.

Keywords: Fire risks, Combustible materials, Chemical hazards, Mitigation strategies, Regulatory compliance, Emergency preparedness.

Introduction

The pulp and paper industry is one of the oldest and most vital sectors in global manufacturing, supplying essential materials for packaging, printing, hygiene, and communication. Pulp and paper mills convert wood, recycled paper, and other fibrous materials into paper products. The process involves mechanical pulping, chemical treatment, drying, and finishing—each stage presenting unique fire risks due to heat, dust, and chemical exposure. These facilities operate with high volumes of flammable raw materials such as wood chips, paper dust, and chemicals, and rely on energy-intensive processes involving heat, pressure, and mechanical equipment. As demand for paper products continues to grow, mills are expanding operations and adopting new technologies—making fire risk management more critical than ever.



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1.1 Fire Incidents In Pulp & Paper Mills

Pulp and paper mills that use the Kraft process also produce ammonia (NH₃), hydrogen sulfide (H₂S), and other volatile Sulphur compounds, all extremely hazardous substances. Due to the flammable nature of these processes, mills are at high risk of catastrophic fires, which demand comprehensive, continuous toxic gas monitoring and flame detection to keep equipment and personnel safe.

Major fire incidents in pulp and paper mills are frequent due to the presence of highly combustible materials and intensive manufacturing processes. Numerous such fires were reported in 2025 across different countries, causing extensive property damage, production downtime, and, in some cases, injuries or fatalities. Numerous fire incidents reported across world in various industry that resulted loss in reputation, production, brand image [1].

1.2 Fire risk in Paper Industry:

Fire risk in the paper and pulp industry is a serious concern due to the combination of combustible materials, high-temperature machinery, and chemical processes.

Combustible Dust: Fine particles from wood and paper processing (e.g., cutting, grinding, drying) can become airborne and ignite under certain conditions [Fig-1]. Equipment like grinders, conveyors, and dryers are common ignition sources.

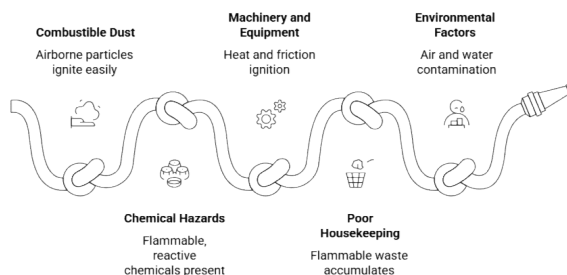


Fig 1: Fire Risk in Paper Industry

Chemical Hazards: Chemicals such as chlorine, sulfuric acid, and sodium hydroxide used in pulping and bleaching can be flammable or reactive. Improper storage or handling increases fire and explosion risks.

Machinery and Equipment: High-speed machines generate heat and friction. Accumulated paper dust and wood chips around hot surfaces can ignite

Poor Housekeeping: Accumulation of flammable waste materials like paper scraps and wood chips can act as fuel for fires.

Environmental Factors: Fires can cause significant environmental damage, including air pollution and water contamination from firefighting runoff.

Hot work: Welding, cutting, and other maintenance activities that create sparks can ignite flammable dust or materials if proper precautions are not taken.

Storage areas: Large volumes of stored raw materials (wood chips, waste paper) and finished products (paper rolls) present a severe fire hazard. Bale storage, especially if outdoors, is particularly vulnerable to ignition from sparks and high winds [2].

1.3 Need for Fire Safety

The need for Fire safety in the paper and pulp industry is critical due to the inherently high-risk environment.

- 1. High Combustibility of Materials:** Mills handle large volumes of flammable substances like wood chips, paper dust, and chemicals. Fine dust particles suspended in the air can ignite easily, leading to dust explosions.
- 2. Heat-Intensive Processes:** Equipment such as boilers, dryers, and steam lines operate at high temperatures. Any malfunction or overheating can trigger fires in surrounding materials [Fig-2].
- 3. Complex Machinery and Electrical Systems:** Aging electrical infrastructure, overloaded circuits, and poor maintenance increase the risk of sparks and short circuits. Mechanical friction and static discharge can also act as ignition sources.

