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Chemical Safety Risk Evaluation and Early Warning Approaches

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Today, China has witnessed a rapid development in the economy, which has seen an explosive growth of the chemical industry. In this context, the safety risk of greater hidden dangers ensues. This paper describes the definition and the classification of safety risks those chemical enterprises face now. There is a reasonable level-to-level management of the risk sources in the chemical enterprises, where the concept of appropriate risk capacity was also introduced. The dangerous substances are also accommodated to a controllable probability of risk occurrence by controlling the appropriate risk capacity of chemical enterprises. A diamond forewarning model for enterprises' safety risk is thereby established. Not only that, the safety risk management case in a chemical enterprise is cited to prove how the model proposed here is feasible and will be available for risk management.

1. Introduction

As the social technology advances at a full speed, China's chemical industry has also gradually evolved into a chemical industry park which integrates chemical production, product processing, reasonable storage, effective transport and proper handling. Those chemical enterprises are fundamental to the safety and security of chemical industry park due to their hazards of chemical substances and potential energy intensity (Zhang, Q. et al., 2016, Torres-Vega, JJ et al., 2014). Chemical enterprises should be ensured at a safety level. They should play a great effect on environmental protection while maintaining a high productivity as a major growth pole of the national economy, thus contributing much to the harmonized and sustainable development of economic production and nature world (Fabbri and Contini, 2009). It is certain that the assessment and early warning of the safety risks in the chemical industry has a positive significance to answer for the steady development of economy, people's life safety and the harmonious development of the ecological environment (Fraaije et al., 2012). In recent years, the explosive growth of chemical industry has seen great safety hazards (Moore et al., 2007). Since 2008, the number of sudden environmental incidents in China has been increasing year by year. In response to this situation, the country has enacted relevant policies, and put teeth in three measures of "total reduction, safety protection and improv quality" to guarantee the safety of chemical enterprises, and underlined the importance of advancing the whole process of environmental risk management (Lemley et al., 2010; Moore, 2006). Existing studies demonstrate that a reasonable safety risk assessment system and early warning approach have a significantly positive impact on the probability of sudden environmental accidents in chemical enterprises (Baesi et al., 2013). It is therefore of great practical significance to explore chemical safety risk assessment system and early warning approaches.

2. Safety risk assessment of chemical enterprises

2.1 Risk and safety risk

The definition of risk focuses on the abruptness of an accident, i.e, on the premise of failure to anticipate the consequences of an incident, it refers to the set of emergencies and their relevant consequences (Coulibaly et al., 2017; Barlow et al., 2015). In the S.H.E management system, the risk is defined as the probability of occurrence of the emergency within a certain period of time and the severity of the ensuing consequences (Giannopoulos, G. et al., 2010).

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The safety risk for chemical enterprises attributes to sudden risk according to the risk classification. The reason is that such risk has a high hazard to the environment and human health, and is characterized by potentiality, concealment and long-standing impact (Godin et al., 2004). In other words, the safety risks of chemical enterprises are usually hidden for a certain time and will not emerge immediately. However, once outbreak, it will produce a violent impact on the human health and ecological environment (Bou-Diab and Fierz, 2002). The risk source of chemical enterprises is shown in Fig. 1. This paper defines the safety risk source of a chemical enterprise as a risk substance pertaining to production, consumption and discharge, and under a certain impact of factors, can lead the surrounding to producing a risk substance which can trigger unexpected accidents, as a tiny unit of safety risk.

