



The situation of hazardous chemical accidents in China between 2000 and 2006

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ABSTRACT

From the aspects of the total quantity of accidents, regional inequality, enterprises scale and environmental pollution accidents, this study makes an analysis of hazardous chemical accidents in China for the period spanning from 2000 to 2006. The following results are obtained: firstly, there were lots of accidents and fatalities in hazardous chemical business, i.e., the number of casualty accidents fluctuated between 200 and 600/year, the number of fatality fluctuated between 220 and 1100/year. Secondly, the accident rate in developed southeast coastal areas, e.g., Guangdong, Zhejiang and Jiangsu, was far higher than that in the northwest regions, e.g., Xizang, Xinjiang, and Qinghai. Thirdly, nearly 80% of dangerous chemical accidents had occurred in small and medium-sized enterprises (SMEs). Finally, various sudden environmental pollution accidents resulted from hazardous chemicals were frequent in recent years, causing a huge damage to human and property. Then, based on the readjustment of economic structure in the last decades, the development status of Occupational Health and Safety (OHS) in SMEs and other factors, the paper explores the main causes, which offers valuable insight into measures that should be taken to reduce hazardous chemical accidents.

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1. Introduction

With the rapid development of China's economy, hazardous chemicals have become indispensable materials for industry, agriculture, national defense and people's daily life. It includes explosives, toxic gases, flammable liquids or gases, oxidant, radiation, corrosive and dangerous wastes, etc., with increasing types and surging demands. According to the statistics [1], there are 3777 categories of hazardous chemicals produced and used in China, including 335 deadly poisonous items. However, although chemicals bring great convenience to people's life, they still pose significant risks to human health, safety and environment; and the safety in production of dangerous chemicals remains harsh currently, because various chemical accidents, such as explosions, fires, chemical leak and unintentional poisoning frequently occurred, which has become a bottleneck for China's petroleum and chemical industrial development. The administration of hazardous chemicals in recent years becomes a hot topic and a difficult issue, and also a serious challenge to many countries and the international community [2–5].

Thus, how to improve the production condition and reduce the risk of accidents has become one very important and urgent close

subject for the petroleum and chemical industrial development. To that end, the analysis of accidents is a good way to describe and assess the evolution of the sinister profile in a country; it can then be used to establish governmental priorities pertaining to implementation of prevention rules, and is crucial in determining indicators of work life [6,7]. Hence, many researchers have been trying to study the accident by using statistical techniques, and different authors have researched the influence of specific variables on the severity of the accident injuries incurred. For instance, after analyzing a 12-year history (1987–1999) of hazardous materials incidents in Chester County (Pennsylvania), Shorten et al. [3] showed that most chemical spills occur in the middle of the day, during the workweek. Macedo and Silva [8] suggested that no pattern in the evolution of index numbers with time throughout the decade (1992–2001) was found for any of the indicators (viz. economic activity, region, day of week, hour of day, age, type of injury and part of the body injured). Salminen [9] and Breslin [10] addressed the factor of age, showing that young workers register higher incident rates and lower fatal accident rates than the older ones. For their part, Chau et al. [11] concluded that young workers have a higher likelihood of being struck with objects and hand tools, or falling at the same level, but the number of sick days is lower than that of experienced by older workers. Recently, Mannan et al. [12] provided a detailed analysis of injuries (e.g., lost work days, length of employee service, age group, parts of the body) due to chemicals, which offers valuable insight into measures that should be taken to reduce injuries due to chemicals.

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In China, chemical safety management is in need of improvement. Judging from the available literatures, the analysis of hazardous chemical accidents in China is mainly from the following six aspects: (1) the kind of hazardous chemicals [13]; (2) the time of accidents happened [14]; (3) the damage of accidents [15]; (4) the kind of accidents (e.g., fires, leaks and explosions) [16,17]; (5) the area of accidents (e.g., rural, urban) [18]; and (6) the life cycle of hazardous chemicals (e.g., production, storage, utilization, operation, transportation and disposal) [19]. However, we also have found there are few relevant studies investigated the new characteristics of hazardous chemical accidents (e.g., the fluctuation of accidents, the regional differences of accidents, and so on) in recent years.

On this basis, the aim of this paper is therefore to summarize and analyze China's hazardous chemical accidents in recent years from four aspects (i.e., the total quantity of accidents, regional inequality, enterprises scale and environmental pollution accidents), and explore the main causes of hazardous chemical accidents, and corresponding safety measures.

