Chemical accident risks in U.S. industry - A preliminary analysis of accident risk data from U.S. hazardous chemical facilities

James C. Belke[+]

United States Environmental Protection Agency
Chemical Emergency Preparedness and Prevention Office
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460
United States of America

September 25, 2000

1. INTRODUCTION

In response to the chemical accident that occurred in Bhopal, India, in 1984, and a series of large chemical accidents in the United States in the late 1980s, the U.S. Congress passed a series of laws intended to minimize the likelihood and consequences of catastrophic chemical accidents. The most recently enacted of these laws created a new regulatory program called the Risk Management Program. This program, which took effect in June 1999, requires certain chemical facilities to implement chemical accident prevention and preparedness measures, and to submit summary reports to the government every five years.

Approximately 15,000 facility reports have been received to date, and these contain significant information on each facility's accident history, accident prevention program, and the potential consequences of hypothetical accidental chemical releases. These data have been assembled into a searchable computerized database, called RMP*Info. The full RMP*Info database was originally intended to be available to the general public via the Internet, so that

---

[+] Unless otherwise noted, all opinions expressed in this paper are those of the author, and do not necessarily represent official positions or policies of the United States or the U.S. Environmental Protection Agency.

concerned citizens could use the information to influence local facilities to adopt safer practices, and to allow researchers to identify factors statistically associated with accident-prone or accident-free facility performance.

However, the chemical industry and U.S. security agencies raised concerns that some of the data would allow terrorists to easily identify those facilities likely to cause the greatest harm to the public in the event of a release, and target those facilities for attack. These concerns prompted Congress to pass legislation in August 1999, that, along with subsequent federal regulations, currently restricts public access to portions of the RMP*Info database.

Therefore, as of this writing, the complete database is only accessible by a relatively few individuals at EPA headquarters, and, with the exception of one other preliminary study that considered only its non-restricted portions, it has not been subject to the robust statistical analysis that might lead to identifying accident indicators or causal factors. This paper proceeds in that direction by providing some basic descriptive statistics that characterize the database, including its restricted portions, within the limitations set by United States law.

2. A BRIEF HISTORY OF U.S. CHEMICAL ACCIDENT LEGISLATION

2.1. Emergency Planning and Community Right-to-Know Act

The first major law intended specifically to address the problem of chemical accidents in the United States was the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) [1]. This law requires states to create State Emergency Response Commissions (SERCs) and communities to form Local Emergency Planning Committees (LEPCs) to prepare local emergency response plans for chemical accidents. It also requires chemical facilities to provide LEPCs with information necessary for emergency planning, and to submit to SERCs, LEPCs and local fire departments annual inventory reports and information about hazardous chemicals. The statute also established the Toxics Release Inventory (TRI), which requires certain facilities to annually report the quantities of their emissions of toxic chemicals. The chemical inventory data are available to the public and EPA maintains a national database containing TRI reports.

2.2. OSHA Process Safety Management standard

EPCRA focused on community emergency planning, but contained no provisions for the prevention of chemical accidents and, because major accidental releases continued to occur, Congress subsequently included two provisions in the Clean Air Act (CAA) Amendments of 1990 to institute federal regulatory programs to prevent chemical accidents that harm workers, the public and the environment [2].

The first of these programs (section 304 of the Clean Air Act Amendments) called for the Occupational Safety and Health Administration (OSHA) to develop chemical accident prevention and emergency response regulations to protect workers at hazardous chemical facilities. OSHA responded by developing the Process Safety Management (PSM) standard (29 CFR Part 1910), which places accident prevention and emergency response requirements on facilities having listed hazardous chemicals above certain threshold quantities. The PSM standard went into effect in 1992 [3].

2.3. EPA Risk Management Program

The other accident prevention program contained in the amended CAA (section 112(r)) called for EPA to develop regulations to prevent and respond to chemical accidents that could affect the public and environment off-site. EPA met this obligation in 1996 by promulgating the Risk Management Program regulations (40 CFR Part 68) [4]. The Risk Management Program is similar to OSHA's PSM standard, as it covers many of the same toxic and flammable substances[+], and requires virtually the same set of accident prevention requirements as the OSHA standard. These requirements include using written operating procedures, providing employee training, ensuring ongoing mechanical integrity of equipment, analyzing and controlling process hazards, and the like.

However, while the accident prevention elements of PSM and RMP are nearly identical[++], section 112(r) of the CAA and the resulting EPA Risk

---

[+] The EPA Risk Management Program covers 77 toxic and 63 flammable substances. In the CAA Amendments of 1990, Congress mandated 16 specific hazardous substances for regulation under the RMP, and required EPA to list at least 100 such substances which pose the greatest risk of causing death, injury, or serious adverse effects to human health or the environment from accidental releases.

[++] The RMP regulation places each covered process into one of three "programs," labeled 1, 2, or 3. The program level assigned to the process is based on the potential for the process to impact the offsite public, the accident history of the facility, and whether the process is already subject to OSHA PSM. Processes that have the greatest potential to affect the offsite public in the event of an accident or that are already subject to OSHA PSM are subject to program 3, which imposes the most rigorous set of accident prevention requirements (essentially the full set of PSM requirements). Processes which are unlikely to affect the offsite public in the event of a worst-case release and that have no history of such accidents in the last five years are placed in program 1, which imposes a minimal set of requirements. All other processes are subject to program level 2, which imposes a streamlined set of requirements [4].

Management Program contain several additional requirements beyond those contained in OSHA PSM. These include the following

- Facilities must prepare a history of accidental releases occurring over the past five-years.
- Facilities must perform an Offsite Consequence Analysis (OCA), which is an analytical estimate of the potential consequences of hypothetical worst-case and alternative accidental release on the public and environment around the facility.
- Facilities must submit a summary report, called a Risk Management Plan (RMP), to the EPA. The RMP contains the facility's five-year accident history, a summary of its accidental release prevention program, its offsite consequence analysis, and a summary of its emergency response plan.
- EPA must make all RMPs available to state and local governments and the public [2, 4].

EPA promulgated RMP requirements in June 1996 and the first RMPs were due three years later. EPA designed software tools and forms so that all RMPs could be submitted electronically to EPA and stored in a central database. This was done to reduce paperwork burden on regulated facilities, while also allowing government officials to have immediate access to the most recent information. Consequently, the majority of RMPs have been submitted electronically and EPA has assembled a searchable electronic database of this information. To date, this database contains RMPs from approximately 15,000 facilities [5].

2.4. U.S. law restricts public access to Risk Management Program data

In designing the Risk Management Program, Congress and EPA anticipated that public scrutiny would help regulate the behavior of hazardous chemical facilities to a greater extent than the regulatory requirements alone [2,4]. In this regard, the government had learned from its experience with the earlier EPCRA legislation. It was found that hazardous chemical information, when conveniently available to the public in an easily understandable format, was often obtained and used by various sectors of the public to influence facility behavior [6].

With this in mind, EPA originally planned to place the entire RMP information system on the Internet for easy access by state and local governments and the public. However, concerns were raised by the chemical industry and U.S. security agencies that Internet access to a large, searchable RMP database, and particularly the portion of that database containing OCA information, could be used as a targeting tool by terrorists and other criminals.

Proponents of this concern postulated that the OCA data contained in RMPs was sufficient to identify those chemical facilities that could result in the greatest number of casualties to the surrounding population. Furthermore, it was argued that a chemical plant could effectively be converted into a weapon of mass destruction (WMD) relatively easily:

> "In recent years, criminals have with increasing frequency attempted to obtain or produce WMD precisely because such weapons are engineered to cause wide-scale damage to life and property. However, traditional means of creating or obtaining WMD are generally difficult to execute. In contrast, breaching a containment vessel of an industrial facility with an explosive or otherwise causing a chemical release may appear relatively simple to such a terrorist [7]."

Although EPA consequently decided not to place the OCA sections of RMPs on the Internet, new concerns were raised that recent amendments to the Freedom of Information Act (FOIA) would compel EPA to release this information in electronic format. Congress responded by passing the Chemical Safety Information, Site Security and Fuels Regulatory Relief Act (CSISSFRRA), which the President signed on August 5, 1999 [8].

CSISSFRRA temporarily exempted OCA information (sections 2 through 5 of RMPs) from public disclosure under FOIA, and prohibited public access in any form, including any statewide or national ranking derived from the information, until federal regulations were issued to codify a system of limited public access. The statute required the President to "assess the increased risk of terrorist and other criminal activity associated with the posting of [OCA] information on the Internet, and the incentives created by public disclosure of OCA information to reduce the risk of accidental chemical releases." Based on these assessments, the President was required to issue regulations "governing the distribution of [OCA] information in a manner that, in the opinion of the President, minimizes the likelihood of accidental releases and [any increased risk of terrorist activity associated with Internet posting of OCA information] and the likelihood of harm to public health and welfare [8]."

The President delegated to the Department of Justice (DOJ) the authority to perform the assessment of the increased risk of terrorism, and to EPA the authority to perform the assessment of the incentives to reduce the risk of accidental releases. DOJ and EPA were jointly delegated the authority to promulgate the required regulations. The risk and benefits assessments [6,7] were completed in April 2000, and are available on the Internet at www.usdoj.gov/criminal/april18final.pdf and www.epa.gov/ceppo/pubs/incenAss.pdf, respectively.

