Analysis on the Causes and Preventive Measures of Fire and Explosion Accidents for Hazardous Chemicals

Jiajun Chen *

School of Resources and Safety Engineering,University of Science and Technology Beijing, Beijing, China

* Corresponding Author Email: u202343270@xs.ustb.edu.cn

Abstract. In recent years, China's industry has developed rapidly, and the demand for chemical materials has surged. However, due to the dangerous characteristics of some chemical materials, they are prone to fire and explosion accidents from production to use. This paper mainly studies the causes and preventive measures of fire and explosion accidents of hazardous chemicals. First of all, the fire and explosion accidents of hazardous chemicals are classified according to the situation that the hazardous chemicals occurred. Through various scientific methods to analyze the specific causes of fire and explosion accidents, finally the corresponding preventive measures are summed up. The results show that the direct cause of fire and explosion accidents of hazardous chemicals is the unsafe state of hazardous chemicals and the improper operation of operators. The root cause is the lack of safety management of relevant business units. In order to prevent accidents, it is necessary to keep hazardous chemicals in a safe state, conduct more safety training for employees, strengthen safety management, and improve the safety management system. The purpose of this paper is to analyze the causes of dangerous chemical fire and explosion accidents, so as to better prevent and deal with the occurrence of accidents.

Keywords: Hazardous chemical; fire and explosion accident; cause analysis; preventive measures.

1. Introduction

With the accelerated development of industrialization, various chemical raw materials are widely used in many fields and become an indispensable part of promoting economic development. However, due to the instability of some chemical raw materials in the daily environment, fire and explosion accidents are easy to occur. This danger is also like a "non-time bomb", which brings potential great threats to human society. Chemical fire and explosion accidents happen from time to time, and each accident is shocking. For example, in the Tianjin Port explosion incident on August 12, 2015, improper storage operations of hazardous chemicals led to serial explosions, and the huge energy immediately released not only damaged the surrounding facilities [1]. This accident ruthlessly took many precious lives, caused immeasurable property losses, and also caused lasting damage to the ecological environment. The frequent occurrence of fire and explosion accidents similar to hazardous chemicals has aroused great concern and deep reflection on the safety of hazardous chemicals from all walks of life. Doing a good job in the management of hazardous chemicals is of great significance for ensuring the safety of people's lives and property, maintaining social harmony and stability, and promoting the safe and sustainable development of the chemical industry.

This paper systematically explores the causes of hazardous chemical accidents. By analyzing the material characteristics, production process, storage environment and unstable factors in the transportation process of hazardous chemicals, effective preventive measures are sought.

2. Accident Cause Analysis

Over the years, fire and explosion accidents of hazardous chemicals have occurred frequently, and most of them fall into three processes including the production process, transportation process and storage process. Table 1 shows the statistics of fire and explosion accidents of hazardous chemicals in recent years.

Table 1. Statistical table of fire and explosion accidents of hazardous chemicals.

Time	Location	Accident Process	Result
May 22, 2019	A chemical workshop	Production Process	Construction damage and 1 injured
July 12, 2018	Yangchun Industrial Park, Jiang 'an County, Sichuan Province	Production Process	19 killed and 12 injured
Nov. 28, 2018	Hebei Zhangjiakou City, China National Chemical Group Hebei Shenghua Chemical Co., LTD	Production Process	24 killed and 21 injured
Aug. 11, 2023	Chengde City, Hebei Province	Transport Process	2 killed
Dec. 30, 2019	G6 Beijing-Tibet Expressway Xining to Lanzhou direction Zhangjiasi service area 1 km east	Transport Process	1 killed and 5 injured
June 13, 2020	Shen-hai Expressway Wenling exit, Taizhou, Zhejiang Province	Transport Process	20 killed and 175 injured
Aug. 12, 2015	Tianjin Binhai New Area Port of Tianjin	Storage Process	165 killed and 798 injured

2.1. Production Process

Some fire and explosion accidents occurred during the production process, and most of them are explosion accidents, so it is necessary to analyze the cause. At around 4:30am on May 22, 2019, a gas division post in a chemical workshop exploded due to improper operation, and someone's hands were injured. Jiang et al. made a qualitative and quantitative analysis of the influencing factors of the accident based on the AcciMap model and combined with the analytic hierarchy process of network analysis [2]. The study pointed out that the main cause of the accident was company management, and inadequate safety training and improper operation were the main influencing factors of the accident. At 18:30 on July 12, 2018, an explosion occurred at an enterprise in Yangchun Industrial Park, Jiang'an County, Sichuan Province, resulting in 19 deaths and 12 injuries [3]. According to the analysis of HFACS-PE framework, Yang et al. concluded that the main cause of the accident was the danger source, while the secondary factors included lack of professionalism, habitual violations, environmental reasons, and insufficient communication and coordination among employees of various departments [3].

