Accident Epidemiology and the RMP Rule: Learning from a Decade of Accident History Data for the U.S. Chemical Industry

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THE WHARTON RISK MANAGEMENT AND DECISION PROCESSES CENTER

Since its creation 23 years ago, the mission of the Wharton Risk Management and Decision Processes Center has been to carry out a program of basic and applied research to promote effective corporate and public policies for low-probability events with potentially catastrophic consequences. The Risk Center has focused on natural and technological hazards through the integration of risk assessment, risk perception and risk financing with risk management strategies. After 9/11, research activities extended also to national and international security issues (e.g., terrorism risk insurance markets, protection of critical infrastructure, global security).

Building on the disciplines of economics, decision sciences, finance, insurance, marketing and psychology, the Center's research program has been oriented around descriptive and prescriptive analyses. Descriptive research focuses on how individuals and organizations interact and make decisions regarding the management of risk under existing institutional arrangements. Prescriptive analyses propose ways that individuals and organizations, both private and governmental, can make better decisions regarding risk. The Center supports and undertakes field and experimental studies of risk and uncertainty to better understand the linkage between descriptive and prescriptive approaches under various regulatory and market conditions. Risk Center research investigates the effectiveness of strategies such as risk communication, information sharing, incentive systems, insurance, regulation and public-private collaborations at a national and international scale.

The Center is also concerned with training decision-makers and actively engaging multiple viewpoints, including the expertise of top-level representatives in the world from industry, government, international organizations, interest groups and academics through its research and policy publications and through sponsored seminars, roundtables and forums.

More information is available at http://opim.wharton.upenn.edu/risk.

ACKNOWLEDGEMENT

This study, "**Accident Epidemiology and the RMP Rule: Learning from a Decade of Accident History Data for the U.S. Chemical Industry,"** culminates some 15 years of research on the RMP Rule in close cooperation with the Office of Emergency Management (OEM) at the U.S. Environmental Protection Agency. This research was made possible through the dedicated commitment and support of the leadership of OEM over this entire period. The authors are particularly grateful for the advice of Jim Makris for his early leadership in helping us launch this project as director of the Chemical Emergency Preparedness and Prevention Office (CEPPO, the organizational predecessor of OEM), and for the unwavering support and advice of Debbie Dietrich, his successor at OEM. We are also deeply appreciative of the advice and assistance of many individuals at OEM over the course of this project, including particularly: Kim Jennings, Kathy Lee Jones, David Speights, Craig Matthiessen, Breeda Reilly and Karen Schneider. Howard Kunreuther, as Co-Director of the Wharton Risk Center, inspired much of this research through his own path-breaking work on low-probability, high-consequence risks. His undaunting support and constructive criticism have added considerably to this program and to this final report. Patrick McNulty and Peter Schmeidler, as Senior Research Fellows of the Wharton Risk Center, played important roles in shaping and guiding several important elements of this research. Finally, this report has benefited greatly from discussions with and comments from corporate associates of the Wharton Risk Center over the years. These perspectives, and the support of the Wharton Risk Center's Advisory Committee, have been critical in supporting this research and in keeping it focused on research of relevance and impact for industry practice and public policy. We are very grateful for this support. None of the above individuals should bear the blame for any errors or omissions in this report.

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EXECUTIVE SUMMARY

This report describes analysis undertaken by an interdisciplinary team of researchers on accident history data collected under Clean Air Act, Section 112(r), enacted as part of the Clean Air Act Amendments of 1990. Section 112(r) is also referred to as the Risk Management Program or RMP Rule, because this law and its implementing regulations impose requirements on facilities that manufacture or handle certain chemicals that encompass the development of a Risk Management Program and Plan for the facility. Each regulated facility must develop a risk management program, and file with the U.S. Environmental Protection Agency a Risk Management Plan (RMP) including accident history data for the five-year period preceding the filing of the RMP. Data were collected in 1999-2000 on 15,145 facilities in the U.S. that stored or used listed toxic or flammable chemicals believed to be a hazard to the environment or to health of facility employees or off-site residents of host communities. A second major set of data under the RMP Rule became available in 2004-2005, covering 12,065 facilities, of which some 10,500 were facilities that also filed in 1999-2000, allowing, therefore, a comparative assessment for these facilities of accident trends over the 10 year period 1995-2005.

