

## Implementation of Fire Prevention Strategies in PPE Production Units

Kirubakaran B<sup>1</sup>, Boopathy K<sup>2</sup>,

<sup>1</sup>PG-Student, M.E-Industrial Safety Engineering, Department of Safety and Fire Engineering, Excel Engineering College, Namakkal, Tamilnadu, India.

<sup>2</sup>Associate Professor, Department of Safety and Fire Engineering, Excel Engineering College, Namakkal, Tamilnadu, India.

**Emails:** kirubaehs@gmail.com<sup>1</sup>, boopathy.k.1978@gmail.com<sup>2</sup>

### Abstract

Personal Protective Equipment (PPE) production units involve processes and materials that are often susceptible to fire hazards, including flammable textiles, chemicals, and high-temperature machinery. Ensuring fire safety in these environments is critical to protecting lives, assets, and maintaining uninterrupted production. This project focuses on the identification, assessment, and implementation of effective fire prevention strategies tailored specifically for PPE manufacturing facilities. The primary objective is to evaluate current fire risks within PPE production units and to introduce a comprehensive fire prevention framework that integrates engineering controls, administrative policies, and employee training. The study encompasses a thorough risk assessment of the production workflow, including raw material storage, cutting, sewing, chemical treatments, and packaging areas. Key strategies proposed include the installation of fire detection and suppression systems, proper ventilation, segregation of flammable materials, routine maintenance of electrical systems, and development of emergency response plans. In addition, the project emphasizes the importance of employee awareness programs and regular fire drills to foster a culture of safety. A pilot implementation in a selected production unit demonstrated significant improvement in hazard identification and response readiness. The outcomes indicate that systematic fire prevention not only reduces the likelihood of fire incidents but also enhances overall operational efficiency and worker confidence. This project provides a scalable model that can be adapted across similar industrial settings to ensure fire-safe PPE manufacturing.

**Keywords:** Fire Prevention Strategies, PPE Manufacturing Units, Fire Risk Assessment, Industrial Fire Safety, Emergency Preparedness and Training.

### 1. Introduction

Personal Protective Equipment (PPE) production units play a vital role in safeguarding workers across various industries; however, the manufacturing processes involved in these facilities often present significant fire hazards. The use of flammable raw materials such as synthetic textiles, foams, plastics, solvents, and chemicals, combined with heat-generating machinery and electrical systems, increases the risk of fire incidents. A fire outbreak in a PPE production unit can lead to severe consequences, including loss of life, damage to

critical assets, production downtime, and disruption of supply chains, especially during emergency demand situations. The implementation of effective fire prevention strategies in PPE production units is therefore essential to ensure a safe working environment and operational continuity. Fire prevention focuses on identifying potential ignition sources, controlling combustible materials, and establishing robust safety management systems before an incident occurs. This includes proper storage and handling of flammable materials, maintenance of electrical and mechanical equipment,

adoption of safe work practices, and training of personnel in fire safety awareness [1-3]. This project aims to study existing fire risks within PPE manufacturing facilities and to implement comprehensive fire prevention measures aligned with relevant safety standards and regulatory requirements. Integrating engineering controls, administrative measures, and workforce training, the project seeks to minimize fire hazards, enhance emergency preparedness, and promote a strong safety culture within PPE production units.

## 2. Literature Review

Recent studies demonstrate significant advancements in fire risk assessment and prevention across industrial, agricultural, and built environments through technological, managerial, and material-based approaches. (Abdennabi Morchid et al., 2025) highlighted the transformative role of Artificial Intelligence (AI) and the Internet of Things (IoT) in fire risk assessment for food and sustainable farming systems. Their review emphasized that AI-driven predictive models combined with IoT-based real-time monitoring overcome the limitations of traditional fire detection by enabling early warning, continuous surveillance, and proactive risk mitigation. However, they also identified challenges related to high implementation costs, data management, and adaptability to diverse climatic and geographical conditions. In the industrial context, (Bekti Utomo et al., 2025) examined the integration of fire prevention strategies with industrial hygiene in textile industries. The study confirmed that coordinated safety management systems, automatic fire detection, effective ventilation, and worker training significantly reduce fire incidents and occupational accidents. Complementing this, (Siraj and Debnath et al., 2023) analyzed fire risks in the apparel manufacturing industry using multi-criteria decision-making models, identifying combustible storage, poor maintenance, and inadequate egress as critical risk factors [4-7]. Knowledge and training also play a vital role in fire safety. (Dennielle Nicollie Cadano et al., 2025) demonstrated that continuous education enhances fire prevention and suppression awareness among both students and employees. Meanwhile, advancements in materials science, such

as nanomaterials for fire protection (Singh et al., Usman, 2025) and steel slag-based composite gels for fire prevention (Tan Li et al., 2024), offer innovative solutions for enhancing fire resistance and durability. Overall, the literature underscores the importance of integrating technology, training, policy support, and advanced materials to develop sustainable and effective fire prevention strategies across sectors.

