Accident History and Offsite Consequence Data from RMP*Info

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Draft: August 6, 2002
Based on a snapshot (6/29/01) of the RMP*Info

Abstract

RMP*Info is the database set up to store Risk Management Plans (RMPs) and Accident History data filed under Rule 112(r) of the Clean Air Act Amendments. This paper analyzes which facilities actually filed under the Rule and presents results on accident frequencies and severities available from the RMP*Info database. This paper also presents summaries of related results from RMP*Info on Offsite Consequence Analysis (OCA), an analytical estimate of the potential

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consequences of hypothetical worst-case and alternative accidental releases on the public and environment around the facility.

Keywords: Risk Management, Clean Air Act, Chemical Accident History, Accident Epidemiology

1. Introduction

The tragedy at Bhopal in December 1984, followed by a subsequent release of aldicarb oxime from a facility in Institute, West Virginia resulted in great public concern in the United States about the potential danger posed by major chemical accidents. This public concern was translated into law in section 112(r) of the 1990 Clean Air Act Amendments. Section 112(r) sets forth a series of requirements aimed at preventing and minimizing the consequences associated with accidental chemical releases. These requirements are the basis of EPA's rule on "Risk Management Programs for Chemical Accidental Release Prevention" (hereafter the "Rule"). The federal regulations promulgated under Clean Air Act section 112(r) apply to facilities (both public and private) that manufacture, process, use, store, or otherwise handle regulated substances at or above specified threshold quantities (which range from 500-20,000 pounds).[7]

The U. S. Environmental Protection Agency (EPA) estimated in its 1996 economic impact analysis justification study (EPA, 1996) to the Office of Management and Budget (OMB) that about 66,000 facilities nationwide would be regulated under the Rule, including many facilities not covered under the Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM). With some exceptions, the Rule requires all regulated facilities to prepare and execute a Risk Management Program (RMP), which contains the following elements:

[7] This is not meant to imply that any facility which does not meet threshold inventory requirements is completely exempt from the accidental release prevention provisions of 112(r) since a General Duty provision may still apply if the facility poses a potential hazard to the public.

1. A hazard assessment to determine the consequences of a specified worst case scenario and other accidental release scenarios on public and environmental receptors and provide a summary of the facility's five-year history of accidental releases

2. An accidental release prevention program designed to detect, prevent and minimize accidental releases

3. An emergency response program designed to protect human health and the environment in the event of an accidental release

The Rule (section 68.42) also requires that regulated facilities maintain the five-year history of accidental releases and submit this history to the EPA as part of their Risk Management Plan beginning June 21, 1999 and periodically update their submission every five years or when significant changes occur. The data reported here reflect the state of the RMP*Info database as of June 29, 2001, corrected for a few additional known errors (as described below in the next section).

The basic approach followed in this study has been the epidemiologic methodology known as retrospective cohort study design. Epidemiology is the study of predictors and causes of illness in humans. Its use in studying industrial accidents has been proposed in a number of quarters (e.g., Saari (1986), Rosenthal (1997)). The motivating idea is to study the demographic and organizational factors of those facilities whose Accident Histories are captured in RMP*Info to determine whether any of these factors have significant statistical associations with reported accident outcomes, positive or negative, just as one might use demographic or life-style data for human populations to determine factors that might be associated with the origin and spread of specific illnesses. The present study is only a first step in a longer-term research project. The purpose of this paper is to present descriptive statistics associated with RMP*Info and not to undertake analytic studies to determine precursors of accidents or their sequellae. The latter studies will be important elements of future research.

As several commentators have already noted, RMP*Info represents a significant step in understanding the scope of accidents in the chemical industry and in promoting more effective accident prevention and mitigation.[8] New business models have emphasized the importance of learning across facilities, based on benchmarking and best practices. Using data in RMP*Info, together with other organizational and financial data on the facilities and companies involved, is taking this approach to another level. Indeed, looking across the entire U.S. chemical industry, as well as across specific segments, technologies and chemicals therein, clearly holds the potential for detecting and validating factors predictive of severity and frequency of accidents. These models can then provide input for rational prioritization of risk management and regulatory policy initiatives designed to prevent future accidents.

The paper proceeds as follows. In section 2 we describe the nature of RMP*Info and the preliminary data screening undertaken to assure data quality for RMP*Info. Section 3 then describes the nature of the facilities that filed, with the Top 20 by chemical use and by the North American Industry Classification System (NAICS) Code listed explicitly. Section 4 presents results on accident frequency and severity, including details by chemical and NAICS Code. Section 5 presents some simple analyses on timing and location of accidents as well as on the size of plants (measured by number of full-time equivalent (FTE) employees) involved in these accidents. Section 6 focuses on the Offsite Consequence Analysis (OCA) based on worst-case and alternative release scenarios in the RMP*Info database. Conclusions are offered in section 7.

2. Introduction to RMP*Info and Preliminary Data Screening

This section describes the information collected under the Rule. We also discuss data quality issues here as a necessary precursor to our analysis in the rest of the paper. As promulgated in the Rule, the following are the data elements required to be filed and recorded in RMP*Info for each covered facility:

- Executive Summary: This must cover the nature of facility and its policies for prevention and emergency response, as well as a verbal summary of the facility's five-year accident history.
- Section 1: Facility identification information and basic demographics on the facility, its parent company and its covered processes, including a listing of regulated chemicals above threshold quantities at the facility and indications of whether the source is covered by various other regulatory processes (e.g., OSHA Process Safety Management (PSM) Standard, Emergency Planning and Community Right-to-Know Act (EPCRA) Section 302, Clean Air Act (CAA) Title V).
- Sections 2 and 4: Description of worst-case release scenarios for regulated toxic (Section 2) and flammable (Section 4) substances above threshold quantities at the facility.
- Sections 3 and 5: Description of alternative release scenarios for regulated toxic (Section 3) and flammable (Section 5) substances above threshold quantities at the facility.
- Section 6: Five-year accident history for the facility, including a separate record for each accidental release from covered processes that occurred during the five-year reporting period for the facility.

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[8] See, for example, Rosenthal (1997) and Mannan and O'Connor (1999) for discussions of the promise of using large-scale comparative data to determine robust predictors of accidents in the chemical industry.

- Sections 7 and 8: Prevention Program descriptions for Program 3 processes (Section 7) and Program 2 processes (Section 8), including details on hazard analysis methods, operating procedures, training, and other related information,, together with a list of the major hazards identified for these processes.

- Section 9: Details on the emergency response plan at the facility, including indications of which of several federal and state regulations on emergency response apply to the facility.

As of June 29, 2001, the RMP*Info database have 15,430 facilities filed. The vast majority (14,500 of 15,430) of facilities covered in this analysis filed their RMP data by the initial deadline of June 21, 1999, and some corrections were made on additions of new filers or exemptions of existing filers until June 29, 2001. Certain other facilities producing or utilizing flammable fuels such as propane sought legislative and judicial relief from the RMP requirements, and were granted a temporary judicial stay from RMP compliance and reporting requirements. And indeed many of these facilities were eventually excluded from the Rule under the Chemical Safety Information, Site Security and Fuels Regulatory Relief Act (PL 106-40) passed in August 1999. In January 2000, the judicial stay was lifted and an additional 930 facilities, primarily propane producing facilities, filed accident history data under the Rule.