Regulations to control public access to OCA data were subsequently published in August 2000 [9]. These regulations allow the public to gain access to OCA data at 50 reading rooms that will be distributed throughout the United States. When the reading rooms are established, a member of the public may view paper copies of the OCA data for up to 10 facilities per month. There are no restrictions on which ten facilities' data a person may view, but the person must show valid identification and may not take the OCA information document from the reading room.

Additionally, the regulations authorized development of a "vulnerable zone indicator system." With this internet-based system, a member of the public may enter a street address or set of geographic coordinates and the system indicates whether or not any facility's vulnerable zone could impact the specified location. However, the system does not identify the name or location of the facility or facilities that could cause the impact, or any information about the scenario (e.g., chemical, release quantity, etc).

The regulations prohibit the general public from analyzing or viewing the full national database of OCA information, and, practically speaking, will likely deter most members of the public from viewing even a small portion of the data. Individual facilities may grant public access to their own OCA data, and federal regulations allow and encourage state and local officials to grant public access, on request, to OCA data for facilities in the jurisdiction of a persons Local Emergency Planning Committee (usually the same as the individual's county of residence), and for facilities with a worst-case scenario extending into that area. However, there is no legal obligation on facilities or state and local governments to grant such access. Some facilities have made their individual OCA data available to the public, but as of this writing, state and local governments have not yet received the OCA data for facilities in their jurisdictions. Even when they do obtain the data, the fact that CSISSFRRA imposes severe penalties for officials who inappropriately release OCA data may deter granting such access.

The CSISSFRRA legislation also contains a provision for the entire OCA database to be made available to "qualified researchers." However, at the time of this writing, the government has not yet disclosed any system to provide researchers with access to the full database, and only a relatively small number of EPA headquarters officials and their contractors have access to the full national database.

In addition to its provisions related to OCA data, CSISSFRRA contained a separate provision that completely exempted most flammable fuel facilities from regulation under the Risk Management Program. Prior to CSISSFRRA, EPA estimated that about 66,000 facilities would be subject to the risk management program, and of these, about half would be subject to the regulations solely due to the presence of listed flammable fuels, mainly propane. However, after an intensive lobbying effort by the propane industry, Congress prohibited EPA from regulating under the risk management program any listed flammable substance when used as fuel or held for sale as fuel at a retail facility. This provision effectively reduced the estimated universe of regulated facilities by about half. In fact, even this estimate turned out to be too high, as facilities that otherwise would have been regulated took actions to legally avoid the regulation.[+]

3. PRELIMINARY RMP DATA ANALYSIS BY THE UNIVERSITY OF PENNSYLVANIA

CSISSFRRA has probably prevented, at least for the time being, easy access to the complete RMP database by criminals and terrorists. However, by denying this same access to academic researchers, environmentalists, industry groups, and other law-abiding members of the public, CSISSFRRA has also prevented, or at least greatly delayed, much of the data from undergoing the robust analysis that might eventually result in benefits to the public.

Fortunately, some preliminary analysis of the non-OCA portions of the data has already been performed. Under a cooperative agreement with EPA, The Wharton School of the University of Pennsylvania has performed preliminary analysis of the non-OCA portions of the database and has published the results in a working paper [10]. The Wharton working paper is available on the internet at www.epa.gov/ceppo/pubs/00-1-215.pdf or http://opim.wharton.upenn.edu/risk/epi_downloads.html, and selected results of the paper are reproduced in Appendix A.

As of this writing, the Wharton working paper contains preliminary results of analysis of the non-OCA portions of the RMP*Info database, with primary focus on its accident history portion. Wharton intends eventually to analyze the complete RMP*Info database using epidemiological techniques, and hopefully to identify factors which may predict chemical accidents or correlate to accident-free

---

[+] To date, approximately 15,000 facilities have submitted RMPs. The discrepancy between the post-CSISSFRRA estimate of 33,000 and the actual number is likely due to three factors. First, significant anecdotal information suggests that a large number of facilities took actions to avoid being regulated under the program. Such actions include reducing chemical inventory below the regulatory threshold, replacing a regulated substance with a non-listed substitute, or eliminating the covered process altogether. Second, EPA may have overestimated the number of facilities subject to the regulation. Third, some facilities may have not yet complied with the regulation.

performance. Identifying such factors could significantly benefit the public by allowing industry and government to better control those underlying factors that are statistically demonstrated to either cause or prevent serious accidents.

However, to date Wharton's research has been hindered in part by the unavailability of the OCA portions of the database. The "qualified researcher" provisions of CSISSFRRA will eventually permit access to the full database for research by academic institutions, industry groups, environmental advocates, and others. In the meantime, for those few people who currently have access to the complete database, nothing currently prohibits publication of the results of OCA data analysis, provided those results do not reproduce the specifically proscribed sections of the OCA information or contain any national or statewide ranking of OCA data derived from the database and identifying individual facilities [9]. This paper takes a first step toward filling the analytical gap by including a preliminary analysis of the OCA portion of the database. In the interest of completeness and in order to put the OCA data in context, it also includes an overview of the non-OCA portions of the database, and somewhat extends Wharton's analysis of the accident history data.

Readers should be aware that, except where noted, the statistics reported here are derived from a more recent version of the RMP*Info database than was used by Wharton in their original working paper, and therefore may differ slightly from statistics reported in that study.[+]

4. OVERVIEW OF RMP DATA ELEMENTS

Each RMP consists of an executive summary and up to nine other sections. It is intended to provide information that can be used by others to judge the risk that a facility poses to the surrounding community and to understand the steps taken by that facility to manage its risk. The executive summary is an overall prose description of a facility's risk management program, including, in general terms, a brief description of the facility's accidental release prevention and emergency response policies, worst-case and alternative case scenarios and their potential consequences, five-year accident history, and planned changes to improve safety. The remaining sections of the RMP contain specific data elements

---

[+] Another reason that statistics reported here may differ markedly from those in the Wharton paper is that in several cases, statistics in this paper are based on the overall number of chemical processes in the RMP database, where statistics in the Wharton paper are generally based on the overall number of facilities in the database.

that generally consist of yes/no, check-off box, and numerical answers to standard questions. There are additional areas where facilities may include prose explanations for various entries, but these are optional (with the exception of the executive summary).

The nine numbered RMP sections contain the following information (the presence of some sections and the total length of RMPs vary depending on the number and type of processes and chemicals present at a facility):

- Section 1: Registration information (e.g., facility name, address, process chemicals, chemical quantities, etc.)

- Sections 2-5: The so-called "OCA data." Modeling methodology, input parameters, analytical assumptions and results for the off-site consequence analyses of worst-case and alternative release scenarios. These sections provide estimates of the possible consequences of the scenarios, in terms of potentially affected population and other public and environmental receptors.

- Section 6: Five-year accident history data. For each accident occurring in the previous five years that exceeded specified severity thresholds, the facility provides the date of the event, chemical(s) released, source of release, on-site and off-site impacts, initiating event, and factors contributing to the release.

- Section 7: Accident prevention program data. Contains descriptions and data for any processes subject to prevention Program 3 (the most rigorous RMP accident prevention requirements - see footnote 2). Besides an optional narrative description of the prevention program, facilities are required to provide information such as the date of completing the last process hazards analysis, the major hazards identified by that analysis, process controls used to address those hazards, and information on maintenance, training, compliance audits, and incident investigations.

- Section 8: Accident prevention program data. Similar to Section 7, but for processes subject to prevention Program 2 (a less rigorous set of accident prevention requirements than those required under Program 3).

- Section 9: Emergency response program. Contains data on the facility's emergency response program and plan.

The advantage of this standard format is that it allows data to be easily submitted, compiled and manipulated in database form. However, also as a result of this format, much data submitted in RMPs do not contain contextual information. For example, a facility would indicate, by checking various choices in a list, what types of release mitigation measures are present in a process, but the reader can not discern precise locations, methods of operation, or design features of those devices unless the facility chooses to add an optional explanation containing these details. Nevertheless, when considered in total, an RMP can often provide a great deal of information about a facility.

4.1. Data Quality

Whenever a large amount of data is collected, there is the potential for errors and steps should be taken to ensure data quality. This is a particular challenge in this case, since each individual RMP is actually a data array consisting of up to hundreds of individual data elements, some of which reflect the results of underlying scientific analysis (i.e., the OCA) that is not submitted along with the RMP itself. So EPA expected that some errors would be introduced into the database. Many errors were prevented by incorporating basic automatic error-checking features into the RMP submission software developed by EPA (RMP*Submit™). The software identifies and prompts the user to correct some obvious errors, such as entering letters in a numerical field, leaving required fields blank, and the like.

However, many content-related errors are not detected by the software. For example, an RMP may report an incorrect value for the quantity of a particular toxic substance contained in a vessel, but if the value is within the allowed range of numerical digits accepted by the software for that field, the program will accept the entry as valid and report no error. Furthermore, an RMP may contain internal inconsistencies that the software is not designed to automatically identify. Such errors may often be manually identified by a knowledgeable analyst comparing various dependent values for logical consistency. For example, in the OCA worst case scenario portion of an RMP, the facility must report the quantity of the toxic or flammable substance contained in the single largest vessel on site, and also the "endpoint distance" (distance beyond which specified harmful effects would no longer be felt) that would occur if that same quantity of substance were accidentally released into the atmosphere. So these two values (quantity in largest vessel and distance to endpoint) are physically related and must make sense together. An RMP reporting a very small quantity of a toxic substance resulting in a very large endpoint distance is a potential outlier (and vice versa).