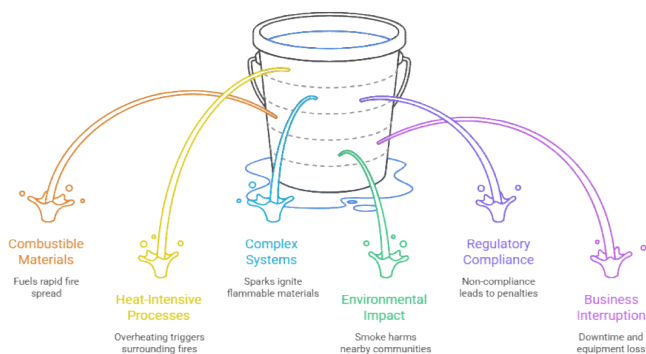


Fig 2: Outcome of not following Fire Safety

- 4. Environmental and Human Impact:** Fires can cause severe damage to property, halt production, and lead to injuries or fatalities. Smoke and chemical release during fires can harm the environment and nearby communities [3].
- 5. Regulatory Compliance:** Fire safety is mandated by laws such as the Factory Act, IS Codes, and ISO 45001 standards in India. Non-compliance can result in legal penalties, shutdowns, and reputational damage.
- 6. Business Continuity and Insurance:** Fire incidents lead to costly downtime, equipment loss, and insurance claims. Proactive fire safety measures reduce risk and improve insurability.
- 7. Workforce Protection:** Ensuring a safe working environment boosts morale and reduces absenteeism. Trained staff can respond quickly and effectively in emergencies

1.4 What is Fire Safety:

Fire safety is the set of practices intended to reduce the destruction caused by fire. Fire safety measures include those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts. Threats to fire safety are commonly referred to as fire hazards. A fire hazard may include a situation that increases the likelihood of a fire or may impede escape in the event a fire occurs. Fire safety is often a component of building safety.

Fire is a chemical reaction. There are many variables that can affect fire. Effective fire safety management programs control the variables that can affect fire. Therefore, it is imperative to understand the variables. A fire is self-sustained oxidation of a fuel that emits heat and light. Fire requires three variables to initiate: fuel, oxygen, and heat.

2.Pulp & Paper process:

The pulp production process involves converting lignocellulosic raw materials—primarily wood—into a fibrous slurry suitable for papermaking. The goal is to separate cellulose fibers while minimizing damage and removing lignin and other non-cellulosic components. The process begins with raw material preparation, where softwood (long fibers) and hardwood (short fibers) are chosen based on desired paper properties [Fig-3]. Logs are mechanically stripped of bark and then chipped into uniform sizes to ensure consistent pulping. There are different pulping methods, including mechanical pulping, chemical pulping, and semi-chemical pulping. Mechanical pulping involves grinding or refining wood chips using mechanical energy, resulting in a high yield but lower strength and durability due to retained lignin.

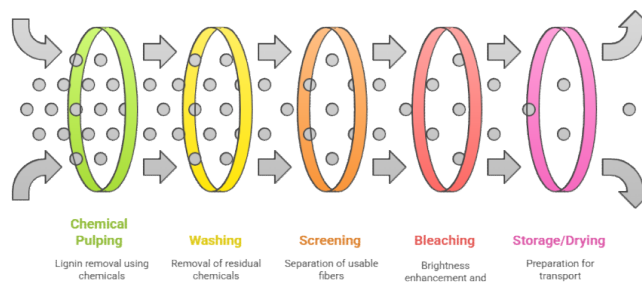


Fig 3: Pulp Production Process

Chemical pulping aims to remove lignin chemically while preserving cellulose fibers, with the Kraft process using sodium hydroxide and sodium sulfide to produce strong, dark-colored pulp, and the sulfite process using acidic chemicals to produce lighter pulp. Semi-chemical pulping combines mild chemical treatment with mechanical refining and is used for corrugated medium and packaging grades. After pulping, the pulp undergoes washing to remove residual chemicals and dissolved lignin, and screening to separate usable fibers from oversized or uncooked particles. The pulp is then bleached to increase brightness and reduce residual lignin, using agents like chlorine dioxide, hydrogen peroxide, and oxygen, with a shift towards Elemental Chlorine-Free (ECF) and Totally Chlorine-Free (TCF) processes. Finally, the pulp is stored in tanks or dried into sheets for transport, ready for immediate use or shipment to paper mills [4].

Paper process: Converting of pulp into roll paper via paper machine. Paper Converting – Converting roll paper into specific type of paper with additional process like coating, sizing, cutting, reeling of winding [Fig-4].