The result of all of these developments in the implementation of the Rule is that the time window represented by RMP*Info is not uniform for all facilities. A facility, for example, that filed its RMP on May 10, 1999 could have interpreted the five-year history covered by the Rule to be May 11, 1994 through May 10, 1999. Other facility owners interpreted more precisely as given above, and anticipated filing updated RMPs if their facility had an accident between the time they filed and June 20, 1999. In addition, as will be discussed below, some facilities were initially exempt from filing, but eventually held to be covered by the Rule. These facilities then filed after the initial filing date of June 21, 1999, and their RMP reported accidents for the five-year period preceding their later filing date. Notwithstanding changes, the vast majority of the data represents accident histories for the period mid-1994 to mid-1999.

While as noted above, the original estimate of covered facilities expected to file under the Rule was 66,000, we will see in the data reported below that the number of facilities actually filing was, in fact, 15,430 (23.2% of the original estimate), with 1,205 of these facilities (7.8% of 15,430) reporting some 1,970 accidents over the five-year period of interest. A further temporary restriction in information available to the public was that worst case data, in the form of the required off-site consequence analysis (OCA) noted under (1) above, was not to be made available to other than "covered persons" in order to reduce the possibility that these data might be used by terrorists to target specific facilities. Members of the public can get limited access to OCA data for individual facilities by visiting any of 50 federal "reading rooms." The database itself has been named RMP*Info and, except for the OCA worst case data, was available to the public via the Internet after August 1999.[9]

Concerning accuracy and consistency, a first step in any epidemiologic study is the screening of data, and we therefore note some of the steps taken with respect to this critical issue in data quality assurance. In this regard, it is important to note that nearly all submissions under the Rule were electronic, with 97% of the final RMP submissions made using standardized software, entered on diskette and mailed to the EPA. While manual submissions using a standard paper form were allowed, these accounted for only 3% of the total.[10] Electronic submission is critical to

[9] However, since September 11, 2001, the EPA database is no longer available to the public on the Internet.
[10] Personal communication of 01/24/00 from Karen Schneider, who guided much of CEPPO's effort in data input and the quality assurance program surrounding RMP*Submit.

data quality since the data submission system, called RMP*Submit, used a standard data entry template and had a number of self-correcting and error checking mechanisms built into it to assure that the data submitted was in a standard format and met other consistency checks (such as range checks).[11] Notwithstanding the significant effort undertaken by EPA to assure the overall quality of the data, the research team also undertook its own data cleaning and screening checks. In particular, the following two steps were undertaken by the research team:

1. Extensive interviews with plant-level and corporate managers responsible for submitting the RMP data were undertaken during the period November, 1998 through June, 1999, to determine whether there were ambiguities in the minds of facility managers as to what data were required. The primary difficulties were with understanding the requirements for the OCA, both worst case and alternative scenarios. The managers at both large and small facilities generally exhibited a clear understanding of the requirements of the Rule and they showed a positive and constructive attitude towards the RMP process, where smaller companies typically relied on trade associations and consultants to assist them in this process. The effort expended on complying with the Rule was considerable. Indeed, data on some 10 companies collected as part of this pre-screening process indicated that, including internal and external consultants' time, person-hours dedicated to putting the data together for RMP*Info ranged from 200 hours for some small companies to nearly 3,000 hours for some large facilities.[12]

2. Standard approaches for quality assurance of data, commonly employed in epidemiologic studies, were employed to look for data errors. For all variables included in this report, frequency distributions were reviewed to look for unusual or unexpected values ("outliers.") Where appropriate, cross-tabulations were performed to look for internal inconsistencies in

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[11] It is not our purpose to review or comment on the extensive effort undertaken to assure data quality in the RMP process and the details of the software developed to assure data quality under the RMP*Submit system. The details of this can be found by consulting the extensive documentation provided by CEPPO at their website http://www.epa.gov/ceppo/.

[12] For restrictions on public access to RMP data, see Kleindorfer et al. (2000).

the data. Outliers were discussed with EPA staff, who reviewed these cases to determine their validity.[13]

Because the number of reported deaths is such an important data element, further checking was done of each accident in which non-employee deaths occurred. This led to the final result (reported in Table 7-8 below) that while there were 32 deaths among employees at reporting facilities, all of the originally reported 45 public responders deaths and 11 public deaths were data errors.[14] We have incorporated these corrections on deaths to public responders and other non-employees into our analysis. However, there may be corrections and revisions to RMP*Info at any time via the submission of a corrected RMP by any facility; other, less obvious changes to the database after June 29, 2001, will not be reflected in this report. In particular, in interpreting results from RMP*Info, it is critical to know the date of the last update incorporated in the analysis and any notable revisions, such as those above, undertaken to the data.

3. Plant Demographics for Facilities Reporting in RMP*Info

[13] An example of this quality assurance process may be informative. A frequency distribution of the number of full-time equivalent employees (FTEs) reported at each facility revealed a range from 0 to 48,000 FTEs. Eight hundred eighty-eight plants reported 0 FTEs and 14 plants reported over 15,000 FTEs. The authors of this report queried EPA staff about these outliers. EPA staff noted that all 14 of the facilities with over 15,000 FTEs were military bases and confirmed that these values were plausible. EPA staff hypothesized that the facilities with 0 FTEs might be related to specific industries. That led the authors to determine the NAICS codes of the facilities reporting 0 FTEs. The most common processes were Water Supply and Irrigation Systems (246 facilities), Farm Supplies Wholesalers (229), and Farm Product Warehousing and Storage Facilities (186). EPA investigated whether it is plausible for such facilities to report 0 FTEs. EPA staff responded, in part, to this question as follows: "Coops are usually large organizations, frequently covering several states, but certainly serving many communities with individual outlets. They reported having zero FTEs because they are reporting on a storage facility that is unmanned except for certain seasons. According to the way FTEs are calculated, if they have one person there for five months, they have less than 0.5 FTE and report zero employees." [Breeda Reilly, CEPPO, personal communication, December 14, 1999.] Further discussion with EPA staff addressed other categories of processes associated with 0 FTEs, until the research team and EPA staff were satisfied that the data were accurate.

[14] Breeda Reilly at EPA/CEPPO confirmed such errors. Four facilities reported total 45 public responders fatalities but they were reporting errors. There was no public responders death. In addition, two facilities reported total 11 on-site public fatalities and two facilities reported total 68 on-site public injuries. But, they turned out to be errors. In fact, there were zero incidents for on-site public fatalities and injuries.

This section reports the basic demographics of the facilities that filed under RMP*Info. There are 15,430 facilities in RMP*Info and there are 1,970 reported accidents in RMP*Info, with 1,205 facilities reporting at least one accident. However, the sample size for various analyses will not remain constant at 15,430 and 1,970, since some sites have multiple processes and some processes use multiple listed chemicals.

Tables 1-3 below list various characteristics of filers under the Rule. Table 1 lists the 20 most commonly reported chemicals, along with the number of plants using each chemical and the number of FTE employees at these facilities. Also listed are the total numbers of facilities reporting use of at least one listed toxic or one flammable chemical. The average facility employees reported 158 FTE, ranging from facilities with less than 0.5 FTE (recorded as 0 FTE in RMP*Info) to 48,000 FTE. Half of facilities have 11 FTEs or fewer. Of the top 20 chemicals in terms of reporting facilities, note that 11 are toxics and 9 are flammables.

Table 2 lists the 20 most commonly reported industrial sectors, along with the number of plants reporting each process and the number of FTE employees at these facilities. Industrial process is specified by the NAICS code of the facility reporting.