Some erroneous values are easy to spot simply because they are implausible.

For example, the largest OCA endpoint distance reported in the database is 255 miles. Since this value is well over an order of magnitude higher than what has been observed in any actual toxic release event, it immediately looks suspicious. Further, as the result of a release of only 114,000 pounds of aqueous ammonia, the reported endpoint distance seems absurd. In this preliminary analysis of the database, these sorts of errors, when identified, were eliminated or corrected where necessary and feasible (many reporting errors do not necessarily call into question the validity of other information in the RMP). The Wharton working paper also addresses data screening to account for errors in the accident history portion of the RMP*Info database [10].

5. PRELIMINARY DESCRIPTIVE STATISTICS

An overview of some basic statistics derived from the RMP*Info database is informative and will help place more detailed assessments in context. As of this writing, the RMP*Info database contains information on a total of 14828 facilities containing 20210 chemical processes[+]. Of these processes, 17529 contain at least one toxic chemical and 8107 contain at least one flammable chemical[++].

5.1. Frequency and Quantity Distributions of RMP Chemicals

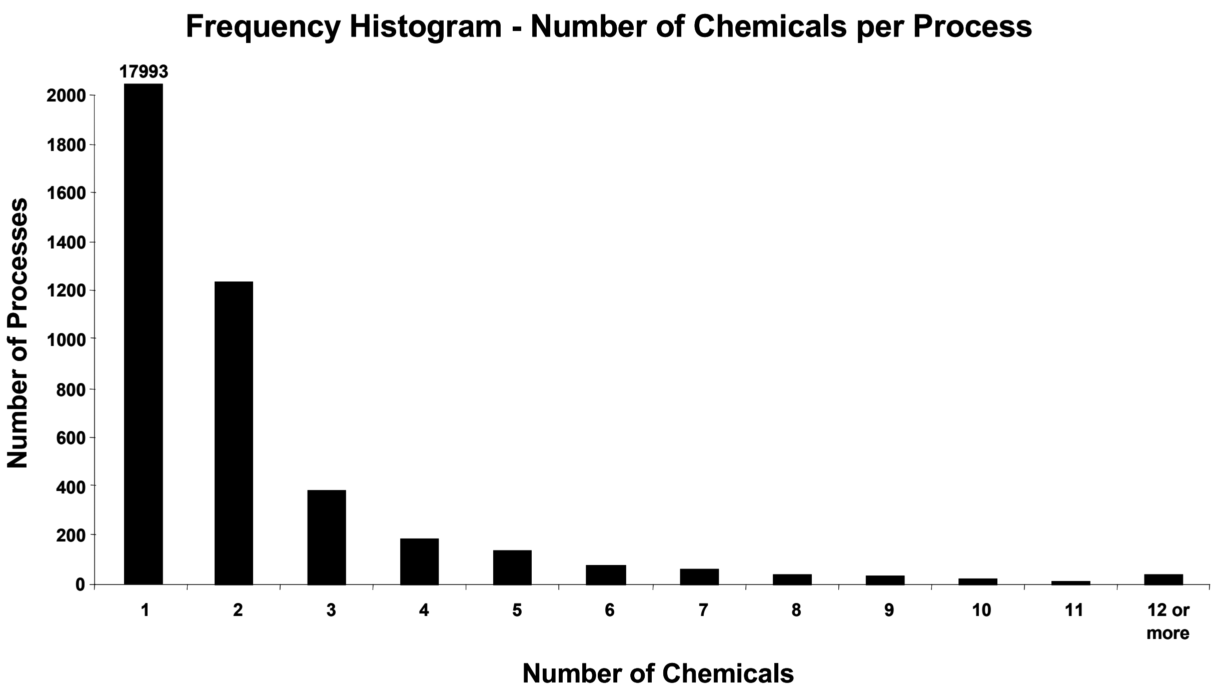
Note that the number of RMP processes exceeds the number of facilities, and that the total number of chemicals exceeds the number of processes. These facts highlight an important consideration. For many purposes, grouping RMP data by either chemical process or chemical type may be more accurate than trying to characterize data on a facility basis. While most facilities contain only one RMP process and one RMP chemical, 11% of facilities contain multiple regulated processes, and many individual processes contain multiple regulated chemicals.

[+] The basic reporting unit within the RMP database is a facility subset called a "process." Simply stated, a process is defined as any system of interconnected or co-located vessels and pipes which contain, in total, more than a threshold amount of at least one regulated substance. Processes can vary in complexity from a single storage vessel to large networks of vessels and pipes. Many facilities contain more than one process. Where this paper reports the number of processes containing a certain chemical, processes containing multiple chemicals are counted once for each chemical in the process.

[++] Each facility need submit only a single RMP to account for all processes at the facility. Some facilities have both toxic and flammable processes, and these facilities' RMPs contain information on both toxic and flammable chemicals.

Figure 1 is a histogram of the number of RMP processes containing multiple chemicals.
Figure 1: Frequency Histogram - Number of Chemicals per RMP Process

The RMP*Info database contains information on 70 toxic and 57 flammable substances or mixtures[+]. As Table 1 illustrates, four chemicals - anhydrous ammonia, chlorine, propane, and flammable mixtures - are present in nearly 70 percent of all RMP processes. Anhydrous ammonia is predominant due to its several widespread uses, including fertilizer production, refrigeration, and land application as an agricultural nutrient[++]. It alone is present in about one third of all



RMP chemical processes, and 48% of all toxic chemical processes. The high number of chlorine processes is mainly due to the common use of chlorine for water disinfection. Propane and flammable mixtures are found as products and chemical intermediates in oil refineries, gas extraction plants, propane distribution

---

[+] The RMP regulation covers a total of 77 toxic and 63 flammable substances. No RMPs have yet been submitted for 7 toxic and 6 flammable substances listed in the RMP rule.

[++] Section 112(r) of the CAA exempts from the risk management program ammonia when held by a farmer for use as an agricultural nutrient. However, when ammonia intended for land application as an agricultural nutrient is not held directly by a farmer, it may be covered by the regulation.

centers, fuel terminals, and chemical plants.

Chemical	Number of Processes	Percentage of Total
Ammonia (anhydrous)	8343	32.5
Chlorine	4682	18.3
Flammable Mixtures	2830	11.0
Propane	1707	6.7
Sulfur Dioxide	768	3.0
Ammonia (aqueous 20% or more conc.)	519	2.0
Butane	482	1.9
Formaldehyde	358	1.4
Isobutane	344	1.3
Hydrogen Fluoride	315	1.2
Pentane	272	1.1
Propylene	251	1.0
Methane	220	0.9
Hydrogen	205	0.8
Isopentane	201	0.8
All Others	4139	16.1

Table 1: Frequency Distribution of RMP Chemicals

While table 1 clearly shows that toxic chemicals (particularly ammonia and chlorine) account for the majority of RMP processes, the opposite is true for chemical quantity. In fact, RMP flammable chemicals far outweigh RMP toxics overall. As table 2 shows, of the top 10 RMP chemicals ranked in order of quantity, eight are flammables, including the top three. Ammonia, which ranks first in number of processes (32.5%), ranks fourth in terms of quantity (13%). Chlorine, which ranks second in number of processes (18.3%), ranks only 13th in quantity (0.9%). While at first glance these results may seem inconsistent, they are easily explained. Many RMP flammable chemical processes are located in refineries, chemical plants, gas extraction plants, fuel terminals and propane distribution centers. These facilities, on average, tend to have extremely large chemical processes. The most prevalent toxic chemical processes, on the other hand, include refrigeration systems, fertilizer storage containers, and water treatment plants, all of which generally contain relatively small chemical quantities.

Chemical	Total Quantity (x 10^6 tons)	Percentage of Total
Flammable Mixtures	13.1	37.4
Ammonia (anhydrous)	4.7	13.3
Propane	4.4	12.5
Butane	2.9	8.3
Ethane	1.7	4.8
Isobutane	1.6	4.4
Ethylene	1.2	3.5
Propylene	1.0	2.7
Methane	0.5	1.3
Sulfur Dioxide	0.4	1.2
2-Methylpropene	0.4	1.1
Pentane	0.3	0.9
Chlorine	0.3	0.9
All Others	2.7	7.5

Table 2 - Quantity of Prevalent RMP Chemicals in the United States[+]

5.2. RMP Facility Industrial Classifications

Each RMP process is assigned an industrial classification code according to the North American Industrial Classification System (NAICS). This system assigns businesses descriptive categories that correspond to five- or six-digit codes. The first three digits of the code define a major business sector and the last two or three digits indicate an establishment's specialty within the major sector. The RMP rule requires facilities to assign NAICS codes that most closely correspond to the function of the individual covered process, rather than the

---

[+] Totals and percentages represent only RMP-regulated facilities. Process quantities reported in RMPs reflect the maximum quantity that a process would contain at any one time. Therefore, these totals represent the sum of all processes' maximum quantities, and will reflect the absolute upper limit of aggregate quantity for RMP facilities. Actual aggregate quantities for RMP facilities will be somewhat lower.

overall facility. Since most facilities have only one process that is closely aligned to the overall facility function, the process NAICS code and facility NAICS code are usually the same. However, facilities with multiple processes, or facilities desiring to identify other aspects of a process not captured by the NAICS code for the primary activity may have multiple NAICS codes.