The resulting database, RMP*Info, has become a key resource for regulators, researchers and external stakeholders concerned with analyzing the frequency and severity of accidents, and understanding the underlying facility-specific factors that are statistically associated with accident and injury rates and potential worst-case scenarios. This report analyzes the key findings arising from the first ten years of data collected under the RMP Rule, including characteristics of facilities that filed under the Rule and associated results on accident frequencies and severities available from the RMP*Info database. This report also presents summaries of related results from RMP*Info on Offsite Consequence Analysis (OCA), which are scenario-based estimates of the potential consequences of hypothetical worst-case and alternative accidental releases on the public and environment around the facility.

The main findings of the Report, chapter by chapter, are briefly summarized as follows.

Chapter 1: Introduction and Background to Process Safety and the RMP Rule

Chapter 1 reviews the background and objectives of the RMP Rule (CFR Part 68 Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act, Section 112(r)(7); § 68.10). The Rule had three major objectives:

1) Prevention of accidental chemical releases to the air;
2) Reduction in the severity of chemical accidents that do occur;
3) Providing the public with information about the chemical hazards in their communities in order to promote a dialogue with industry on the reduction of facility risks that affect the public and the environment.

This study is focused on the first two objectives, as the emphasis on widely disseminating information on the potential impact to the public from "worst-case accident scenarios" was reduced because of security concerns.

Chapter 1 traces the association between the occurrence of major process accidents and changes in process safety regulation. In the U.S., for example, the 1984 Bhopal and the 1989 Phillips Pasadena accidents were important precursors of the 1990

CAA amendments, which contained the statutory basis for both the OSHA 1992 Process Safety Management (PSM) rule and EPA's 1996 RMP Rule. Chapter 1 also provides an introduction to the structure of the RMP Rule, compares this structure with similar forms of risk regulation in Europe (the Seveso II Directive 1995-96) and summarizes the available data on the incidence of process accidents in Europe and Japan.

Chapter 2: RMP Accident History Database and Demographics of Reporting Facilities

Chapter 2 describes the accident history database of the RMP Rule and the nature of the facilities that reported under this Rule, beginning with the first filings in 1999. The chapter begins with an expanded introduction to the structure of the RMP Rule and the key elements of the Rule that are particularly pertinent to this study, and then reviews the data quality procedures undertaken to screen the data and to cope with the data quality problems that were encountered. The chapter then presents a description of the facilities reporting under the Rule. The Rule has undergone two major waves of filings since the implementing regulation for the Rule was first promulgated in June, 1996. The first wave occurred in 1999-2000 and the second in 2004-2005. Chapter 2 notes that data generated by the Rule exhibit many similarities between these two waves in terms of the regulatory programs that applied to RMP covered facilities, the regulated chemicals used by the covered facilities and the type of business sectors covered.

A major finding of Chapter 2 is that there has been a significant decrease in the number of facilities filing in these two waves, with 15,145 filing in the 1999-2000 wave and 12,065 filing in the 2004-2005 wave. Chapter 2 examines the changes in the pattern of registrations between the two waves of filings and we conclude from this that the reduction in the number of filers is in line with what one would expect after the initial introduction of a major regulation. Facility owners across the industry were naturally motivated to reduce regulatory burdens, and they accomplished this in large part by reducing inventories or the concentration of regulated substances in a solution below threshold-reporting requirements. Many facilities also shifted to alternative intrinsically safer raw materials that were not subject to the RMP Rule (e.g., alternative disinfection technologies in place of chlorine gas for water and wastewater treatment).

This reported reduction in the inventories of hazardous chemicals and movement to less hazardous substitutes is arguably a step forward towards accomplishing the second of the RMP Rule's three major objectives noted above, namely reducing the consequences and severity of chemical accidents. However, notwithstanding EPA's enforcement efforts, there are still some gaps in observed registration and de-registration of facilities under the RMP Rule, so some facilities that should have reported under the Rule may not have done so. Moreover, research on data quality reported in Chapter 2 notes that facilities reported substantial variability in how they interpreted questions about a number of issues, including how to compute quantities of hazardous chemicals onsite. Therefore, we must be cautious in interpreting the decrease in the number of facilities filing under the RMP Rule as representing an actual reduction in the inventories of hazardous chemicals or in the inherent hazards of the chemical industry.