2. Materials and methods

2.1. Data sources

The data used by the study are chiefly from the State Work Accident Briefing system (SWAB), which is a part of the State Administration of Work Safety (SAWS). The SWAB system contains fatal and nonfatal work injuries from SAWS-mandated employer reports of fatal events according to severity of the event. For example, all fatal injuries must be reported within 24 h, while major accidents (three or more deaths) must be reported to SAWS within 12 h. The report must include information on the enterprise, the time, address, fatality count of the incident and a primary conclusion on the accident cause. SWAB is responsible for collecting and analyzing statistics of all industrial accidents throughout the country each year and publicizing the results on a timely basis. With the statistics, we are able to identify the distribution of hazardous chemical accidents causes, deaths and injuries involved in the accidents, and the trend of accidents in China in recent years.

This paper also contains data from other sources [20,21], for example, data about the Gross Domestic Product (GDP)¹ for 31 provinces in China originated from the National Bureau of Statistics of China (www.stats.gov.cn), data about environmental pollution come from the State Environmental Protection Administration (SEPA) of China (www.zhb.gov.cn), data about dangerous chemical enterprises come from China Chemical Safety Website (www.nrcc.com.cn).

2.2. Methods

After the extraction process, the data (e.g., the number of accidents, the GDP, the number of dangerous chemical enterprises and so on) were transformed into an Excel-format database. The analyses were performed by the frequency of accidents and number of related deaths, secular trend and geographic distribution. Adopting comparative analysis (e.g., transversal comparisons and longitudinal comparisons), we have used statistical figures to show the features of dangerous chemical accident-related data as time passed by or as result of regional differences or

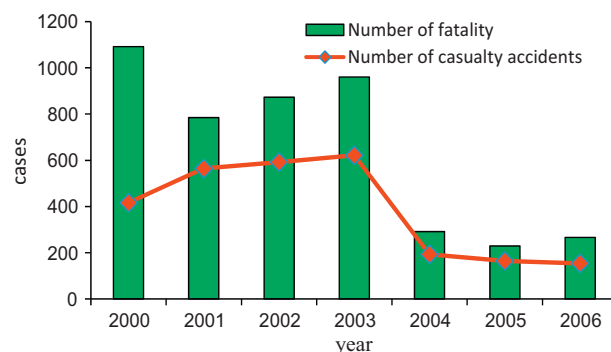


Fig. 1. Numbers of hazardous chemical casualty accidents and fatality in China from 2000 to 2006.

enterprise scale, or environment pollution accidents resulted from hazardous chemical and discussed the causes of these characteristics.

3. The characteristics of hazardous chemical accidents

3.1. The trend of hazardous chemical accidents

According to statistics of the data, the quantity variation of China's casualty accidents and death tolls of hazardous chemicals from 2000 to 2006 is shown in Fig. 1. From the chart, we can see that the number of casualty accidents fluctuated between 200 and 600/year, the number of fatality fluctuated between 220 and 1100/year. Obviously, the year 2003 was no doubt a turning point. From 2000 to 2003, the average accidents are twice more than that of the next three years. The reasons for this phenomenon mainly include: firstly, the State Council passed the Work Safety Law and Hazardous Chemical Materials Safety Management Regulations Act in 2002, and all localities of China would set up and improve the supporting rules and measures for the implementation of the Work Safety Law; secondly, SAWS became a separate agency from the State Economic and Trade Commission (SETC) and began reporting directly to the State Council, which makes a new era for hazardous materials safety management in China. So, to sum up, at present, dangerous chemicals production situation in China is extremely stern; the condition of large accident total quantity with lots of malignant accidents and serious occupation harm has not been reversed. In terms of the death toll of each dangerous chemical accident, Chongqing has the largest number, because Chongqing had a well blast on December 23rd, 2003, resulting in 243 deaths [22].

3.2. Most of the hazardous chemical accidents happened in the economical developed coastal provinces in southeast China

According to statistics of 1565 dangerous chemical accidents in the period between August 2005 and July 2008, the economically developed provinces and cities have more hazardous chemical accidents, as is shown in Fig. 2. From this picture, we can see that the southeast coastal provinces (e.g., Guangdong, Zhejiang, and Jiangsu) has more hazardous chemical accidents over the northwest provinces (e.g., Xizang, Xinjiang, and Qinghai). In terms of the death toll of every accident, Guangdong Province has the largest number, followed by Shandong. In general, the large regional inequality is another important feature of dangerous chemical accidents in China.