Table 3 indicates the number of RMP processes in the most commonly reported NAICS codes. The most frequent RMP process NAICS codes roughly mirror the results of Table 1, as ammonia, chlorine, flammable mixtures, and propane - the top four chemical in terms of process frequency - are also among the RMP chemicals most commonly associated with the top NAICS codes.

NAICS Code and Description	**Number of Processes**	**NAICS Code and Description**	**Number of Processes**
42291 Farm Supplies Wholesalers	4409	49313 Farm Product Warehousing	345
22131 Water Supply & Irrigation	2059	32511 Petrochemical Manufacturing	321
22132 Sewage Treatment	1646	454312 Liquefied Petroleum Gas Dealers	311
32411 Petroleum Refineries	1609	11511 Support Activities for Crop Production	302
325199 All Other Basic Organic Chemical Manufacturing	655	311615 Poultry Processing	253
42269 Other Chemical and Allied Products Wholesalers	607	115112 Soil Preparation, Planting, and Cultivating	207
49312 Refrigerated Warehousing and Storage Facilities	549	32512 Industrial Gas Manufacturing	205
211112 Natural Gas Liquid Extraction	533	325998 All Other Miscellaneous Chemical Product Manufacturing	193
325211 Plastics Material and Resin Manufacturing	418	325311 Nitrogenous Fertilizer Manufacturing	159
325188 All Other Basic Inorganic Chemical Manufacturing	358	49311 General Warehousing and Storage Facilities	151

Table 3: Most Frequently Occurring RMP Process NAICS Codes

6. ACCIDENT HISTORY OVERVIEW

The Risk Management Program regulation requires covered facilities to include a five-year accident history in their RMP. The history must describe all accidental releases from covered processes in the last five years that resulted in deaths, injuries, or significant property damage on site, or known offsite deaths, injuries, evacuations, sheltering in place, property damage, or environmental damage.

These criteria were intended to capture only the most serious accidents affecting covered processes, and exclude minor incidents and accidents unrelated to covered processes. Fortunately, such accidents are fairly infrequent. As a result, fewer than 8% of facilities reported any accidents in their five-year accident history. Nevertheless, an analysis of the over 1900 accidents contained in the database can potentially yield important results. Since the Wharton working paper provides a thorough description of RMP*Info accident history data, this paper does not attempt to cover the same ground in any detail, but rather extends Wharton's research in this area somewhat by considering normalized accident rates. Selected results from Wharton's analysis are included in Appendix A, and readers are encouraged to refer to the Wharton paper for a full description of that analysis.

6.1. Normalized Accident Rates

When evaluating the actual risks of different hazardous chemicals, it is necessary to know what chemicals and chemical processes suffer the highest frequency of accidental releases. The Wharton working paper reported the total numbers of accidents over the five year reporting period, categorized by chemical type and process NAICS code (see Appendix A). While such totals technically represent an accident rate (i.e., number of accidents over a time interval) they are not normalized to account for disparities in the opportunities for accidents to occur among different substances or process types.

Incident rates are commonly normalized by dividing the number of incidents by some measure of the number of opportunities for an accident to occur. For example, the U.S. Department of Labor calculates occupational injury and illness rates by dividing the number of occupational injuries at a facility by the total number of person-hours worked at the facility over a given period. This allows large and small facilities to be fairly compared, assuming that, all else being equal, the overall number of occupational injuries at a workplace over a given time period will generally be directly proportional to the number of employees working there. Likewise, when calculating transportation accident rates, the number of transportation accidents for a given vehicle or cargo type is often divided by either the number of miles traveled or by the number of shipments of that type in order to normalize the accident rate.

Likewise, this study builds on Wharton's analysis by normalizing the accident totals. However, since hazardous chemical facilities vary so greatly in size, number of processes, chemical quantities stored and produced, operating schedule, and other characteristics, it is difficult to say which single divisor best represents the number of accident opportunities over the full spectrum of facilities represented in RMP*Info.

This study uses the number of processes and aggregate chemical quantity as normalization factors. In choosing these factors, the assumptions implied are that, all else being equal, a chemical contained in a large number of processes or in large quantities has more opportunities to be accidentally released than does a chemical contained in fewer processes or smaller quantities. While these divisors are certainly not perfect, they appear to be reasonable. Other divisors than these, such as the quantities of each chemical produced (instead of the amounts stored) might also be chosen as normalization factors.

6.1.1. Accident Rate by Chemical Type

Table 4 indicates the rate of accidents for each chemical[+] divided by the total number of processes in which the chemical is present, and the rate of accidents for that chemical divided by the total quantity of the chemical in all processes containing it.

[+] Table 4 contains information on only those RMP chemicals involved in more than ten accidents over the five-year reporting period, as reported in the Wharton working paper.

Chemical Name (listed in order of un-normalized accident frequency)	Number of Accidents per Process per Year	Rank	Number of Accidents per Mlbs stored per Year	Rank
1. Ammonia	0.016	16	0.014	14
2. Chlorine	0.022	13	0.16	7
3. Hydrogen Fluoride	0.064	3	0.27	4
4. Flammable Mixture	0.007	24	0.00075	24
5. Chlorine Dioxide	0.155	1	1.97	2
6. Propane	0.006	25	0.0012	20
7. Sulfur Dioxide	0.013	20	0.011	15
8. Ammonia (aqueous)	0.017	15	0.018	13
9. Hydrogen Chloride	0.060	4	0.25	5
10. Hydrogen	0.031	10	0.24	6
11. Methane	0.027	11	0.0064	17
12. Butane	0.011	21	0.00089	23
13. Ethylene Oxide	0.027	12	0.045	11
14. Hydrogen Sulfide	0.067	2	0.50	3
15. Formaldehyde	0.009	23	0.024	12
16. Isobutane	0.010	22	0.011	21
17. Pentane	0.013	18	0.0052	18
18. Titanium tetrachloride	0.056	5	0.090	9
19. Phosgene	0.044	6	2.49	1
20. Nitric Acid	0.038	8	0.047	10
21. Ethane	0.014	17	0.00071	25
22. Oleum	0.022	14	0.011	16
23. Ethylene	0.014	19	0.00089	22
24. Vinyl Chloride	0.042	7	0.0051	19
25. Trichlorosilane	0.034	9	0.10	8

Table 4 - Normalized Accident Rates for RMP Chemicals, 1994 - 1999

Table 4 yields a number of interesting results. First, many of the substances with the highest gross accident totals are not among the substances with the highest normalized accident rates (and vice versa). For example, ammonia, chlorine, flammable mixtures, and propane rank first, second, fourth, and sixth, respectively, in terms of gross number of accidents, but all rank much lower when their accident total is normalized by either number of processes or chemical quantity. In fact, of these chemicals, only chlorine ranks in the top ten by either normalized rate measure (it ranks 7th in number of accidents per Mlbs stored per year).

Next, several chemicals have notably high normalized accident rates relative to the other chemicals listed. The most obvious example is chlorine dioxide, which in terms of number of accidents per process-year, has an accident rate 7 times the median, and in terms of number of accidents per Mlbs stored per year, has an accident rate over 40 times the median. Other chemicals that have relatively high normalized accident rates include hydrogen sulfide, hydrogen fluoride, phosgene, and hydrogen chloride.

Lastly, table 4 indicates that in general, the substances with the highest normalized accident rates are all toxic, while most of the substances with the lowest accident rates are flammable. In both rankings in table 4, the five highest accident rates are due to toxic chemicals.

6.1.2. Accident Rates by Industrial Sector

Table 5 is similar to table 4, except that it indicates normalized accident rates by NAICS code for the 25 NAICS codes having the highest gross number of accidents (Table 5 does not include the accident rate in terms of chemical quantity for each NAICS code, since a single NAICS code may be associated with several different RMP chemicals, so it is not possible to associate the aggregate quantity of a single chemical with each NAICS code).[+]

[+] It should also be noted that some of the individual NAICS codes in table 5 are closely related, and might fairly be combined when analyzing the accident rate from a particular industrial sector. For example, NAICS code 311411, Frozen Fruit, Juice, and Vegetable Manufacturing, is a subset of NAICS code 31141, Frozen Food Manufacturing. They are reported separately here because these statistics reflect the codes that individual facilities assigned to their own processes. One reviewer of this paper has indicated that some facilities apparently assigned incorrect NAICS codes to their processes or facilities. This is undoubtedly true, and such errors have not been accounted for in this analysis. When this error is accounted for, the accident rate statistics reported here may need to be revised.