## 3. Methodology



**Figure 1 Methodology**

### 3.1. Project Planning and Objective Definition

Project planning and objective definition form the foundation for the successful implementation of fire prevention strategies in PPE production units. This phase focuses on establishing a clear framework that guides all subsequent activities, ensuring that the project is systematic, achievable, and aligned with

safety regulations and organizational goals. Effective planning begins with understanding the operational processes of PPE manufacturing, identifying key stakeholders, and defining the scope of the project in terms of facilities, equipment, and workforce involvement. The primary objective of the project is to identify potential fire hazards within PPE production units and to develop and implement practical fire prevention measures to minimize the risk of fire incidents. Specific objectives include assessing fire risks associated with raw materials, machinery, electrical installations, and storage areas; evaluating existing fire safety systems and compliance with statutory requirements; and recommending improvements based on industry best practices and applicable standards. Another key objective is to enhance worker awareness and preparedness through structured fire safety training and clear emergency procedures. During the planning stage, a project timeline is developed outlining major activities such as site assessments, risk analysis, strategy design, implementation, and evaluation. Resource allocation, including manpower, equipment, and budget, is also defined to ensure efficient execution. Clearly defining objectives and planning activities in advance, the project ensures a proactive and organized approach to fire prevention, ultimately contributing to a safer working environment and sustainable operations in PPE production units shown in Figure 1.

### 3.2. Site Assessment and Data Collection

Effective fire prevention in PPE production units requires a detailed understanding of the site's layout, operations, and potential hazards. Site assessment and data collection form the foundation of a reliable fire prevention strategy, allowing for risk-based planning and prioritization of mitigation efforts. This section outlines the methodology and findings from the on-site assessment process, which involved a facility walkthrough, systematic risk identification, data gathering using structured tools, and the review of historical fire-related incidents.

### 3.3. Fire Risk Assessment and Gap Analysis

A structured fire risk assessment and gap analysis is essential for understanding the severity of fire hazards, determining compliance with fire safety

standards, and identifying shortcomings in current fire prevention strategies within PPE production units. This phase builds upon the findings from the site assessment and provides a risk-based prioritization for mitigation planning.

### 3.4. Design of Fire Prevention Strategies

Effective fire prevention in PPE (Personal Protective Equipment) production units requires a multi-layered approach that integrates engineering solutions, administrative frameworks, emergency planning, and employee awareness. Based on the findings from the risk assessment and gap analysis, this section outlines a comprehensive fire prevention strategy tailored to the specific operational characteristics and fire hazards present in PPE manufacturing facilities. The strategy focuses on both eliminating ignition sources and minimizing the potential for fire spread through a combination of engineering controls, emergency preparedness, and training programs [8-12].

### 3.5. Implementation of Fire Prevention Measures

The successful implementation of fire prevention measures is the most critical phase in enhancing fire safety in PPE production units. This phase transitions the project from planning and design into actionable changes within the facility. Implementation must be systematic, well-coordinated, and inclusive to ensure all strategies are properly installed, integrated, and adopted by personnel. This section outlines the steps for effective implementation, including pilot testing, procurement and installation, and comprehensive documentation to sustain the improvements.

### 3.6. Monitoring and Evaluation

Future efforts should focus on strengthening the Monitoring and Evaluation (M&E) framework to ensure continuous tracking of key performance indicators (KPIs), outcomes, and long-term impact. Advanced data analytics tools and real-time dashboards can be integrated to provide more responsive insights and improve decision-making. stakeholder feedback loops must be formalized to validate results and inform future iterations of the project. Regular performance audits and third-party evaluations can enhance transparency and accountability shown in Table 1-12.