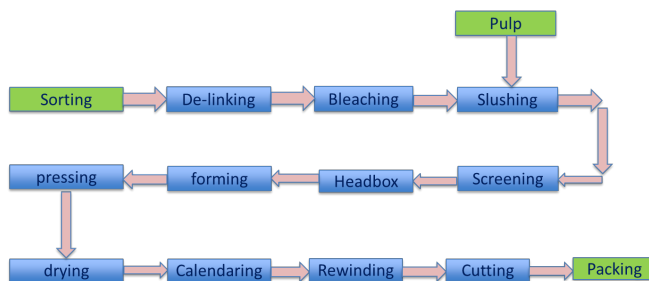


Fig 4: Recycle Paper Process

3. HIRAC (Hazard Identification, Risk Assessment, and Control):

The pulp and paper industry involves complex mechanical, chemical, and thermal processes that pose significant risks to workers and the environment. HIRAC is a systematic safety process to identify potential hazards, evaluate their associated risks, and implement measures to eliminate or reduce those risks to an acceptable level to ensure workplace safety, regulatory compliance, and operational efficiency [Table-1].

Hazard Identification: This involves spotting anything in the workplace that could potentially cause harm. Hazards can be physical (e.g., faulty equipment), chemical (e.g., hazardous substances), biological, ergonomic (e.g., repetitive motions), or psychosocial (e.g., workplace stress).

Table 1: Category & Type of Hazards

Category of Hazard	Type of Hazards
Chemical Hazards	<ul style="list-style-type: none"> Sodium hydroxide (NaOH), sodium sulfide (Na₂S) – used in Kraft pulping. Chlorine dioxide, hydrogen peroxide – used in bleaching. Black liquor – a by-product with corrosive and flammable properties.
Physical Hazards	<ul style="list-style-type: none"> High-temperature equipment (boilers, digesters). Rotating machinery (chippers, refiners, presses). Noise from continuous operations. Slippery floors due to water and pulp residues.
Ergonomic Hazards	<ul style="list-style-type: none"> Manual handling of heavy paper rolls. Repetitive tasks in packaging and inspection.
Fire and Explosion Hazards	<ul style="list-style-type: none"> Dust accumulation. Flammable chemicals and gases. Recovery boilers prone to explosions if improperly maintained. Dry end section of paper machine Broke pit area Hydraulic fluid leakages Lube oil leakages
Confined Spaces	<ul style="list-style-type: none"> Digesters, tanks, and silos requiring entry for maintenance.
Electrical Hazards	<ul style="list-style-type: none"> High-voltage systems in wet environments.
Biological Hazards	<ul style="list-style-type: none"> Mold and bacteria in recycled paper processing.

b) **Risk Assessment:** Risk assessment evaluates the likelihood and severity of each identified hazard to prioritize control measures [Table-2].

♦Low: Acceptable with routine controls ♦Medium: Requires mitigation and monitoring ♦High: Demands immediate corrective action

Table 2: Risk Assessment Matrix [5]

Hazard	Area	Likelihood	Severity	Risk Level	Control Measures
Chemical exposure (NaOH, ClO ₂)	Pulping/Bleaching	Medium	High	High	PPE, enclosed systems, training
Noise	Papermaking	High	Medium	High	Hearing protection, noise barriers
Machine entanglement	Finishing	Medium	High	High	Guarding, emergency stops
Slips and falls	Wet areas	High	Low	Medium	Anti-slip flooring, signage
Boiler explosion	Utilities	Low	High	High	Maintenance, pressure monitoring
Ergonomic strain	Packaging	High	Medium	Medium	Job rotation, mechanical aids
Dust inhalation	Chipping	Medium	Medium	Medium	Ventilation, respirators

c) Control:

Elimination and substitution involve replacing hazardous chemicals with safer alternatives, such as Totally Chlorine-Free bleaching, and automating manual tasks to eliminate ergonomic risks.