Table 3 lists the numbers and percentages of reporting facilities, which indicated that they were covered under various state and federal regulatory programs covering process safety, notification requirements and emergency response regulations. Table 3 also lists the maximum Prevention Program Level of any process at reporting facilities (this was computed by considering all processes at each reporting facility and taking the maximum of the Prevention Program Levels across all processes at a given facility).[15] We note that 7,209 (or 47%) of the reporting facilities had at least one process at level 3, requiring therefore a full Process Hazards Analysis to be undertaken and reported in the facility's RMP.

As noted in the introduction, there is a substantial difference between the number of facilities that were originally projected to file under the Rule (66,000) and the number of actual filers (15,430). While a full study of this matter is beyond the scope of the present paper, a few reasons should be noted. First, the original estimate was intended to be a conservative estimate to OMB to assure that the full costs of the regulatory burden imposed by the Rule would not be underestimated. Second, as noted, several large groups including propane distributors, were excluded by P.L. 106-40. Third, a number of companies are likely to have responded to the Rule by reducing their inventories below the specified threshold limits required for reporting. Finally, non-compliance is always a possible explanation for the observed results. Which of these or other explanations are valid in various industrial sectors is clearly an important area for future research.

4. Facility Accident Rates and Severities

Accident rates in RMP*Info (over the entire five-year reporting period). These are given in Tables 4-6. Table 4 provides data on the frequency of accidents at facilities in RMP*Info. In particular, we note that 1,205 facilities (7.8% of 15,430 facilities) had at least one accident during

[15] EPA has defined three different Prevention Program Levels to reflect the potential for public impacts and the level of effort needed to prevent accidents. Only minimal requirements are imposed on Program Level 1 processes, while Program Level 3 processes are subject to much higher compliance requirements; Program Level 2 processes face intermediate requirements. Program 3 processes are those processes that are either subject to OSHA's PSM standard or belong to nine specific SIC codes placed in Program 3 by the EPA.

the reporting period, and 355 facilities (2.3% of 15,430 facilities) had multiple accidents during the five-year reporting period. The cumulative incidence of accidents, expressed as a fraction of total reporting facilities, was 1970/15430 (or 12.8%). Thus, there was an average of just over 394 accidents per year over the period.

Table 5 reports all accidents by listed chemical involved in the accident for the 25 chemicals most frequently involved in accidents. The three most frequently involved chemicals were ammonia (anhydrous), chlorine, and flammable mixtures. Chemical frequencies ranged from 696 accidents for anhydrous ammonia facilities to a single accident for 22 listed chemicals. Exactly half (80) of the 160 chemicals listed under the Rule were involved in at least one accident during the reporting period. Table 6 lists accidents by NAICS Code of the process involved in the reported accident for the top 25 processes in terms of frequency of accidents.[16]

Tables 7-8 report the number of injuries and deaths for employees/contractors and non-employees, respectively. There were a total of 1,987 injuries and 32 deaths to workers/employees, and there were 167 injuries and 0 deaths to non-employees, including public responders. Of 1,969 accidents with data on injuries, 999 (51%) resulted in worker injuries and 18 (0.9%) in worker deaths; 21 accidents (1.1%) resulted in injuries to public responders; 0 resulted in deaths to public responders. Regarding non-employees, 15 (0.8%) resulted in injuries to members of the public on-site in the facilities; 0 resulted in deaths to members of the public on-site in the facilities; and there were no off-site deaths reported. Note, however, that there were 215 total hospitalizations and 6,057 individuals given other medical treatments.

[16] For greater detail on all chemicals and processes in reported accidents, see a Wharton Risk Center Working Paper (2002).

Table 9 notes the damage to property and the non-medical off-site consequences resulting from accidents during the reporting period. Property damages alone were in excess of $1 billion, and they do not include business interruption costs, including losses in shareholder value and lost business associated with accidents.[17] In particular, we note both the large number of community residents who have been affected by accidents (over 200,000 involved in evacuations and shelter-in-place incidents). The ecological consequences of the accidents are also reported in Table 9. 408 accidents (21%) resulted in any on-site property damage; 51 (2.6%) resulted in off-site property damage; 174 (8.8%) resulted in evacuations; and 97 (5.0%) resulted in individuals being sheltered in place.

5. Basic Descriptive Analysis of Accident History

Analytic studies are concerned with establishing statistical associations between predictor variables such as facility characteristics and outcome variables such as frequency and severity of accidents of facilities having various characteristics. We will only pursue the simplest such studies here, in the spirit of merely describing the basic characteristics of RMP*Info in this paper.[18] We report only univariable studies here (see Tables 10-12), relating overall accident rates to the time or location of their occurrence and to the size of plants as measured by FTEs. We begin by noting the frequency of accidents by year of occurrence and by the day of the week on which accidents occurred.

[17] These latter costs are likely to be larger, and perhaps much larger, than losses due to property damage. For a study of the full shareholder costs of environmental accidents, see Klassen and McLaughlin (1996).

[18] For a more detailed analysis of RMP*Info data relating facility characteristics and regulations to accident frequency and severity, see Elliott, Kleindorfer, and Lowe (2001).

Table 10 displays the incidence of reported accidents over the five years in RMP*Info.[19] The lower numbers for 1994, and 2001 are the obvious result of the fact that these years were only partly within the five-year reporting window for most companies. There is a natural tendency to compute accident incidence rates based on these data, e.g., accidents per plant year. However, this cannot be reliably done since there is no information in RMP*Info indicating the age of facilities reporting to it. All we know is that, if facilities reported, they existed as of the date they initially reported (or as of the earliest date specifically reflected in their RMP submission), but we do not know if they existed during the entire five-year time period prior to their initial submission. Without this information, it is not possible to compute the incidence rate of accidents per plant per year, nor to deduce anything about the general trend in accidents per plant per year.[20] It should be noted that if accident-prone plants from the early days of the reporting period went out of business prior to June 21, 1999 (and are therefore omitted from the database), then the actual trend in accidents over time could well be negative even though reported accidents in RMP*Info indicate the opposite. Given these uncertainties, we cannot state whether the incidence rate of accidents has increased or decreased over the last five years.

Table 11 reports the day of the week on which accidents in RMP*Info took place. A small peak in accident rates is noticeable in mid-week. Of course, one should not infer from this anything about "safe weekend operations" since we do not know how many of the facilities in RMP*Info

[19] Three accidents are omitted from this table because they were reported to occur in 1992 (2 cases) or 1993 (1 case). It is unclear if these represent data entry errors in the submissions, with the wrong date reported, or unnecessary reporting of accidents that occurred prior to requirements of the Rule. One accident was reported to occur in 1966 (1 case) but it was a data entry error. Breeda Reilly at EPA/CEPPO confirmed that the accident happened in 1996. We included the accident in our analysis.

[20] Of course, this might be done for particular sectors or technologies if plant ages for these sectors or technologies can all be reliably determined.

operated as intensively on weekends as they did during weekdays. Similarly, we do not know whether the lower number of accidents on Mondays and Fridays is a result of shorter periods of operation on these days, different work attitudes on these days, or other factors. Additional data would be required in order to study this issue. A number of other factors should also be considered in analyzing the temporal pattern of accidents, including seasonal manufacturing facilities, continuous versus batch operations, and specific process characteristics.