**Table 1 Planning**

Obj. No.	Objective	Variables / Indicators	Data Collection Method	Sample Size / Unit	Statistical Tool / Method	Performance Target
1	Identify & assess fire risks	Fire incidents, fire load (MJ/m <sup>2</sup> ), hazard count	Site inspection, records review	5–10 departments	Descriptive statistics, risk scoring	100% hazard identification
2	Analyze existing fire safety gaps	Compliance score (%), gap frequency	Safety audit checklist	1 production unit	Gap analysis, Pareto analysis	≥90% gaps identified
3	Design tailored fire prevention measures	Control effectiveness index	Expert evaluation	Fire systems installed	Weighted scoring method	Effectiveness ≥85%
4	Reduce fire risk levels	Risk rating before vs after	Risk assessment matrix	All risk zones	Pre–post comparison	Risk reduced by ≥40%
5	Improve emergency response time	Response time (seconds)	Fire drill observation	≥2 mock drills	Mean, standard deviation	≤120 seconds
6	Enhance employee awareness	Training score, drill participation	Questionnaire, tests	≥50 employees	Mean score, t-test	≥80% awareness score
7	Ensure regulatory compliance	Compliance percentage	Inspection checklist	1 facility	Compliance index	100% compliance
8	Evaluate sustainability & scalability	Audit score over time	Periodic audits	Quarterly reviews	Trend analysis	Consistent improvement

**Table 2 Area-wise Fire Load & Hazard**

S. No.	Area	Fire Load Density (MJ/m <sup>2</sup> )	No. of Hazards	Risk Index (1-5)
1	Raw material storage	1,250	18	4
2	Cutting section	1,080	16	4
3	Sewing section	1,120	17	4
4	Heat bonding section	1,480	22	5
5	Lamination unit	1,520	21	5
6	Chemical treatment area	1,620	24	5
7	Packaging section	980	11	3
8	Finished goods store	1,100	14	4
9	Electrical control room	1,300	15	4
10	HVAC ducting zone	1,050	10	3
11	Waste collection area	1,150	13	4
12	Loading/unloading bay	920	9	3

**Table 3 Fire Safety Equipment – Quantity & Compliance**

S. No.	Equipment	Required	Installed	Compliance (%)
1	ABC extinguishers	50	42	84
2	CO <sub>2</sub> extinguishers	24	18	75
3	Foam extinguishers	14	10	71
4	Water extinguishers	10	6	60
5	Smoke detectors	58	41	70.7
6	Heat detectors	32	21	65.6
7	Manual call points	36	24	66.7
8	Fire alarm panels	3	2	66.7
9	Fire hose reels	14	9	64.3
10	Hydrant points	6	4	66.7
11	Emergency exits	10	8	80
12	Exit signages	64	47	73.4
13	Emergency lights	48	35	72.9
14	Fire blankets	18	11	61.1
15	Sprinkler heads	220	0	0

**Table 4 Electrical Fire Risk Assessment**

S. No.	Parameter	Observed	Standard	Deviation (%)
1	Electrical panels inspected	28	28	0
2	Panels with overheating	9	0	32.1
3	Overloaded circuits	7	0	25
4	Exposed wiring points	12	0	42.9
5	Panels with proper labeling	19	28	32.1
6	Equipment properly earthed	23	28	17.9
7	MCC rooms with detectors	1	3	66.7
8	Thermal scanning done	0	2/year	100
9	Preventive maintenance cycles	1/year	4/year	75
10	Electrical SOP availability	Partial	Full	—

**Table 5 Employee Fire Safety Awareness**

S. No.	Parameter	Sample Size	Mean Score (%)	Std. Dev.
1	Fire hazard identification	60	56.4	12.3
2	Extinguisher handling	60	48.9	14.6
3	Alarm response	60	51.7	13.9
4	Evacuation route knowledge	60	62.1	10.8
5	Assembly point awareness	60	59.3	11.2
6	Chemical fire response	60	45.6	15.1
7	Electrical fire response	60	49.8	14.3
8	Overall fire safety awareness	60	54.8	12.9

**Table 6 Fire Risk Assessment Summary**

Hazard	Probability (1-5)	Severity (1-5)	Initial Risk Rating (P x S)	Existing Controls	Residual Risk	Control Effectiveness (%)
Flammable chemical storage (e.g., solvents)	4	5	20 (High)	Fire-rated cabinets, warning signs	8 (Medium)	60%
Electrical equipment overloading	3	4	12 (Medium)	Circuit breakers, PAT testing	6 (Low)	50%
Static discharge in cutting/sewing areas	2	3	6 (Low)	Antistatic flooring, grounding straps	3 (Low)	50%
Heat from sealing/welding machines	4	4	16 (High)	Machine maintenance, operator training	6 (Low)	62.5%
Dust accumulation in filter or exhaust areas	3	5	15 (High)	Regular cleaning, dust extraction system	6 (Low)	60%
Smoking or ignition source near materials	2	5	10 (Medium)	No-smoking policy, signage, surveillance	2 (Low)	80%
Blocked or inadequate fire exits	3	5	15 (High)	Exit route audit, clear signage	4 (Low)	73%
Lack of fire response training	4	4	16 (High)	Training, fire drills, posters	6 (Low)	62.5%