NAICS Code and Description (listed in order of un-normalized accident frequency)	Number of Accidents per Process per Year	Rank
32411 - Petroleum Refineries	0.024	18
22131 - Water Supply and Irrigation Systems	0.011	24
22132 - Sewage Treatment Facilities	0.013	22
325199 - All Other Basic Organic Chemical Manufacturing	0.027	17
325188 - All Other Basic Inorganic Chemical Manufacturing	0.050	8
42269 - Other Chemical and Allied Products Wholesalers	0.029	16
42291 - Farm Supplies Wholesalers	0.004	25
325181 - Alkalies and Chlorine Manufacturing	0.116	3
325311 - Nitrogenous Fertilizer Manufacturing	0.086	5
311615 - Poultry Processing	0.053	7
32511 - Petrochemical Manufacturing	0.034	14
32211 - Pulp Mills	0.101	4
49312 - Refrigerated Warehousing and Storage Facilities	0.018	20
311611 - Animal (except poultry) Slaughtering	0.134	1
211112 - Natural Gas Liquid Extraction	0.013	23
325211 - Plastics Material and Resin Manufacturing	0.016	21
311411 - Frozen Fruit, Juice, and Vegetable Manufacturing	0.064	6
311612 - Meat Processed from Carcasses	0.048	9
322121 - Paper (except newsprint) Mills	0.132	2
32512 - Industrial Gas Manufacturing	0.023	19
32519 - Other Basic Organic Chemical Manufacturing	0.036	13
32518 - Other Basic Inorganic Chemical Manufacturing	0.040	12
32532 - Pesticide and Other Agricultural Chemical Manufacture	0.033	15
31152 - Ice Cream and Frozen Dessert Manufacturing	0.044	10
31141 - Frozen Food Manufacturing	0.044	11

Table 5 - Normalized Accident Rates for RMP Process NAICS Codes, 1994 - 1999

At this point, no firm conclusions can be drawn from these results. There are a number of possible explanations for why these measures might favor certain chemicals or industrial sectors over others, and some of these are unrelated to chemical hazards or risk management practices. For example, the accident rate for a chemical or industrial sector with a relatively low gross accident total can be greatly affected by a small increase in that total - perhaps even by accidents attributed to a single facility[+]. Alternatively, when normalized with other (and presumably better) factors, some seemingly high rates may prove to be insignificant. On the other hand, if after eliminating other explanations these results are upheld, they may indicate a need to improve the safety practices or other hazard controls associated with the chemicals or industrial sectors having the highest accident rates. Clearly, further study in this area is needed.

7. OCA INFORMATION

Perhaps the most interesting, and, for reasons already stated, certainly the most closely guarded, information in the RMP*Info database is the Offsite Consequence Analysis information. OCA information consists of data related to worst-case and alternative release scenarios. These scenarios represent hypothetical estimates of the potential consequences of accidental chemical releases occurring under specified atmospheric and topographic conditions. The OCA data reported in the RMP include the following:

- Name, physical state, and percent weight (if a mixture) of chemical involved in the release
- Analytical model used to perform the analysis
- Type of scenario (e.g., gas release, explosion, fire, etc.)
- Quantity released
- Release rate and duration
- Atmospheric conditions and topography
- Distance to toxic or flammable endpoint
- Residential population living within the endpoint distance.
- Other public or environmental receptors within the endpoint distance (e.g., schools, hospitals, churches, state or national parks, etc.)
- Mitigation measures accounted for in conducting the analysis

---

[+] This effect was limited by considering only those chemicals and industrial sectors involved in the greatest number of accidents over the five year reporting period, but even taking this into account, some of the results in tables 4 and 5 result from relatively small samples.

OCA information does not include any estimate of the probability of a scenario actually occurring. However, OCA scenarios are considered to be unlikely. Worst-case scenarios in particular are considered to be very unlikely. This is because they are based on the assumption of a very large accidental release (an unlikely event under any conditions) occurring under a combination of atmospheric conditions (low wind speed and stable atmosphere) that occurs rarely and does not persist for very long. Further, the regulatory requirements for conducting the worst-case scenario analysis prohibit facilities from accounting for any active release mitigation features such as water deluge systems and automatic shutoff valves that might significantly reduce the effects of an actual release. Facilities may, however, account for passive mitigation features such as containment dikes and building enclosures.

7.1. Worst Case Scenarios

EPA defined the worst-case scenario as the release of the largest quantity of a regulated substance from a single vessel or process line failure that results in the greatest distance to an endpoint. In broad terms, the distance to the endpoint is the distance a toxic vapor cloud, heat from a fire, or blast waves from an explosion will travel before dissipating to the point that serious injuries from short-term exposures will no longer occur. For toxic worst case scenarios, EPA specified certain input parameters for conducting the analysis, such as wind speed and atmospheric stability. For flammable worst case scenarios, EPA specified that the scenario consist of a vapor cloud explosion.

EPA placed numerous specifications on worst-case scenarios in order to simplify the analysis and to ensure comparability among facilities. However, EPA did not specify that any particular analytical model be used to conduct the analysis. When comparing worst-case scenarios, this is a potentially confounding variable, since the same scenario analyzed using two different analytical models can sometimes produce significantly different results. Fortunately, nearly 70% of worst case scenarios were conducted using EPA OCA modeling,[+] and most others

---

[+] EPA published several guidance documents and one computer software program to assist facilities in conducting OCA modeling. Foremost among these is *Risk Management Program Guidance for Offsite Consequence Analysis*, which contains generic OCA lookup tables and modeling equations for all RMP-regulated chemicals. EPA also published several industry-specific guidance documents which contain lookup tables for regulated chemicals of particular concern to certain large industry sectors regulated under the RMP rule. Additionally, EPA and the National Oceanic and Atmospheric Administration together produced a software program, called RMP*Comp, which conducts OCA modeling according to the same methodologies were conducted using other widely-accepted analytical models that usually produce similar results, so inconsistencies in OCA data resulting from model choice are somewhat limited.

7.1.1. Endpoint distances

In general, toxic release scenarios result in greater endpoint distances than flammable worst case scenarios. This is mainly due to the fact that for flammable substances, EPA specified the endpoint distance to be the distance from the source of a vapor cloud explosion to the point where the overpressure from the explosion falls to 1 psi. For most regulated flammable substances, this distance tends to be significantly shorter than the toxic endpoint distance resulting from the release of a similar quantity of the most prevalent RMP toxic chemicals.

Figures 2 and 3 are frequency histograms of endpoint distance for RMP toxic and flammable chemical process worst case scenarios, respectively. Each bar represents the number of processes having endpoint distances in a particular distance interval. Note that both graphs are positively skewed distributions with long right-hand tails, indicating that relatively few processes of either type result in extremely long endpoint distances. However, while the shapes of the two distributions are similar, flammable scenarios are differentiated from toxics by their significantly shorter endpoint distances. The median endpoint distance for toxic worst case scenarios is 1.6 miles, while the median endpoint distance for flammable worst case scenarios is 0.4 miles. This reflects the differences in the physical nature of the two hazard classes and their worst case scenarios, as described above.

---

contained in the EPA guidance documents. OCA results achieved using any of these sources are derived from the same set of models.