Chapter 3: Frequency and Severity of Accidents at RMP Facilities

Chapter 3 analyzes the frequency and severity of accidents separately for the two waves of filings that have now been received under the RMP Rule, the first for 1999-2000 and the second on the five-year anniversary of the first filing, namely in 2004-2005. These data provide an informative record of the accident histories of the U.S. chemical industry. The descriptive data reviewed, and the studies undertaken on the basis of this data thus far, suggest a complex set of interactions determining facility performance in terms of accident frequency and severity. First and foremost, these data provide benchmark statistics on deaths, injuries and direct property damage at U.S. chemical facilities resulting from process accidents and accidental releases over the 10-year period covered by the Rule. Second, these data enabled us to undertake a number of analytic studies to investigate facility, company, socio-demographic and regulatory factors that appear to be statistically associated with accident frequency or severity. The results of such studies based on the 1999-2000 filing data are detailed in Chapter 3. These include studies on the impact of size, hazardousness, community characteristics and parent company characteristics on facility accident rates and severities. These studies are of interest in understanding how process and chemical characteristics of RMP facilities, and the financial structure of their parent companies, interacted with the regulations they faced and the communities in which they were located to give rise to the observed accident rates and impacts reported in the accident histories of these facilities.

Chapter 4: Analysis of Off-site Consequences of Chemical Accidents

Analysis of hypothetical estimates of the potential consequences of chemical accidents is a necessary pre-condition for understanding whether a major objective of the RMP Rule has been achieved, namely that of providing the public with information about the chemical hazards in their communities in order to promote a dialogue with industry to reduce facility risks. This chapter presents the results of a study of the off-site consequence analysis (OCA) of hazards at all RMP facilities for both waves of RMP data. We discuss only the worst-case scenarios in Chapter 4, leaving the analysis of alternative release scenarios to Chapter 5, which focuses on the cohort of facilities that filed in both waves (referred to as the cohort of joint filers). These scenarios represent hypothetical estimates of the potential consequences of accidental chemical releases occurring under specified atmospheric and topographic conditions. Worst-case scenarios are valuable information for both host communities and policy makers, as they approximate the magnitude of the largest problem that might result from an accident at a chemical facility.

The data presented in Chapter 4 show that the characteristics of the OCA scenarios reported have not changed very substantially across the two waves of filings. The significance of this finding is explained and a more detailed comparative analysis of the OCA data is undertaken in Chapter 5.

Chapter 5: Trend Analysis for Cohort of Dual Filers

This chapter reports on trends in accident rates and consequences for an important subset of the facilities filing under the RMP Rule, namely for those that filed during both the initial wave of filings in 1999-2000 and the five-year anniversary filings in 2004-2005. As noted above, there were 15,145 facilities that filed in 1999-2000 and 12,065 that filed in 2004-2005. Of these facilities, we studied the cohort of 10,446 that filed in both waves of RMP reporting and that had not de-registered by December 31, 2005. A number of comparative findings are provided in Chapter 5.

RMP reported accident rates significantly declined between Waves 1 and 2 of RMP filings, both for all accidents and for accidents with reportable consequences. However, in contrast to this finding, we also found that there was no decrease in the total accidents with reportable off-site consequences, so that the major reason for the decline was a drop in on-site consequence accidents. The principal cause for this drop in accidents with on-site consequences is a decrease in the sub-category “injuries to employees and contractors” which are in essence those injuries reportable under OSHA OII. Second, except for the decrease in accidents that reported employee and contractor injuries, the rates of accidents with particular types of impact were not statistically different across the two waves of filings. Third, the severity of the 5-year consequences for RMP reported accidents for our cohort facilities was not substantially or statistically different between the two waves of filings for any of the reportable categories of specific impacts. In particular, the total number of reported accidents involving worker injury declined between the two waves, and the number of reported workers injured per facility decreased as well, but the change in the latter was not statistically significant. Fourth, there was a significant increase in the hazardousness of the cohort facilities between the two waves (the hazardousness measure used reflects essentially the inventories of regulated substances onsite relative to regulatory thresholds). However, notwithstanding this increase in hazardousness, there were only small changes in the worst-case “footprints” of cohort facilities.

There are several possible explanations for the above noted results on the decreases in accident rates between the two filing periods. First is the possibility that the

RMP Rule may have had its intended effect in lowering accidents and consequences, at least for on-site employees and contractors. For example, the observed reduction in injuries to employees and contractors may have been the result of technical or management system improvements at facilities, such as more protective process control rooms, relocation of employees to such control rooms, and generally reducing the number of employees working in close proximity to process hazards, or improving maintenance or operating practices. An additional factor that could explain all or part of the decrease in reported accidents is the possibility that facility practices for reporting worker injuries may have changed, with different reporting criteria being used in the second wave than in the first wave. Such changes have been noted for OSHA OII rates, so there is reason to believe that such changes could have occurred also with respect to RMP reporting. This matter is examined in Chapter 5 and we concluded that a change in facilities' *de facto* reporting criteria is a reasonable explanation for at least some of the reduction in reported RMP accidents and their consequences.