**Table 7 Fire Safety Gap Analysis Comparison**

S. No.	Fire Safety Element	Standard Requirement	Existing Condition	Gap Identified	Priority Level
1	Fire-rated construction	Fire-rated walls & doors	Not provided	Structural gap	High
2	Detection system (chemical zone)	Smoke/heat detectors	Not installed	Critical safety gap	High
3	Detection system (thermal areas)	Automatic detection	Partial coverage	Coverage gap	High
4	Central alarm system	Integrated alarm panel	Absent	Systemic gap	High
5	Fire extinguisher placement	As per NFPA 10	Uneven spacing	Accessibility gap	Medium
6	Firefighting equipment access	<15 m travel distance	>25 m in some zones	Coverage gap	Medium
7	Fire evacuation plan	Posted at all locations	Not displayed	Awareness gap	High
8	Fire drills	≥2 per year	Infrequent	Preparedness gap	High
9	Training documentation	Training records	Not maintained	Administrative gap	Medium
10	Electrical room protection	Fire-rated enclosure	Open panels	Ignition risk	High
11	Electrical suppression	Clean agent system	Not installed	Critical gap	High
12	Chemical inventory control	MSDS for all chemicals	Partial MSDS	Documentation gap	Medium
13	Spill containment system	Spill kits & bunds	Inadequate	Environmental gap	Medium
14	Emergency lighting	Full coverage	Partial	Visibility gap	Medium
15	Fire department connectivity	Alarm linkage	Not available	Response delay risk	High

**Table 8 Design and Implementation of Fire Prevention in PPE Production Units**

Strategy Type	Component	Description	Implementation Approach	Responsible Party	Relevant Standard
Engineering Control	Fire and Smoke Detectors	Multi-sensor detectors in high-risk areas linked to central alarm system	Install interconnected units, test regularly	Safety Engineer / IT Team	NFPA 72
Engineering Control	Automatic Sprinkler Systems	Wet-pipe for production; dry-pipe for cold storage zones	Procure UL/FM-certified systems; install per fire code	Facilities Management	NFPA 13
Engineering Control	Heat-Resistant Insulation	Insulation and thermal cut-off switches for high-heat machinery	Retrofit critical equipment; inspect insulation monthly	Maintenance Supervisor	NFPA 79, ISO 12100
Engineering Control	Fire-Rated Doors and Barriers	Fire-rated doors for compartmentalization	Install in chemical, textile, and electrical rooms	Facility Safety Officer	NFPA 80
Engineering Control	Ventilation and Exhaust Systems	Exhaust with spark arresters and dampers for fire spread control	Audit existing systems; upgrade ducting and airflow control	Mechanical Engineer	OSHA 1910.94
Engineering Control	Flame-Retardant Materials	Flame-retardant coatings, textiles, and structural protection	Apply intumescent coatings; replace flammable furniture	Procurement / Construction	NFPA 701, ISO 11612
Administrative Control	SOPs for Flammable Materials	Safe handling, storage, and labeling of chemicals	Develop/revise SOPs per OSHA HazCom; train staff	HSE Officer	OSHA 1910.1200
Administrative Control	Maintenance Schedules	Routine servicing of electrical, HVAC, fire systems	Create digital logs; perform monthly audits	Maintenance Manager	ISO 45001
Administrative Control	Waste Disposal Protocols	Safe removal of flammable and textile waste	Daily disposal routine; metal-lid bins near production	Floor Supervisors	NFPA 30B
Administrative Control	Emergency Communication	Protocol for alarms, backup communication systems	Create flowcharts; install radios/PA systems	Emergency Planning Lead	ISO 22320
Emergency Preparedness	Emergency Response Plans	Scenario-specific evacuation and fire response plans	Design based on risk zones; post maps throughout	Safety Officer	NFPA 1600

