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Accident History Database: An Opportunity

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Paper presented at the 1st Annual Symposium of the Mary Kay O'Connor Process Safety Center, "Beyond Regulatory Compliance, Making Safety Second Nature",
George Bush Presidential Conference Center, College Station, Texas
March 30-31, 1998.

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ABSTRACT

The Clean Air Act Amendments of 1990 mandated the development of regulations for the protection of workers, public, and the environment from catastrophic releases and chemical plant accidents. As a result, the US Environmental Protection Agency promulgated the Risk Management Program rule in June 1996. Approximately 66,000 regulated facilities are required to comply with all the requirements by June 1999 and submit a risk management plan to the EPA. Each risk management plan will contain amongst other things, a 5-year accident history for the facility.

The 5-year accident history database that will become publicly available sometime in 1999 represents a very large and useful database. This presents a potential opportunity for determining macroscopic as well as microscopic causal factors for chemical plant accidents and then using these determinations for solving the underlying problems. However, there are various issues and potential pitfalls that must be kept in mind. For example, data integrity, taxonomy of the database, and the wide differences in the 66,000 facilities are issues that represent challenges that require some novel approaches. The authors of this paper present their approach to using the 5-year accident history database for attempting to identify the fundamental precursor situations that result in significant chemical plant accidents.

BACKGROUND

Accident prevention and mitigation of consequences is the focus of a number of industry programs, regulatory initiatives, and public queries. As part of these programs and regulations, accident history data is often collected. Analysis of these accident history databases provide a very intriguing insight into accident prevention activities. The analysis and conclusions obtained from the accident database analysis is limited by the limitations and shortcomings of the databases themselves. The fact remains, however, that accident history databases are very useful and can be a powerful tool in focusing risk reduction efforts. In addition, the conclusions can be used to systematically identify the greatest risk in terms of severity of consequences and probability of occurrence to allow prioritization of projects concerning certain processes; types of process, storage and transportation systems; and various chemicals. Thus, the analysis of accident history databases can be used to:

$ Systematically identify those projects which would most effectively address the risks identified by risk analysis.

$ Develop inherently safer process schemes for the most common and most hazardous processes.

Analysis of accident history databases and the resulting insights into the nature of chemical accidents also builds understanding of accident prevention issues. In addition, these types of analysis and conclusions provide a means of focusing the attention of researchers and practitioners on chemical accident prevention. Furthermore the analysis can be used to:

$ Identify common types of releases and publicize ways to prevent them.

$ Increase the knowledge base of emergency responders, state emergency response commissions, and local emergency response committees about specific chemical releases in their areas and appropriate chemical accident prevention.

$ Identification of technologies and practices to prevent chemical accidents. For example, conclusions could indicate that inspection and preventive maintenance on equipment and instruments should become more widespread, especially on piping systems.

As part of the sweeping requirements of the Clean Air Act Amendments of 1990, Congress directed the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) to promulgate regulations to protect the workplace employees and the public and the environment respectively. Congress' intent in mandating these regulations is to reduce the frequency and severity of chemical plant accidents.

OSHA fulfilled its mandate by promulgating the 14-element ***Process Safety Management*** (PSM) rule (' 29 CFR 1910.119)[1]. Regulated facilities must develop and implement the 14-element program and accomplish initial compliance within five years. The 5-year compliance period expires on May 24, 1997. Discussion of the various requirements of the PSM rule and strategies for compliance are addressed elsewhere[2,3].

On June 20, 1996, EPA published in the Federal Register the final rule for ***Risk Management Programs for Chemical Accident Release Prevention*** (' 40 CFR 68)[4]. The rule is applicable to stationary sources that process listed substances[5] above specified threshold quantities. The rule requires regulated facilities to develop and implement appropriate risk management programs to minimize the frequency and severity of chemical plant accidents. To determine if a facility is affected by the EPA rule, facility owners and operators must determine whether more than the threshold quantity of one or more of the listed toxic or flammable substances is present in the process. EPA defines a process as "any activity involving a regulated substance including any use, storage, manufacturing, handling, or on-site movement of such substances, or combination of these activities."