<u>Chapter 6: Concluding Commentary on the RMP Rule</u>

Chapter 6 provides a preliminary assessment of the regulatory effectiveness of the RMP Rule in sharing information on environmental risks with affected stakeholders and in reducing the frequency and severity of chemical accidents. The most important conclusion from our study is that the RMP Rule provides, at a relatively modest cost, data that enhance our understanding of the actual outcomes of U.S. chemical facilities in respect to accidental releases. In terms of the initial results of the first 10 years of data, we also note the following summary conclusions: (1) the RMP data show a modest decline in reported accident frequency and worker injury rates over the two filings of data received thus far, in conjunction with no change in reported accident severity over a period when facility hazardousness and industry output were significantly increasing; (2) some or all of this decline may be due to changes in facility reporting criteria, and further studies on data quality going forward will therefore be important; (3) the initial regulatory benefit estimates on the RMP Rule appear to have been very optimistic (more recent EPA policy documents suggest that EPA's current expectations for the RMP Rule are more in line with its observed effects as reported here); and (4) there are additional, as yet unquantified, benefits associated with the Rule's information provisions and its potential impact on improving management systems associated with process safety and environmental impacts of U.S. chemical facilities.

Chapter 6 concludes with a discussion of limitations of this study and suggestions for future research. The results obtained thus far and the potential future research topics outlined underline the significance for public policy of the RMP data collection and analysis effort. As we note in detail in Chapter 6, the RMP data provide a foundation for developing and evaluating industry risk management and regulatory strategies aimed at reducing the consequences of chemical process safety risks on the environment and the public.

CHAPTER 1: INTRODUCTION AND BACKGROUND TO PROCESS SAFETY AND THE RMP RULE[1]

Outline of the Chapter

1. Introduction

2. Major Process Accidents as Precursors for Risk Regulation

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Appendix 1: Some Major "Watershed" Accidents

Appendix 2: Accidental Release Prevention Program Requirements of RMP Rule

Appendix 3: RMP Requirements Regarding Facility "Registration" (Demographics) and Five-Year Accident History

Appendix 4: Definition of Accidents Reportable Under the EPA Risk Management Rule and the Seveso II Directive

Appendix 5: Some Seveso and Japan Process Accident Data

[1] Research on this paper was supported in part by the Corporate Associates Program at the Wharton Risk Management and Decision Processes Center and by a Cooperative Agreement with the Office of Emergency Management (OEM) of the U.S. Environmental Protection Agency (EPA). The opinions and analyses expressed in this report are, however, solely the responsibility of the authors and do not necessarily reflect the views or policies of any Corporate Associate of the Wharton Risk Center or of OEM.

1. Introduction

This report describes analysis undertaken by an interdisciplinary team of researchers on accident history and risk data collected under Section 112(r) of the Clean Air Act Amendments (CAAA) of 1990. Section 112(r) is also referred to as the Risk Management Program or RMP Rule, because this law and its implementing regulations impose requirements on facilities that manufacture or handle certain chemicals that encompass the development of a Risk Management Program and Plan for the facility.

This introductory chapter lays the groundwork for the remainder of this report. We describe here the origins of the RMP Rule, partly in response to several major accidents that provided the impetus to reexamine chemical process safety around the world. We will review some of the elements of the regulatory response to public concern about these events, including both the changes in the United States as well as Europe and elsewhere. In particular, we discuss the OSHA responses to the requirements of Section 304 of the CAAA that it implement regulations to protect the safety and health of workers exposed to chemical risks, and we will discuss the RMP Rule, which implemented the requirements imposed on the Environmental Protection Agency by Section 112(r). We conclude with an outline of the remainder of this report.

2. Major Process Accidents as Precursors for Risk Regulation

There is a long history of chemical process accidents that have caused severe injuries to members of the public and to facility employees, along with substantial harm to the environment.[2,3] While these accidents may have been viewed as isolated incidents for a while, public attention became more focused on these events as the frequency and magnitude of process accidents increased. This increase was likely partly the result of the growth in the chemical industry and the accompanying increased complexity of processes that were designed and operated to achieve higher through-puts per dollar of investment. (See Appendix 1.)

The 1974 explosion and fire in the U.K. at Flixborough, followed by the massive release of highly toxic Dioxin at Seveso in 1976 generated a high level of societal concern in the European Union (EU). These societal concerns about both the local and trans-boundary impacts of process accidents on the public and the environment caused the EU to address the problem of reducing the number and consequences of process accidents and led to adoption of the initial Seveso Directive in 1982.