¹ The gross domestic product (GDP) is a measure of a country's overall economic output. It is the market value of all final goods and services made within the borders of a country in a year.

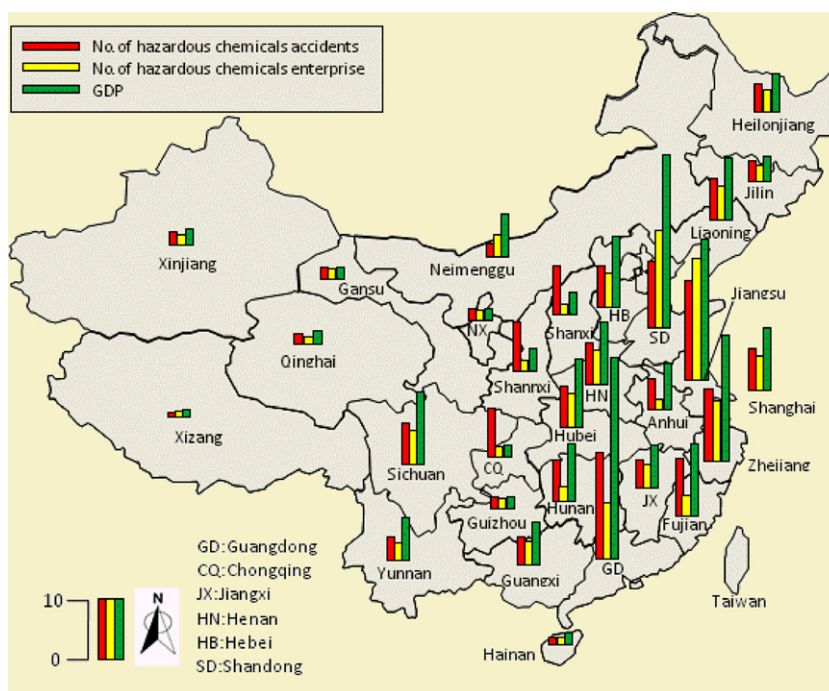


Fig. 2. Sketch map of locations involved in the present study and spatial distribution of dangerous chemical accidents in China during 2005–2008.

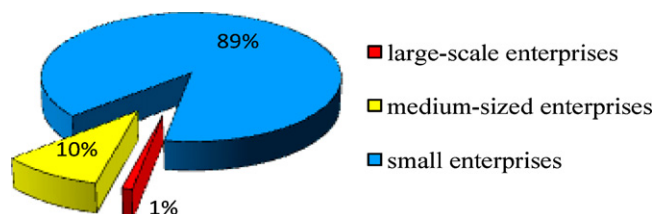


Fig. 3. Proportion of the different scale hazardous chemicals enterprises of China in 2008.

3.3. Most of hazardous chemical accidents happened in small and medium-sized enterprises (SMEs)

Nearly 80% of dangerous chemical accidents had occurred in small and medium-sized enterprises (SMEs).² According to the outcome of survey, about 99% of the hazardous chemical enterprises are SMEs, while 1% are large enterprises (see Fig. 3). So, at present, how to develop and improve the safety management system in SMEs is particularly important.

3.4. Most of hazardous chemical accidents are environmental pollution accidents

Hazardous chemical accidents often lead to negative consequences for the environment, which is an issue of serious international concern. From Fig. 4, we can see that there are many environmental pollution accidents resulted from hazardous chemicals in China. According to the analysis of sources of pollutants, environmental pollution accidents are classified as chemical leak,

waste gas, wastewater and solid waste [24]. In recent years, the most serious water pollution incident is the pairs of benzene plant explosion of Jilin Petrochemical that triggered a major pollution incident. The accident happened on 13 November 2005 in Jilin Province, in northeast China, which severely polluted one of China's biggest rivers, the Songhua River, causing water supplies to be shut down and inaccessible for millions of people in cities along the river for various periods (see Fig. 5) [25].

4. Discussion

4.1. Why there are many hazardous chemical accidents?

The level of socio-economic development is determinant of the safety in production. With the development of social economy, the safety in production will undergo five stages [26]. The five stages are as follows (see Fig. 6):

- Stage 1: the stage of agricultural economy. Industrial accidents are relatively rare at this stage.
- Stage 2: the early stage of industrialization. Numbers of industrial accidents rise at this stage.