In general, the EPA rule requires the development and implementation of a Risk Management Program which includes a hazard assessment, a prevention program, and an emergency response program. The prevention program includes several elements which are similar to those required under OSHA PSM. The EPA rule also requires regulated facilities to develop a Risk Management Plan (RMP). The RMP includes a description of the hazard assessment, prevention program, and the emergency response program. The RMP will be submitted to a central location in Washington, DC and be made available to the state emergency response commission, the local emergency planning committees, and as needed the RMP would be communicated to the public.

THE 5-YEAR ACCIDENT HISTORY

Facilities must submit the Risk Management Plan before June 21, 1999. The hazard assessment included in the RMP consists of an offsite consequence analysis and 5-year accident history. The 5-year accident history is a compilation of accidental releases involving the regulated substances from a covered process that results in deaths, injuries, or significant property damage on site, or known offsite deaths, injuries, evacuations, sheltering in place, property damage, or environmental damage. Table 1 provides a listing of the "effects that would result in an accident being included in the 5-year accident history".

TABLE 1

ACCIDENTS THAT WOULD CAUSE INCLUSION IN THE 5-YEAR ACCIDENT HISTORY

Location	**Effects that would cause the accident to be included in the 5-year accident history**
Onsite	$ Deaths $ Injuries $ Significant property damage
Offsite	$ Deaths $ Injuries $ Evacuations $ Sheltering in place $ Property damage $ Environmental damage

For each accident meeting the criteria shown in Table 1, facilities must report the following information:

(1) Date, time, and approximate duration of the release;

(2) Chemical(s) released;

(3) Estimated quantity released in pounds;

(4) The type of release event and its source;

(5) Weather conditions, if known;

(6) On-site impacts;

(7) Known offsite impacts;

(8) Initiating event and contributing factors if known;

(9) Whether offsite responders were notified if known; and

(10) Operational or process changes that resulted from investigation of the release.

As mentioned earlier, this database represents a large and potentially useful source of information which could be used to focus risk reduction efforts and resources. However, key questions we must ask ourselves is what data is important, how should this data be analyzed, and what do we want to learn from the analysis? Another issue is the potential that because of the specificity of the requirements, the reported accidents in the 5-year database may be much less than the actual accidents which may of interest for the analysis. Also, because of varying degrees of expertise in the industry and lack of understanding, the integrity of the data may also be of concern. Therefore, before the data is used for any analysis and conclusions, the whole database should be reviewed for data integrity. The process could be similar to the one published by *McIntosh and Taylor*[6] or the questionnaire methodology used by EPA in developing the Accidental Release Information Program (ARIP) database. Once the data is reviewed, audited, and standardized; it can then be used for analysis and conclusions. In this research, we use the ARIP database to introduce our approach and preliminary results. Similar analysis can be conducted on the EPA 5-year accident history database when it becomes available in 1999.

THE ARIP DATABASE

The Chemical Emergency Preparedness and Prevention Office (CEPPO) within the Office of Solid Waste and Emergency Response (OSWER) leads the Environmental Protection Agency's (EPA) effort to prepare for and prevent chemical accidents. The Agency began its chemical accident prevention program in 1986. To identify the steps that could be taken by industrial facilities to prevent releases, the Agency needed information on the causes of accidents and industry prevention practices. At that time, the only data available focused on the quantities released rather than causes.

To develop new information on accident causes, EPA initiated the Accidental Release Information Program (ARIP). The program involves collecting questionnaire information from facilities that have had significant releases of hazardous substances, developing a national accidental release database,analyzing the collected information, and disseminating the results of the analysis to those involved in chemical accident prevention activities. ARIP also helps to focus industry's attention on the causes of accidental releases and the means to prevent them.

Selection of Facilities to Survey

U.S. facilities are required by law to report non-routine releases of certain substances when those releases exceed a reportable quantity (RQ). These reports are called into the National Response Center, the U.S. Coast Guard, and EPA regional offices. EPA compiles the reports into the Emergency Response Notification System (ERNS) database. EPA then uses ERNS data to select releases for the ARIP questionnaire.

The ERNS database includes a wide range of releases from both fixed facilities and transportation. Since the Department of Transportation is responsible for transportation accidents and OSHA is responsible for accidents affecting workers, ARIP targets those accidental releases at fixed facilities that resulted in off-site consequence or environmental damage. Off-site consequence includes any casualty, evacuation, shelter-in-place, or any other necessary precaution taken by individuals off-site as a result of the release. Environmental damage includes wildlife kills, significant vegetation damage, soil contamination, and ground and surface water contamination.