The Seveso and Flixborough accidents did not give rise to comparable concerns in the U.S. It took the tragic 1984 accident at the Union Carbide plant in Bhopal and a subsequent release of aldicarb oxime from a Union Carbide facility in Institute, West Virginia to raise the US public's concern about the dangers posed by process chemical accidents.

[2] At 7:30 a.m. on September 21, 1921, two powerful explosions occurred at the BASF plant in Oppau, Germany. The explosions destroyed the plant and approximately 700 nearby houses, and killed 430 persons. Location: Oppau, Germany, Date of incident: September 21,1921, Hazardous material: Ammonium sulfate & ammonium nitrate (50/50), Type of accident: Explosion, Facility type/Transport: Chemical plant (fertilizer),Owner of facility: BASF, Deaths: 430.

[3] On April 16, 1947 a ship carrying ammonium nitrate fertilizer blew up in the port on Galveston Bay. The blast took nearly 600 lives and many millions of dollars in property.

The initial Congressional response to this public concern was passage of the Emergency Planning and Community Right-to-Know Act[4] (EPCRA) (42 U.S.C. 11001-11050) enacted in 1986 as Title III of the Superfund Amendments and Reauthorization Act (P.L. 99-499). EPCRA created State Emergency Response Commissions (SERCs), emergency planning districts, and Local Emergency Planning Committees (LEPCs). The Act also required EPA to publish a list of Extremely Hazardous Substances (EHS) and threshold planning quantities, required LEPCs to prepare community emergency plans for responding to accidental releases of EHSs, required facilities that manufactured, used, or store hazardous chemicals, including EHSs, at or above the designated threshold amount to submit chemical inventory reports to SERCs, LEPCs, and local fire departments, and required facilities to provide emergency notification to SERCs and LEPCs in the case of a release of a hazardous substance exceeding specified reportable quantities. EPCRA also required facilities within specified industry categories using listed toxic chemicals above threshold quantities to complete a Toxic Release Inventory[5] (TRI) form and submit it annually to EPA.

Following the major explosion at the Phillips plant in Pasadena, Texas, in 1989, which led to 23 deaths, about 100 severe injuries and over $1 billion in losses (See Appendix 1) Congress enacted the 1990 CAAA[6] which among other things required:

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[4] EPA information Center at Emergency Planning and Community Right-to-Know Act.

[5] Electronic-Facility Data Release (e-FDR) The "Electronic - Facility Data Release (e-FDR)" query tool allows retrieval of 2006 data (reported in 2007) from the Toxics Release Inventory (TRI) database in Envirofacts.

[6] Chemical Accident Prevention and the Clean Air Act Amendments of 1990 - Fact Sheet, United States Environmental Protection Agency; Office of Solid Waste and Emergency Response, (5101) 550-F-96-004. May, 1996.

- OSHA to issue regulations aimed at preventing and reducing the impact of process accidents that could injure employees;
- EPA to issue regulations aimed at reducing the frequency and impact of process accidents that might impact the public and/or the environment.

3. OSHA and EPA Responses to Requirements of the CAAA

OSHA fulfilled its requirements under CAAA Section 304 in 1992 by issuing the OSHA standard 29 CFR 1910.119 “Process Safety Management of Highly Hazardous Chemicals” (PSM).[7] PSM focused on worker injuries from process accidents in facilities that had more than a specified amount of a listed substance on-site. It required execution of a specified set of process safety practices such as training, management of change, hot work permits, mechanical integrity, etc. The OSHA PSM standard does not have provisions requiring that process accidents in covered processes be reported to the agency.

EPA addressed its CAAA Section 112(r) mandates by issuing the regulation “Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act, Section 112(r)(7)” in 1996 (the “RMP Rule”).[8] The RMP Rule incorporates compliance with OSHA PSM good process safety practices and explicitly requires covered facilities to develop a risk management program and submit a risk management plan for each facility covered under the RMP Rule. The RMP Rule focused on the impact of

[7] OSHA PSM Standard: “Process Safety Management of Highly Hazardous Chemicals; Explosives and Blasting Agents,” 1910.0119; 1920.0109, Final Rules, Federal Register, Vol. 57, page 6356, 02/24/1992.

