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Lessons learned for process safety management in China

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ABSTRACT

A number of chemical accidents have occurred in China over the past two decades with significant impact on humans and the environment. It is expected that lessons will have been learned from these accidents that will help industries to reduce the risk that catastrophic chemical accidents occur in future. In fact, to some extent there is evidence that lessons have been learned, to the extent that the Chinese government has substantially strengthened legislation and regulatory standards. Nonetheless, there remains a concern that much more still needs to be done to reduce chemical accidents risks in China. Important progress in this area requires not only government support but a commitment across all hazardous industries to learn from past accidents that may in many cases require establishment or considerable improvement of their safety management systems. To assist small and medium-sized enterprises (SMEs), in this effort, results of an analysis of common causes of the chemical accidents reported in the Major Accident Information (MAI) website of Chinese State Administration of Work Safety (SAWS) are presented in this paper In particular, inadequate process hazard analysis (PHA), training and emergency response planning (ERP) were identified as the top three process safety management (PSM) elements that contribute to most of the SMEs accidents in China. Seven recommendations are proposed in order to improve the effectiveness of lesson learning for government agencies and SMEs.

1. Introduction

Since the USA OSHA's process safety management (PSM) standard and Europe's Seveso Directive[1] were promulgated more than 20 years ago, major chemical accidents still deprive hundreds of people of their lives every year worldwide. Society continues to ask why these accidents have not been eliminated, why people have been making the same mistakes and why lessons have not been learned from past accidents. In fact, since the series of chemical disasters in the 1980s, i.e. Bhopal's methyl isocyanate release (1984), Mexico City's Liquid Petroleum Gas (LPG) terminal explosion (1984), Piper Alpha offshore platform explosion (1988), Pasadena's polyethylene plant explosion (1989), there has been a significant impulse for increased research and efforts in the field of safety. However, the effectiveness of learning from reported incidents can often be questioned. Jacobsson, Ek, and Akselsson (2011) proposed a six-step method for evaluating learning from incidents. Based on their preliminary study of six companies, they found that the levels of learning from incidents were mostly level 0 or level 1 which means essentially no learning or learning only at the specific place in the plant where the incident occurred with limited documentation and organizational learning. None of the companies had a very structured way of dealing with their incident reports on an aggregated basis so that the general patterns of underlying causes could not be derived. Besides individual learning, multilevel learning including organization learning, sector learning and authority learning is indispensable for effective learning from incidents.

However, the effectiveness of learning from incidents can often be questioned. In many cases the learning process stops at the reporting step. The analysis of the incident reports and the following implementation of appropriate measures and improvements are often ineffective and the full lessons are therefore seldom learned (Jocobsson et al., 2011). For example, on March 23rd 2005, the isomerization unit at the BP Texas City refinery exploded. Fifteen workers were killed and more than 170 people were injured. The investigation of the BP US Refineries Independent Safety

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[1] Council Directive 82/501/EEC of 24 June 1982 on the major accident hazards of certain industrial activities, Official Journal of the European Communities, P 196, Brussels, 16.8.67. http://mahbsrv.jrc.it/downloads-pdf/Seveso1-LEGEN.pdf.

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Review Panel (the so-called Baker Panel) found that potential weaknesses in process safety had been highlighted in numerous reports from prior accidents that had occurred previously on the site. According to the Baker Panel, BP had not learned those lessons because of a kind of organizational "learning disability" associated with issues regarding safety management, cost cutting, reward structure, decentralization and leadership (Hopkins, 2008).