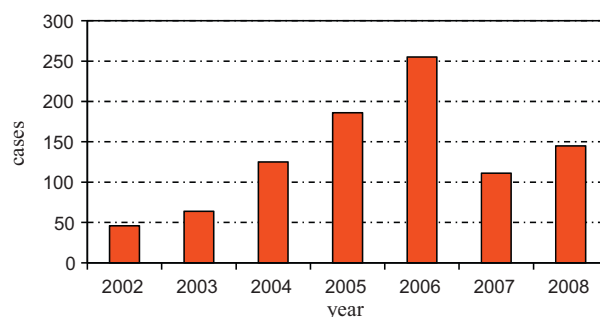


Fig. 4. Number of environment pollution accidents caused by dangerous chemicals in China from 2002 to 2008.

² According to the Interim Provisions in China [23], the criteria for the classification of small and medium-sized enterprises as following: Industry, small and medium enterprises must meet the following conditions: the number of workers less than 2000, or sales below 300 million RMB, or the total assets less than 400 million RMB. Among them, medium-sized enterprises must at the same time meet the condition that 300 or above 300 workers, sales achieve 30 million RMB or above, and total assets is 40 million RMB or above; the other for small business.



Fig. 5. Contaminated sites from the benzene plant explosion in 2005.

- Stage 3: the middle stage of industrialization. Numbers of industrial accidents reveal a general trend of fluctuations at this stage.
- Stage 4: the advanced stage of industrialization. Numbers of industrial accidents exist in the general decline phase at this stage.
- Stage 5: the stage of information society. Numbers of industrial accidents in production have stabilized.

Judging from the current situation of socio-economic development, China is at the middle and advanced stage of industrialization. Accordingly, China is also in the third stage of safety in production. Moreover, at present, with per-capita GDP less than US\$3000, China is undergoing a period of vigorous economic development, which is characterized by close relation between dangerous chemical accidents and death tolls on the one hand and economic development on the other.

Since China introduced Reform and Opening-Up Policy, with the rapid economic development, the industrial structure has undergone tremendous changes, especially the percentage of the second industry has been on the rise year after year. In 2007, the proportion of the three industries' added value in GDP became 11:49:40 from 27:41:32 in 1990, with the second industry increasing by 8 percentage points. And in China, the petroleum and chemical industry is a main part of the second industry, which naturally is an important part of the second industry growth. Following the analysis of the economic growth situation of the petroleum and chemical industry from 2000 to 2007 (see Table 1), we can draw a conclusion that the output value has grown at an average rate of 16.11%, far higher than the national average increase of GDP. In 2005, the gross industrial output of the petroleum and chemical industry reached RMB 3.38 trillion, up 36.88% year-on-year, the biggest increase in nearly eight years. And at present, China has become a great country for chemical production and consumption, and there are about 10 million petroleum and chemical enterprises. It is the second largest coun-

try for oil refining capacity, chemical consumption and ethylene production after the U.S. Its outputs of sulfuric acid, ammonia, fertilizer, calcium carbide, dyes, phosphate and synthetic fiber, and its consumption of polypropylene and synthetic rubber all rank first in the world. But because the petroleum and chemical industry is the largest one of heavily dangerous industries, when improving the growth of economy and the development of society, the petroleum and chemical industry also makes great impacts on a country's socio-economic development. As a result, more and more people are exposed to great danger. Thus, China, in the process of fast petroleum and chemical industry development, will inevitably face the challenge of accidents, environmental pollution and Occupational Health and Safety (OHS).

In addition, the high level of the absolute number of accident death and injuries is also closely linked to the increase of labors. In 2006, China's GDP totaled 20.9407 trillion RMB, more than doubling that of 2000. With the expansion of economic magnitude, the number of petroleum and chemical industry workers soared. At the end of 2006, 6.66 million rural labors swarmed to cities, most being engaged in labor-intensive industries (e.g., high-risk mining, construction, and petroleum and chemical industry). Their educational level and awareness of safety are far below the requirements of large-scale modern production. In addition, training can hardly be as intensive as the requirements of laws and regulations. In China, therefore, expansion of the national economy may lead to greater risks in terms of both probability and outcome, and finally rise of accidents and deaths.