ARIP Questionnaires

The ARIP questionnaire consists of 23 questions about the facility, the circumstances and causes of the incident, and the accidental release prevention practices and technologies in place prior to, and added or changed as a result of, the event. The questionnaire focuses on several areas of accident prevention including hazard assessments, training, emergency response, public notification procedures, mitigation techniques, and prevention equipment and controls.

ANALYSIS AND RESULTS

The ARIP database used in this analysis includes a total of 4,920 releases from the year 1986 through 1997. The chemicals reported are the ones reported to EPA under existing statutes and regulations. This tends to exclude gasoline, methane, ethane, propane and other chemicals some of which will be included in the EPA 5-year accident history database. Also, during the data compilation process, EPA took steps to streamline the database in later years by including only releases with significant offsite consequences. In fact, as shown in Table 2, this reduced the number of reported releases in a number of years to a low number that would have no statistical significance. Fortunately, the total database is adequately large to provide meaningful analysis and conclusions. Table 2 provides an important conclusion and that is the criteria and/or taxonomy used in selecting accidents may very well produce a statistically insignificant database. Another key finding is that nearly half of the reported releases are from industries other than chemical manufacturers and petroleum refiners. The others use or transport chemicals. Also, of 309 chemicals released, 35 chemicals account for 75% of the releases and 80% of the injuries. Transportation releases are however excluded from the database. Tables 3 through 7 provide analysis results for the ARIP database.

The data shown in Table 3 indicates that releases are more or less equally distributed at different locations in the plant. This seems to indicate that all parts of the plant including storage areas need equal attention.

Table 4 shows that 71% of the releases are caused by equipment failure. In addition, as indicated by Table 6, 54% of the releases occur during normal operation due to mechanical failure. These results seem to suggest a strong correlation between accidents and mechanical integrity programs or lack thereof.

Table 7 also provides some interesting results. First, water and wastewater treatment and refrigeration add to the high totals for ammonia and chlorine. This seems to indicate that we probably need to take a closer look at ammonia and chlorine processes with the objective of designing inherently safer processes and implementing improved prevention programs. In general, the information in Table 7 and other analysis presented here can be used to identify major hazard areas, develop guidance for risk reduction efforts, and dedicate resources.

The analysis and results shown here represent only part of some of the applications of accident history databases. There are many other applications which can improve the prevention, preparedness, and emergency response programs. Further studies being considered include analysis and comparison of ARIP/ERNS database with HazMat databases in order to develop a more scientific basis for emergency planning. For example, Houston has a HazMat team and they have detailed records of releases over a period of years. It would be interesting to take the ARIP and ERNS databases and compare the Houston experience to those, eventually identifying the most probable types of releases in Houston. By analyzing the results by SIC we could probably identify sites that haven't filed SARA reports or are not required to file SARA reports but still have the potential for releases. This would provide a more scientific basis for emergency planning. Experience in Houston could be more easily applied to other locations by basing the analysis on SICs. Various databases and on-line phone-books could be used to identify the types and number of businesses (by SIC) in a community. HazMat teams and other responders could thus be better prepared, with equipment and training, to deal with the most likely and most serious accident scenarios.

CONCLUSIONS

Accident history databases represent a powerful and unique tool which can be used to systematically identify the greatest risk in terms of severity of consequences and probability of occurrence to allow prioritization of projects concerning certain processes; types of process, storage and transportation systems; and various chemicals. Efforts can then be dedicated to develop inherently safer process schemes for the most common and most hazardous processes. However, the effective use of accident history databases is limited by the limitations of the database itself, e.g., criteria, taxonomy, and data integrity. This paper represents work-in-progress to develop a systematic approach towards using EPA's 5-year accident history database for the overall objective of reducing process plant accidents.

A major issue is that most accident history databases are segregated by factors such as release media, stationary source compared to transportation, regulatory agency. However, we should remember that "chemical process" involves manufacturing, transportation, and use. Risk reduction and accident prevention efforts can be effective if complete databases on all sources and types of releases are available. This would mean that accidental release information available from EPA, OSHA, DOT, Coast Guard, other agencies and organizations be compiled into one master database. Analysis of such a database can then be used to develop meaningful conclusions for overall risk reduction and accident prevention.