In the process of producing hazardous chemicals, enterprise safety management is particularly important. If the safety training and skills of the staff are not enough, and the production expertise is insufficient, it will lead to various illegal operations, which can easily cause fire and explosion accidents.

2.2. Transport Process

In the process of transportation, once the explosion occurs due to traffic accidents or other environmental reasons, it will cause serious consequences. For example, on June 13, 2020, a tank truck transporting liquefied petroleum gas (LPG) ran off the highway near Liangshan Village, Daxi Town, Wenling City, and the LPG on board eventually leaked and caused an explosion, resulting in 20 deaths and more than 100 injuries.

Fang analyzed the causes of the transportation safety accidents of hazardous chemicals and pointed out that China's supervision of safe transportation was not strong enough, resulting in some transportation operators overloading and speeding transportation to maximize profits [4]. In addition, due to the incomplete information of vehicles transporting hazardous chemicals on the road surface and the incomplete knowledge of hazardous chemicals, the emergency handling ability after an accident is insufficient. Secondly, China's approval of the conditions for the registration of hazardous chemical transportation enterprises is not strict, the qualification examination of transport drivers is not strict, and the supervision of safety accident plans and drills of transport enterprises is not strict. Yuan et al. also carried out an analysis to find out the causes of safety accidents during the

transportation of some hazardous chemicals [5]. The first is the state of transportation personnel, which is affected by transportation time and profit, and there is fatigue driving. Secondly, in the transportation process, the bad weather will also affect the safety of transportation, in rain and snow weather, the driver's vision will be affected, unable to observe the changes in the road conditions in time. In low temperature freezing weather, it is easy to enter the wet section during transportation, and if the operation is improper, the vehicle will slip out of control. Last but not least, China's traffic conditions are relatively complex, and it is easy to be affected by car accidents in areas with large traffic flow and dense population. In summary, insufficient supervision of the safe transportation of hazardous chemicals, various illegal driving of drivers and various environmental reasons ultimately lead to the transportation of hazardous chemicals safety accidents.

2.3. Storage Process

Most hazardous chemicals are chemically unstable and easy to be in an unsafe state, so proper and reasonable storage is very important. If stored improperly, it may lead to serious fire and explosion accidents. For example, at 22:51 on August 12, 2015, a fire and explosion accident involving hazardous chemicals occurred at the dangerous goods warehouse of Ruihai Company in Tianjin Port, Binhai New Area, Tianjin, causing serious casualties and economic losses [1].

After the big explosion in Tianjin Port, many scholars have made a specific analysis on the cause of the fire and explosion accident. Hua et al. analyzed the Tianjin Port big explosion accident according to the causal relationship model of the accident, and believed that the causes of the accident were divided into four categories: environment, human, management, facilities and goods, which were intertwined and complementary [6]. At the same time, according to the Fault Tree Analysis (FTA) method, the minimum cut set of accident factors and the structural importance coefficient, they also pointed out that in this explosion accident, management factors and human factors were the key pathogenic factors of the Tianjin Port explosion, while environmental factors, facilities and cargo factors were the secondary pathogenic factors [6]. Ma and Chang also analyzed the accident based on the causation chain of the accident [7]. The direct cause is the unsafe behavior of people and the unsafe state of things. The indirect reason is people's lack of safety cognition and bad safety habits. The root cause is the defect of safety management system. The root cause is the lack of organizational safety culture. To sum up, factors such as illegal excess storage of hazardous chemicals and substandard safety management caused this serious accident.

3. Preventive Measures

In view of the fire and explosion accidents that may occur during the three process of hazardous chemicals, safety management and prevention should be carried out. Specific measures should include the following aspects:

(1) Unsafe behavior against people and unsafe state of things

In all kinds of hazardous chemical fire and explosion accidents, the unsafe behavior of people and the unsafe state of things are the direct causes of accidents, so it is necessary to prevent them. In view of the safety accidents occurred during the transportation of hazardous chemicals, the access conditions of drivers should be strictly controlled, illegal driving, fatigue driving, and overloading and speeding for profit maximization should be strictly prohibited. In the production process, the relevant staff must comply with the operation and improve their own knowledge of safety production.