With the fast economic development in China, the production scale of many chemicals such as synthetic ammonia, sulfuric acid and sodium carbonate has surpassed most of other countries in the world. The living standard of the Chinese population has increased to a historically high level. Unfortunately, public safety and health are being threatened by chemical accidents resulting in societal stability issues. Serious accidents involving the release of dangerous substances continue to occur at fixed sites, particularly chemical, pharmaceutical, refining facilities, as well as in transport, involving pipelines transferring chemical and crude oil transport of dangerous goods on highways and waterways. Since about 70% of chemical facilities in China are located near rivers, lakes and seas, these accidents have resulted in environmental disasters. However, most of these accidents are not well-known and well-published in China, therefore limiting the opportunities for uptake of lessons learned, and a number of major accidents and environmental emergencies still occur every year in China. Even though lesson learning has been emphasized after every chemical accident, its effectiveness of learning, and uptake of lessons from chemical accidents has not well been studied in China.

By learning from past incidents operating companies can improve reliability, reduce risk and improve financial performance. In the spirit of 'safety is not proprietary', the authors here once again ask the chemical companies and relevant government agencies to share their accident reports. In order for this to work effectively, operating companies must be willing to share experience by reporting accidents and near misses to the chemical process safety community at large. However, few chemical accidents reports are currently available for sharing lessons in China. One of the obstacles to an effective and proactive lesson learning effort is the lack of public access to accident investigation reports. While public registers of industrial accidents are available from various government sources, the information disclosed about the accident is superficial; moreover, finding accidents involving specific substances, processes or equipment in these registers is an additional challenge. To help address these challenges, the authors will present in this paper an overview of lesson learning in China and identify the areas in need of further research and improvement.

2. Current progress in lessons learning in China

Learning has been a core value in the Chinese philosophy. Confucius even said "In a group of three people, there is always something I can learn from". One of the key points in the Chinese policy on reforming and opening is to encourage Chinese people to learn advanced culture and technologies from other countries. In the area of chemical safety management, China has also learned many lessons from developed countries and international organizations.

2.1. Past history of industrial accidents in China

Around a decade ago, China ranked No. 1 in the world not only in terms of population but also of the total death toll from industrial accidents (Table 1). In the chemical industry, according to Liu (2004), 416 chemical accidents were recorded in 2000 with 1092 deaths and 2156 injuries while 564 accidents occurred in 2001 with 785 deaths and 1421 injuries. In the year 2000, only 47 people died of chemical accidents in the United States. Therefore, there was a huge gap in loss prevention in the chemical industry between China and the United States (Liu, 2004).

Table 1
Comparison of death tolls and rates of industrial accidents between China and some other countries (Liu, Zhong, & Xing, 2005).

Country	Death	Death rate (1/10^5)	Year
United States	5900	4.0	2001
Japan	1790	2.79	2001
Germany	1155	7.0	2001
Canada	882	7.1	2000
France	730	4.4	2000
Australia	198	2.0	2002
United Kingdom	210	0.8	2001
Austria	122	4.5	2001
Denmark	50	2.0	2001
China	14,924	14.14	2002
Russia	4370	15	2001
Brazil	2503	11.5	2000
South Korea	1298	6.16	2001
Italy	1155	7.0	2000
Ukraine	1321	9.2	1999
Mexico	1502	12.0	2001
Argentina	915	18.6	2000
Malaysia	858	10.8	2002
Thailand	616	11.3	2000
Polland	510	5.0	2001

2.2. Subsequent changes to the legislative and regulatory framework

Learning from these tragic incidents, the Chinese government enacted its first Work Safety Law in 2002. Many key articles in the law, such as the duties of employers and employees, inspections, investigations and recordkeeping and so on were enacted with reference to the Occupational Health and Safety Act promulgated in the U.S.A. in 1970. In addition, the Chinese National Standard on Identification of Major Hazard Installations (GB 18218) was released in 2000 in alignment with C174 – Prevention of Major Industrial Accidents Convention (ILO, 1993).

SAWS also released its first Process Safety Management (PSM) regulation AQ/T 3034-2010 (SAWS, 2010). It resembles OSHA's PSM standard which contains requirements for the management of hazards associated with processes using highly hazardous chemicals (US Department of Labour, 1992). Fig. 1 briefly describes the 12 elements which form the basis of the SAWS's PSM standard.