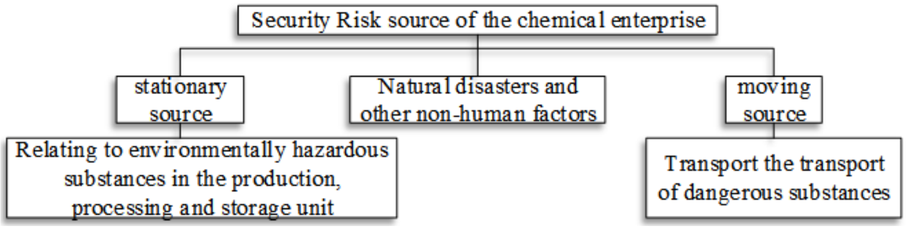

Figure 1: Safety risk source of the chemical enterprise

2.2 Safety risk evaluation of chemical enterprises

For the safety risk assessment of chemical enterprises focuses on the violent and irreversible consequences caused by natural irreversibility or improper activities of mankind, which are propagated through the environment, and eventually undermine the ecological environment and human society to a certain extent, provided that the narrow sense of safety risk source limited above is underlaid. The safety risk assessment in chemical enterprise includes three parts, i.e. risk identification, risk assessment and safety risk decision, each of which can be further subdivided, as shown in Fig. 2.

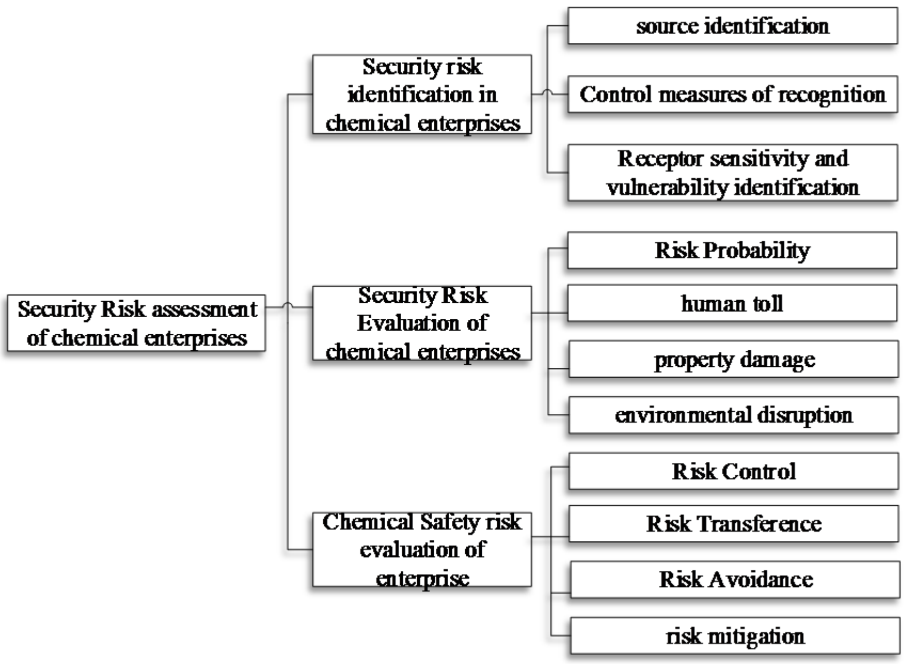

Figure 2: Safety risk assessment of chemical enterprise content

3 Construction of safety risk assessment model

3.1 Classification management of safety risk sources

When the classification management of safety risk sources is carried out for chemical enterprises, along with the potential risks, dosages, storages and actual storage volumes which must be classified, great attention must be paid to the inherent causes why safety risks occur, such as risks of production plants, human factors, etc. The key to the classification management of safety risk sources lies in the investigation of the environmental risk sources, including hazardous substances, storage areas, production management and the surrounding ecology environment, in general and detailed ways. Among them, the hazardous substances shall be investigated in accordance with the relevant standards issued for substance hazards. As shown in Table 1, the surrounding environmental conditions as investigated mainly include the sensitive targets within 500 meters around the chemical enterprises such as residential areas, rivers, hospitals and natural ecology preservation areas, etc. After a reasonable classification of risk sources, different classes can be disposed separately.

