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Evaluation of major polluting accidents in China—Results and perspectives

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ABSTRACT

Lessons learnt from accidents are essential sources for updating state-of-the-art requirements in pollution accident prevention. To improve this input in the People's Republic of China in a systematic way, a database for collecting and evaluating major pollution accidents is being established. This is being done in co-operation with Chinese Society for Environment Sciences and other national Institutions. At the time of writing over 80 major events from 2002–2006 have been collected. In this paper, a summary evaluation on the major polluting events in China from 2002 to 2006 is presented and some basic lessons drawn shown. There is no a systematic pollution accident notification system currently in China. The results from root cause analysis underline the importance of emergency measures, maintenance, human factor issues and the role of safety organization. Chronic pollution, especially water pollution and air pollution should be paid the same attention as the sudden pollution. It is important to keep in mind that collecting information from major accidents represents a small percentage of the actual number of events taking place.

1. Introduction

The experiences of analysis of major pollution accidents are indispensable sources for the further development of accident prevention [1]. To improve this input in the People's Republic of China in a systematic way, a systematic major pollution accident database is being established by Tsinghua University and Chinese Society for Environmental Sciences in China. The essential tasks presently are:

- collection, evaluation and forwarding of reports;
- editing annual reports;
- exchange of lessons learnt with other organizations in charge of evaluating major accidents.

2. Data screening and quality

Databases are designed to meet several objectives: examine compliance with regulations, codes of practice and standards; assist national and international regulators, financial and insurance companies to formulate proactive policies; help to identify whether current emergency procedures are appropriate; improve total quality management of safety and training of operators and managers; develop research projects for understanding of hazardous phenomena, hazardous situations and accident initiating events; improve public information on risk issues; identify relevant accident scenarios; identify deficiencies in design/operation of hazardous installations and transportation systems; assist consultants in their tasks dealing with safety cases and experts in accident investigations; develop quality aspects for data and software; collect information on equipment failure, etc. These objectives often complement each other. In summary, pollution accident databases are important tools for assisting in the formulation of new regulations and principles in environment safety and emergency procedures, coping with "what-if" requests from the public, industrial management boards and governmental institutions, assisting in risk analysis as a qualitative tool in identifying relevant accident scenarios and quantitative tool in producing estimates of event frequencies.

Data is collected from Internet, scientific literature, state environmental protection administration (SEPA) of China and other related agencies. These sources differ from each other in their interests, data collection procedures, definitions and scope, and each of these sources analyzes the data to achieve and accomplish different goals and missions. Thus, the information on accidents is heterogeneous in both content and form. Each accident consists of hundreds of thousands of records. But when there are so many trees, how is it possible to draw meaningful conclusions about the forest? By classifying the information into groups, interesting patterns of incidents according to characteristics such as type of pollution, type of equipment involved, type of chemical released and causes involved have been revealed so as to be helpful with decreasing pollution risks [2]. The resulting building blocks of the accident report form

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Table 1
Major pollution accident report building blocks.

1. Database administration	Event coding Information sources Dates of entry and last revision Operator and data provider details
2. Pre-event conditions	Event details Weather details Scenario details Technical details
3. Nature of event	Contaminants Systems and components affected/involved Emergency action and evaluation Chain of events Causal relations Safety systems Releases Leak hole characteristics Ignition details Explosion details
4. Consequences of event	Consequences on people (injured and fatalities) Other consequences (physical, environment and economical costs; cost of emergency response actions)
5. Post-event actions	Clean-up and restoration Event investigation Research investment Legal and other official actions Preventive actions Emergency improvements Risk awareness Lessons learned
6. References	Hyperlinks/references to files and documents, websites, etc. Specification of attachments, e.g. maps, drawings, photos, etc.

Table 2
Summary of the collected major accidents.

	Period under review					Total number
	2002	2003	2004	2005	2006	
Total number	18	16	15	15	18	82

are shown in Table 1. Table 2 is a summary of accidents collected by this study. Eighty two accidents from 22 provinces (cities) have been collected by this study. Since 2006, an improvement in the quality of the accident reports has been observed. The report form is often seen as a report structure rather than a checklist. A comprehensive figure of the process and effects of the accident can normally be derived from these reports. As for the investigation of causes, it should be mentioned that in most cases the reports are restricted to the predominant cause, e.g. an operating error. Lower-level causes are rarely regarded and are scrutinized even more rarely.

Even taking into account the improvement in the quality of reporting since 2006, almost all accidents were reported 6 h to 10 days behind its occurrence due to local interference. As a result, it is possible that the information included in these reports is not complete and/or is of low quality. In many/some cases, the event description and cause analysis might be incomprehensible and no clear lessons can be drawn.