[8] “Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act, Section 112(r)(7). Guidelines, Final Rules and Notice,” Federal Register: June 20, 1996 Volume 61, Number 120, Page 31667.

chemical process accidents on the public and the environment and had three major objectives:

1) Prevention of accidental chemical releases to the air;

2) Reduction in the severity of chemical accidents that do occur;

3) Providing the public with information about the chemical hazards in their communities in order to promote a dialogue with industry on the reduction of facility risks that affected the public and the environment

The risk management program requires covered facilities to:

1. Assess the possible consequences to the public resulting from defined worst-case and alternative release scenario(s) including administrative controls and mitigation measures that could limit the impact of the scenario
2. Develop and implement an accidental release prevention program based on the OSHA PSM system elements
3. Develop emergency response programs and plans, and coordinate them with public responders
4. Maintain a five-year accident history
5. Submit a summary of the risk management program – called the risk management plan or RMP - to EPA.

Covered facilities were required to submit their initial risk management plan (RMP) to EPA no later than June 21, 1999 and to resubmit their RMP at least every five years and whenever substantive changes occurred in the covered operations.

The information that a facility covered under the RMP Rule must submit to EPA in its RMP comes under several headings:

- Registration (demographics) (Appendix 3)
- Accidental release prevention program (Appendix 2)
- Five-year accident history (Appendix 3)
- Worst-Case and Alternative Release Scenarios (Chapters 4 and 5)

These data constitute the best body of data for research on the incidence and causes of process accidents available today. This body of data contains information on many more process accidents than those collected under the Seveso II Directive. The basis for these assertions is discussed immediately below.

4. Seveso II and the RMP Rule Accident Reporting Requirements

As noted in Appendix 1**,** the EU adopted the Seveso II Directive[9] in 1996. The thrust of this regulation has many similarities with the RMP Rule (emphasis on risk management systems, requirements for risk assessment, etc.) as well as some major differences (accident reporting requirements, trans-boundary risks arising from transportation or diffusion of hazardous materials from one country to another, etc.). It is therefore interesting to compare the objectives of the Seveso II Directive with the RMP

[9] Directive 96/82/EC on the control of major-accident hazards (so-called Seveso II Directive) was adopted by the Council of the European Union on 9 December 1996. Following its publication in the Official Journal (OJ) of the European Communities (No. L 10 of 14 January 1997) the Directive entered into force on 3 February 1997.

Rule. In their somewhat simplified summary of the Seveso II Directive's provisions, Wettig and Porter[10] note that:

> *"The aim of the Seveso II Directive is two-fold:*
>
> - *Firstly, the Directive aims at the prevention of major-accident hazards involving dangerous substances.*
> - *Secondly, as accidents do continue to occur, the Directive aims at the limitation of the consequences of such accidents not only for man (safety and health aspects) but also for the environment.*
>
> *Both aims should be followed with a view to ensuring high levels of protection throughout the Community in a consistent and effective manner.*"

Both the EPA RMP Rule and the Seveso II Directive require facilities to report process accidents in covered processes if the accident's consequences exceed the damage criteria specified in the regulations in Appendix 4 of this chapter. However both the requirements on when, and how, a "reportable" accident report must be submitted to the EU and EPA, as well as the consequences that render an accident "reportable" to these two agencies are quite different. Accident reporting mechanisms under Seveso II and the RMP Rule can be briefly summarized as follows:

- In the EU, responsibility for collecting Seveso II "reportable" accident reports falls on the "Member States" (EU countries). They are required to ensure that, "as soon as practicable following a major accident" regulated facilities report specified

[10] See Wettig J. and S. Porter, "The Seveso II Directive," available at http://mahbsrv.jrc.it/downloads-pdf/Seveso2-Directive.pdf

information on a covered accident and take appropriate action on remedial measures. In practice however, "Member States" have significantly delayed (three or more years) their scheduled submission of Seveso II accidents to the EU, and in some cases, the quality of the data is less than what one might hope for.

- Under the initial 1996 RMP Rule, facilities were not required to file an accident report immediately. Data on accidents could be accumulated in the facility's Five-Year Accident History section of their RMP and facilities could postpone delivering accident information to EPA until the June 21, 1999 deadline[11] for submission of their RMP.
- On April, 2004, EPA's 2004 data issued amendments to the RMP submission schedule and data requirements.[12] In this notice, EPA pointed out that the majority of facilities would need to fully update and resubmit their RMP to EPA by June 21, 2004, which of course included their 5-year accident history for the June 21, 1999 – June 20, 2004 period. Among the new amendments introduced were the following two which are directly pertinent to this research:

    (1) A requirement that information on reportable chemical accidents must be added to the RMP within six months of the date of the accident;

[11] It should be noted that a facility Risk Management submitted by June 21, 1999 would need to cover any RMP reportable accident that occurred after June 20, 1994, which is of course prior to when the rule went into effect.

