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**QUẢN LÝ KHO HÀNG CHỨA HÀNG DỄ CHÁY NỔ: CÁC NGHIÊN CỨU  
ĐIỂN HÌNH VÀ BÀI HỌC CHO VIỆT NAM**

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**Tóm tắt**

Quản lý kho chứa hàng hóa dễ cháy nổ là một vấn đề cấp thiết tại Việt Nam, nơi các vụ cháy nổ đã gây ra thiệt hại kinh tế nghiêm trọng và đe dọa sự an toàn của con người. Nghiên cứu này phân tích các vụ cháy kho ở Hà Nội và Bình Dương, qua đó chỉ ra những bất cập trong quy định an toàn hiện nay. Thông qua việc nghiên cứu các trường hợp quốc tế, bao gồm vụ nổ amoni nitrat tại Beirut (2020) và vụ nổ nhà máy hóa chất tại Xiangshui (2019), nghiên cứu này đề xuất các chiến lược hiệu quả nhằm giảm thiểu rủi ro cháy nổ. Những bài học quan trọng được rút ra bao gồm tăng cường thực thi quy định, cải cách quản lý, đào tạo chuyên sâu cho nhân viên, và nâng

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cao khả năng ứng phó khẩn cấp nhằm giảm thiểu nguy cơ cháy nổ, góp phần bảo vệ tính mạng con người, tài sản và môi trường.

*Từ khóa:* quản lý kho hàng, hàng dễ cháy nổ, an toàn cháy nổ, quản lý rủi ro, phòng chống cháy nổ

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## MANAGING FLAMMABLE AND EXPLOSIVE GOODS WAREHOUSES: CASE STUDIES AND LESSONS FOR VIETNAM

### Abstract

The management of warehouses storing flammable and explosive materials is a critical issue in Vietnam, where fires and explosions have caused severe losses. This study examines major incidents like the Hanoi and Binh Duong warehouse fires, highlighting gaps in safety regulations. By comparing Vietnam's current regulations with international cases such as the Beirut (2020) and Xiangshui (2019) explosions, the research proposes key solutions: stricter enforcement of safety standards, institutional reforms, mandatory employee training, and improved emergency preparedness. These measures aim to enhance safety, reduce risks, and protect lives and property.

*Keywords:* warehouse management, flammable and explosive goods, fire and explosion safety, risk management, fire and explosion prevention

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### 1. Introduction

Warehouses storing flammable and explosive goods are crucial to industries like manufacturing, construction, and logistics but pose significant fire hazards. Vietnam's rapid industrial growth has led to an increase in such warehouses, amplifying challenges related to outdated infrastructure and weak regulatory enforcement. The Ministry of Construction's Circular No. 02/2021/TT-BXD introduced fire safety standards (QCVN 06:2021/BXD) to enhance safety measures (AOKI Kenji, 2021).

However, many warehouses still fail to meet safety standards due to unclear guidelines on fire-resistant materials and inconsistent compliance (Vietnam Law & Legal Forum, 2023). Issues like unauthorized chemical production, improper storage, and weak fire prevention measures persist. Likewise, global cases demonstrate the consequences of poor regulatory oversight and risk management. Enhancing regulatory clarity and compliance can help mitigate fire risks and improve warehouse safety.

This study analyzes international cases to lessons for Vietnam. It aims to (1) identify key fire and explosion hazards, (2) evaluate Vietnam's fire safety regulations in comparison to global standards, and (3) propose practical solutions to enhance safety measures. Key research questions include: What are the main fire hazards in these warehouses? How effective are Vietnam's current regulations? What global lessons can improve Vietnam's warehouse safety? By addressing these issues, the research provides practical solutions for policymakers, safety regulators, and warehouse operators to minimize risks and improve fire safety management.

## **2. Literature review**

### ***2.1. Overview of warehouse management***

Warehouse management plays a crucial role in supply chain operations by coordinating various processes to enhance efficiency and meet customer demand (Harmon, 1993; Tompkins et al., 2003; Slack et al., 2001). Effective management involves inventory control, space utilization, order fulfillment, labor management, technological integration, supplier collaboration, sustainability initiatives, and continuous improvement. Inventory control ensures accurate stock tracking through barcode scanning and Radio-Frequency Identification (RFID) systems, reducing stockouts and overstocking (Patel, 2021). Space optimization strategies, such as vertical storage solutions and Automated Storage and Retrieval Systems (AS/RS), help maximize warehouse capacity. Order fulfillment is streamlined through automated sorting systems, conveyor belts, and Warehouse Management Systems (WMS), which enhance inventory tracking, order processing, and labor management. The adoption of Internet of Things (IoT) devices and data analytics further enables real-time decision-making and operational visibility.