3. Evaluation of major pollution accidents 2002–2006

From the total number of major accidents in the period 2002–2006 (82 events) the following conclusions can be deduced: the area distribution of accident number (Fig. 1) shows that Hunan, Jiangsu and Zhejiang provinces rank in the top three. Accidents happened most frequently in these three provinces in 2002–2006. As a whole, it is observed that most pollution accidents happened in relatively developed areas such as the Yangtze river delta, the Pearl river delta and the old industrial base such as the Northeast of China, Sichuan and Chongqing area. It illustrates on one hand that the environment of these areas has been overloaded and thus have a high probability of accidents. On the other hand, high rate of reporting shows that people in these areas have a stronger sense of environment protection due to their higher income and life quality.

4. Accident analysis

4.1. Accident types

Among the 82 cases, water pollution incidents and air pollution incidents account for 47% respectively, while 6% of the incidents were soil pollution. Sixty-one accidents (75%) were sudden unexpected events. Eighteen percent were continued pollution events. Seven percent are unclassified. This suggests to some extent that Chinese authorities pay more attention on the report of sudden pollution incidents than continued pollution incidents. On the other hand, the total number of 82 accidents during the four year period is far from satisfactory for China's fast-developing economy. This is mainly due to two reasons:

a. lack of sufficient data collecting;
b. Vagus definition of major pollution accidents for the reporting structure.

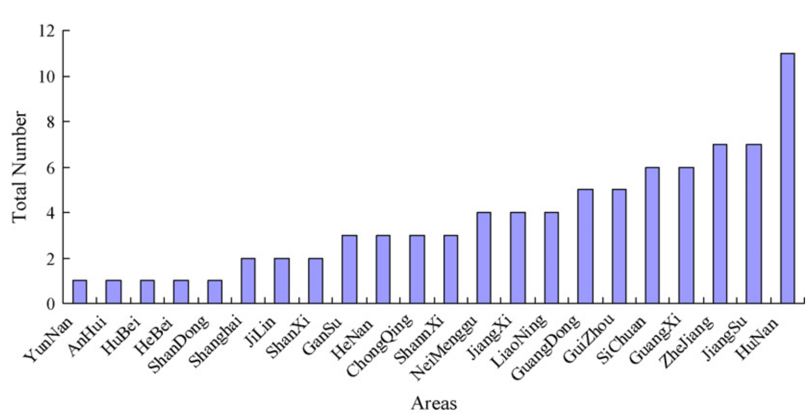

Fig. 1. Areas distribution of major pollution accidents in 2002–2006.

Table 3
Operating states for event occurrences in 2002–2006.

Operating states	Relative part in %
Normal process	32
Loading/unloading	2
Maintenance/repair/test/construction	5
Start-off and shut-down process	2
Storage	17
Others	5
Unknown	37

4.2. Pollution causes

Half of the reported events (50%) were connected with production accidents. This shows the weakness of management, training and safety operation in the Chinese industrial and manufacturing sectors. Production accidents are by definition events in which there is a deviation from the desired state, resulting in loss or damage to equipment or personnel, or increased potential for such outcomes [3].

- 28% of the events were caused by accidental releases;
- 16% of the events were due to traffic accident;
- 2% of the events were caused by inadequate supervision by environmental authorities.
- 4% of the events were unclassified.

4.3. Production accident causes

More in-depth analysis shows that production accidents were usually triggered by technical failures (42%) rather than human failures. Human failures occurred at approximately 12% of the events due to operating errors. Thirty seven percent of these events were unidentified; two percent were due to environmental changes, seven percent were due to other reasons such as intended behaviors, storehouse collapse, etc.

The operating states at the time of the occurrences are shown in Table 3 for every type of installation. With 32%, the normal process conditions were determined as most frequent states in which events occurred. Storage as well as maintenance/repair was represented with approximately 22%. The start-up, shut-down and loading processes contributed approximately 4%. Summing up all constituents except “others” and “unknown” yields approximately 68%. Accidents therefore seem to occur in all operating states. The relatively high contribution of equipment failures highlights the fact that facility maintenance should play an important role in accident prevention.

A more detailed analysis of the causes indicates that production accidents represent approximately 50% of the events, subdivided into failures of the container/flange (approximately 29%), of valves/pumps (approximately 10%), piping (approximately 15%) and unknown (approximately 46%). Records titled as “unknown” and/or “others” are relatively high (37%, 32%, and 46%) shows inadequate data collection.

4.4. Pollutant characters

According to pollutants source, environmental pollution accidents are classified as (a) accidental leakage, (b) waste gas, (c) waste water and (d) solid waste. Sixty two percent of the accidents were due to accidental leakage. Pollution resulted from waste gas, waste water and solid waste account for 36% in total (see Fig. 2).