[12] Accidental Release Prevention Requirements: Risk Management Program Requirements Under Clean Air Act Section 112(r)(7); Amendments to the Submission Schedule and Data Requirements [Federal Register: April 9, 2004 Volume 69, Number 69), [Rules and Regulations, Pages 18819-18832].

(2) Removal (because of security concerns) of the requirement to include a brief description of the off-site consequence analysis (OCA) in the RMP executive summary.

The consequences of an accident that render the accident reportable under Seveso II and the RMP Rule can be briefly summarized as follows:

- Both the RMP Rule and the Seveso II Directive require facilities that experienced an accident to investigate, record, and report to the authorities accidents that resulted in more than a specified amount of damage to specified subjects of concern, e.g., employees, members of the public, the environment, property, etc.
- Although many of the specified subjects of concern under the Seveso II Directive and the EPA RMP Rule are similar, the threshold of consequences that render an accident reportable[13] to the EU are generally much higher than those that that render an accident reportable to EPA.
- As an example of the magnitude of these differences in consequence-reporting thresholds, the RMP Rule specifies that an accident in a process covered under the RMP Rule is reportable if it results in only one injury to an employee that required medical treatment or caused any level of site property damage outside the facility. The corresponding reporting requirements under the Seveso II Directive are six persons injured within the establishment and hospitalized for at least 24 hours and damage to property outside the establishment of at least ECU 0.5 million. (See

[13] Data on accidents are initially collected in the EU by the member nations under each nation's enactment of laws to implement the EU Seveso II Directive. They are then forwarded on to the European Commission.

Appendix 2 for a complete listing of the specified damage thresholds that make an accident reportable to the U.S. EPA and the EU.)

The differences in accident consequence-reporting thresholds and the fact that the Seveso II Directive accident reporting requirements cover a much smaller number of facilities[14] (≈ 3,000 in the years 2000 through 2002) than the number covered under the RMP Rule (≈ 14,000 for the same period) leads to significant differences in the total incidence of process accidents reportable under these two regulations. Table 1.1 presents an example of the number of RMP accidents and Seveso II accidents reported by year. It shows that about 10 times more accidents are reported under the RMP Rule than under the Seveso II Directive.

For the most part, the authors believe that the difference between the number of reported RMP and Seveso II accidents is due to differences in number of regulated facilities and accident consequence reporting thresholds. Other explanations could include the following factors (although the authors are not aware of evidence or studies that the differences in accident incidence rates arise from differences between the EU and the U.S. in these factors):

1. Hazardousness of the substances being processed,
2. Employed process technology,
3. Quality of management systems, or
4. Regulatory mandated practices and their enforcement.

[14] Draft report on the application in the Member States of Directive 96/82/EC on the control of major-accident hazards involving dangerous substances for the period 2000-2002, http://ec.europa.eu/environment/Seveso/pdf/report_en.pdf

TABLE 1.1.
NUMBER OF ACCIDENTS REPORTED
UNDER THE RMP RULE AND THE SEVESO II DIRECTIVE

Year	Number[15] of Seveso Accidents by Regulated Facilities	Number of RMP Accidents Reported[16] by All Regulated Facilities
2000	27	174
2001	20	188
2002	29	201

It is clear from this brief comparative overview of the RMP Rule and Seveso II Directive that the RMP Rule's requirements for reporting accidents encompasses more unplanned events that result in damage or injury than the latter. Because process accidents are low-probability events, the best facilities often track "near misses" in order to study the accident propensities of their processes. In one sense, many RMP reportable accidents could be considered as a type of Seveso II "near-miss." As a result, it is much easier to uncover possible relationships between the characteristics of a class of facilities and their accident propensities using RMP Rule accident data than is the case with facilities covered under the Seveso II Directive.

The primary reason this is important is that it allows greater precision in drawing policy conclusions about the nature and consequences of accidental chemical releases. This is important not just for research, but also for governmental and industrial policies

[15] The number of facilities regulated under the Seveso II Directive has been estimated by Kirchsteiger (2001) to be on the order of 10,000. But this has grown since this earlier estimate because of EU enlargement. See Appendix 5 of this chapter and Christou (2004), Sales et al. (2007) and European Commission (2005) for more details on Seveso accidents.

[16] Approximately 12,000 facilities were regulated under the RMP regulation over the 2000-2005 period. The number of RMP accidents listed reflect accidents with consequences that the RMP Rule required facilities to report. There were additional accidents reported by facilities ("no-consequence" accidents). See Chapter 3 of this Report for discussion of the details on RMP reported accidents and information on "no-consequence" accidents.

that rely on this data. We will have more to say on the subject of policy implications of the RMP Rule below.