Despite technological advancements, warehouse management faces persistent challenges, including inventory inaccuracies, inefficient space utilization, labor shortages, and inadequate technological infrastructure (Riyaz, 2023). These issues contribute to stock discrepancies, shipping delays, and increased operational costs, ultimately affecting customer satisfaction. Effective labor management through workforce scheduling, training programs, and safety compliance is essential to maintaining productivity and reducing workplace risks. Supplier collaboration facilitates accurate information exchange, improving supply chain coordination. Sustainability practices, such as energy-efficient designs and waste reduction strategies, align with environmental goals while offering cost benefits. Continuous improvement, driven by performance assessments and adaptability to e-commerce trends, is vital for sustaining competitive advantage in modern warehouse operations.

## 2.2. Flammable and explosive goods

### 2.2.1. Overview of dangerous goods

According to the Queensland Government, dangerous goods are substances and articles that exhibit hazardous properties such as explosiveness, flammability, toxicity, infectivity, or corrosiveness, thereby posing significant risks to public safety, property, and the environment. These materials are systematically categorized into nine primary classes, with some further subdivided into divisions based on their specific hazardous characteristics.

Table 1. Classification of Dangerous Goods by Class and Division

Class	Division	Description
Class 1: Explosives	Division 1.1	Substances and articles that have a mass explosion hazard
	Division 1.2	Substances and articles that have a projection hazard but not a mass explosion hazard
	Division 1.3	Substances and articles that have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
	Division 1.4	Substances and articles that present no significant hazard
	Division 1.5	Very insensitive substances that have a mass explosion hazard
	Division 1.6	Extremely insensitive articles that do not have a mass explosion hazard
Class 2: Gases	Division 2.1	Flammable gases
	Division 2.2	Non-flammable, non-toxic gases
	Division 2.3	Toxic gases
Class 3: Flammable liquids	-	Flammable liquids
Class 4: Flammable solids; substances liable to	Division 4.1	Flammable solids, self-reactive substances and solid desensitised explosives

spontaneous combustion; substances which, on contact with water, emit flammable gases	Division 4.2	Substances liable to spontaneous combustion
	Division 4.3	Substances that emit flammable gases when in contact with water
Class 5: Oxidizing substances and organic peroxides	Division 5.1	Oxidising substances
	Division 5.2	Organic peroxides
Class 6: Toxic and infectious substances	Division 6.1	Toxic substances
	Division 6.2	Infectious substances
Class 7: Radioactive material	-	Radioactive material
Class 8: Corrosive substances	-	Corrosive substances
Class 9: Miscellaneous dangerous substances and articles	-	Miscellaneous dangerous substances and articles

*Source: Queensland Government*

In addition, dangerous goods are assigned to one of three packing groups based on the degree of risk they pose.

Table 2. Packing Groups for Dangerous Goods

<b>Packing Group</b>	<b>Description</b>
Packing Group I	Substances presenting high danger
Packing Group II	Substances presenting medium danger
Packing Group III	Substances presenting low danger

*Source: Queensland Government*

### 2.2.2. Flammable and explosive goods

Flammable and explosive goods are classified as hazardous materials due to their propensity to ignite or detonate under specific conditions, thereby posing substantial risks to human safety, infrastructure, and the environment. According to the United Nations Recommendations on the Transport of Dangerous Goods (UN, 2021), these substances are categorized based on their physical and chemical properties, as well as their potential hazards.

## **Flammable goods**

Flammable goods comprise substances that readily ignite when exposed to ignition sources such as heat, sparks, or flames. According to the International Maritime Organization (IMO), these substances are classified into the following categories:

- Flammable liquids (Class 3): These include liquids, liquid mixtures, or solutions containing solids that emit flammable vapors at or below a flashpoint of 60°C (closed-cup test) or 65.6°C (open-cup test). Examples include gasoline, ethanol, and acetone.
- Flammable solids (Division 4.1): These materials are highly combustible under transport conditions and can initiate or propagate fires due to friction. Examples include self-reactive substances and desensitized explosives.
- Substances liable to spontaneous combustion (Division 4.2): These are substances that undergo spontaneous heating under normal transportation conditions or self-ignite upon exposure to air. Examples include phosphorus and oily rags.
- Substances that emit flammable gases when in contact with water (Division 4.3): These materials react with water to release dangerous quantities of flammable gases. Examples include sodium and calcium carbide.