			facility		
Emergency Preparedness	Fire Wardens and First Responders	Trained personnel for each department	Assign roles, provide vests, conduct drills	HR / Safety Committee	Local Fire Dept Guidelines
Emergency Preparedness	Emergency Kits	Kits with first aid, extinguishers, contact lists	Distribute in zones; replenish monthly	Safety Coordinator	Company Emergency SOPs
Training & Awareness	Fire Extinguisher Training	Hands-on use, PASS method	Conduct quarterly sessions	Training Manager	NFPA 10
Training & Awareness	Evacuation Drills	Route familiarization and timed response drills	Rotate scenarios quarterly	Fire Safety Team	ISO 45001
Training & Awareness	Hazard Identification	Teach spotting of risks (e.g., frayed wires, leaks)	Monthly toolbox talks; hazard reporting system	HSE Trainers	OSHA
Training & Awareness	Visual Aids and Signage	Posters, markings, digital signage	Regular updates; multilingual signs where needed	Facility Management	ISO 3864
Training & Awareness	Induction & Refresher Programs	New employee orientation and annual updates	Integrate into onboarding; test knowledge retention	HR and Safety Team	Internal Training Policy
Training & Awareness	Safety Culture Promotion	Recognition, suggestion programs	Reward compliance; track feedback	Management / HSE	ISO 45001
Implementation Step	Pilot Implementation	Test strategies in high-risk zone	Select area (e.g., thermal processing); monitor effectiveness	Project Implementation Lead	Internal Fire Safety Plan
Implementation Step	Procurement and Contractor Engagement	Purchase certified equipment and hire skilled installers	Create procurement plan; vet contractor certifications	Procurement Officer	NFPA, Local Building Codes
Implementation Step	Equipment Installation & Labeling	Install equipment with clear signage	Follow layouts; ensure visibility and accessibility	Installation Supervisor	NFPA / OSHA

Documentation	SOPs and Safety Manuals	Comprehensive manuals for procedures, systems, and emergencies	Distribute digital and hard copies; review annually	Documentation Manager	ISO 9001 / Internal QMS
Documentation	Maintenance Logs and Training Records	Logbooks for inspections, tests, and drills	Store in centralized system; audit quarterly	Safety Admin Officer	OSHA Recordkeeping Standard
Documentation	Fire Safety Signage	Emergency exits, extinguisher locations, hazard zones	Use durable, clear signs with icons; update with changes in layout	Facilities Coordinator	NFPA 170, ISO 7010

**Table 9 Fire Prevention for PPE Production Units**

Sl. No	Risk Area	Identified Fire Hazard	Fire Prevention Strategy	Type of Control	Technical / Operational Details	Applicable Standard	Priority Level
1	Raw material storage	Flammable textile ignition	Fire-rated storage rooms	Engineering	2-hour fire-rated walls, metal racks, 1 m aisle space	NFPA 13, IS 1646	High
2	Raw material storage	Rapid fire spread	Segregation of materials	Administrative	Separate synthetic, chemical, and packaging storage	NFPA 400	High
3	Chemical storage	Solvent vapor ignition	Explosion-proof ventilation	Engineering	Local exhaust ventilation, ATEX fans	NFPA 45	High
4	Chemical handling	Improper labeling	MSDS implementation	Administrative	MSDS display, chemical labeling system	OSHA 1910.1200	High
5	Cutting section	Lint & dust accumulation	Scheduled dust removal	Operational	Vacuum cleaning twice per shift	NFPA 654	Medium
6	Sewing section	Electrical overheating	Load balancing	Engineering	Separate circuits for heavy machines	NFPA 70	High
7	Heat bonding area	Open heat sources	Thermal shielding	Engineering	Heat-resistant guards & insulation	NFPA 86	High
8	Thermal processing	Overheating	Auto shutdown	Engineering	Temperature sensors & trip	NFPA 86	High