The distribution of pollutant type is as follows: forty two percent of the total involved inorganic pollutants (chlorine, sulfureted hydrogen, vitriol, etc.); twenty eight accidents were due to organic pollutants (benzene, ethylene, petroleum, etc.), which account for 34% of the total. Heavy metal pollutants (arsenic, manganese, chromium, etc.) account for 11%. Mixed pollutants (mixture of industrial waste water and sewage water) were six percent. The pollutants were unknown for nearly seven percent of the events. Chemical pollution accidents contributed to 54.9% (45 accidents) among all events.

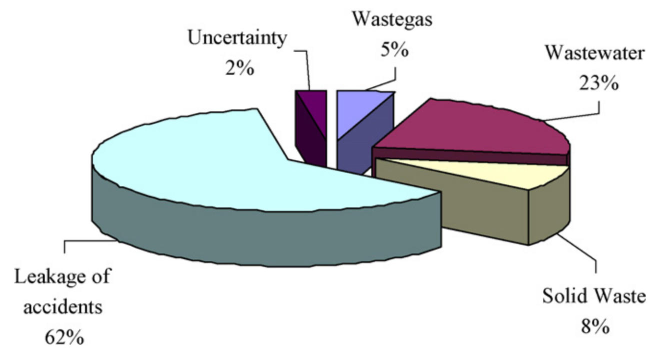

Fig. 2. Pollutant sources distribution.

4.5. Health damage and trend analysis

Among the 82 cases cited, 41 resulted in adverse health effects such as irritancy, psychosocial effects, and death. The cases involving fatalities did not give specify causes of death. For the majority of the events reported, no data on the effect route, the extent of effect and exposure population are available. For the majority of the events reported, no detailed data on the extent of environmental damages are available either.

Fig. 3 is the trend of health damage incidents from 2002 to 2006. A decreasing trend for the proportion of health damage incidents between 2002 and 2005 can be observed, a tendency which did not continue in 2006. The trend in the future years remains open to speculation.

5. General conclusions

The following general conclusions can be drawn from this analysis:

- There is currently a lack of a systematic pollution accident notification system in China. In the examination of the collected accidents, there is no a clear definition of reportable events nor a unified reporting system. Many occupational health and safety incidents go unreported.
- As shown above, no legislation exists obliging related units to provide any information about pollution incidents to authorities in a timely fashion. Therefore, the collection of accident data information depends on mandatory reports being filed to authorities

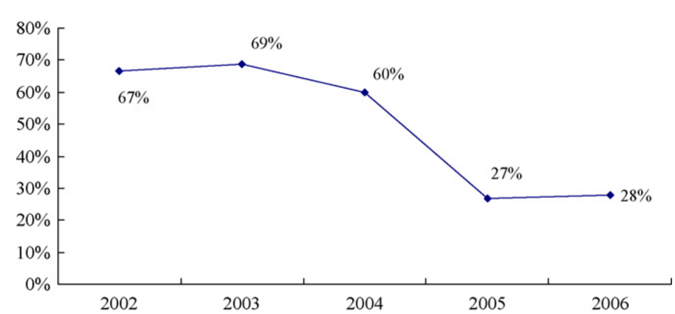

Fig. 3. Trend of health damage incidents.

with no time limit after the event has taken place. In spite of this, many events go unreported due to local intervention.

- One may easily conclude that industrial/commercial operating regulations are either imperfect or outdated and often do not consider critical operating states.
- Lack of expert knowledge was observed not only during maintenance operations but also in some cases where incompatible materials were stored or loaded together, leading to irregularities.
- Lack of an emergency system was also observed during the period of accidents treatment, which led to more unnecessary damage.
- Imperfect operating procedures were particularly observed in cases of deviations from routine tasks. Such situations should therefore be addressed in the operating instructions and especially be considered for training purposes.

6. Suggestion

A large number of incident related databases have been established in the last three decades [4]. Pollution accident history databases are a powerful and unique tool which can be used to systematically identify risks in terms of severity of consequences and probability of occurrence to allow prioritization of programs concerning certain processes; types of process, storage and transportation systems; and various chemicals. Efforts should be made to develop inherently safer process schemes for the most common and most hazardous situations.

A major issue is that most pollution accident history databases are limited in scope by factors such as release media, stationary source versus transportation, and jurisdiction of regulatory agencies. However, it should be kept in mind that pollution accidents involve manufacturing, transportation, and using. Risk reduction and accident prevention efforts can be effective if complete databases on all sources and types of releases are implemented and made available. Detailed accident information from the Environmental Protection Agency, the Occupational Safety and Health Administration, the Department of Transportation, Agency for Toxic Substance and Disease Registry, and other institutions should be compiled into one master database. Analysis of such a database could then be used to develop meaningful conclusions for overall risk reduction and accident prevention.

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