## **Explosive goods**

Explosives (Class 1) include substances that can cause sudden releases of gas, heat, and pressure, leading to explosions. However, materials that do not explode on their own but could create an explosive atmosphere when mixed with gas, vapor, or dust are not included in this class. This category also covers explosive articles, except for those designed in a way that accidental ignition during transport would not cause significant external effects such as fire, smoke, heat, or loud noise. Additionally, it includes substances and articles specifically created to produce explosive or pyrotechnic effects. They are classified into six divisions:

- Division 1.1: Substances with a mass explosion hazard (e.g., TNT, dynamite)
- Division 1.2: Substances with a projection hazard but not a mass explosion hazard (e.g., certain ammunition types)
- Division 1.3: Substances with a fire hazard and minor explosion effects (e.g., fireworks)
- Division 1.4: Substances with minimal explosive risk (e.g., signal cartridges)
- Division 1.5: Very insensitive substances with a mass explosion hazard (e.g., ammonium nitrate fuel oil mixtures)
- Division 1.6: Extremely insensitive articles without a mass explosion hazard (e.g., specialized military explosives)

### ***2.3. Standards and regulations for hazardous goods storage***

#### *2.3.1. International standards*

Several international standards provide a regulatory framework for the safe handling, storage, and transportation of hazardous materials. The United Nations (UN) Recommendations on the Transport of Dangerous Goods provide a global framework for classification and regulation, standardizing transport rules across countries. Similarly, the Occupational Safety and Health Administration (OSHA) enforces regulations on hazardous material storage, focusing on worker safety through hazard communication, labeling, and exposure control. In Europe, the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) regulates hazardous material storage and transportation, ensuring compliance among member states. Additionally, the National Fire Protection Association (NFPA) Codes establish fire prevention and safety protocols to minimize fire and explosion risks in industrial and commercial settings.

#### *2.3.2. Storage requirements*

Strict safety regulations govern hazardous goods storage to minimize risks. Facilities must be fire-resistant, using compartmentalized storage areas to prevent fire spread (NFPA, 2021). Proper ventilation is also essential to prevent toxic vapor buildup and reduce explosion risks (OSHA, 2019). Additionally, clear labeling and signage following the GHS ensure proper material identification (UNECE, 2019). Advanced monitoring systems, such as gas detectors and temperature sensors, also enhance safety through early leak detection and proactive risk management (ISO, 2023).

#### *2.3.3. Handling and emergency procedures*

Proper handling and emergency protocols are vital for hazardous materials management. Workers must receive regular training on risk identification, spill management, and personal protective equipment (PPE) usage (OSHA, 2019). Fire prevention measures, including extinguishers, sprinklers, and alarms, are also critical for minimizing hazards (OSHA, 2019). Finally, robust incident response protocols, such as emergency evacuation plans, first aid measures, and PPE availability, ensure a structured and effective response to accidents, protecting workers and the environment (OSHA, 2019).

### ***2.4. Current regulations and practices in Vietnam***

#### **Legal framework**

Vietnam regulates hazardous goods storage through key laws and regulations. The Fire Prevention and Fighting Law (Law No. 27/2001/QH10, amended in 2013) mandates fire safety

measures, emergency response protocols, and firefighting equipment. Circular 48/2020/TT-BCT, issued by the Ministry of Industry and Trade (MOIT) sets technical safety standards for hazardous chemicals in production, storage, and transport. Law on Environmental Protection (Law No. 72/2020/QH14) defines responsibilities of government agencies, businesses, and individuals to prevent contamination and promote sustainability.

### **Implementation in practice**

Despite a strong legal framework, Vietnam still faces several remaining compliance challenges. Frequent regulation updates require continuous adaptation, straining businesses with limited resources (Nguyen, 2009). Furthermore, inadequate training programs also leave workers unprepared for proper handling, labeling, and emergency response. Another significant challenge is financial constraints, particularly for SMEs, that make investing in safety infrastructure difficult. (Nguyen, 2009)

### **Comparison with international standards**

Vietnam's hazardous goods storage regulations align with several international frameworks but also exhibit key differences in terms of enforcement and compliance mechanisms. Vietnam aligns with the UN Recommendations on the Transport of Dangerous Goods. However, fire prevention regulations are less stringent than NFPA and OSHA standards, which impose stricter requirements for fire suppression systems, emergency response planning, and hazard mitigation. Penalties for non-compliance are also weaker than in developed countries, where stricter enforcement ensures higher compliance. Enhancing regulatory oversight and penalties would improve safety and compliance.