Table 1: Physical hazard criteria

substance class	Level	Rats by oral mg/kg	Rats by skin mg/kg	The four - hour inhalation in mice Mg/L
toxic substance	1	<5	<1	<0.01
	2	5<L<25	10<L<50	0.1<L<0.5
	3	25<L<200	50<L<400	0.5<L<2
inflammable substance	1	Flammable gases, substances between boiling point of 20 degrees centigrade and 50 degrees Celsius		
	2	Flammable liquid, boiling point substances above 20 degrees Celsius		
	3	Flammable liquid, which remain liquid under pressure		
explosive substances		Under the influence of flame could explode		

3.2 Computation of safety capacity

The basic concept of safety capacity is introduced in order to achieve the scale control on hazardous substances. A quantitative relationship between the risk and the size of the hazardous substances is constructed, so that it is critical to obtain the maximum safety capacity. The safety risks triggered due to the scales of hazardous substances in the chemical enterprises include four parts, i.e. hazards of goods, inherent safety risks, transport safety risks and safety capacity. The interrelation among these four parts is shown in Fig. 3. The safety capacity of chemical enterprises mainly refers to the maximum and reasonable scale of hazardous substances. This paper limits the types of hazardous substances in chemical enterprises. It is supposed that there are only three types of explosive, flammable and toxic substances in chemical enterprises. Based on safety risk capacity, the average risk on personnel can be figured out. Then the chemical safety risk assessment model is built in combination with specific hazardous substances, refer to Fig. 4 for its main procedure.

$$C \leq (C_1 \cdot R_1 + C_2 \cdot R_2 + C_3 \cdot R_3) \quad (1)$$

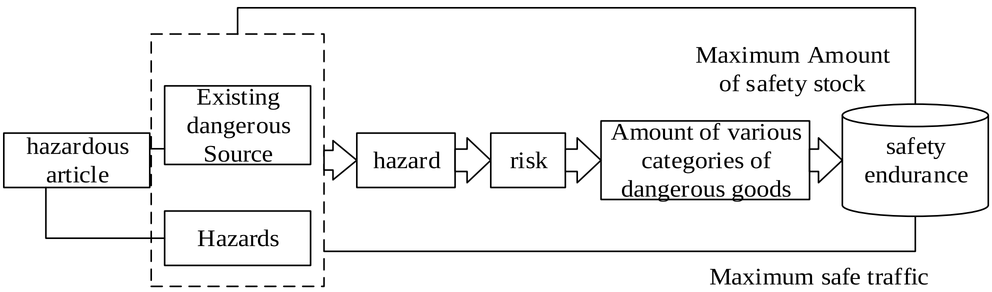

Figure 3: Dangerous goods, the relationship between risk and security capacity

When the above expression is not true for C, the chemical enterprises must make some adjustments to the scales of hazardous goods until it is true. In the equation, the risk of different hazardous goods is evaluated by using the technology proposed by our country in the Labor and Social Security. A comprehensive analysis shall be made on the hazards of dangerous goods themselves, and their process and technological risks and toxic components.

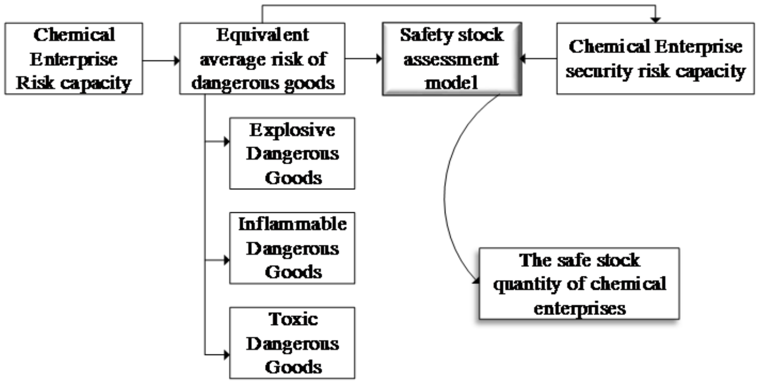

Figure 4: Capacity of chemical enterprise safety risk research ideas

4 Forewarning of safety risks

4.1 Preparations

In chemical enterprises, most of the raw materials and products used in the production are dangerous chemicals, numerous in types and huge in quantity. Rather, these chemicals involve complicated chemical process, large-scale experimental equipment and production facilities, so that the risk of incurring sudden accidents are hidden, such as fire, explosion, toxicosis and leakage, etc., and these emergencies have secondary hazards to the ecological environment. The key to effectively evaluate the safety risks of chemical enterprises lies in effective classification management of risk sources with effective procedures, thus to provide instructive suggestions for the emergency preparedness of chemical enterprises for safety risks.