Next, we report results related to the size of plant, as measured by FTEs at the plant, and accident rates during the reporting period. Several caveats must be kept in mind in reviewing these data. First, these data do not account for many possible confounders with plant size. For example, we do not control for the inherent hazards in the processes in question and this could be a significant confounding influence on the statistical association of plant size and accident frequency and severity. Generally, a much more detailed analysis controlling for such factors as process hazard, OSHA PSM membership, and so forth, would be required in order to understand the nature of the association of plant size with accident frequency and severity.

With these cautions in mind, Table 12 shows the association of increasing plant size with a higher frequency of accidents. We separated the data into those facilities reporting 0 FTEs, between 1 and 10 FTEs and more than 10 FTEs. Plants with more employees are significantly more likely to have accidents ($p < 0.001$, chi-square for trend). As explained earlier (see footnote14), the FTE category "0" represents mostly seasonal or part-time farm operations that have less than 0.5 FTEs and, therefore, report 0 FTEs.

6. Offsite Consequence Analysis: Information and Analysis

Perhaps the most interesting, and certainly the most closely guarded, information in the RMP*Info database is the Offsite Consequence Analysis (OCA) 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 (i.e., scientific technique used to estimate the distance to which a toxic vapor cloud, overpressure blast wave, or radiant heat effects will travel)
- 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

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.

6.1. 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 (for most facilities, this is the amount contained in the largest vessel or pipe in the process).[21] In broad terms, the distance to the endpoint is the distance, based on a release of the specified quantity of material, that 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 consisted 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

[21] Usually, each facility has a single worst case scenario, but there are a couple of thousand facilities that must report more than one worst case scenario, for either of two reasons. First, facilities that have both toxic and flammable substances must report one worst

potentially confounding variable, since the same scenario analyzed using two different analytical models can sometimes produce significantly different results. However, most worst case scenarios were conducted using EPA OCA modeling.[22]

6.1.1. 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 1 and 2 are frequency histograms of endpoint distance for RMP toxic and flammable chemical process worst case scenarios, respectively. Each bar represents scenarios 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 shorter endpoint distances. The median endpoint distance for toxic worst case scenarios is 1.6 miles, while the median

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case scenario for each class of substance. Second, the rule requires facilities to report more than one worst case scenario when the facility has multiple processes that could affect significantly different off-site populations.

[22] 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,

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.

(Figure 1 and 2 here)

6.1.2. 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 as the square of endpoint distance.

Figures 3 and 4 are histograms of the potentially affected population for toxic and flammable worst case scenarios. 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 a plume that travels in the downwind direction.[23] Should an accidental release occur, only the portion of the population covered by the plume could feel its effects. This population usually represents only a minor fraction of the population inside the worst case circle. Therefore, the OCA generally over-estimates the impact of a toxic release.

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called RMP*Comp, which conducts OCA modeling according to the same methodologies contained in the EPA guidance documents. OCA results achieved using any of these sources are derived from the same set of models.

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 3 and 4 indicate a very large disparity between potentially affected population for toxic and flammable worst case scenarios, the disparity is, in fact, not as great as these figures indicate.

(Figure 3 and 4 here)

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[24]. 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.

6.2. 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

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[23] 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.

the scenario must be more likely to occur than the worst-case scenario and that it reaches 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. Except for including the basic parameters of the data distribution in Table 13, this study has not attempted any in-depth analysis of alternative scenario data.

Table 13 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, shorter endpoint distances and affect smaller populations than do the worst case scenarios for the same hazard class. Similarly, 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. Table 13 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).

[24] Due to the extremely wide range of potentially affected population (0 to 12 million for toxic worst case scenarios) both

7. Conclusions and Directions for Future Research

This paper represents a start in harvesting the informational value of the data collected under the RMP Rule. Among the many open issues, an important area is continuing research on how complete RMP*Info is, i.e., to what extent does RMP*Info capture the entire population of plants covered by the Rule. Another important area, going forward, will be to evaluate desirable changes in RMP*Info for the next reporting of accident history data, scheduled to take place in 2004. 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 at the tail end of the distribution?

- Using the combined accident history data from the 1999 filing, together with the 2004 filing, what trends or patterns in accidents are evident?

- What changes to the database or RMP regulation might be necessary to correct deficiencies in this important database to make the data more meaningful and useful for accident prevention?

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distributions are plotted on a logarithmic scale.

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Table 1: Twenty Most Commonly Reported Chemicals and Characteristics of the Facilities Reporting Them[25]

Chemical Name	Chem Type	Chem ID	Number of Filers	Avg FTEs of Filing Facilities	StDev FTEs
Ammonia (anhydrous)	T	56	8207	120	345
Chlorine	T	62	4450	227	2088
Propane	F	98	1324	189	649
Flammable Mixture	F	155	823	139	356
Sulfur dioxide (anhydrous)	T	49	762	180	1029
Ammonia (conc 20% or greater)	T	57	513	138	346
Butane	F	118	323	225	436
Formaldehyde (solution)	T	1	279	280	1092
Hydrogen fluoride/Hydrofluoric acid (conc 50% or greater) [Hydrofluoric acid]	T	55	269	310	699
Isobutane [Propane, 2-methyl]	F	107	247	238	513
Pentane	F	125	171	241	348
Propylene [1-Propene]	F	129	163	479	888
Toluene diisocyanate (unspecified isomer) [Benzene, 1,3-diisocyanatomethyl-]	T	77	161	268	779
Methane	F	93	160	394	749
Vinyl acetate monomer [Acetic acid ethenyl ester]	T	29	154	241	449
Hydrogen	F	149	137	591	1085
Isopentane [Butane, 2-methyl-]	F	115	116	272	381
Acrylonitrile [2-Propenenitrile]	T	25	115	301	638
Ethylene oxide [Oxirane]	T	9	107	359	721
Propylene oxide [Oxirane, methyl-]	T	12	104	325	695
Total Facilities Reporting at Least One Toxic Chemical	T		13714	158	1229
Total Facilities Reporting at Least One Flammable Chemical	F		2648	207	669

[25] If the same chemical is used in more than one process at a facility, it is only listed once in Table 1; however, the same facility may appear more than once in this Table if more than one of the Top 20 chemicals are present at the facility. For the same reason, the number of facilities indicating the use of at least one toxic or flammable will exceed the total number of filers since some facilities have both toxic and flammables on site.

Table 2: Twenty Most Commonly Reported NAICS Codes and Characteristics of the Facilities Reporting Them [26]

NAICS Code	NAICS_DESCRIPTION	Filers with the specified NAICS Code	Avg FTEs of Filing Facilities	StDev of FTEs of Filing Fac's
42291	Farm Supplies Wholesalers	4357	7	11
22131	Water Supply and Irrigation Systems	2000	206	2337
22132	Sewage Treatment Facilities	1421	216	2153
49312	Refrigerated Warehousing and Storage Facilities	576	196	303
211112	Natural Gas Liquid Extraction	482	14	23
42269	Other Chemical and Allied Products Wholesalers	371	26	38
49313	Farm Product Warehousing and Storage Facilities	342	5	17
11511	Support Activities for Crop Production	305	7	7
325211	Plastics Material and Resin Manufacturing	255	263	519
325199	All Other Basic Organic Chemical Manufacturing	252	248	500
454312	Liquefied Petroleum Gas (Bottled Gas) Dealers	242	16	94
311615	Poultry Processing	226	805	510
115112	Soil Preparation, Planting, and Cultivating	194	10	10
325188	All Other Basic Inorganic Chemical Manufacturing	193	243	577
32411	Petroleum Refineries	168	370	396
221112	Fossil Fuel Electric Power Generation	140	86	113
32512	Industrial Gas Manufacturing	135	58	163
49311	General Warehousing and Storage Facilities	131	600	4273
42271	Petroleum Bulk Stations and Terminals	128	17	86
311612	Meat Processed from Carcasses	124	424	411

[26] In Table 2, if a facility has multiple processes with the same NAICS code, it is reported only once. However, the same facility may appear more than once if it supports processes in more than one NAICS code.