## **3. Methodology**

### ***3.1. Research approach***

This study adopts a qualitative research approach utilizing secondary data to examine warehouse safety regulations, risk mitigation strategies, and management practices for flammable and explosive goods. Through document and case study analysis, it systematically reviews government regulations, industry reports, and academic literature. Two major case studies—the Beirut Ammonium Nitrate Explosion (2020) and the Xiangshui Chemical Plant Explosion (2019)—are analyzed to identify regulatory shortcomings, safety lapses, and emergency response effectiveness, providing critical insights for Vietnam.

The qualitative approach facilitates an in-depth exploration of fire and explosion risks, regulatory deficiencies, and safety enhancements. Case studies further strengthen this analysis by

demonstrating actual failures and best practices, offering empirical evidence to inform policy recommendations and industry improvements.

### **3.2. Data sources**

The research integrates multiple data sources to ensure analytical rigor and validity:

1. **Safety regulations and standards:** Examination of Vietnamese fire safety laws, hazardous materials handling guidelines, and international standards (e.g., NFPA, OSHA) to assess regulatory compliance and best practices.
2. **Government reports and industry statistics:** Review of data from agencies such as the Ministry of Industry and Trade and the Vietnam Fire and Rescue Police to analyze past incidents, enforcement measures, and safety trends.
3. **Existing research and literature:** Analysis of peer-reviewed studies and technical reports on warehouse safety, fire prevention, and explosion risk assessment.
4. **Case studies:** Investigation of warehouse incidents to evaluate causal factors, emergency responses, and safety improvements.

By synthesizing qualitative insights with empirical data, this study provides a comprehensive assessment of hazardous goods warehouse management in Vietnam, offering evidence-based recommendations for enhanced safety practices

## **5. Case study analysis**

### **5.1. Case study 1: Beirut Ammonium Nitrate Explosion (2020)**

#### **5.1.1. Incident overview**

Lebanon, an upper middle-income country, is strategically located on the Mediterranean Sea. The Port of Beirut, one of the Middle East's largest ports, serves as Lebanon's main entry point and a regional hub for trade with Syria, Jordan, Iraq, and the Gulf States. Covering 1.2 km<sup>2</sup>, it includes cargo and container terminals, a grain silo storing 85% of the nation's grain, and a duty-free zone. The port handled over two-thirds of Lebanon's external trade, generating \$313 million in annual revenue and a \$124 million net profit in 2017, playing a crucial role in Lebanon's economy (Al-Hajj et al., 2021).

On August 4, 2020, at approximately 15:00 GMT, one of the deadliest non-nuclear explosions in history occurred at the Port of Beirut. Initial reports, largely disseminated through social media platforms, documented the fire and subsequent blasts, with civilians capturing and sharing videos before formal news coverage ensued (The Guardian, 2020). The explosion originated from a warehouse containing ammonium nitrate, alongside several bags of fireworks,

as indicated in investigative reports. The sequence of events involved an initial smaller explosion, followed by a significantly larger detonation, producing shockwaves that extended across the surrounding regions. According to reports, fireworks stored in proximity to a confiscated shipment of ammonium nitrate caught fire. Lebanese customs authorities had seized approximately 2,750 metric tons of ammonium nitrate from the cargo vessel Rhosus in 2014 and stored it at the port for nearly six years. Preliminary assessments described thick grey smoke emerging from the initial fire, followed by visible flames, sparks, and subsequent detonations. The first explosion produced dense white and grey smoke, rapidly followed by the second, more powerful explosion, which resulted in a fireball and the release of red and orange fumes. The second explosion generated a distinctive spherical blast wave, often described as resembling a white mushroom cloud (Sivaraman and Varadharajan, 2021).

### *5.1.2. Cause of the incident*

The explosion was triggered by over 2.7 kilotons of ammonium nitrate, ignited by flames from a nearby burning warehouse. The shockwave was heard 200 km away in Cyprus, destroying the epicenter, nearby warehouses, grain silos, and ships, and leaving a 140-meter-wide crater filled with seawater (Al-Hajj et al., 2021).

No official report has been released, but analyses from The New York Times (Hubbard et al., 2020) and BBC News (BBC NEWS, 2020) have provided detailed insights into the events leading to the explosion. The ammonium nitrate stored in Hangar 12, originally bound for Mozambique, was offloaded in 2014 after the vessel Rhosus was impounded due to legal disputes. It was improperly stored without safety measures (Sivaraman & Varadharajan, 2021).