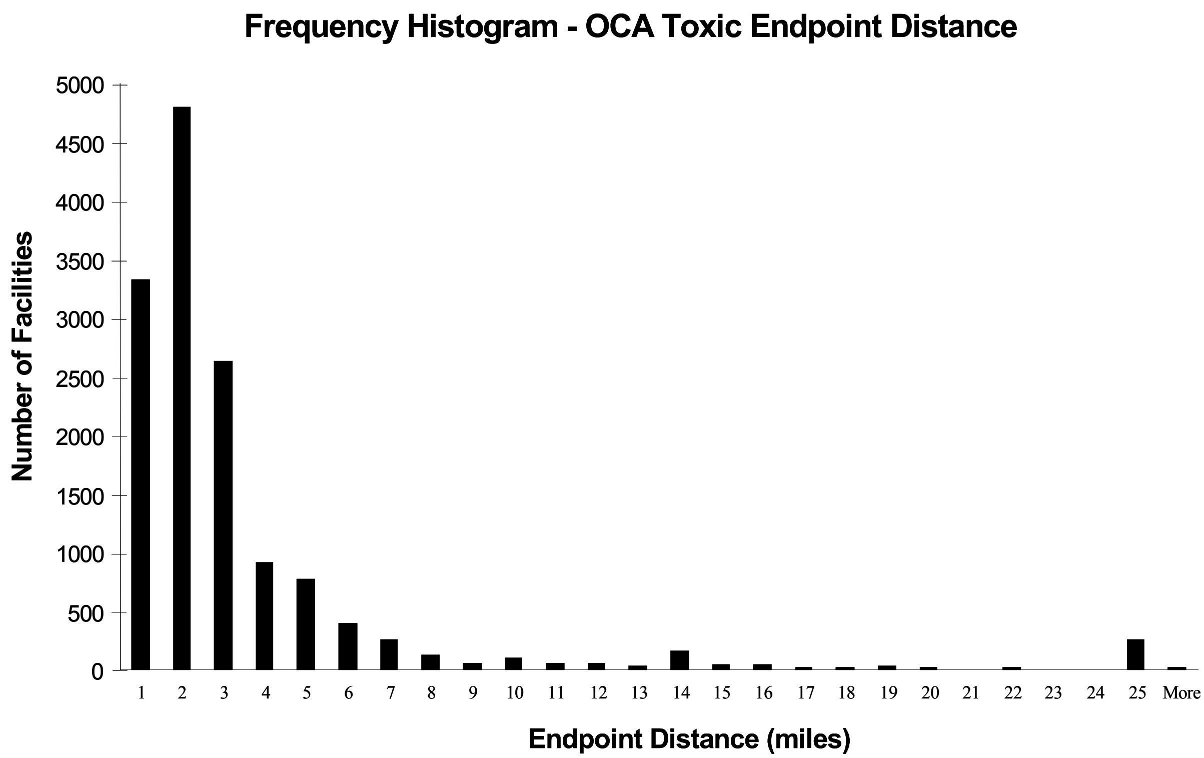


Figure 2: Frequency Histogram - Endpoint Distance for Toxic Worst Case Scenarios

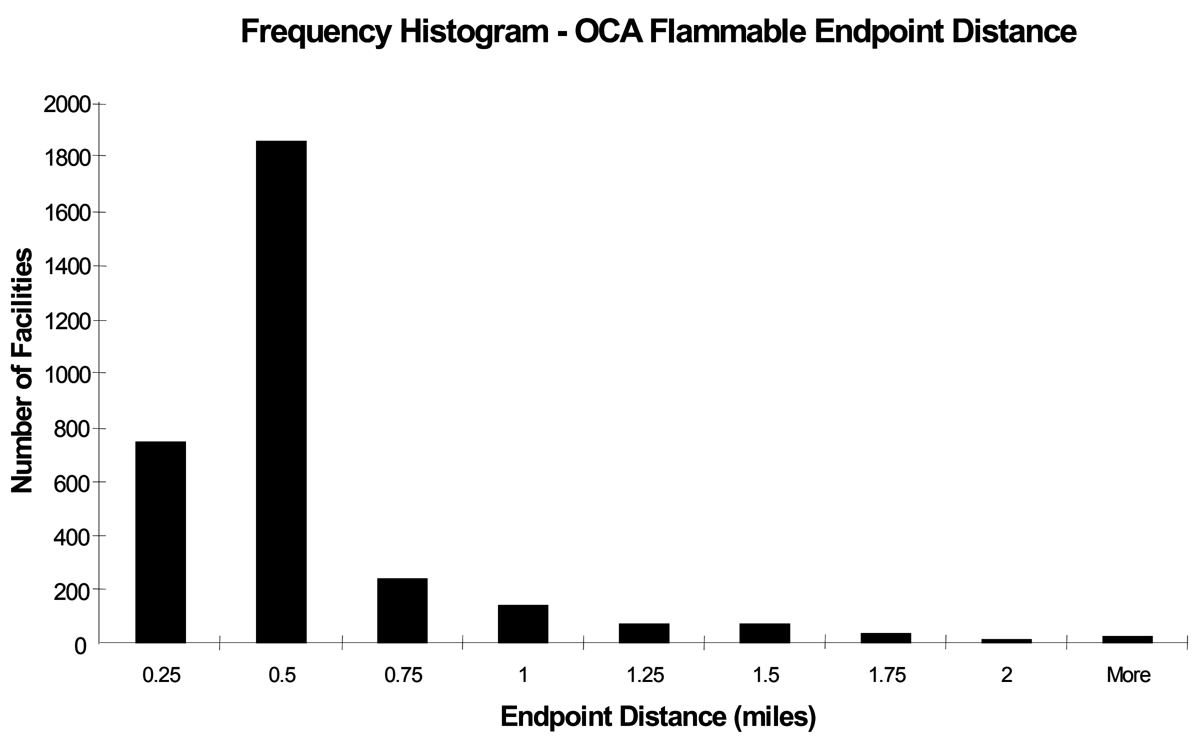


Figure 3: Frequency Histogram - Endpoint Distance for Flammable Worst-Case Scenarios

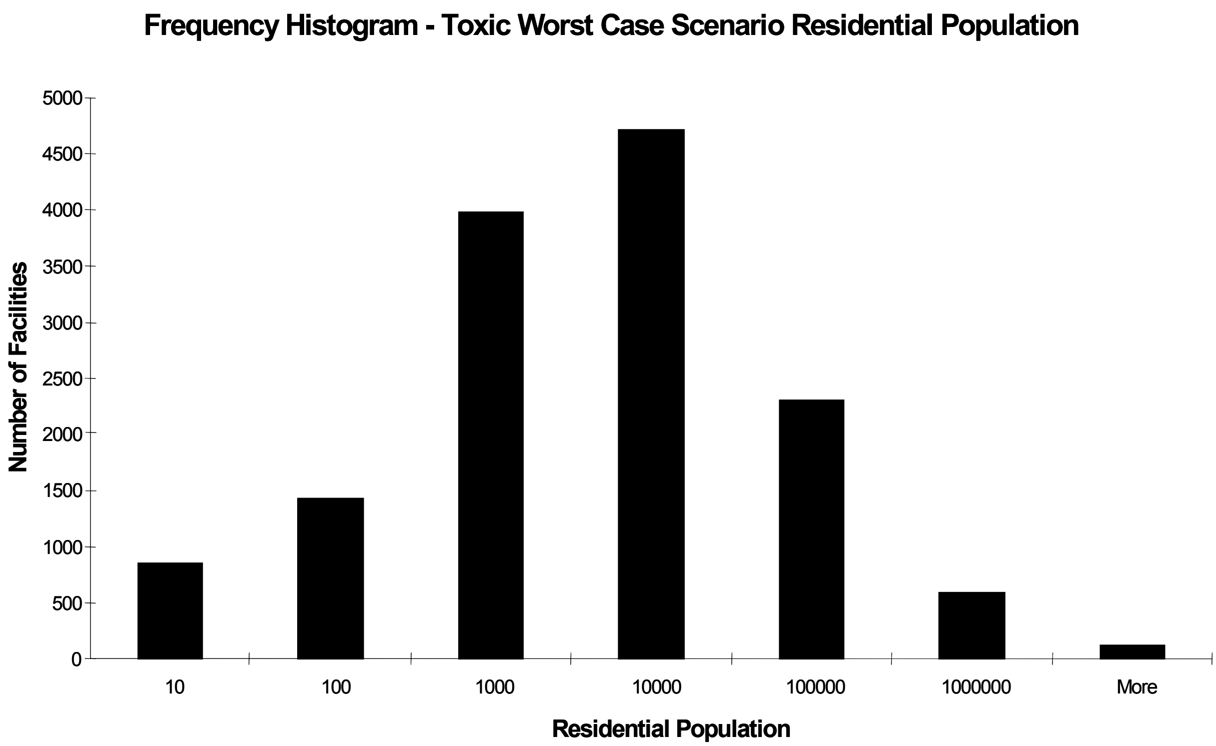
In the distribution of toxic worst case scenario endpoint distances (figure 2) there are two class intervals representing long endpoint distances that contain a large number of facilities relative to surrounding class intervals. These occur at 14 and 25 miles, respectively. The high number of facilities in both class intervals is primarily due to the prevalent use of 90-ton rail tank cars for chlorine storage in the United States. When the release of 90 tons of chlorine is modeled using EPA's OCA lookup tables or RMP*Comp modeling software under urban terrain conditions, the resulting endpoint distance is 14 miles.

When the same release is modeled under rural terrain conditions, the resulting endpoint distance is 25 miles. 25 miles also happens to be the upper cutoff of EPA's lookup tables and RMP*Comp software for all chemicals, so this interval also contains the OCA results from scenarios involving large releases of other highly toxic, highly volatile chemicals. Other chemicals that result in multiple scenarios with endpoint distances of at least 25 miles include anhydrous ammonia (33 scenarios with endpoint distance at least 25 miles), hydrogen fluoride (32 scenarios), sulfur dioxide (22), chlorine dioxide (8), oleum (7), sulfur trioxide (5), hydrogen chloride(4), hydrocyanic acid (3), phosgene (2), propionitrile (2), bromine (2), and acrylotnitrile (2).

7.1.2. Potentially Affected Population

Under the RMP rule, the population potentially affected by a release is defined as the residential population inside a circle with radius equal to the endpoint distance. Therefore, for a given population density, the population inside the "worst case circle" will increase according to the area of the circle, or proportionally to the square of the endpoint distance. Naturally, population density is not constant, and other factors such as terrain, geography, zoning, etc., also affect this correlation. But in general, one would expect to see population increase exponentially with increasing endpoint distance.

Consequently, the disparity between toxic and flammable worst case scenarios as measured by potentially affected population should be even more pronounced than when measured by endpoint distance. Figures 4 and 5, which are histograms of the potentially affected population for toxic and flammable worst case scenarios, respectively, confirm this notion. In fact, the median population for flammable worst case scenarios is 15 people, while the median for toxic worst case scenarios is 1500 people - two full orders of magnitude greater, whereas the difference in median values for endpoint distance is only a factor of four.