Table 3: Reporting Facilities Covered by Various Regulatory Programs

Name of Regulatory Program	Number of Facilities Covered (from a Total of 15,219 Reporting)	Percent of Total Facilities Reporting under the Rule Covered by Each Specific Program
<u>Process Safety and Hazards Permitting Programs</u>		
OSHA-PSM	7,600	49%
CAA-Title V	2,267	15%
EPCRA-302	12,689	82%
<u>Emergency Response Programs</u>		
OSHA 1910.38	12,98	84%
OSHA 1910.12	9,190	60%
RCRA (40 CFR 264, 265, 279.52)	3,176	21%
OPA 90 (40 CFR 112, 33 CFR 154, 49 CFR 194, 30 CFR 254)	1,424	9%
State EPCRA Rules/Law	11,215	73%
<u>Prevention Program Level</u>		
Level 1	647	4%
Level 2	7,574	49%
Level 3	7,209	47%

Table 4: 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	850	850
2	197	394
3	69	207
4	31	124
5	25	125
6	12	72
7	7	49
8	4	32
9	1	9
10	3	30
11	2	22
13	1	13
14	2	28
15	1	15
Totals	1205	1970

Table 5: Accidents Reported in RMP*Info by Chemical Involved in the Accident for the Entire Period 1994-2000

Chemical Name	Chemical ID	Number of Accidents
Ammonia (anhydrous)	56	696
Chlorine	62	534
Flammable Mixture	155	100
Hydrogen fluoride/Hydrofluoric acid (conc 50% or greater) [Hydrofluoric acid]	55	98
Chlorine dioxide [Chlorine oxide (ClO2)]	71	59
Propane	98	51
Sulfur dioxide (anhydrous)	49	46
Ammonia (conc 20% or greater)	57	46
Hydrogen chloride (anhydrous) [Hydrochloric acid]	54	33
Hydrogen	149	31
Methane	93	27
Formaldehyde (solution)	1	21
Hydrogen sulfide	63	21
Butane	118	21
Ethylene oxide [Oxirane]	9	19
Pentane	125	16
Titanium tetrachloride [Titanium chloride (TiCl4) (T-4)-]	51	15
Ethylene [Ethene]	95	14
Isobutane [Propane, 2-methyl]	107	14
Ethane	94	13
Trichlorosilane [Silane, trichloro-]	153	13
Nitric acid (conc 80% or greater)	58	12
Oleum (Fuming Sulfuric acid) [Sulfuric acid, mixture with sulfur trioxide]	69	12
Toluene diisocyanate (unspecified isomer) [Benzene, 1,3-diisocyanatomethyl-]	77	11
Vinyl chloride [Ethene, chloro-]	101	11
Isopentane [Butane, 2-methyl-]	115	10
Propylene [1-Propene]	129	10
Phosgene [Carbonic dichloride]	10	8
Methyl chloride [Methane, chloro-]	5	7
Acrylonitrile [2-Propenenitrile]	25	7

Table 5 (Cont.): Accidents Reported in RMP*Info by Chemical Involved in the Accident for the Entire Period 1994-2001

Chemical Name	Chemical ID	Number of Accidents
Hydrochloric acid (conc 37% or greater)	53	7
1,3-Butadiene	120	7
Propylene oxide [Oxirane, methyl-]	12	6
Sulfur trioxide	50	6
Bromine	60	6
Trimethylamine [Methanamine, N,N-dimethyl-]	113	6
Carbon disulfide	8	5
Epichlorohydrin [Oxirane, (chloromethyl)-]	21	5
Ethylenediamine [1,2-Ethanediamine]	26	5
Vinyl acetate monomer [Acetic acid ethenyl ester]	29	5
Cyclohexylamine [Cyclohexanamine]	31	4
Acetylene [Ethyne]	96	4
Dimethylamine [Methanamine, N-methyl-]	133	4
Silane	152	4
Chloroform [Methane, trichloro-]	4	3
Hydrocyanic acid	6	3
Methyl mercaptan [Methanethiol]	7	3
Phosphorus oxychloride [Phosphoryl chloride]	70	3
2-Methylpropene [1-Propene, 2-methyl-]	131	3
Methyltrichlorosilane [Silane, trichloromethyl-]	16	2
Allyl alcohol [2-Propen-1-ol]	27	2
Hydrazine	38	2
Crotonaldehyde [2-Butenal]	48	2
Methylamine [Methanamine]	97	2
Acetaldehyde	104	2
Isopropylamine [2-Propanamine]	109	2
Isoprene [1,3-Butadiene, 2-methyl-]	116	2
Dichlorosilane [Silane, dichloro-]	150	2
1,1-Dimethylhydrazine [Hydrazine, 1,1-dimethyl-]	2	1
Dimethyldichlorosilane [Silane, dichlorodimethyl-]	15	1
Toluene 2,6-diisocyanate [Benzene, 1,3-diisocyanato-2-methyl-]	20	1

Table 5 (Cont.): Accidents Reported in RMP*Info by Chemical Involved in the Accident for the Entire Period 1994-2001

Chemical Name	Chemical ID	Number of Accidents
Acrolein [2-Propenal]	22	1
Chloromethyl methyl ether [Methane, chloromethoxy-]	28	1
Toluene 2,4-diisocyanate [Benzene, 2,4-diisocyanato-1-methyl-]	44	1
Boron trifluoride [Borane, trifluoro-]	52	1
Hydrogen selenide	64	1
Arsine	67	1
Nitric oxide [Nitrogen oxide (NO)]	72	1
CBI Acids	78	1
Ethyl chloride [Ethane, chloro-]	100	1
Ethyl mercaptan [Ethanethiol]	105	1
Vinylidene fluoride [Ethene, 1,1-difluoro-]	112	1
1-Butene	119	1
Vinyl methyl ether [Ethene, methoxy-]	123	1
Tetrafluoroethylene [Ethene, tetrafluoro-]	132	1
Propadiene [1,2-Propadiene]	135	1
2-Butene-cis	142	1
2-Butene-trans [2-Butene, (E)]	145	1
Butene	154	1
Nitrogen Tetroxide	160	1

Table 6: Accidents Reported in RMP*Info by NAICS Code of the Process Involved in the Accident for the Entire Period 1994-2000