Over six years, the ammonium nitrate absorbed moisture, making it unstable. Investigative reports indicate that the warehouse also contained approximately 15 tons of fireworks, wooden spools, and several containers of kerosene and hydrochloric acid. On the day of the explosion, welding work on the warehouse door likely ignited the explosion. Despite ammonium nitrate's well-documented risks, no safety measures, fire protection, or evacuation plans were in place, even with 100,000 residents nearby (Reza, 2020; Sivaraman & Varadharajan, 2021).

### *5.1.3. Consequences*

The Beirut explosion caused 218 deaths, injuring 6,500 and displacing 300,000 people. The blast inflicted significant damage on hospitals, residential areas, hotels, and commercial establishments. According to the World Health Organization (WHO), approximately 55 hospitals sustained severe damage, significantly hampering medical response efforts. Many hospitals were forced to turn away incoming patients due to insufficient capacity (Dyer, 2020; WHO, 2020).

The blast affected multiple neighborhoods such as JISR, Karantina, Geitawi, Gemmayzeh, Sodeco, Bachoura, and Bourj Abi Haydar, causing structural damage up to 15 miles away, with shockwaves felt 240 km away in Cyprus (Sivaraman & Varadharajan, 2021). Infrastructure losses were estimated at USD 390–475 million, while total damages reached USD 3.8–4.6 billion (World Bank, 2020).

Furthermore, the explosion released ammonia gas and nitrogen oxides into the atmosphere, raising significant environmental concerns. The resulting air pollution posed risks to respiratory health, while hazardous chemicals from construction debris threatened soil and water quality. The United Nations Development Programme (UNDP) estimated that the environmental cleanup costs would exceed USD 100 million.

#### *5.1.4. Policy and solution*

After the explosion, Lebanon declared a state of emergency, and international organizations launched the 18-month Reform, Recovery, and Reconstruction Framework (3RF) to coordinate aid and rebuilding (United Nations, 2020). To ensure accountability, Lebanese authorities initiated an investigation, leading to the arrest of several senior officials responsible for port safety and customs oversight. International scrutiny was encouraged to enhance transparency and restore public trust in governmental institutions (Yacoubian and Abouaoun, 2020).

Reconstruction efforts prioritized the restoration of essential infrastructure, including homes, hospitals, and schools. The 3RF framework emphasized the equitable distribution of aid and aimed to revitalize Lebanon's economy through sustainable development initiatives. Governance reforms were also introduced to improve institutional accountability, transparency, and community participation in decision-making processes (United Nations, 2020).

## ***5.2. Case Study 2: Xiangshui Chemical Plant Explosion (2019)***

### *5.2.1. Incident overview*

On March 21, 2019, a massive explosion occurred at the Jiangsu Tianjiayi Chemical Co. plant in Xiangshui County, Jiangsu Province, China. The explosion was one of the deadliest industrial accidents in recent Chinese history, resulting in significant casualties, extensive damage, and environmental contamination (BBC News, 2019). The plant specialized in producing hazardous chemicals, including pesticides and raw chemical materials. Due to the intensity of the explosion, it registered as a seismic event, causing widespread devastation within a several-kilometer radius (The Guardian, 2019). The impact of the explosion was not only physical but also led to long-term socioeconomic and environmental consequences.

Emergency responders were dispatched immediately, but the intensity of the fire and chemical release complicated rescue efforts. More than 900 firefighters and medical personnel were deployed to control the situation and provide aid to victims (South China Morning Post, 2019). The blast caused extensive structural damage to surrounding industrial facilities, schools, and residential areas, leading to mass evacuations. The immediate response efforts focused on containing secondary explosions and minimizing chemical exposure to nearby communities.

### *5.2.2. Cause of the incident*

Investigations by Chinese authorities identified multiple critical factors that contributed to the explosion. One of the primary causes was poor safety management. The Jiangsu Tianjiayi Chemical Co. had a history of safety violations and had been fined multiple times for failing to meet safety standards (Ministry of Emergency Management of China, 2020). Despite these warnings, the company continued to operate without implementing adequate risk assessment and safety protocols for handling hazardous chemicals.

Another major contributing factor was the unsafe storage of volatile chemicals. The facility stored large quantities of highly flammable substances under inappropriate conditions. Over time, the improper management of these chemicals led to their degradation, making them highly reactive (South China Morning Post, 2019). Furthermore, illegal and unsafe production practices were also cited as major concerns. Unauthorized chemical processes were carried out without sufficient regulatory oversight, and many workers lacked formal training in handling hazardous materials, leading to high-risk operational conditions.