To conclude, with the development of the socio-economic in the last decades, the safety in production has become a vital issue in China. Especially, with the readjustment of economic structure, the petroleum and chemical industry has rapidly developed, and more and more workers are engaged in. But at the same time, because the challenge of accidents, environmental pollution and

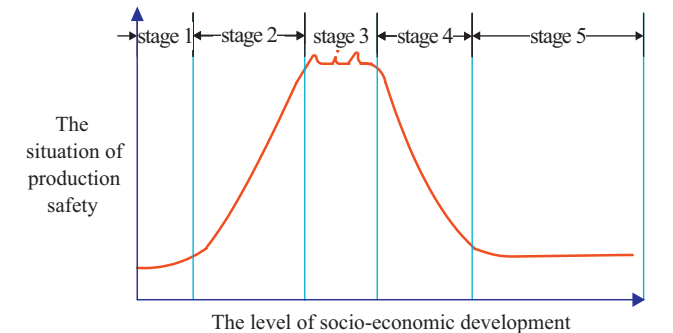


Fig. 6. The relation between production safety and socio-economic development.

Table 1
The link between the growth of gross industrial output value of the petroleum and chemical industry and the Gross Domestic Product (GDP) from 2000 to 2007 in China.

Year	Gross industrial output value (million RMB)	Industry increase rate (%)	GDP increase rate (%)
2000	13,500	–	8.0
2001	13,812	2.31	7.3
2002	15,029	8.81	8.0
2003	18,403	22.45	9.1
2004	24,666	34.03	9.5
2005	33,762	36.88	9.9
2006	42,602	26.18	10.7
2007	51,900	21.83	11.5

OSH increase ceaselessly, it should be no surprise that hazardous chemical accidents occur at times.

4.2. Why there are more dangerous chemical accidents in the economical developed coastal provinces?

China has experienced a high rate of economic growth since its reform, which began in 1978 [27]. Its average growth rate in terms of real GDP has been about 9.5% per annum between 1978 and 2006, and the country has emerged as the “world’s workshop” and economic powerhouse, all of which has greatly impressed the world. This outstanding growth, however, cannot mask the fact that there are a few problems. One of these is regional inequality, which contains the economic growth, income, education, and so on. These high levels of inequality erode the development of the production safety, whose most prominent feature is that there are more dangerous chemical accidents in the economically developed coastal provinces in southeast China.

In a nutshell, due to the imbalance of the development, there are more dangerous chemical enterprises in the economical developed coastal provinces in southeast China. Associated with this, these places where there are more hazardous chemical accidents, such as Guangdong, Zhejiang, and Jiangsu. On the other hand, for relatively less-well-developed western provinces, there are less hazardous chemical enterprises and thus fewer accidents, such as Xizang, Xinjiang, and Qinghai. Therefore, under the same safe production supervision and management system, it is no wonder that there are more dangerous chemical accidents in the economically developed coastal provinces in southeast China, as is shown in Fig. 2.

4.3. Why is the OHS record in the SMEs so poor?

Among most of dangerous chemical accidents which have occurred in SMEs, more than half of the instances have also occurred SMEs found to be related with occupational disease hazards, such as dust, asbestos and organic solvents. Why is the OHS record in the SMEs so poor? The first major reason is that the safe production supervision and management system is not perfect. In recent years, the Chinese government attaches great importance to safety production work and endeavors to protect workers’ safety and health. As a result, the state has laid down the safety production guideline of “safety being the most important, prevention holding a dominant position and practising a comprehensive management” and has established and improved a safety production supervision and management system under the unified leadership of the government, with government departments’ supervision and inspection, with the full responsibility undertaken by enterprises, with supervision and participation by the masses and with the support of public opinions. But it must be seen that China is still in the elementary stage of socialist, lower social productive forces determine lower productive work safety level. As the government organization has undertaken several reforms, new and old systems of supervision and management for work safety alternate, characteristic of China and authoritative, efficient and united systems of supervision and management for work safety have not been set up.

The second major reason is that funding and resources devoted to government OHS institutions are extremely insufficient [28]. The government’s safe production inspection system is consequently grossly understaffed, with one inspector for every 35,000 workers [29], compared with the International Labor Organization’s (ILO) benchmark of 1/10,000 [30]. Moreover, the quality of work-safety personnel is low, partly because in the rush to establish work-safety organizations, personnel from other branches of government unrelated to OHS were transferred to the newly established organizations; as a result, they lack adequate professional knowledge and legal awareness. Because of chronic underfunding, the major-

ity of work-safety institutions can only focus their attention on urgent problems and are left with few resources to deal with preventive measures. Worse yet, a few local governments, in trying to entice investment, collude with investors to keep wages down and to ignore OHS concerns. Local authorities relax OHS control measures in their own locale, provide OHS agencies with little support, and in some cases even put obstacles in their way [31]. As a result, the work-safety department has difficulty working independently, without interference from local government.