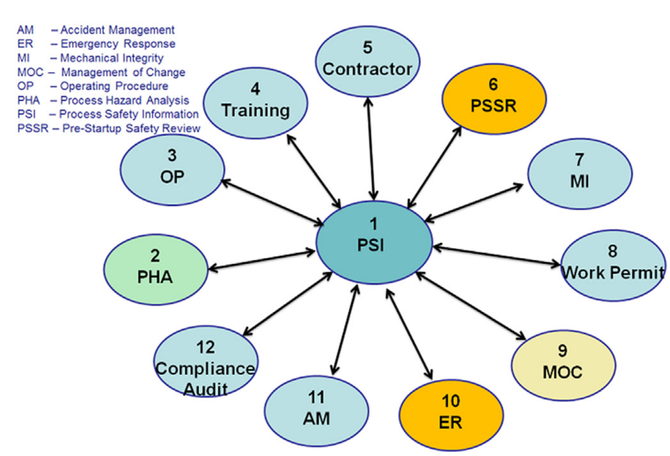

Fig. 1. Twelve elements of the PSM standard of China.

China has also significantly improved chemical accident prevention and preparedness legislation as a result of lessons learned from specific accidents. The enactment of the Emergency Event Response Law of 2007 also represents the implementation of new requirements as a result of an important lesson learned from two major chemical accidents in China: the 2003 gas well blow out in Chongking that caused 243 deaths (Li, Zhang, Wang, & Liu, 2009), mainly from hydrogen sulfide inhalation, and the 2005 release of toxic substances into the Songhua River (Zhang, Lin, & Su, 2010). According to this law, each chemical plant is required to produce an emergency response plan for the site and each level of government is required to produce an emergency response plan for chemical and other emergencies that could occur within its territory. Another lesson learned from the Chongking accident resulted in the new SAWS standard 'Specification for ignition time of out of control on wellhead of natural gas well involving hydrogen sulfide' enacted in 2008 which gives specific procedures for responding to this type of incident.

2.3. Promoting safety in chemical industrial parks

In addition, to facilitate safer and more environmentally friendly handling of chemicals, China has actively promoted re-location of industrial sites into chemical industrial parks. Currently, about 30% chemical companies have been built in or relocated to CIPs (Peng & Zhao, 2013). Chemical industrial parks allow a concentration of chemical companies into a specified zone, such that common management and administration of safe work and environment protection practices are easily facilitated. In this way the SMEs benefit from resource sharing to create safer and more environmental friendly work places. According to statistics of China Petroleum and Chemical Industry Federation (CPCIF) (www.cpcia.org.cn/english/parks), there are 1568 national and provincial development zones, among which 357 are primarily engaged in the chemical or petrochemical industry. However, SMEs continue to pose severe environment risks in China (He, Zhang, Mol, Wang, & Lu, 2014). Because of the high concentration of chemical facilities in the CIPs, in the event of an accident, it could possibly lead to a domino effect (Abdolhamidzadeh, Abbasi, Rashtchian, & Abbasi, 2011; Cozzani et al., 2014), causing damages which might be extensive to the environment and the surrounding population.

To promote safety in SMEs in China, two UNEP approaches have been tested. A pilot project on Responsible Production was implemented in China through the support of the United Nations' Environment Programme (UNEP) (Zhao, Joas, Abel, Marques, & Suikkanen, 2013) further demonstrating the need for enhanced capacities of SMEs to implement PSM. SMEs face special challenges because of the limited number of employees, technical resources and tools to handle chemical risks. Many SMEs do not have adequate emergency preparedness plans. An accident will negatively impact the image of a company, and could put an SME out of business. These aspects highlight the need for systematic and effective approach to improve chemical safety in SMEs.