The final trigger for the explosion was believed to be an uncontrolled chemical reaction. Reports suggested that a leak of toxic substances, combined with poor storage conditions, created an unstable environment. An ignition source, possibly from machinery or electrical equipment, then led to a catastrophic chain reaction, culminating in the massive explosion (BBC News, 2019).

### *5.2.3. Consequences*

The explosion resulted in severe and far-reaching consequences, affecting human lives, infrastructure, the environment, and the economy.

Firstly, the human casualties and injuries were staggering. The explosion killed at least 78 people and injured more than 600 others (The Guardian, 2019). Many victims suffered severe burns, fractures, and exposure to toxic chemicals, leading to long-term health complications. Hospitals in the region were overwhelmed with casualties, and extensive medical relief efforts were required to treat the injured.

Secondly, the destruction of infrastructure was immense. The explosion flattened buildings within the chemical plant and severely damaged surrounding structures, including residential homes, schools, and other industrial facilities. The blast impact was so strong that windows were shattered as far as six kilometers away. Many buildings that remained standing were rendered structurally unsound and had to be demolished (South China Morning Post, 2019).

The environmental contamination caused by the explosion was also a major concern. The release of hazardous chemicals resulted in severe soil and water pollution, which affected local agriculture and contaminated water sources (Ministry of Emergency Management of China, 2020). Additionally, airborne toxins increased the risk of respiratory illnesses among residents, raising concerns about long-term health impacts.

Economically, the disaster led to substantial financial losses. The estimated cost of damages ran into billions of Yuan, including compensation for victims, medical expenses, cleanup efforts, and regulatory fines imposed on the company. Several businesses in the region were forced to shut down, leading to job losses and economic downturn in the affected areas (The Guardian, 2019). The long-term financial repercussions of the explosion further strained the local economy, making recovery efforts more challenging.

#### *5.2.4. Policy and solution*

In response to the disaster, the Chinese government implemented several policies and regulatory measures aimed at preventing similar incidents in the future. One of the key actions taken was stricter regulatory enforcement. Authorities conducted extensive inspections of chemical plants across the country, shutting down facilities that failed to comply with safety regulations. Existing policies were revised to impose stricter compliance requirements and higher penalties for violations (Ministry of Emergency Management of China, 2020).

To improve workplace safety, enhanced safety protocols were introduced. Chemical companies were mandated to implement rigorous safety training programs for workers and establish real-time monitoring systems for chemical storage conditions. Additionally, investment in modern safety technologies was encouraged to reduce the risk of future accidents (South China Morning Post, 2019).

Recognizing the risks posed by hazardous industries near residential areas, the government initiated a policy of relocation of hazardous industries. Many chemical plants were required to move their operations to designated industrial zones away from densely populated areas. This relocation aimed to minimize the potential impact of future industrial accidents on civilian populations (Ministry of Emergency Management of China, 2020).

Increased corporate accountability was another significant policy shift. Companies found to be in violation of safety regulations faced heavy penalties, and executives responsible for negligence were prosecuted. In the case of Jiangsu Tianjiayi Chemical Co., several senior executives were arrested and held accountable for their role in the disaster (BBC News, 2019).

Additionally, the government launched public awareness campaigns to educate communities on industrial safety and emergency response procedures. These initiatives aimed to enhance preparedness and response capabilities in the event of future industrial accidents (The Guardian, 2019).

Despite these efforts, industrial safety in China remains a critical challenge. The Xiangshui explosion highlighted the urgent need for continuous improvement in safety culture, enforcement, and technological innovations in hazardous material management. Future safety measures must focus on comprehensive risk assessment, transparent regulatory oversight, and fostering a culture of safety compliance within the chemical industry (Ministry of Emergency Management of China, 2020).

### **5.3. Summary**

Both case studies highlight the severe consequences of inadequate safety measures, regulatory failures, and mismanagement in handling hazardous materials. In the Beirut ammonium nitrate explosion (2020), the primary root cause was the prolonged improper storage of 2,750 metric tons of ammonium nitrate in a densely populated area without adequate safety protocols. The failure to enforce strict regulations, combined with negligence in addressing known risks, directly contributed to the catastrophic explosion. Similarly, in the Xiangshui chemical plant explosion (2019), systemic weaknesses in regulatory oversight and inadequate enforcement of safety policies played a critical role in the incident. Both cases underscore the importance of proactive risk management in preventing large-scale disasters.