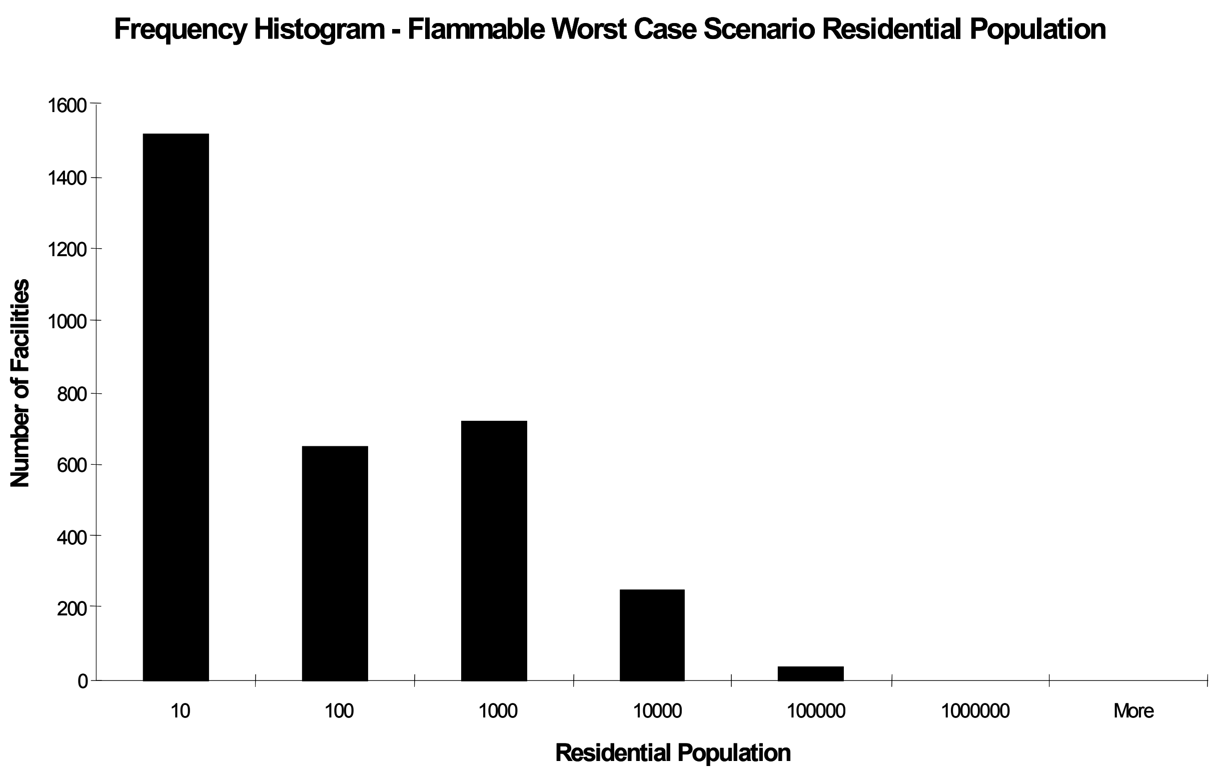


Figure 4: Frequency Histogram - Toxic Worst Case Scenario Residential Population

Figure 5: Frequency Histogram - Flammable Worst Case Scenario Residential Population

In evaluating these results, it is again important to consider the physical difference between toxic and flammable worst case scenarios. Toxic chemical releases generally result in plume that travels in the downwind direction.[+] Should an accidental release occur, only the portion of the population covered by the plume could feel its effects. This population necessarily represents only a fraction of the population inside the worst case circle.

Flammable worst-case scenarios, on the other hand, consist of an overpressure blast wave which generally travels in all directions from the source. While terrain and obstructions will affect the propagation of the blast wave to some degree, in general everyone within the worst case circle would feel the effects of a vapor cloud explosion resulting from a flammable substance release. So, while figures 4 and 5 indicate a very large disparity between potentially affected population for toxic and flammable worst case scenarios, this disparity is, in fact, not as great as it may appear.

It is interesting to note that the distribution of residential population potentially affected by toxic worst case scenarios appears to be log-normal in shape, but that the flammable worst case scenario distribution is clearly not log-normal[++]. It is unclear why the two distributions have such markedly different shapes, but the difference may be due in part to the fact that each distribution is actually a collection of underlying distributions, one for each different chemical represented in the database. Further, while EPA modeling (i.e., EPA lookup tables and RMP*Comp software) was used to obtain the majority of OCA results in the database, the fact that several other analytical models were used to obtain the remaining results probably induces some artificial variations in these distributions.

7.2. Alternative Release Scenarios

The RMP regulation provides much greater flexibility in defining alternative release scenarios than worst-case scenarios. The only "hard" requirements for alternative release scenarios are that the scenario must be more

---

[+] Under certain conditions, the direction that a toxic gas plume travels may be dictated more by the elevation of surrounding terrain than by wind direction.

[++] Due to the extremely wide range of potentially affected population (0 to 12 million for toxic worst case scenarios) both distributions are plotted on a logarithmic scale.

likely to occur than the worst-case scenario, and that it reach an endpoint offsite, unless no such scenario exists. Facilities may account for both passive and active mitigation measures that may be in place when calculating the potential consequences from an alternative release scenario. Alternative scenarios are generally considered to be more representative of actual emergency scenarios that might occur.

Since there are no objective criteria for developing alternative scenarios, the results vary widely, even among similar facilities. For this reason, it is not clear what may be learned from broad statistical investigation of alternative release scenario data. Except for including the basic parameters of the data distribution in Table 6, this study has not attempted any in-depth analysis of alternative release scenario data.

Distance or Population	**Type of Scenario**			
	Toxic Worst Case	Toxic Alternative Release	Flammable Worst Case	Flammable Alternative Release
Endpoint Distance (miles)				
Mean	2.9	0.45	0.44	0.14
Median	1.6	0.22	0.40	0.1
Mode	1.3	0.1	0.40	0.1
Standard Deviation	4.2	0.65	0.40	0.18
Range	60	18	6.9	4.4
Potentially Affected Population				
Mean	40247	1024	668	87
Median	1500	40	15	0
Mode	0	0	0	0
Standard Deviation	2.8×10^5	1.5×10^4	3.8×10^3	9.2×10^2
Range	1.2×10^7	1.6×10^6	1.2×10^5	4.0×10^4

Table 6 - Descriptive Statistics for Worst-Case and Alternative Release Scenarios

Table 6 indicates basic descriptive statistics for endpoint distances and populations for toxic and flammable worst-case and alternative release scenarios. As expected, alternative release scenarios for both toxic and flammable scenarios have, in general, significantly shorter endpoint distances and affect smaller populations than do the worst case scenarios for the same hazard class. And, as flammable worst case scenarios are generally less severe than toxic worst case scenarios, so are flammable alternative scenarios less severe than toxic alternative scenarios (and for similar reasons).

Table 6 also effectively highlights the much larger scale of toxic scenarios relative to flammable scenarios. All statistical measures for the distribution of flammable scenarios are far lower than those for the distribution of toxic scenarios. In fact flammable *worst case* scenarios are, on average, even less severe than toxic *alternative* scenarios. Notably, most flammable alternative release scenarios would not even affect any members of the off-site public (i.e., the median population value for flammable alternative scenarios is zero).

8. CONCLUSIONS

Catastrophic chemical accidents, while fortunately rare, nevertheless can have a great and lasting (perhaps even disproportionate) impact on the public perception of chemical facility risk. Information such as the RMP*Info database might provide us with a better understanding of this risk and thereby help us to prevent accidents. This paper, which supplements the previous work done by Wharton, is a preliminary characterization of the RMP*Info database, and is therefore only a first step toward investigating the data for clues to the nature and causes of catastrophic chemical accidents. Much work remains to be done. Some questions for further study include:

- Do the data reveal the need for any policy, practice, or regulatory changes with regard to particular chemicals, industrial sectors, processes, or equipment?

- Do correlations exist between accident history data and other data elements (in RMP*Info or other databases) that might serve as predictors of accident-prone or accident-free performance?

- Does the database constitute a large enough sample of chemical facilities to determine risk distributions with significant confidence to make decisions about low-frequency, high-consequence events?

- Do the accident history data contain enough information to identify any trends or patterns in accidents, or is more data needed?

- What changes to the database or RMP regulation might be necessary to correct deficiencies in the database or make the data more meaningful?

The full value in this database can only be realized if it is made available to organizations with the willingness and capability to rigorously analyze the data and publish the results. Researchers at Wharton have stated their intent to conduct further investigations. Hopefully, when the full RMP*Info database becomes more widely available, other organizations will make similar contributions.

REFERENCES

[1] Public Law 99-499, Superfund Amendments and Reauthorization Act of 1986, Title III, Emergency Planning and Community Right-to-Know Act.

[2] Public Law 101-549, Clean Air Act Amendments of 1990, Title III, Sections 304, 301, November 15, 1990.

[3] 29 CFR Part 1910, Process Safety Management of Highly Hazardous Chemicals; Explosives and Blasting Agents, Final Rule, 57 FR 6356, February 24, 1992.

[4] 40 CFR Part 68, Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act, Section 112(r)(7); List of Regulated Substances and Thresholds for Accidental Release Prevention, Stay of Effectiveness; and Accidental Release Prevention Requirements: Risk Management Programs Under Section 112(r)(7) of the Clean Air Act as Amended, Guidelines; Final Rules and Notice, 61 FR 31668, June 20, 1996.

[5] U.S. Environmental Protection Agency, RMP*Info Database, Ariel Rios Building, 1200 Pennsylvania Avenue., NW, Washington, D.C., 20460.

[6] U.S. Environmental Protection Agency, Chemical Emergency Preparedness and Prevention Office, Assessment of the Incentives Created by Public Disclosure of Off-site Consequence Analysis Information for Reduction in the Risk of

Accidental Releases, April 18, 2000.

[7] U.S. Department of Justice, Department of Justice Assessment of the Increased Risk of Terrorist or Other Criminal Activity Associated with Posting Off-Site Consequence Analysis Information on the Internet, April 18, 2000.