An APELL pilot project sponsored by Dow Chemical was implemented in ZhangJiaGang Chemical Park in Jiangsu province in China from 2008 to 2010. UNEP associated experts including the first author of this paper provided trainings on risk identification technologies, APELL methodologies, and emergency drills to the stakeholders in the chemical park. Awareness and Preparedness for Emergency at Local Level (APELL)[2] is a programme developed by UNEP in 1986 in conjunction with governments and industry with the purpose of minimizing the occurrence and harmful effects of technological accidents and environmental emergencies. The strategy of the APELL approach is to identify and create awareness of risks in an industrialized community, to initiate measures for risk reduction and mitigation, and to develop coordinated preparedness between the industry, the local authorities and the local population. APELL can be regarded as a guideline for coordinating some PSM elements such as process hazard analysis, emergency response planning and training among the relevant involved actors.

Under the APELL programme, the comprehensive emergency response plan of the ZhangJiaGang Chemical Park was evaluated by UNEP associated experts and 14 recommendations were given to improve the plan. One recommendation, for example, was to establish an emergency warning system in the nearby community. A joint emergency drill, based on a possible emergency chemical release scenario in a chemical facility, which involved four neighboring companies was observed by the UNEP associated experts and 17 recommendations were given to the chemical park's management for highlighting the weakest points in the emergency response process. The drill was first of this kind of a joint drill in China without any script, which set up an excellent example for other chemical parks to learn.

2.4. Progress in learning lessons leads to notable safety performance improvement

Due to the work safety law enforcement and implementation of other lessons learned by government, enterprises and academic organizations, safety performance in the chemical industry has been significantly improved in China over the past ten years. From Fig. 2, it can be seen that the number of chemical accidents and death toll have dropped consecutively from 2004 to 2012. Chemical accidents caused in the transport sector or in the mining industry are excluded in those statistics. Over the past 9 years, the number of chemical accidents decreased 77% while the fatalities decreased 66%. In 2012, 44 chemical accidents occurred with a 99 death toll.

Hence, developments of the past two decades demonstrate an important step forward in China's progress in prevention of chemical accidents and mitigation of their consequences. However, more attention to learning other lessons from these and similar accidents is still needed to make further progress in reducing chemical accident risks in China in future.

3. Learning lessons in SMEs: an analysis of past accident reports

Learning from accidents has been an important factor contributing to the improvement in chemical accident prevention observed over the past half century worldwide. To improve learning from accidents in the chemical industry, accident reporting and publication of analyses of report findings are useful

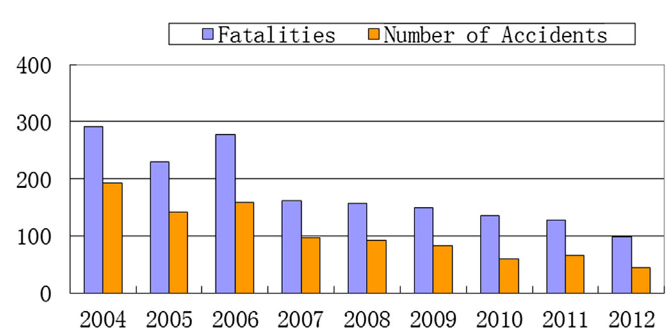

Fig. 2. Chemical accident statistics in China from 2004 to 2012.

[2] http://www.unep.org/apell.

Table 2
Accident causal analysis information extracted from the MAI website.