A common policy failure observed in both incidents was the lack of stringent regulatory frameworks governing the storage and handling of hazardous materials. In the Beirut case, the ammonium nitrate was confiscated and stored without clear accountability or adherence to international best practices, leading to its deterioration and heightened risk of detonation. Likewise, in the Xiangshui chemical plant explosion (2019), the absence of comprehensive monitoring systems allowed for dangerous conditions to persist unchecked. These failures point to a broader issue of governance inefficiencies and insufficient inter-agency coordination, which ultimately exacerbated the severity of the incidents.

To mitigate similar risks in the future, both cases highlight the need for comprehensive policy reforms and the implementation of robust safety measures. One key solution is the adoption of stricter regulations aligned with international safety standards for hazardous material

management. Governments must establish clear guidelines on the proper storage, transportation, and disposal of such substances, ensuring compliance through rigorous inspections and enforcement mechanisms. Additionally, investing in advanced risk assessment technologies and real-time monitoring systems can help detect and address potential hazards before they escalate into full-scale disasters.

Furthermore, strengthening institutional accountability is crucial. Both cases demonstrated how bureaucratic inefficiencies and lack of transparency contributed to poor crisis management. Establishing independent regulatory bodies with the authority to oversee safety compliance and enforce punitive measures against negligence can enhance accountability and deter regulatory breaches. Moreover, fostering collaboration between public institutions, private entities, and international organizations can facilitate knowledge-sharing and capacity-building initiatives, ultimately improving disaster preparedness and response strategies.

Finally, community engagement and public awareness play a vital role in mitigating risks associated with hazardous materials. Governments and organizations must prioritize public education on safety measures and emergency response protocols. Implementing comprehensive training programs for personnel handling hazardous substances and conducting regular emergency drills can enhance overall preparedness. By integrating these policy solutions, authorities can build more resilient systems that prevent future disasters and safeguard public safety effectively.

## **6. Lessons for Vietnam**

There are no official statistics on the number of flammable and explosive goods warehouses in Vietnam. However, the University of Fire Prevention and Fighting estimates that 22,524 warehouses and industrial facilities face fire and explosion risks, a number that continues to grow.

One major incident occurred on June 30, 2020, when a fire erupted at Cuong Viet Company's warehouse in Hanoi. Though the facility was licensed to trade chemicals, it was secretly producing them, storing flammable substances like Isopropanol, Toluene, and Acetone. A leaking chemical tank intensified the fire, leading to explosions and toxic smoke. Toluene levels in the air exceeded safety limits by 17.53 times, posing severe health risks. Poor safety practices and illegal operations turned this warehouse into a disaster waiting to happen (VTV Online, 2020).

Another devastating case took place on August 24, 2022, in Binh Duong Province. A fire broke out at a chemical warehouse, killing one person and causing extensive damage. The warehouse stored large quantities of improperly labeled, highly flammable chemicals. Nearby homes were destroyed, forcing residents to relocate, while toxic chemicals like Benzene and Xylene polluted the air for months. Despite a prior inspection in May 2022, the company ignored safety regulations, directly leading to the disaster (Bao Tien Phong, 2022).

These incidents reveal serious gaps in Vietnam's management of hazardous goods. Strengthening regulations, enforcing compliance, and improving safety standards are essential to preventing future tragedies. Learning from these failures and adopting international best practices will be key to creating a safer warehouse management system.

### **Improve enforcement of safety standards**

Vietnam must strengthen enforcement to prevent industrial disasters like the Xiangshui explosion in China (2019) and the Beirut port explosion (2020), both caused by regulatory failures. Weak enforcement in Vietnam has led to similar risks in hazardous material warehouses.

To improve safety, Vietnam should establish specialized inspection teams trained in chemical and fire safety. These teams must conduct unannounced inspections to ensure compliance with fire suppression, labeling, and safe storage requirements. Stronger penalties, including heavier fines, license revocations, and criminal charges, should deter negligence. Additionally, an anonymous reporting system will empower workers and citizens to report unsafe practices, preventing government inaction, as seen in Beirut. By enhancing inspections, imposing strict penalties, and promoting public oversight, Vietnam can close regulatory gaps and ensure safer warehouse operations, reducing the risk of catastrophic accidents.