[8] Public Law 106-40, Chemical Safety Information, Site Security, and Fuels Regulatory Relief Act, August 5, 1999.

[9] 40 CFR Chapter IV, Accidental Release Prevention Requirements; Risk Management Programs Under the Clean Air Act Section 112(r)(7); Distribution of Off-Site Consequence Analysis Information; Final Rule, 65 FR 48108, August 4, 2000.

[10] P. Kleindorfer, H. Feldman, and R. Lowe, Epidemiology and the U.S. Chemical Industry: Preliminary Results from RMP*Info, Center for Risk Management and Decision Processes, Wharton School, University of Pennsylvania, March 6, 2000.

Appendix A: Five-Year Accident History Information

Selected Results from "Accident Epidemiology and the U.S. Chemical Industry: Preliminary Results from RMP*Info," by Paul R. Kleindorfer, Harold Feldman, and Robert A. Lowe, Working Paper 00-01-15, Center for Risk Management and Decision Processes, The Wharton School, University of Pennsylvania, March 6, 2000.

Frequency of Accidents at Individual Facilities

Number of Accidents at Facility	Number of Facilities in RMP*Info with the Indicated Number of Accidents in the Reporting Period	Total Accidents Represented
1	799	799
2	193	386
3	66	198
4	28	112
5	26	130
6	11	66
7	7	49
8	4	32
9	1	9
10	3	30
11	2	22
13	1	13
14	1	14
15	1	15
17	1	17
21	1	21
Totals	1145	1913

Accidents Reported in RMP*Info by Chemical Involved in the Accident for the Entire Period 1994-1999

Chemical Name	Number of Accidents
Ammonia (anhydrous)	656
Chlorine	518
Hydrogen Fluoride	101
Flammable Mixture	99
Chlorine Dioxide	55
Propane	54
Sulfur Dioxide	48
Ammonia (concentration 20% or greater)	43
Hydrogen chloride (anhydrous)	32
Hydrogen	32
Methane	30
Butane	26
Ethylene oxide	19
Hydrogen Sulfide	19
Formaldehyde	17
Isobutane	17
Pentane	17
Titanium tetrachloride	15
Phosgene	12
Nitric Acid (conc 80% or greater)	12
Ethane	12
Oleum	11
Ethylene	11
Vinyl chloride	11
Trichlorosilane	11
Methyl chloride	10

Accidents Reported in RMP*Info by Chemical Involved in the Accident for the Entire Period 1994-1999 (continued)

Chemical Name	Number of Accidents
Toluene diisocyanate	10
Propylene	10
Acrylonitrile	8
Hydrochloric acid	8
1,3-Butadiene	8
Epichlorohydrin	7
Bromine	7
Isopentane	7
Propylene oxide	6
Sulfur trioxide	6
Trimethylamine	6
Carbon disulfide	5
Ethylenediamine	5
Vinyl acetate monomer	5
Hydrocyanic acid	4
Cyclohexylamine	4
Dimethylamine	4
Silane	4
Chloroform	3
Methyl mercaptan	3
Phosphorous oxychloride	3
Acetylene	3
Methylamine	3
2-Methylpropene	3
Methyltrichlorosilane	2
Allyl alcohol	2
Hydrazine	2

Accidents Reported in RMP*Info by Chemical Involved in the Accident for the Entire Period 1994-1999 (continued)

Chemical Name	Number of Accidents
Crotonaldehyde	2
Acetaldehyde	2
Isopropylamine	2
Isoprene	2
Dichlorosilane	2
1,1-Dimethylhydrazine	1
Dimethyldichlorosilane	1
Toluene 2,6-diisocyanate	1
Acrolein	1
Chloromethyl methyl ether	1
Toluene 2,4-diisocyanate	1
Boron Trifluoride	1
Hydrogen selenide	1
Arsine	1
Nitric oxide	1
CBI Acids	1
Ethyl chloride	1
Ethyl mercaptan	1
Vinylidene Fluoride	1
1-Butene	1
Vinyl methyl ether	1
Tetrafluoroethylene	1
Propadiene	1
2-Butene-cis	1
2-Butene-trans	1
Butene	1
Nitrogen Tetroxide	1

Accidents Reported in RMP*Info by NAICS Code of the Process Involved in the Accident for the Entire Period 1994-1999 (Most frequently occurring NAICS codes only)

NAICS Description	NAICS Code	Number of Accidents
Petroleum Refineries	32411	192
Water Supply and Irrigation Systems	22131	116
Sewage Treatment Facilities	22132	110
All Other Basic Inorganic Chemical Manufacturing	325188	89
All Other Basic Organic Chemical Manufacturing	325199	89
Other Chemical and Allied Products Wholesalers	42269	87
Farm Supplies Wholesalers	42291	85
Alkalies and Chlorine Manufacturing	325181	80
Nitrogenous Fertilizer Manufacturing	325311	68
Poultry Processing	311615	67
Petrochemical Manufacturing	32511	55
Pulp Mills	32211	54
Refrigerated Warehousing and Storage Facilities	49312	50
Animal (except Poultry) Slaughtering	311611	47
Natural Gas Liquid Extraction	211112	34
Plastics Material and Resin Manufacturing	325211	34
Frozen Fruit, Juice, and Vegetable Manufacturing	311411	32
Meat Processed from Carcasses	311612	31
Paper (except Newsprint) Mills	322121	25
Industrial Gas Manufacturing	32512	24
Other Basic Organic Chemical Manufacturing	32519	24
Other Basic Inorganic Chemical Manufacturing	32518	22
Pesticide and Other Agricultural Chemical Manufacturing	32532	22
Ice Cream and Frozen Dessert Manufacturing	31152	19

Accidents Reported in RMP*Info by NAICS Code of the Process Involved in the Accident for the Entire Period 1994-1999 (Most frequently occurring NAICS codes only) (continued)

NAICS Description	NAICS Code	Number of Accidents
Frozen Food Manufacturing	31141	17
Paper Mills	32212	17
All Other Miscellaneous Chemical Product Manufacturing	325998	17
Fluid Milk Manufacturing	311511	15
Aluminum Sheet, Plate, and Foil Manufacturing	331315	13
All Other Chemical Product Manufacturing	32599	12
Other Warehousing and Storage Facilities	49319	12
Frozen Bakery Product Manufacturing	311813	11
Fertilizer (Mixing Only) Manufacturing	325314	11
Secondary Smelting and Alloying of Aluminum	331314	11
Dairy Product (except Frozen) Manufacturing	31151	10
Cheese Manufacturing	311513	10
Animal Slaughtering and Processing	31161	10

On-Site Injuries and Deaths Resulting from Accidents During Reporting Period

	Mean or Total	**Standard Deviation**	**Minimum**	**Maximum**	**Number of Observations**
On-Site Injuries to Workers/Contractors					
Total On-Site Injuries	1,897				1,912
Injuries per Accident	.9922	2.810	0	67	1,912
Injuries per FTE per Accident	.0202	.0784	0	1	1,896
On-Site Deaths to Workers/Contractors					
Total On-Site Deaths	33				1,911
Deaths per Accident	.0173	.2224	0	6	1,911
Deaths per FTE per Accident	.0003	.0071	0	0.25	1,895

Property Damage and non-Medical Off-Site Consequences Resulting from Accidents During Reporting Period

	Mean or Total	Standard Deviation	Min	Max	Number of Observations
On-Site Property Damage ($ Millions)					
Total On-Site Damage	$1,006				1907
Damage per Accident	$0.528	$6.716	$0	$219	1907
Off-Site Property Damage ($ Millions)					
Total Off-Site Damage	$11				1907
Damage per Accident	$0.006	$0.109	$0	3.8	1907

Property Damage and non-Medical Off-Site Consequences Resulting from Accidents During Reporting Period (continued).

	Mean or Total	Standard Deviation	Min	Max	Number of Observations
Off-Site Consequences					
Total Number of Evacuations	154				1908
Total Number of Evacuees in all Accidents	25,745				1908
Number of Evacuees per Accident	13.49	122.02	0	3,000	1908
Total Number of Accidents Involving Shelter in Place	97				1909
Total Number of Individuals Confined to Shelter in Place in All Accidents	198,460				1909
Number of Individuals Confined to Shelter in Place per Instance	104.0	1,956.4	0	55,000	1909
Number of Accidents with Effects on the Eco-System					
Fish or Animal Kills	17				1913
Minor Defoliation	54				1913
Water Contamination	24				1913
Soil Contamination	31				1913
Any Environmental Damage	101				1913

Pattern of Accidents over the Five-Year Period

Year	Number of Accidents in the Year	Percent of Total Accidents
1994	157	8.2%
1995	336	17.6%
1996	390	20.4%
1997	426	22.3%
1998	431	22.6%
1999	170	8.9%
Totals	1910	100.0%

Day-of-the-Week Pattern of Accidents

Day of the Week	Number of Accidents	Percent of Total Accidents
Sunday	153	8.0%
Monday	301	15.7%
Tuesday	313	16.4%
Wednesday	333	17.4%
Thursday	333	17.4%
Friday	271	14.2%
Saturday	209	10.9%
Totals	1913	100.0%

Plant Size vs. Accident Frequency

FTEs at Facility	Proportion of Facilities with Accidents	Number of Facilities
0	1.7%	888
1-10	2.9%	6,304
>10	13.0%	7,308
Total	7.9%	14,500