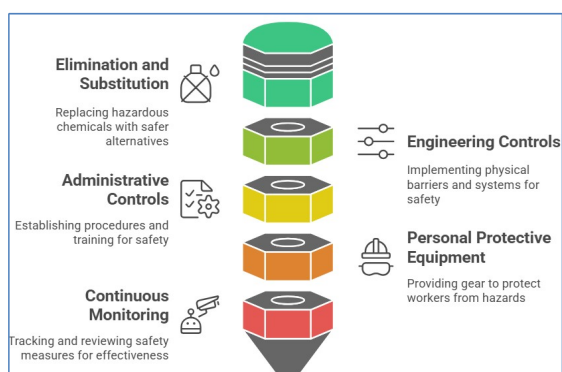


Fig 5: Comprehensive Safety Management Overview

Engineering controls include enclosed systems for chemical handling, machine guarding and interlocks, noise dampening systems, and ventilation and dust extraction units [Fig-5].

Administrative controls encompass Standard Operating Procedures (SOPs), permit-to-work systems for confined spaces, safety signage and hazard communication, scheduled maintenance and inspections, and safety training and awareness programs.

Personal Protective Equipment (PPE) includes chemical-resistant gloves, goggles, face shields, hearing protection (earplugs/muffs), respirators in high-dust or chemical zones, and flame-resistant clothing in boiler areas.

Continuous monitoring involves tracking incidents, performing audits, and gathering worker feedback to ensure control remains effective and relevant. Incident reporting and investigation help identify root causes through incident reports, preventing recurrence and strengthening safety measures. Periodic review and adaptation allow regular reviews of risk assessments to adapt to operational, technological, and regulatory changes. Fostering continuous improvement promotes a dynamic approach that encourages proactive risk management and sustains high safety performance.

4. How Regulation & Codes address these risk

Although some code guidance exists specifically for Pulp & Paper facilities, multiple codes do exist for addressing process, bulk storage and sprinkler system installation and assist in safe plant design and operation.

IFC prescribes Occupational health and safety issues should be considered as part of a comprehensive hazard or risk assessment, including, for example, a hazard identification study [HAZID], hazard and operability study [HAZOP], or other risk assessment studies. The results should be used for

health and safety management planning, in the design of the facility and safe working systems, and in the preparation and communication of safe working procedures [6].

The Factories Act mandates safe working conditions, including proper ventilation and lighting. It also requires hazardous process management under Sections 41A to 41H, along with occupational health surveillance and emergency preparedness. The Act addresses various risks such as chemical burns and inhalation, noise-induced hearing loss, and ergonomic injuries from manual handling [Fig-6].

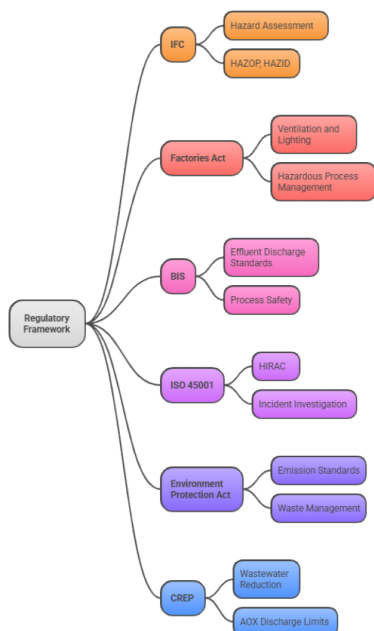


Fig 6: Regulatory Framework

Similarly, The Bureau of Indian Standards (BIS) issues IS codes for effluent discharge standards, process safety, and equipment design. These codes help mitigate risks like chemical exposure, fire hazards, and mechanical injuries. The ISO 45001 standards guide risk identification and mitigation, incident investigation and corrective actions, and worker training and PPE compliance. These frameworks are widely adopted by mills to reduce workplace injuries and improve safety culture.

Environmental issues cannot be ignored in Pulp & Paper industry and The Environment Protection Act, 1986 empowers the government to set standards for emissions and waste management. The Extended Producer Responsibility (EPR) Rules 2024 require producers, importers, and brand owners (PIBOs) to register with CPCB/SPCB, meet recycling targets (70% by 2026–27, 100% by 2028–29), and ensure safe disposal of sanitary and packaging waste. These rules promote a circular economy and reduce environmental risks from packaging and production waste.

Other regulations sets voluntary but enforceable norms for pollution control in the pulp and paper sector. Key targets of The Charter on Corporate Responsibility for Environmental Protection (CREP) include the reduction in wastewater discharge (100 m³/ton for large mills, 150 m³/ton for small mills), AOX discharge limits (≤1.0 kg/ton of paper), and mandatory incineration of odorous emissions (NCGs) in lime kilns or recovery boilers. CREP encourages the adoption of modern fiber line technologies like oxygen delignification and chlorine dioxide bleaching to reduce color and chemical loads.