Case# Date	PSI	PHA	OP	Training	CM	PSSR	MI	WP	MOC	ERP	SME	D/I
Case 1 08/05/2006	1	1	1	1		1				1	Yes	22/29
Case 2 11/02/2006	Causal analysis not available										No	13/0
Case 3 03/03/2007	Causal analysis not available										Yes	4/1
Case 4 05/15/2007	Crude oil pipeline broken by criminals										No	0/0
Case 5 05/28/2007			1	1						1	No	5/80
Case 6 07/24/2007	1	1				1	1				Yes	9/1
Case 7 09/12/2007		1		1				1		1	Yes	6/3
Case 8 12/11/2007		1		1		1				1	Yes	8/5
Case 9 06/29/2008		1		1		1				1	Yes	6/29
Case 10 09/18/2008	Causal analysis not available										Yes	20/60
Case 11 08/01/2010	1				1			1			Yes	13/120
Case 12 07/13/2011		1		1						1	Yes	3/1
Case 13 07/25/2011	Causal analysis not available										No	0/0
Case 14 08/09/2011		1		1			1			1	Yes	3/2
Case 15 08/09/2011	Causal analysis not available										Yes	3/1
Case 16 02/24/2012				1					1	1	Yes	3/0
Case 17 03/13/2012		1		1			1		1	1	Yes	29/46
Case 18 03/23/2012		1	1					1		1	Yes	3/0
Case 19 09/14/2012		1	1	1		1				1	Yes	3/7
Case 20 09/14/2012		1		1			1			1	Yes	3/2
Case 21 09/14/2012		1		1						1	Yes	3/4
Case 22 04/26/2013		1				1	1	1			Yes	7/0
Case 23 05/20/2013	Illegal production										Yes	3/1
Case 24 05/20/2013	Causal analysis not available										No	3/0
Case 25 06/08/2013		1			1			1			No	4/0
Case 26 07/09/2013		1							1		Yes	1/5
Subtotal of SMEs	3	14	3	12	1	6	5	4	3	13	20	152/317

Note: PSI = process safety information; PHA = process hazard analysis; OP = operating procedure; CM = contractor management; PSSR = pre-startup safety review; MI = mechanical integrity; WP = work permit; MOC = management of change; ERP = emergency response planning; D/I = deaths/injuries.

complements to the incident investigation itself. Examples of organizations that are continually publishing the analyses include the US Chemical Safety Board and the European Major Accident Hazards Bureau.

3.1. A study of 17 cases from 2006 to 2013

To support prevention of future accidents, accident reports are gradually being published by the SAWS and the Ministry of Environmental Protection (MEP) of China either through websites or through book publications. In 2011, approximately 50 selected environmental accident reports were compiled and published by MEP in a book through the China Environmental Science Press. The MEP accident reports focused on emergency response. The lesson learned section was aimed specifically at improving emergency response to similar accidents in the future. However, they do not provide guidance for preventing chemical accidents.

In the Major Accident Information (MAI) website (http://www.chinasafety.gov.cn/newpage/wxhxp/wxhxp2013_jdys.htm) of the State Administration of Work Safety (SAWS), 26 accident cases are recorded from April 2006 through July 29, 2013. Among these 26 cases, 20 cases contain a causal analysis section and a lesson learning section. Of the total cases, 20 accidents also occurred in SMEs, of which only three lacked any causal analysis.

The Tsinghua University's research team led by the first author of this paper conducted a preliminary statistical analysis of the causes of the 17 SME accidents in which sufficient causal detail had been provided. Even though some underlying causes were not directly available in the accident reports, a method similar to the sequential method (Jacobsson, Sales, & Muthtaq, 2009) was adopted by the study in order to deduce possible causes related to PSM elements. Specifically, if any cause or any lesson is found to be relevant to a PSM element, then '1' was used to mark the relationship between the accident and the PSM element (see Table 2). Through this simple statistical approach, inadequate process hazard analysis, emergency response plan, and training were identified as the top three PSM element related causes. Of the 17 accidents, 14 accidents were caused by poor PHA, 13 accidents were caused by inadequate emergency preparedness while 12 accidents were caused by inadequate training or no training (Fig. 3).

The study of the 17 accidents that occurred in SMEs in China that had been reported by the MAI database concluded that inadequate process hazard analysis, training and emergency response planning repeatedly contributed to the occurrence of chemical accidents. The SME accidents might therefore have been prevented if the Chinese SMEs took proactive actions to improve their process designs and PSM procedures by periodically reviewing collected lessons learned by others.