		equipment	systems		relays		
9	Electrical panel room	Short circuits	Clean agent suppression	Engineering	FM-200 / Novec system	NFPA 2001	High
10	Electrical wiring	Aging insulation	Flame-retardant cabling	Engineering	FRLS copper cables	IS 694	High
11	Production floor	Delayed fire detection	Addressable fire alarm system	Engineering	Smoke + heat detectors networked	NFPA 72	High
12	Packaging area	Combustible load	Storage limitation	Administrative	Max stack height $\leq 1.5$ m	NFPA 230	Medium
13	Waste storage	Textile scrap ignition	Covered metal bins	Engineering	Flame-resistant waste containers	NFPA 1	High
14	Waste disposal	Waste accumulation	Daily disposal schedule	Administrative	End-of-shift waste removal	OSHA 1910	Medium
15	HVAC system	Dust ignition	Duct cleaning program	Operational	Quarterly duct inspection	NFPA 90A	Medium
16	Ventilation system	Vapor buildup	Continuous air monitoring	Engineering	Gas sensors with alarms	NFPA 54	High
17	Emergency exits	Blocked evacuation	Exit clearance policy	Administrative	1.2 m clear path enforcement	OSHA 1910.37	High
18	Emergency exits	Poor visibility	Photoluminescent signage	Engineering	Glow-in-dark exit signs	IS 9457	High
19	Firefighting equipment	Delayed response	Strategic extinguisher placement	Engineering	$\leq 15$ m travel distance	NFPA 10	High
20	Fire extinguishers	Wrong extinguisher type	ABC & CO <sub>2</sub> allocation	Engineering	Fire class-based distribution	IS 2190	High
21	Control rooms	Fire spread	Fire-rated doors	Engineering	120-minute rated doors	NFPA 80	High
22	Electrical maintenance	Human error	Lockout-Tagout system	Administrative	Authorized access only	OSHA 1910.147	Medium
23	Hot work activities	Sparks ignition	Hot work permit system	Administrative	Welding/cutting authorization	NFPA 51B	High
24	Chemical	Secondary	Spill	Engineering	Absorbents &	NFPA 400	Medium

	spills	fire risk	containment kits		neutralizers		
25	Fire drills	Poor response readiness	Regular mock drills	Administrative	2 drills/year, documented	OSHA 1910	High
26	Employees	Lack of awareness	Fire safety training	Administrative	Hands-on extinguisher training	NFPA 600	High
27	Supervisors	Poor enforcement	Fire safety audits	Administrative	Monthly internal audits	ISO 45001	Medium
28	Incident reporting	Repeat hazards	Digital incident log	Administrative	Near-miss & incident database	OSHA	Medium
29	Alarm response	Slow evacuation	Voice evacuation system	Engineering	PA-based alarm guidance	NFPA 72	High
30	Fire service coordination	Delayed external response	Fire department liaison	Administrative	Pre-incident planning	Local Fire Code	Medium

**Table 10 Site Assessment and Data Collection**

Sl. No.	Parameter	Observed Data / Measured Value	Assessment Method	Fire Risk Level
1	Total plant area	4,800 m <sup>2</sup>	Layout drawing review	Medium
2	Production floor area	3,200 m <sup>2</sup>	Physical measurement	High
3	Number of employees	180 workers	HR records	Medium
4	Shifts per day	2 shifts (10 hrs)	Attendance data	Medium
5	Flammable materials stored	~12.5 tons	Inventory review	High
6	Chemical types used	8 chemicals	MSDS review	High
7	Fire extinguishers available	76 units	Physical count	Medium
8	Extinguisher coverage	1 per 63 m <sup>2</sup>	NFPA calculation	Adequate

9	Fire alarm detectors	68 units	Installation checklist	Medium
10	Smoke detectors	42 units	Site inspection	Medium
11	Heat detectors	26 units	Site inspection	High areas
12	Emergency exits	8 exits	Layout verification	Medium
13	Average evacuation distance	28 meters	Walk-through	Acceptable
14	Electrical panels	12 panels	Maintenance logs	High
15	Electrical load utilization	82% capacity	Load analysis	Medium
16	HVAC units	6 units	Equipment list	Medium
17	Waste generated per day	320 kg	Waste records	High
18	Fire drills conducted	1/year	Safety records	Inadequate
19	Fire training coverage	42% employees	Training logs	High
20	Distance to fire station	3.2 km	GPS data	Acceptable

**Table 11 Monitoring Outcomes and Impact Assessment**

Parameter	Before Implementation	After Implementation	Improvement (%)
Fire incident rate	3–4 / year	≤ 1 / year	70–80%
Detection time	6–10 minutes	1–2 minutes	~75%
Evacuation time	> 8 minutes	< 3 minutes	~65%
Compliance level	30–40%	> 90%	~60%
Employee preparedness	Low	High	Qualitative
Near-miss reporting	Nil	Regular	Positive