5. Mitigation strategy

Chemical risk mitigation in the pulp and paper industry involves addressing hazards such as chlorine dioxide, sodium hydroxide, hydrogen peroxide, and sulfuric acid. Strategies to mitigate these risks include using automated dosing systems to reduce manual handling, installing chlorine sensors and emergency showers near chemical storage areas, and training workers on Material Safety Data Sheets (MSDS) and emergency response procedures. Additionally, adopting green chemistry alternatives like oxygen delignification and elemental chlorine-free (ECF) bleaching can further enhance safety [Fig-7].

Fire and explosion risk mitigation involves addressing hazards such as combustible dust, boiler explosions, and electrical faults. Strategies to mitigate these risks include conducting HAZOP studies and installing fire detection systems. It is also essential to maintain CO₂ and foam extinguishers, fire

hydrants, and overhead tanks. Implementing hot work permits and electrical safety audits, as well as using dust suppression systems and ensuring proper ventilation, are crucial steps in reducing fire and explosion risks [7].

Mechanical and physical risk mitigation involves addressing hazards such as machine entanglement, slips, falls, and ergonomic injuries. Strategies to mitigate these risks include installing machine guards and enforcing Lockout/

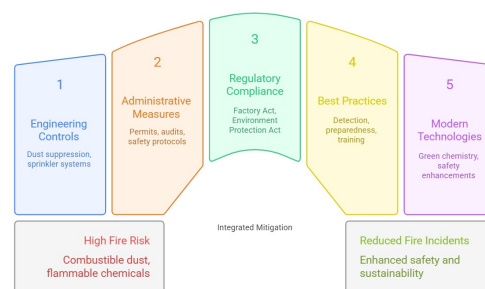


Fig 7: Integrated Risk Mitigation Overview

Tagout (LOTO) procedures. Providing personal protective equipment (PPE) such as helmets, gloves, and earplugs, and conducting safety drills are also essential. Improving housekeeping to prevent skidding and tripping, using lifting aids, and rotating tasks to reduce strain injuries are crucial steps in ensuring a safer working environment.

Noise and airborne particle mitigation involves addressing hazards such as hearing loss and respiratory issues from dust and fibers. Strategies to mitigate these risks include installing acoustic barriers and issuing noise-canceling earmuffs. Additionally, using local exhaust ventilation and air quality monitoring systems, as well as conducting annual hearing tests and respiratory health checks, are essential steps in ensuring a safer working environment.

Environmental risk mitigation involves addressing hazards such as effluent discharge, water pollution, and odorous emissions. Strategies to mitigate these risks include upgrading Effluent Treatment Plants (ETPs) with tertiary treatment, adopting zero liquid discharge (ZLD) systems and reusing treated water, implementing the Charter for Water Recycling and Pollution Prevention in the Ganga Basin, and regularly monitoring AOX, COD, and BOD levels.

Emergency preparedness involves developing Disaster Management Plans for fire, chemical spills, and natural disasters. It includes conducting mock drills and maintaining emergency contact boards. Additionally, it is essential to train fire-fighting teams and equip them with spray hoses and extinguishers.

6. Conclusion

Fire risks in pulp and paper mills pose a significant threat to worker safety, operational continuity, and environmental sustainability. Given the highly combustible nature of paper dust, the presence of flammable chemicals, and the use of high-temperature equipment, proactive fire prevention is not just a regulatory requirement, it is a moral and operational imperative.

This paper has highlighted the critical fire hazards across various stages of the pulp and paper process and emphasized the importance of integrated mitigation strategies. These include engineering controls like dust suppression systems, administrative measures such as hot work permits and fire safety audits, and compliance with Indian regulations like the Factory Act, Environment Protection Act, and CREP guidelines.

By adopting best practices in fire detection, emergency preparedness, and employee training, mills can significantly reduce the likelihood of fire incidents. Furthermore, embracing modern technologies and green chemistry can enhance both safety and sustainability.

Ultimately, a culture of safety—supported by strong leadership, continuous monitoring, and regulatory compliance—is the cornerstone of fire risk prevention in the pulp and paper industry.

Acknowledgements: Nalco Water India Pvt Ltd, Pune

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