NAICS_DESCRIPTION	NAICS Code	Number of Accidents
Petroleum Refineries	32411	182
Water Supply and Irrigation Systems	22131	118
Sewage Treatment Facilities	22132	112
All Other Basic Inorganic Chemical Manufacturing	325188	93
Farm Supplies Wholesalers	42291	93
Other Chemical and Allied Products Wholesalers	42269	89
All Other Basic Organic Chemical Manufacturing	325199	81
Alkalies and Chlorine Manufacturing	325181	79
Poultry Processing	311615	71
Nitrogenous Fertilizer Manufacturing	325311	70
Pulp Mills	32211	55
Refrigerated Warehousing and Storage Facilities	49312	55
Petrochemical Manufacturing	32511	52
Animal (except Poultry) Slaughtering	311611	47
Plastics Material and Resin Manufacturing	325211	37
Natural Gas Liquid Extraction	211112	35
Frozen Fruit, Juice and Vegetable Manufacturing	311411	31
Paper (except Newsprint) Mills	322121	30
Meat Processed from Carcasses	311612	29
Industrial Gas Manufacturing	32512	25
Other Basic Organic Chemical Manufacturing	32519	23
Pesticide and Other Agricultural Chemical Manufacturing	32532	21
Other Basic Inorganic Chemical Manufacturing	32518	20
Ice Cream and Frozen Dessert Manufacturing	31152	19
Frozen Food Manufacturing	31141	18
Secondary Smelting and Alloying of Aluminum	331314	18
Paper Mills	32212	17
All Other Miscellaneous Chemical Product Manufacturing	325998	17
Fluid Milk Manufacturing	311511	16
Dairy Product (except Frozen) Manufacturing	31151	14
Aluminum Sheet, Plate and Foil Manufacturing	331315	13
Frozen Bakery Product Manufacturing	311813	12

Table 6 (Cont.): Accidents Reported in RMP*Info by NAICS Code of Process Involved in the Accident for the Entire Period 1994-2001

NAICS_DESCRIPTION	NAICS Code	Number of Accidents
All Other Chemical Product Manufacturing	32599	12
Fertilizer (Mixing Only) Manufacturing	325314	11
Other Warehousing and Storage Facilities	49319	11
Cheese Manufacturing	311513	10
Animal Slaughtering and Processing	31161	10
Cyclic Crude and Intermediate Manufacturing	325192	9
General Line Grocery Wholesalers	42241	9
Fertilizer Manufacturing	32531	8
Pharmaceutical and Medicine Manufacturing	32541	8
Farm Product Warehousing and Storage Facilities	49313	8
Corn Farming	11115	7
Paperboard Mills	32213	7
Toilet Preparation Manufacturing	32562	7
Polystyrene Foam Product Manufacturing	32614	7
Flour Milling	311211	6
Inorganic Dye and Pigment Manufacturing	325131	6
Phosphatic Fertilizer Manufacturing	325312	6
Iron and Steel Mills	331111	6
Petroleum Bulk Stations and Terminals	42271	6
Support Activities for Crop Production	11511	5
Other Electric Power Generation	221119	5
Fresh and Frozen Seafood Processing	311712	5
Wineries	31213	5
Organic Dye and Pigment Manufacturing	325132	5
Surface Active Agent Manufacturing	325613	5
Other Grain Farming	11119	4
Broilers and Other Meat Type Chicken Production	11232	4
Postharvest Crop Activities (except Cotton Ginning)	115114	4
Fossil Fuel Electric Power Generation	221112	4
Fats and Oils Refining and Blending	311225	4
Frozen Specialty Food Manufacturing	311412	4
Fruit and Vegetable Canning	311421	4
Seafood Product Preparation and Packaging	31171	4

Table 6 (Cont.): Accidents Reported in RMP*Info by NAICS Code of Process Involved in the Accident for the Entire Period 1994-2001

NAICS_DESCRIPTION	NAICS Code	Number of Accidents
Ethyl Alcohol Manufacturing	325193	4
Primary Aluminum Production	331312	4
Waste Treatment and Disposal	56221	4
Soil Preparation, Planting, and Cultivating	115112	3
Wet Corn Milling	311221	3
Dried and Dehydrated Food Manufacturing	311423	3
All Other Miscellaneous Food Manufacturing	311999	3
Newsprint Mills	322122	3
All Other Petroleum and Coal Products Manufacturing	324199	3
Pharmaceutical Preparation Manufacturing	325412	3
Urethane and Other Foam Product (except Polystyrene) Manufacturing	32615	3
Cold-Rolled Steel Shape Manufacturing	331221	3
Electroplating, Plating, Polishing, Anodizing and Coloring	332813	3
All Other Miscellaneous Manufacturing	339999	3
Liquefied Petroleum Gas (Bottled Gas) Dealers	454312	3
Hazardous Waste Treatment and Disposal	562211	3
Space Research and Technology	92711	3
Electric Power Generation	22111	2
Confectionery Manufacturing from Purchased Chocolate	31133	2
Fruit and Vegetable Canning, Pickling and Drying	31142	2
Creamery Butter Manufacturing	311512	2
Cookie and Cracker Manufacturing	311821	2
Other Snack Food Manufacturing	311919	2
All Other Food Manufacturing	31199	2
Perishable Prepared Food Manufacturing	311991	2
Breweries	31212	2
Fiber, Yarn, and Thread Mills	31311	2
Synthetic Rubber Manufacturing	325212	2
Other Plastics Product Manufacturing	32619	2
Glass and Glass Product Manufacturing	32721	2
Flat Glass Manufacturing	327211	2

Table 6 (Cont.): Accidents Reported in RMP*Info by NAICS Code of Process Involved in the Accident for the Entire Period 1994-2001

NAICS_DESCRIPTION	NAICS Code	Number of Accidents
Primary Smelting and Refining of Nonferrous Metal (except Copper and Aluminum)	331419	2
Aluminum Foundries	331524	2
Other Nonferrous Foundries	331528	2
Printed Circuit Board Manufacturing	334412	2
Motor Vehicle Brake System Manufacturing	33634	2
Motor Vehicle Fabric Accessories and Seat Manufacturing	33636	2
Gasket, Packing, and Sealing Device Manufacturing	339991	2
All Other Pipeline Transportation	48699	2
Other Services to Buildings and Dwellings	56179	2
Unclassified Establishments	99999	2
Total of Other NAICS Sectors with 1 Accident		58
Total Accidents from All NAICS Sectors Identified		1970

Table 7: On-Site Injuries and Deaths Resulting from Accidents During Reporting Period

	Mean or Total	Std Dev'tion	Min	Max	Number of Observations
On-Site Injuries to Workers/Contractors					
Total On-Site Injuries	1,987				1,969
Injuries per Accident	1.0091	2.828	0	67	1,969
Injuries per FTE per Acc.	.0207	.0783	0	1	1,951
On-Site Deaths to Workers/Contractors					
Total On-Site Deaths	32				1,968
Deaths per Accident	.0163	.218	0	6	1,968
Deaths per FTE per Acc.	.0003	.0070	0	0.25	1,950

Table 8: Non-Employee Injuries and Deaths Resulting from Accidents During Reporting Period

	Mean or Total	Std Dev'tion	Min	Max	Number of Observations
Non-Employee Injuries					
Total Injuries to Public Responders for All Accidents	63				1,968
Injuries to Public Responders Per Accident	.032	.5537	0	21	1,968
Total On-Site Injuries to Other Members of the Public for All Accidents	104				1,968
On-Site Injuries to Other Members of the Public Per Accident	.0528	1.390	0	59	1,968
Total Hospitalizations for All Accidents	215				1,968
Hospitalizations Per Accident	.109	1.931	0	80	1,968
Total Other Medical Treatment for All Accidents	6,057				1,968
Other Medical Treatment/Accident	3.078	104.51	0	4,624	1,968
Non-Employee Deaths					
Total Public Responder Deaths	0				1,968
Total On-Site Deaths by Other Members of the Public	0				1,968
Overall Non-Employee Deaths/Accident	0				1,968

Table 9: Property Damage and non-Medical Off-Site Consequences Resulting from Accidents During Reporting Period