**Table 12 Continuous Improvement Framework – Fire Prevention System**

Sl. No	Improvement Area	Identified Issue (From M&E)	Improvement Action	Methodology Applied	Performance Indicator (KPI)	Review Frequency	Responsible Authority
1	Fire detection	Delayed detection in some zones	Additional smoke/heat detectors	PDCA Cycle	Detection time $\leq 2$ min	Monthly	Safety Officer
2	Fire response	Slow evacuation during drills	Re-design evacuation routes	Lean safety mapping	Evacuation time $\leq 3$ min	Quarterly	Safety Committee
3	Electrical safety	Repeated panel overheating	Upgrade to FRLS cabling	Root Cause Analysis	Zero overheating cases	Monthly	Electrical Engineer
4	Chemical handling	Improper chemical labeling	Implement MSDS tracking	SOP revision	100% MSDS compliance	Monthly	Chemical Supervisor
5	Training effectiveness	Low training retention	Hands-on refresher training	Continuous learning model	$\geq 95\%$ trained staff	Quarterly	HR Dept
6	Waste management	Scrap accumulation	Increase disposal frequency	5S methodology	Zero waste backlog	Weekly	Housekeeping
7	Fire equipment readiness	Inconsistent extinguisher checks	Digital inspection logs	Preventive maintenance	100% functional	Monthly	Safety Officer
8	Incident reporting	Low near-miss reporting	Anonymous reporting system	Safety culture model	$\geq 3$ reports/month	Monthly	Supervisors
9	Ventilation	Chemical fume buildup	Upgrade exhaust systems	Engineering redesign	Air quality within limits	Monthly	Maintenance Dept
10	Compliance monitoring	Audit non-conformities	Corrective action tracking	ISO 45001	$\geq 95\%$ compliance	Quarterly	Safety Manager

### 3.7. Continuous Improvement and Scaling

The project has laid a strong foundation, but ongoing refinement is essential. Future work should emphasize continuous improvement by applying adaptive project management techniques, incorporating lessons learned, and adjusting methodologies based on feedback and M&E data. For scaling, replication models should be developed to expand the project's reach across different regions or sectors. This includes designing scalable frameworks, securing long-term funding, and building strategic partnerships with local organizations and governments [13-14]. The successful implementation of fire prevention strategies in PPE production units marks a significant milestone toward enhancing workplace safety, operational resilience, and regulatory compliance. However, fire safety is not a one-time achievement; it is a dynamic process that requires continuous improvement and long-term scalability to remain effective under changing operational, technological, and regulatory conditions. This project has established a strong foundational framework, but sustained success depends on the organization's ability to systematically refine practices, integrate lessons learned, and expand the model to broader contexts.

### 3.8. Project Closure and Knowledge Transfer

Project closure is a vital phase in the implementation of fire prevention strategies in PPE production units, as it formally concludes project activities while ensuring long-term sustainability of outcomes. Effective closure confirms that all planned objectives such as fire hazard identification, installation of preventive measures, employee training, and monitoring systems have been successfully achieved. A final evaluation is conducted using key performance indicators including reduction in fire risks, compliance with fire safety standards, and improved emergency response preparedness. Completion reports and corrective action plans provide assurance to management and stakeholders regarding operational readiness. Administrative closure ensures transparent accounting of financial, material, and human resources. All contracts are formally closed, assets are documented, and

responsibility for maintenance of fire safety systems is transferred to relevant departments. A structured handover process, supported by updated fire safety manuals, SOPs, and maintenance schedules, ensures continuity and accountability. Knowledge transfer is essential for sustaining fire prevention initiatives. Comprehensive documentation of best practices, challenges, and technical guidelines is developed to support organizational learning. Training modules and digital learning resources facilitate consistent fire safety awareness and onboarding of new employees. Additionally, digital knowledge repositories enhance accessibility and scalability across facilities. Through systematic closure and effective knowledge transfer, fire safety projects evolve into enduring systems that protect lives, assets, and operational continuity.

## 4. Results and Discussion

This chapter presents the outcomes of implementing structured fire prevention strategies in a PPE production unit and evaluates their effectiveness against the project objectives. The initial site assessment confirmed a high fire risk profile due to combustible textiles, chemical usage, dense electrical installations, and continuous machinery operation. Data revealed inadequate fire-rated segregation in raw material storage, lack of detection systems in chemical areas, electrical overloading, and insufficient emergency signage, highlighting critical safety deficiencies. Fire risk assessment and gap analysis further identified significant deviations from NFPA, OSHA, IS codes, and local fire authority requirements. High-risk zones were concentrated in chemical processing areas, raw material storage, and electrical panel rooms, validating the need for a comprehensive fire prevention framework. Post-implementation results demonstrated substantial improvements across engineering, administrative, and behavioral domains. Installation of automatic fire detection systems achieved full coverage in high-risk areas, while optimized extinguisher placement and electrical maintenance reduced ignition potential. Administrative measures, including SOPs, evacuation plans, and maintenance schedules, resulted in a 55–60% improvement in compliance scores. Employee training proved highly effective, with over 90% participation and a 35–40%

improvement in fire drill response times. Monitoring and evaluation showed zero fire incidents during the observation period and increased near-miss reporting, indicating improved hazard awareness and safety culture. Overall, the results confirm that an integrated fire prevention approach enhances safety performance, regulatory compliance, and operational continuity, while remaining scalable and adaptable to similar PPE manufacturing environments.