3.2. *The need for SMEs to learn lessons from past accidents*

This study, although small in scope, shows that there is already accident information available on accidents in Chinese SMEs that could be used to prevent future accidents in other SMEs. While China adopted process safety management formally into its regulatory standards in 2009, the elements of PSM are already in practice in high hazard industries throughout the world. Moreover, lessons learned relating to SME deficiencies are also available from well-publicized studies outside China. For example, the results of the Chinese study were compared with a study by Blair (2004) of U.S. Chemical Safety Board (CSB) data from 21 chemical accident investigations. The top five ranked causes were identified as "maintenance procedures", "process hazard analysis", "engineering design and review", "management change", and "operation procedures". Similar deficiencies were also cited in the ten common lessons learned identified by Yang et al. (2011) from their study of 10 historical accidents, that also included "periodically conduct process hazard analysis", "develop effective worker training program", "periodically inspect and maintain equipment to ensure adequate equipment reliability", "develop and effectively implement a good emergency response plan", and "take proactive actions to use lessons learned to prevent potential hazards".

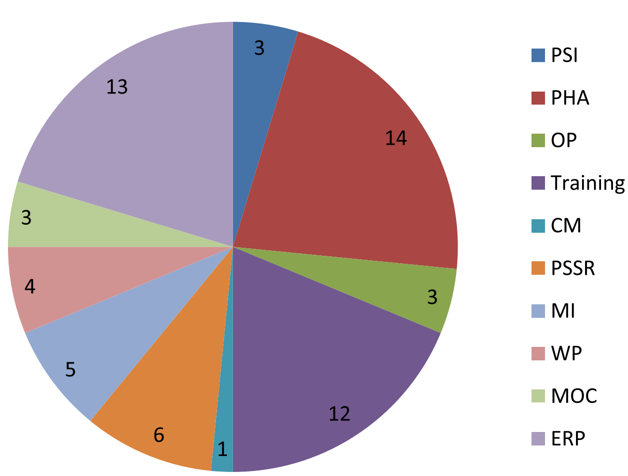

Fig. 3. Causes of the SME accidents studied.

It seems notable that Chinese SMEs are unaware of the findings from accidents whether they occur in China or elsewhere, or alternatively, they do not think that the lessons learned from them apply. It could be that Chinese SMEs suffer from organizational "learning disability" much like BP Texas City or perhaps they are not sufficiently aware at all of the need to learn lessons from other accidents in order to prevent having one of their own. Greater emphasis on this important aspect of safety management may be necessary through both education and legal means.

4. Recommendations

In reality, compliance with regulatory frameworks such as the PSM standards requires substantial resources and may therefore appear too complex to be effectively implemented by SMEs in the chemical sector. According to the SME accident statistics noted above, inadequate process hazard analysis, training and emergency response planning contribute significantly to the SMEs accidents in China. In fact, these three PSM elements need to be coordinated in order to effectively prevent accidents. However, how to coordinate the PSM element activities has not been specified in the PSM standards.

The following recommendations are given to SMEs and government agencies that intend to help SMEs in accident prevention.

4.1. *Build on the UNEP APELL approach in chemical industrial parks in China*

In order to engage different stakeholders in SMEs' efforts to apply and improve their PSM, UNEP approaches are recommended. The Responsible Production Approach provides a simple step by step methodology addressing PSM elements targeting SMEs. In addition large companies should implement the UNEP Responsible Production approach to help their SME suppliers, SME contractors, and SME customers particularly in the areas such as process hazard analysis, training and emergency response planning. To coordinate PSM relevant activities between SMEs, industry park administration, local authorities and communities, the Awareness and Preparedness for Emergency at Local Level (APELL) is recommended. The APELL approach offers SMEs and Chemical Industry Parks a simple structured method to assess and improve their operating procedures to reduce risk. It particularly focuses on a strategic approach to preparing for and responding to emergency events with community involvement. Therefore, in addition to strengthening risk management within SMEs in industrial parks, the APELL approach has also a proven ability to increase the credibility of the industry in the eyes of the community for its willingness and capacity to reduce risk. Recently, an APELL website[3] in Chinese has been created at Tsinghua University allowing the Chinese SMEs and the Chemical Industry Parks to have further guidance for PSM for learning lessons and developing sustainably.