According to the theory of risk symptoms, the risks on the production field are classified as the cause symptoms and the status symptoms, etc. Different elements are subjected to the early warning approaches which are combined with each other for use as the early warning mode of the whole process of risk. The early warning mode of the whole process of risk is shown in Fig. 5. In this mode, the risk factors and its consequences contained in the practical production field of the chemical enterprise are incorporated for building the safety risk forewarning method, i.e. a diamond early-warning approach, as shown in Fig. 6. This method defaults the conditional and random outbreak of arbitrary safety risks, but there is a complex relationship among them.

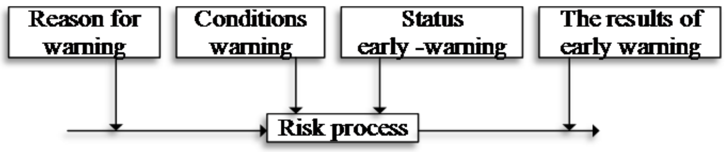

Figure 5: The whole process of risk early - warning model

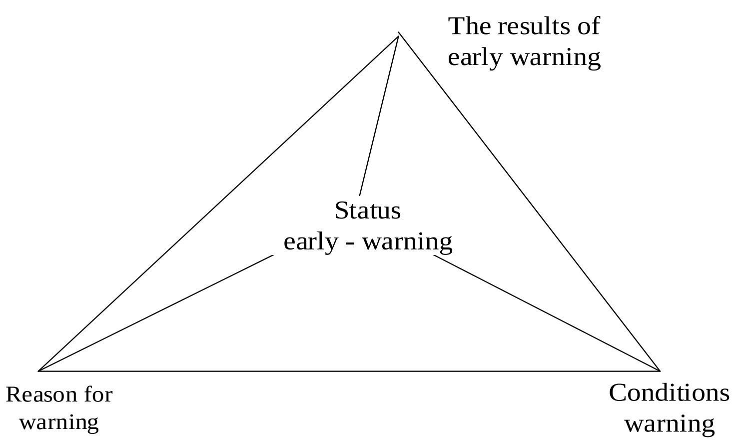

Figure 6: Diamond Risk Early - Warning Method

4.2 Establishment of forewarning model of safety risk

Given that there are four major elements for risk early warning in practical production and combined with the diamond forewarning approach, this paper proposes a diamond forewarning model for safety risk as shown in Fig. 7. The model consists of risk forewarning analysis, risk symptom identification, early warning program design and optimization and early warning program test.