	Mean or Total	Std Dev'tion	Min	Max	Number of Observations
On-Site Property Damage ($ Millions)					
Total On-Site Damage	$1,041				1,966
Damage per Accident	$0.529	$6.641	$0	$219	1,966
Off-Site Property Damage ($ Millions)					
Total Off-Site Damage	$11.7				1,967
Damage per Accident	$0.006	$0.108	$0	$3.8	1,967
Off-Site Consequences					
Total Number of Evacuations	174				1,968
Total Number of Evacuees in all Accidents	31,921				1,968
Number of Evacuees per Accident	16.22	140.97	0	3,000	1,968
Total Number of Accidents Involving Shelter in Place	97				1,968
Total Number of Individuals Confined to Shelter in Place in All Accidents	184,839				1,968
Number of Individuals Confined to Shelter in Place per Instance	93.9	1,913.4	0	55,000	1,968
Number of Accidents with Effects on the Eco-System					
Fish or Animal Kills	19				1,970
Minor Defoliation	55				1,970
Water Contamination	25				1,970
Soil Contamination	29				1,970
Any Environmental Damage	104				1,970

Table 10: Pattern of Accidents over the Five-Year Period

Year	Number of Accidents in the Year	Percent of Total Accidents
1994	141	7.2%
1995	319	16.1%
1996	393	20%
1997	436	22.1%
1998	440	22.3%
1999	204	10.4%
2000	34	1.7%
2001	3	0.2%
Totals	1970	100.0%

Table 11: Day-of-the-Week Pattern of Accidents

Day of the Week	Number of Accidents	Percent of Total Accidents
Sunday	157	8.0%
Monday	310	15.7%
Tuesday	308	15.6%
Wednesday	355	18.0%
Thursday	351	17.8%
Friday	281	14.3%
Saturday	208	10.6%
Totals	1970	100.0%

Table 12: Plant Size vs. Accident Frequency

FTEs at Facility	Proportion of Facilities with Accidents	Number of Facilities
0	1.8%	932
1-10	2.9%	6,838
>10	12.9%	7,654
Total	7.8%	15,424

Table 13 - Descriptive Statistics for Worst-Case and Alternative Release Scenarios

Distance or Population	Type of Scenario			
	Toxic Worst Case	Toxic Alt. Release	Flammable Worst Case	Flammable Alt. Release
Endpoint Distance (miles)				
Mean	2.9	0.45	0.44	0.13
Median	1.6	0.22	0.4	0.1
Mode	1.3	0.1	0.4	0.1
Std. Deviation	4	0.66	0.39	0.15
Range	40	18	6.4	4.4
Residential Population				
Mean	38,161	937	713	66
Median	1,410	40	12	0
Mode	0	0	0	0
Std. Deviation	2.8 x10^5	1.4 x10^4	4.7 x10^3	4.5 x10^2
Range	1.2 x10^7	1.6 x10^6	1.5 x10^5	1.1 x10^4

Figure 1: Frequency Histogram - Endpoint Distance for Toxic Worst Case Scenario

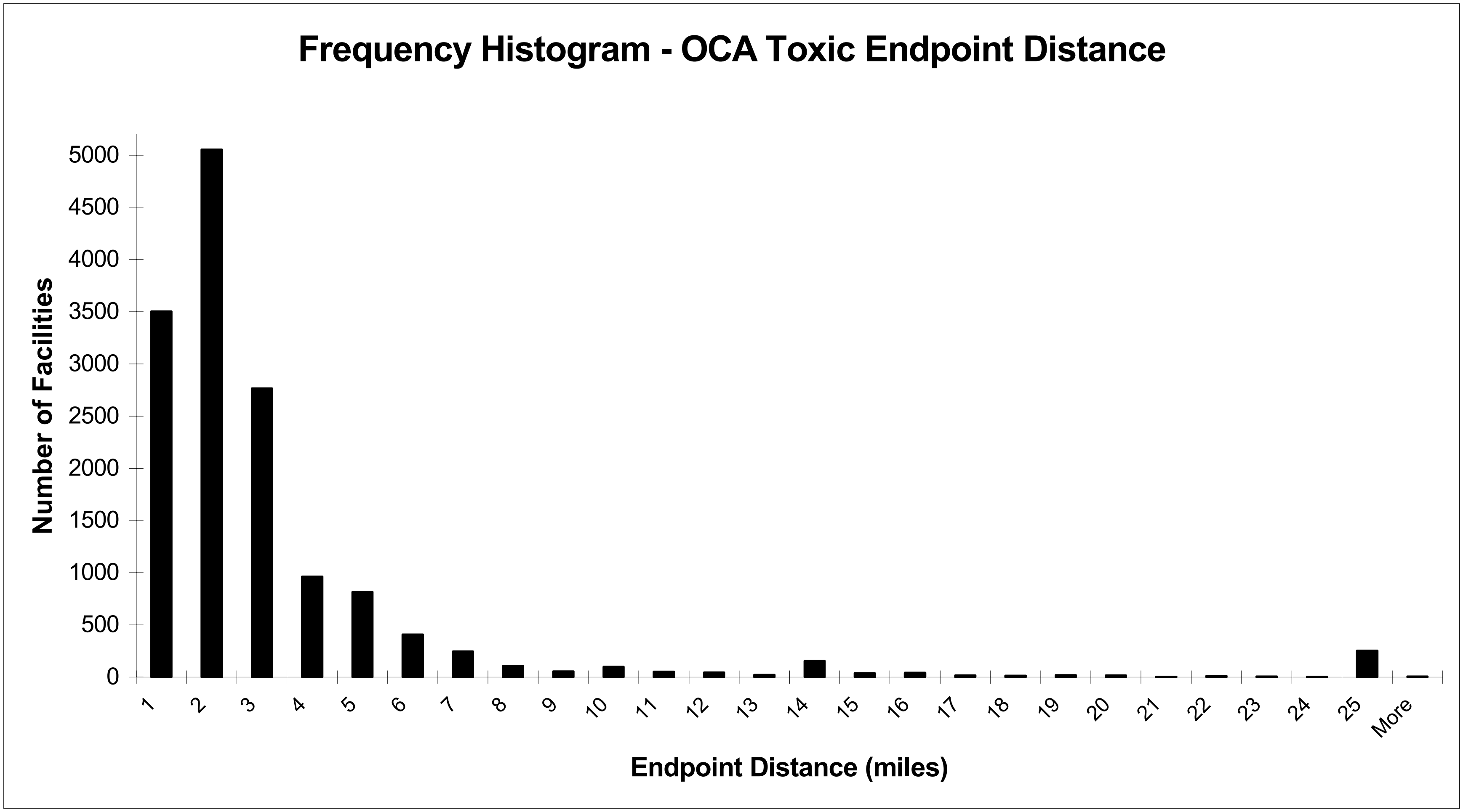

Figure 2: Frequency Histogram - Endpoint Distance for Flammable Worst Case Scenarios