4.2. *Investigate root cause into the PSM system level*

The analysis of causes usually is a weak point in accident investigation so that the effectiveness of lesson learning is often questioned. Accident investigations often stop at events close to the accident, which usually concern only the behavior of the hardware and of the operators directly concerned with carrying out the

[3] http://www.chemeng.tsinghua.edu.cn/APELL.

activity. Changing hardware or disciplining operators will not systematically eradicate the root causes that exist in the safety management system. With the deterioration of the performance of the hardware or the operators, similar accidents will inevitably occur again. Therefore causal analysis should be sufficiently robust such that it does not stop at the technical causes (e.g., equipment failure, human error), but instead it should eventually determine what failure(s) occurred in the process safety management (PSM)'s system that created the conditions for the technical failures to occur. Root causes on PSM elements should be examined and reported thoroughly and systematically.

4.3. Disclose information to public

More information about chemical accident risks and accidents need to be shared with the public, particularly in areas where a significant lack of information has made citizens distrust local agencies. Information also needs to be shared on the causes and lessons learned of accidents so that government and industry experts can improve their accident prevention, preparedness and response programs and procedures. In this regard, the government should establish information systems and requirements that can achieve these goals. There should be information for the public on accidents that have occurred in a region, on sites where potential accidents could occur, and what to do in case of a major accident on one of these sites. When people are treated with fairness and honesty, and their right to make their own decisions is respected, they are less likely to overestimate small hazards and will support the government and companies actively.

4.4. Build dedicated website for lesson learning

Government and industry also need additional knowledge about causes and lessons learned from accidents that can be used to update their standards, systems and procedures supporting accident prevention, preparedness and response. The government should therefore also create a common register specifically for reporting causes and lessons learned from investigations of major chemical accidents directly by industry or by government on the basis of its own or industry investigations. Full accident reports should be published in a dedicated website that is publicly accessible so that other operators and industries can learn from these accidents. Examples of such websites can be found in Europe (e-Mars) and US (CSB).

Issues of whether operators and names and locations should be disclosed in this database can be discussed since the register would not serve separate risk communication and public awareness objectives.[4] To illustrate the benefits of such a register, one can consider the accident that occurred in Chongqing in November 2005 that resulted in a significant benzene release caused by a reactor explosion. The explosion was triggered by excessive addition of hydrogen peroxide into the reactor for removing sulfur-containing impurities in benzene. This accident report is available in the MEP's environmental emergency case book published in 2011 by the China Environmental Science Press. An oil pipeline explosion accident occurred in July 2010 in the storage tank farm of PetroChina's Dalian subsidiary. The explosion accident resulted in severe pollution of surrounding sea waters. According to the accident investigation report, it was also caused by excessive addition of hydrogen peroxide into the crude oil pipeline for removing hydrogen sulfide from the crude oil. If the lessons learned from the 2005' benzene pollution accident were accessible before the 2010' oil pipeline explosion, the latter accident may have been prevented.

[4] This specifically concerns the lessons learned database. To encourage of causes and lessons learned to prevent future similar accidents, it is common practice in all open source databases of this type to leave out company names. However, it does not exclude the existence of other registers that the public can consult to research a company's accident record or the accident history surrounding specific geographic location, but these databases would not necessarily disclose full causal information. Of course, the public may be able to link accidents based on date or other information, but since the two types of registers serve different purposes, the practice is generally to keep them separate.