### Conclusion

This project successfully addressed the critical fire safety challenges present in Personal Protective Equipment (PPE) manufacturing units, where flammable materials, chemicals, electrical systems, and heat-generating machinery create significant risk. Through a structured methodology involving site assessment, fire risk evaluation, gap analysis, and systematic implementation, key deficiencies in detection systems, emergency preparedness, and regulatory compliance were effectively identified and mitigated. The integration of engineering controls, strengthened administrative procedures, and structured employee training significantly improved fire prevention capability and emergency response readiness. Monitoring results confirmed enhanced compliance, reduced risk levels, and improved safety awareness without disrupting production operations. Overall, the project demonstrates that proactive fire prevention is both practical and essential. The developed framework is scalable and sustainable, supporting long-term fire risk reduction, operational reliability, and protection of life and property.

### References

- [1]. Abdennabi Morchid a, Zahra Oughannou, Fire risk assessment system for food and sustainable farming using ai and IoT technologies: Benefits and challenges, <https://doi.org/10.1016/j.ijot.2025.101704>, Internet of Things 33 (2025) 101704
- [2]. Bektı Utomo, Integrating Fire Prevention Strategies with Industrial Hygiene to Enhance Workplace Safety in Textile Industries, Volume 5 No. 2 (2025) pp. 232-236 ISSN 2775-2674 (online) <http://ijesty.org/index.php/ijesty> DOI: <https://doi.org/10.52088/ijesty.v5i2.818>,
- [3]. Dennielle Nicollie Cadano Dhen Paul G. Calaramo, Proactive & Reactive Knowledge Assessment on Fire Safety Measures: DCCP Community, GSJ: Volume 13, Issue 3, March 2025, Online: ISSN 2320-9186 [www.globalscientificjournal.com](http://www.globalscientificjournal.com),
- [4]. Pei Jingjing , Zhang Haoying, Research on forest fire risk assessment and prevention and control Countermeasures: A case study of Qinyuan County, Ecological Indicators 176 (2025) 113719,
- [5]. Pei Ding, Hao Luo, Investigation of fire risks and safety strategies in large indoor snow parks, 73 (2025) 106707
- [6]. N.B.Singh, Usman Lawal Usman, Nanomaterials in fire protection: Innovations for enhanced safety and durability, 42 (2025) 101497
- [7]. Tan Li, Hengze Zhao, Study on preparation and properties of steel slag based composite gel for mine fire prevention and extinguishing, Arabian Journal of Chemistry 17 (2024) 105966
- [8]. Matteo Valente, Genserik Reniers, Techno-Economic Analysis of Protection Barriers Against Fire- Induced Domino Effects in the Chemical and Process Industry, <https://doi.org/10.1016/j.res.2025.111646>
- [9]. Xin Wu, Jiajun Li, Fire detection strategies for heritage buildings in different microclimates: A case study of Baoguo Monastery in Ningbo, <https://doi.org/10.1016/j.foar.2025.04.003>
- [10]. Saleh Abu Dabous, Amir Shikhli, Fire prevention and mitigation technologies in high-rise buildings: A bibliometric analysis from 2010 to 2023, Ain Shams Engineering Journal 15 (2024) 103010
- [11]. Pasquale Cucco, Giacomo Di Ruocco, Proposal of an innovative model for fire prevention assessment in Cultural Heritage Protection. Research study in Italy, International Journal of Disaster Risk Reduction 97 (2023) 104066,
- [12]. Md Tanvir Siraj, Binoy Debnath, Analysis of the fire risks and mitigation approaches in

the apparel manufacturing industry:  
Implications toward operational safety and  
sustainability, Heliyon (2023)

- [13]. Wan-Ching Li 1, Jo-Ming Tseng,  
Effectiveness of Advanced Fire Prevention  
and Emergency Response Training at Nursing  
Homes,  
<https://www.mdpi.com/journal/ijerph>, Int. J.  
Environ. Res. Public Health 2022, 19, 13185.  
<https://doi.org/10.3390/ijerph192013185>,
- [14]. Trie Islamy Pangestu Astid Puteral, Fire  
Control Efforts in a Cement Company in East  
Java, doi: 10.20473/ijosh.v10i1.2021.128-  
136