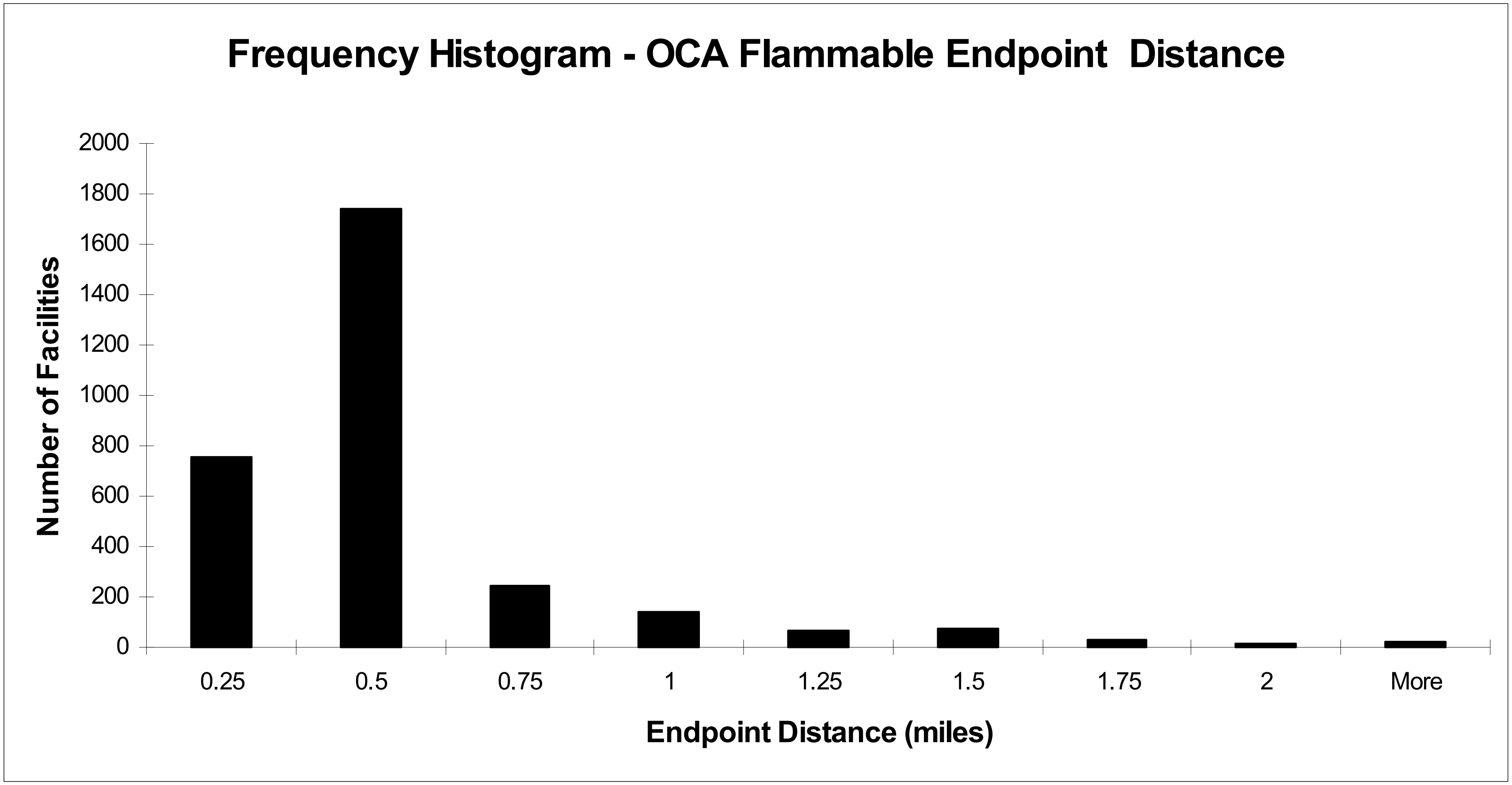

Figure 3: Frequency Histogram - Toxic Worst Case Scenario Residential Population

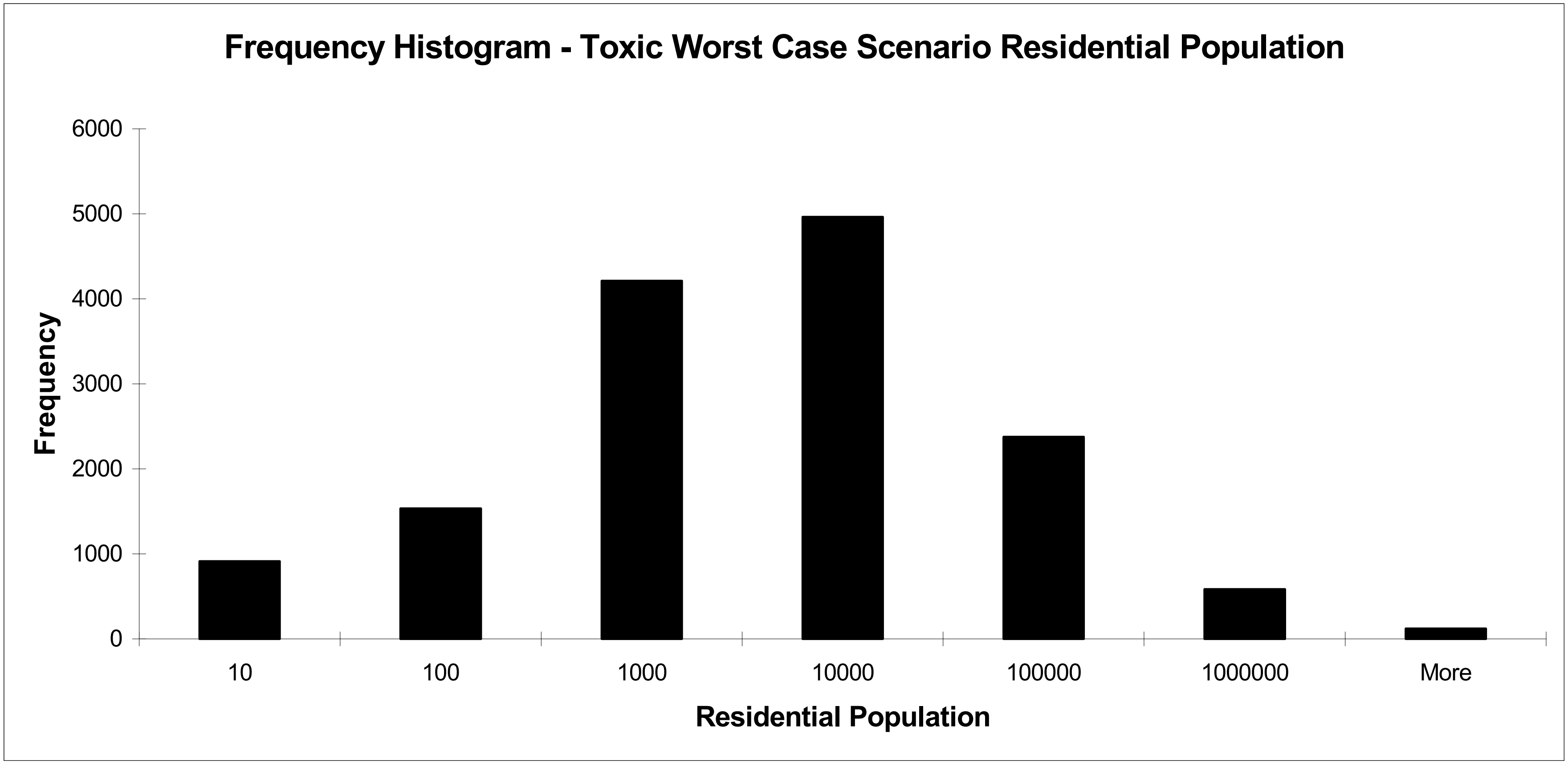

Figure 4: Frequency Histogram - Flammable Worst Case Scenario Residential Population