### **Institutional reform and enhanced cooperation**

Institutional reform and enhanced cooperation are essential elements in Vietnam's efforts to improve disaster management. The country should actively participate in partnerships to strengthen its resilience to natural disasters, in addition to the collaborations it has already engaged in, such as the Disaster Risk Reduction Partnership's plan for 2025–2030. This initiative aims to enhance Vietnam's disaster resilience by emphasizing coordinated policies, risk-informed development planning, and community awareness (Vietnamplus, 2024). It involves multiple stakeholders, including UN agencies, non-governmental organizations (NGOs), and government bodies, to ensure a comprehensive and integrated approach to disaster risk management.

Enhanced cooperation among different sectors should also be a key strategy. Vietnam has been actively emphasizing the importance of establishing effective communication and collaboration channels among various stakeholders, including ministries, local authorities, the private sector, and NGOs (Sai Gon News, 2024; Netzero.vn, 2024). The Ministry of Health's 2024 natural disaster management plan includes strengthening the capacity of its organizational system and establishing mobile teams for disaster response, demonstrating a strong commitment to inter-agency collaboration (Lawnet, 2024). Furthermore, Vietnam's participation in regional initiatives, such as the ASEAN Disaster Risk Financing and Insurance Programme, underscores its efforts to leverage international cooperation for more effective disaster management (Vietnamnews, 2023).

Institutional reforms should be implemented to strengthen the legal and policy framework for disaster management. Vietnam has developed a comprehensive system, including the Law on Disaster Prevention and Control and Decree No. 66/2014/ND-CP, which provide guidelines for disaster risk management. Additionally, the government should focus on enhancing the disbursement of international aid and improving strategic disaster management planning through partnerships with organizations such as GIZ (Hoai T. Q. & Dirk Pauschert, 2018). These reforms aim to streamline decision-making processes, ensure regulatory compliance, and enhance the effectiveness of disaster response and recovery efforts.

To further strengthen cooperation, Vietnam should promote early action strategies in disaster management, aligning with ASEAN's vision for proactive prevention and preparedness (Vietnamnews, 2023; Netzero, 2024). A notable initiative is the National Week for Natural Disaster Prevention and Control, which highlights the importance of accurate warnings, reliable forecasts, and the timely dissemination of information to vulnerable communities (Netzero.vn, 2024). By integrating these strategies into its institutional framework, Vietnam aims to build a more resilient society capable of effectively mitigating the impacts of natural disasters.

### **Mandatory training for handling hazardous materials**

A key challenge in Vietnam's hazardous material management is the lack of structured training programs for employees. Past disasters, such as the Beirut explosion and the Xiangshui disaster, highlight the catastrophic consequences of insufficient knowledge of chemical risks. Similarly, recent warehouse fires in Vietnam have shown that untrained workers and first responders struggle to handle chemical fires, leading to greater damage and health risks.

To improve safety, Vietnam must enforce mandatory training programs covering chemical storage, labeling, emergency response, and risk assessment. Workers should be trained to recognize hazards, use safety equipment, and follow protocols. Regular hands-on safety drills, especially in industrial zones, will ensure swift and effective responses in emergencies. Introducing safety certifications and periodic refresher courses will further enhance preparedness. By institutionalizing comprehensive training and drills, Vietnam can reduce human error in warehouse disasters and align its safety practices with international standards.

### **Increase awareness and emergency preparedness**

Vietnam should implement a public awareness strategy to improve preparedness for chemical hazards, as limited knowledge increases risks during industrial accidents. Without proper education, people may fail to recognize warning signs, take ineffective protective measures, or delay evacuation, leading to preventable injuries and fatalities.

To address this issue, nationwide education campaigns should be introduced to inform citizens about hazardous materials, safe handling, emergency response, and exposure prevention. Schools, workplaces, and communities should integrate chemical safety training, while brochures and online platforms can help spread awareness.

Additionally, the Vietnam government should establish an early warning system that effectively communicates chemical hazard risks to the public. Authorities should develop a centralized platform that provides real-time updates on industrial safety incidents, air quality monitoring, and evacuation guidelines. Leveraging multiple communication channels, such as SMS alerts, public service announcements, and social media, would ensure that timely and accessible information reaches all affected communities.

## 7. Conclusion

The management of flammable and explosive goods warehouses in Vietnam presents significant challenges, as evidenced by recent fire and explosion incidents. This study identifies critical safety deficiencies and draws lessons from international cases, notably the Beirut and Xiangshui explosions. These cases emphasize the necessity of stringent regulatory oversight, proper chemical storage, advanced fire detection systems, and comprehensive employee training. Adopting best practices from industrialized nations can enhance fire prevention, emergency preparedness, and risk mitigation. Effective implementation of these measures is crucial for safeguarding lives, infrastructure, and ensuring long-term economic and environmental sustainability.

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