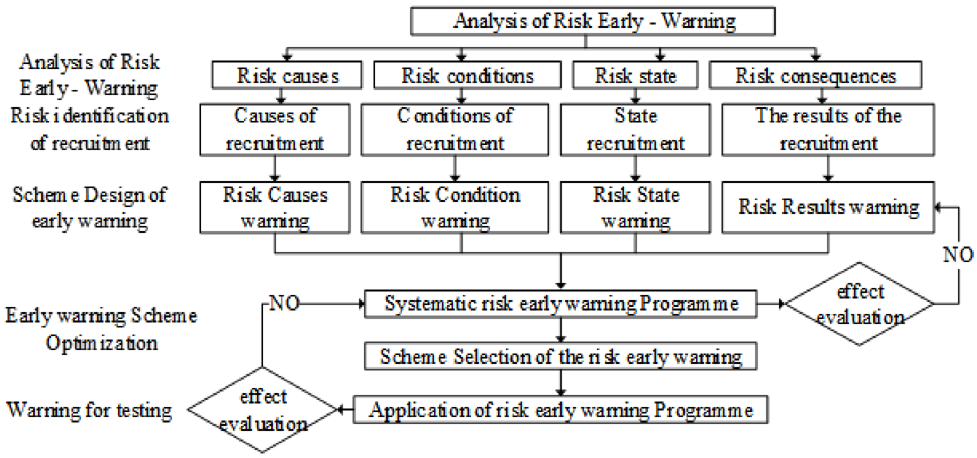

Figure 7: Diamond chemical enterprise safety risk early - warning model

4.3 Verification of risk forewarning model

This paper takes a large-scale chemical enterprise as a case to verify the proposed diamond forewarning model of safety risk in chemical industry. Most of the company's staple products are hazardous and toxic, and produced in a streamline mode. It is difficult to control and early warning of the safety risk in this company, The curve of total contingencies occurred in recent years in this company is shown in Fig. 8. It is the trend of rising year by year. According to the actual situation of the company, given that the risks originate from toxic and hazardous substances, the relationship between them is shown in Table 2. According to Table 2, a systematic index - Safety Index (SI) is constructed. Based on the size and the variation trend of SI, the safety risk of chemical enterprises can be warned early. By analyzing the SI of the chemical enterprise in recent months, it can be seen from Fig. 9 that the safety risk of the enterprise is effectively controlled.

Table 2: Relationship between structural variables

structure variable	mismanagement			Unsafe behavior			Material insecurity		
Impact Factor	direct	indirect	all	direct	indirect	all	direct	indirect	all
Unsafe behavior	0.49		0.49						
Material insecurity	0.28	0.26	0.54	0.53		0.53			
safety accident	0.31	0.65	0.96	0.59	0.36	0.95	0.67		

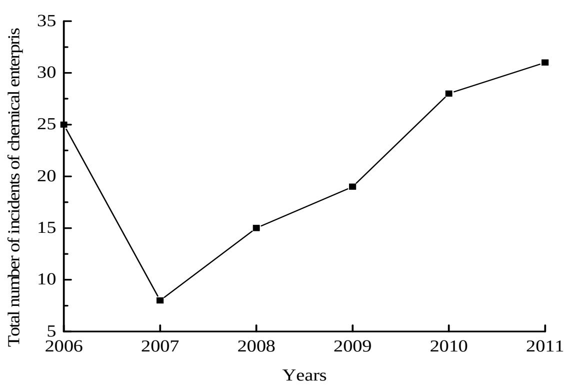

Figure 8: Total number of accidents

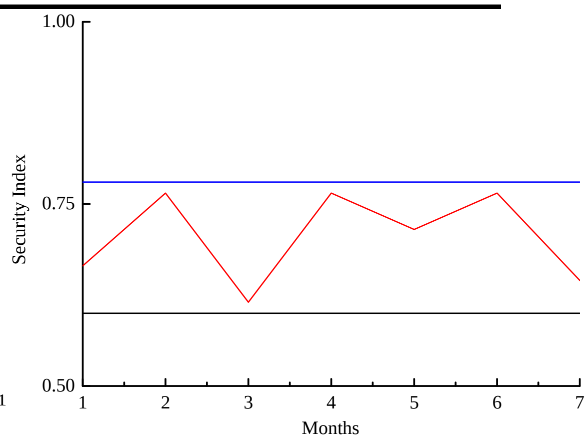

Figure 9: Security Index trend chart

5. Conclusion

Aiming at the explosive growth of chemical industry, this paper probes into the safety risk assessment of chemical enterprises and advances the appropriate early warning approaches. The conclusions are drawn as follows:

(1) Reasonable classification management of risk sources is the premise for safety risk assessment of chemical enterprises. In the process of classification management, along with the classification of the potential risks, dosage, storage methods and actual storage volume of risk sources, great attention should also be paid to the inherent causes of safety risk.

(2) Risk Safety capacity can well characterize the scale of hazardous substances in chemical industry. The probability of occurrence of safety risks in chemical industry can be controlled an effective regulation of safety risk capacity.

(3) Diamond early-warning method is the basis for establishing rhombus forewarning model for safety risk in chemical enterprise. The accidents occurred in chemical industry is taken as study case to verify the availability and reasonability of the model, which has an instructive significance for practical chemical production.

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