4.5. Enhance regulatory capacity

Although some officials have authority to enforce accident prevention and preparedness regulations in a developing country like China, they can still be less effective in preventing and mitigating the consequences of major accidents than their counterparts in developed countries. Limited regulatory capacity and limited accountability in developing countries are among the major reasons why regulatory efforts may be less than effective in this regard. For one, regulatory agencies in China are usually short of resources. This situation can result in a lack of competence in certain areas necessary to fulfill their duties. In particular, the recent accidents in China raise concerns as to whether the government is sufficiently empowered to fulfill its duty in working toward preventing and mitigating the impacts of such accidents. For example, the major reason why a Guanidine Nitrate reactor exploded in Hebei province in February 2012 is that the operating temperature of the heating oil was raised about 40 °C without going through management of change procedures.

Regulators can play a role in preventing such accidents but first they have to have the knowledge of essential elements of good risk management practice, such as management of change. Secondly, they need to have the authority to work with operators to encourage and motivate them to implement these practices to reduce risks on their sites. While regulators cannot take responsibility for the failure of operators to adhere to good practice, their role as proactive enforcers can minimize the potential that such good practices are violated and result in serious accidents. In China it is expected that enhanced collaboration among authorities and industry could further promote safety management and accident prevention.

4.6. Manage corporate near misses

To influence companies to become more open to and recognize the value of lessons learning, Mannan and Waldram (2012) suggested an element of compulsion in certain conduct codes or government legislations that would force the people into regularly using the accident databases. For example, as in the new Seveso Directive (2012/18/EC), in which the company's safety report is expected to include a "review of past accidents and incidents with the same substances and processes used, consideration of lessons learned from these, and explicit reference to specific measures taken to prevent such accidents." Hence, it is recommended here that Chinese regulations should be modified to require the companies to keep a register of their incidents and near misses. At the same time, companies should be encouraged to share them with the public and with other industry. In particular, the government and the public should be able to look at the register upon request. Learning these lessons from minor events can greatly decrease the likelihood that a major event from the same scenario will ever occur in future.

4.7. Establish lesson sharing mechanism for industry

While this paper is mostly directed at the role of government, safety is in the end in the hands of industry. The chemical process industries must take a leading role in preventing accidents with big companies in particular investing resources to build industry-wide awareness and capacity. In particular, the industry should establish mechanisms to voluntarily share lessons learned with each other, by expanding existing industry and professional associations to support forums, publications, workshops and training events on risk management and lessons learned. The establishment of the Chinese equivalents to the Center for Chemical Process Safety (CCPS) and Chemical Safety Board (CSB) of the United States should also be considered.

5. Conclusion

Most accidents are preventable. As Kletz (1993) puts it, "It might seem to an outsider that industrial accidents occur because we do not know how to prevent them. In fact, they occur because we do not use the knowledge that is available." Taking this into account, then prevention of industrial accidents relies very much on tracking accidents (both serious and minor), extracting the key lessons for prevention, and making that knowledge accessible to those who may need it.

Lesson learning is not only difficult for SMEs that have limited human resources and expertise, but also for large multinational corporations. Incident investigation is regulated under Chinese law. However, how to effectively and systematically learn lessons from incident investigation reports has not been specified by the standard. Lesson learning does not only require high quality investigation reports, but also a high self-learning capability. A continuously learning organization has been recognized as one of the ten attributes that are important to create a best-in-class safety culture (Mannan, Mentzer, & Zhang, 2013). Learning is not completed until a relatively permanent change of behavior including process design or procedure is verified. Lesson learning should not be constrained within one organization. It should be encouraged and facilitated across industries and countries as a long term process. Priorities for Chinese SMEs should be put on improving their capabilities in process hazard analysis and emergency preparedness and providing all necessary trainings to their employees. In order for an effective uptake of these practices, the UNEP approaches introduced in this paper can provide easily applicable methodologies for SMEs with limited resources to coordinate their PSM activities. Improving chemical process safety management and emergency preparedness supports sustainable industrial development.

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