(2) Security management

In view of incidents similar to the Tianjin port explosion, daily safety supervision should be strengthened for the relevant management departments of the port government and the safety management system should be improved. Daily safety supervision should be done: early safety supervision, business license supervision, daily operation safety supervision and penalties for port dangerous goods projects that do not fulfill safety responsibilities. The improvement of the safety management system needs to strengthen the contact between The State Council and the local

administrative departments at all levels, and do a good job of safety management at all levels from top to bottom [1, 6, and 7]. For the transportation and production of hazardous chemicals, safety supervision of business entities should be done well, such as for the safety accidents that occur during transportation, it is necessary to strictly supervise the transportation business entities to prevent the occurrence of dangerous behaviors such as overload operation for seeking profits. For production safety accidents, enterprises that produce hazardous chemicals must be required to do a good job of training employees, make emergency plans, and do a good job of safety drills in order to achieve safe production. Finally, each enterprise needs to establish a sound safety management system, so that the strict implementation of various management and strict supervision of the safety of various operations.

Therefore, whether it is from the safety supervision of hazardous chemicals themselves or the safety management of personnel, effective prevention is needed. It is necessary to carry out strict safety supervision for major hazards such as hazardous chemicals, train employees on safety behaviors and habits, and strengthen accident emergency management capabilities.

4. Conclusion

This paper mainly analyzes the causes of fire and explosion accidents of hazardous chemicals and puts forward relevant preventive measures, and draws the following conclusions:

(1) From the production to the transportation to the storage of hazardous chemicals, the unsafe behavior of people and the unsafe state of things have been the direct cause of accidents. In the production process, workers due to their own lack of professional knowledge or their own character defects caused by operational errors caused by accidents abound. In the process of transportation, the driver's overloading, speeding, disobeying traffic rules and other illegal driving also caused many accidents. When storing hazardous chemicals, the storage personnel over-store the major dangerous sources such as hazardous chemicals, and do not understand their own storage requirements and illegal storage will easily cause fire and explosion accidents.

(2) The methods and measures of hazardous chemical accidents are first to eliminate the unsafe state of the material as far as possible. In the production process, workers should strictly follow the operating procedures and carry out production under the safety conditions given by experts. In transportation, it is necessary to do not overload, not speed driving, so as to ensure that hazardous chemicals are in a safe state. It is also extremely important to ensure that the storage environment of hazardous chemicals meets the requirements during storage. Secondly, the enterprise security management is also particularly important. It is necessary to establish and improve the safety management system, strictly supervise the compliance of workers, make emergency plans in advance, and do safety training and safety drills.

(3) Although a number of preventive measures have been proposed, such accidents cannot be completely eliminated due to various reasons such as the difficulty for enterprises to implement them in place and the failure of individuals to be alerted when carrying out hazardous chemicals related operations. From the perspective of energy release, hazardous chemicals in the energy category can be changed to some stable new energy with little harm after an accident. And more stringent protection for such major hazards, such as the use of new materials with high strength and high temperature resistance to reduce the loss of hazardous chemicals after fire and explosion. In the production of hazardous chemicals, intelligent robots can be used to replace human beings to reduce human mistakes and casualties after mistakes.

References

[1] State Council, Tianjin Port "8.12" Ruihai Company dangerous goods warehouse especially major fire and explosion accident investigation report, 2016-02-05.

[2] Jiang Wei, Yang Ning, Li Jixiang, et al. Study on the Causes and Importance of4 ww Fire and Explosion Accidents in the Production of Dangerous Chemicals. Safety, 2023, 44(02): 60-65.

[3] Yang Ling, Li Yinghui, Chen Meng-meng. Analysis of Typical Hazardous Chemical Explosion Accidents Analysis Based on HFACS-PE. Guangzhou Chemical Industry, 2022, 50(19): 295-298.

[4] Fang Jian. Accidents Analysis of Hazardous Chemicals Transportation in City and its Countermeasures.Chemical Industry Times, 2022, 36(09): 31-35.

[5] Yuan Hongyong, Liu Wei, Mi Wenzhong.Analysis of Road Transportation Accidents of Hazardous Chemicals and Preventive Suggestions. Journal of China People's Police University, 2021, 37(10): 63-66.

[6] Hua W, Chen J, Qin Q, et al. Causation analysis and governance strategy for hazardous cargo accidents at ports: Case study of Tianjin Port's hazardous cargo explosion accident.Marine pollution bulletin, 2021, 173(PB): 113053.

[7] Ma Xiaoling, Chang Weiwei. Analysis on Tianjin Port "8.12"fire and explosion Based on Accident-Causing Chains. Ssafety, 2022, 43(05): 56-61.