ACKNOWLEDGEMENTS

The authors would like to thank researchers at the Mary Kay O'Connor Process Safety Center for the many discussions and research which assisted in the evolution of the ideas and concepts presented herein.

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TABLE 2

RELEASES REPORTED BY YEAR IN ARIP DATABASE

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Releases	34	173	391	1155	1219	1124	635	97	34	15	9	1

Note: Complete ARIP database includes 4,920 datapoints of which information is not available for 33 datapoints.

TABLE 3

RELEASE LOCATION FOR ACCIDENTS IN ARIP DATABASE

Release Location	Number	Percent
Piping	1,083	22.1
Process Vessel	965	19.7
Valve	924	18.9
Storage Vessel	747	15.3
Pumps	162	3.3
Others	1,102	20.7

TABLE 4

CAUSE OF RELEASE FOR ACCIDENTS IN ARIP DATABASE

Cause of Release	Number	Percent of total	Percent with responses
Equipment failure	2,934	60	71
Operator error	1,211	25	29
No response	774	16	

TABLE 5

CONTRIBUTING CAUSES AS A FUNCTION OF PRIMARY CAUSE

Contributing Cause	**Primary cause**				Average percent
	Mechanical failure		**Operator error**		
	Number	**Percent**	**Number**	**Percent**	
None	1,033	35.2	407	33.6	34.4
Other	735	25.0	240	19.8	22.4
Maintenance activity	252	8.6	262	21.6	15.1
Upset conditions	360	12.3	100	8.2	10.3
Inappropriate operating procedures	50	1.7	168	13.9	7.8
Improper training	21	0.7	98	8.1	4.4
By-pass conditions	86	2.9	57	4.7	3.8
Unsuitable equipment	125	4.3	21	1.7	3.0
Faulty process design	108	3.7	25	2.1	2.9
Weather conditions	76	2.6	21	1.7	2.2
Unknown	378	12.9	83	6.8	9.9

TABLE 6

INITIATING CAUSE AS A FUNCTION OF OPERATING MODE

Operating mode	**Initiating cause**			
	Mechanical failure		**Operator error**	
	Number	**Percent of all releases with a reportable primary cause**	**Number**	**Percent of all releases with a reportable primary cause**
Routine operation	2,252	54	747	18
Routine startup	145	3	119	3
While shutting down	87	2	42	1
While shutdown for maintenance	129	3	106	3
During special test, trial	14	0	20	0
Startup of new construction/equipment	30	1	21	1
Other	265	6	145	3
Operating mode not reported	12	0	11	0

TABLE 7

RELEASES SORTED BY CHEMICALS FOR ARIP DATABASE

Chemical released	Number of Releases	Deaths	Hospitalization	Injuries	Incidents with injuries
Ammonia	880	7	37	277	99
Chlorine	648	1	128	1190	187
Sulfur Dioxide	370	0	54	187	21
Sulfuric Acid	326	2	11	37	30
Hydrogen Sulfide	186	1	40	87	15
Ethylene Oxide	147	0	31	36	10
Sodium Hydroxide	143	1	9	21	18
HCl Acid	108	0	14	95	18
Methyl Chloride	101	0	1	6	4
Vinyl Chloride	100	0	1	1	1
Sodium Hypochlorite	90		18	114	7
Benzene	84	1	5	8	3
Phosphoric Acid	64	0	5	15	4
Nitric Acid	55	0	15	19	6
DiMethyl Sulfide	43	0	0	0	0
Tetra Chloro Ethylene	42	0	3	9	6
Formaldehyde	41	0	1	29	4
Chloroform	38	0	0	3	3
HF Acid	35	2	12	27	10
HCl Vapor	35	0	17	75	7
Toluene	33	1	3	9	8
Propylene Oxide	21	1	4	6	2
HF Vapor	19	0	1	1042	2
Phosgene	16	0	37	63	7
Naphthalene	16	0	18	18	1

Styrene (Monomer)	12		10	13	2
Vinyl Acetate	6	1	0	4	1
Tri Chloro Fluoro Methane	5		18	19	1
Tetra Hydro Furan	4	0	13	13	2
Phosphorus Oxychloride	3		1	46	2
2 Nitropropane	2	8	15	57	2
Silane	2	2	1	1	2
Tri Chloro Silane	2		8	150	1
Chloro Tri Fluoro Ethylene	1	1	0	24	1
Paint Thinner	1	1	1	1	1

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