For their part, the first-generation peasant-workers who work in petroleum and chemical industry in the factories of the export sector, as well as in SMEs, have little knowledge of petroleum and chemical industry systems, occupational diseases, hazardous production processes, and unguarded machines. They toil for 60 or more hours a week, too often exposed to dust and toxic fumes, and have little idea of how to protect themselves. Even if they are aware of the dangers, there is no recourse to any means of protection except quitting their jobs [32]. For instance, in the Pearl River Delta region, a major center of foreign-invested export industry, a survey of 54 hospitals revealed that in one recent year, attempts had been made to reattach more than 40,000 severed fingers. One 35-year-old surgeon had reattached 4000 fingers in 10 years [33]. What is worse, those workers can only claim for injuries compensation and unpaid wages and their demands for demanding improvements in workplace health and safety are frequently ignored, which sometimes lead to protest actions inside and outside factories [34].

In a word, SMEs have not been as active in organizational development, usually because they lack the expertise, time and economic resources. In addition, for the SMEs, there is a lack of awareness of what specific health and safety legislation.

4.4. Why are the hazardous chemical accidents likely to become environmental pollution accidents?

In general, China has entered a period of high environmental pollution [35], especially resulting from hazardous chemical accidents. Firstly, by their nature, it is easy to have an accident in the petroleum and chemical industry, which could cause environmental damage because dangerous chemicals possess the characteristics of explosion, inflammation, poison, erosion, radiation, etc. Secondly, there is currently a lack of a systematic pollution accident management system in China [23]. This mainly manifests in the following two aspects: (1) there is currently a lack of a systematic emergency rescue system during the treatment process of hazardous chemical accidents and (2) lack of a good environment protection awareness for hazardous chemical, it was not until after the 9th 5-year plan (i.e., 1996–2000) that Chinese officials began to develop an awareness of environmental issues, and that these issues started to influence domestic politics and economy. Thus, improvement of the environmental management in China is no doubt an onerous task.

5. Conclusions

According to the analysis of the hazardous chemical accidents between 2000 and 2006, it is demonstrated that the accident is a real challenge for the development of petroleum and chemical industry in China. Firstly, with the readjustment of economic structure in the last decades, the petroleum and chemical industry has rapidly developed, and more and more workers are engaged in; besides, the challenge of accidents, environmental pollution and OSH increases ceaselessly. And therefore many dangerous chemical accidents occurred in China. The number of casualty accidents fluctuated between 200 and 600/year, the number of fatality fluctuated between 220 and 1100/year. Secondly, due to the imbalance

of the development, the more developed southeast coastal areas such as Guangdong, Zhejiang and Jiangsu Provinces have higher incidence of accidents and deaths than the western regions such as Xizang, Xinjiang, and Qinghai. Thirdly, in SMEs, because of lack of awareness of OHS and the expertise, time and economic resources, the situation of safety production in SMEs is very severe, and nearly 80% of dangerous chemical accidents have occurred in SMEs. Finally, sudden environmental pollution accidents resulting from hazardous chemicals are frequent in recent years because the petroleum and chemical industry is an industry with high risk and the pollution accident management system in China still needs to be improved, causing a huge damage to human and property.

6. Suggestion

Based on the analysis, it can be concluded that the petroleum and chemical industry should be more active in safety management. Regarding the causes of hazardous chemical accidents, the government should take the following initiatives:

- Speed up the development of socio-economic, and further minimize the cycle time of the third stage. For maintaining fast socio-economic growth, strengthening the balanced socio-economic development is very important. Therefore, to develop the socio-economy of center-west region energetically, make incline to its balanced, it is a main strategic task undoubtedly. At the same time, to enhance safe production of SMEs, environmental protection, health, resource exploitation, land use in areas such as the guidance, supervision and services.
- By strengthening relevant laws and regulations system, and setting up effective supervision system of hazardous chemicals, and through scientific and technological supports, we should get high risk in line with high profit and high input in the basic safety conditions.
- Strive to develop science and technology research on safety and intensively study the mechanism, factors and control measures of various hazardous chemical accidents. Improve the safety conditions of techniques and equipment, raise the safety function of equipment and fitting, increase input in science and technology, explore new technology and technique, develop new safety equipment and testing instrument, improve safety of production, set up environmental monitoring in real-time and early-warning, and minimize injury to personnel in case of hazardous chemical accidents.
- Education programs on safe production should be carried out in hazardous chemical enterprises, security supervisions on enterprises and businesses strengthened to avoid hazardous chemical accidents.

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