5. Objectives of this Study

This study is an extension of previous work[17] done on the Wharton Risk Management and Decision Processes Center project aimed at evaluating the RMP Rule's impact on two of the Regulation's three initial major objectives:

1) Prevent accidental chemical releases to the air;
2) Reduce the severity of chemical accidents that do occur;
3) Provide the public with information about the chemical hazards in their communities in order to promote a dialogue with industry to reduce facility risks.

Work on the third objective became significantly more difficult shortly after the RMP Rule was promulgated when EPA reduced its emphasis on widely disseminating information on the potential impact to the public from worst-case and alternative accident scenarios because of security concerns.

The initial Wharton research work on this project centered on the June 1995-June 1999 body of accident data (which we will refer to below as the "first RMP data tranche" or "the first wave of RMP data") submitted by regulated facilities in response to RMP Rule requirements. The thrust of the initial work was primarily descriptive and focused on the demographics of the covered facilities, (ownership of the facilities, covered processes and

[17] See Kleindorfer et al. (2003); Elliott et al. (2003); Elliott et al. (2004); Kleindorfer et al. (2004); Rosenthal et al. (2006). This work is summarized in detail in Chapters 2 and 3.

substances, and worst-case accident scenarios). It also studied associations between economic characteristics of parent firms and accident risk, and environmental justice issues, but did not focus on trends in accident frequency, because such trends could not reflect the full impact of the regulation since covered facilities did not have to comply with the accident prevention requirements of the RMP until as late as June 21, 1999.[18]

In 2004, EPA issued amendments to the RMP Rule's "Submission Schedule and Data Requirements."[19] Among other things,[20] the notice reinforced and strengthened the requirement that the vast majority of covered facilities had to submit a 5-year update of their RMP Plan (which includes, of course, their accident history for the June 21, 1999-June 21, 2004 period. This gave rise to a second major wave of RMP report filings (referred to below as the "2004-2005 data," or the "second RMP data tranche").

This research report will review our findings for the first RMP data filings, covering the reports filed in 1999-2000, and we will provide descriptive statistics for the second

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[18] 40 CFR Part 68 Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act, Section 112(r)(7); § 68.10 Applicability.

> (a) An owner or operator of a stationary source that has more than a threshold quantity of a regulated substance in a process, as determined under § 68.115, shall comply with the requirements of this part no later than the latest of the following dates:
> (1) June 21, 1999;
> (2) Three years after the date on which a regulated substance is first listed under § 68.130;
> (3) The date on which a regulated substance is first present above a threshold quantity in a process

[19] Accidental Release Prevention Requirements: Risk Management Program Requirements Under Clean Air Act Section 112(r)(7); Amendments to the Submission Schedule and Data Requirements, [Federal Register: April 9, 2004 (Volume 69, Number 69)][Rules and Regulations][Page 18819-18832]

> "The Agency is therefore clarifying that the Rule's 5-year update provision requires that RMP Plans initially due on June 21, 1999 be updated by June 21, 2004, not before. Early filers that received an EPA letter acknowledging receipt and indicating an update deadline prior to June 21, 2004, should disregard that date, which was calculated without consideration of potential early filings, and instead submit their 5-year update by June 21, 2004."

[20] One item in the April 9th 2004 EPA 2004 Rule Amendment, of particular importance to the subject of this report, required covered facilities to inform EPA about RMP Reportable accidents within six months of the accident, rather than within 5 years or until such time as they were previously required to file their RMP Plan.

data tranche, covering the reports filed in 2004-2005. Thereafter, we will compare the findings on the two tranches and then identify whether significant trends exist in regard to achievement of either the first or second of the RMP Rule's major objectives noted above. In particular, we will investigate whether the RMP Rule allows any statistical inferences concerning (1) whether there has been a reduction in RMP process accidents; (2) whether the severity of the accidents that did occur has decreased; and (3) whether the worst-case consequences associated with RMP covered facilities have decreased. Our findings are briefly summarized below.

Among other important contributions, the analysis of RMP accident data presented in this report will demonstrate that the amount and quality of the demographic and accident data submitted[21] under the RMP Rule makes it possible to explore statistically significant changes in accident frequency or severity that may have occurred over the ten-year period, 1995 – 2004, covered thus far by the RMP data. While the RMP data also have limitations in terms of policy conclusions that can be drawn from the data thus far assembled, we will note that the RMP data provide a solid foundation for understanding the evolving trends in accident frequency and severity, and worst-case consequences, of accidents in the U.S. chemical industry.[22]

[21] RMP*Submit 2004™ User's Manual, http://yosemite.epa.gov/oswer/ceppoweb.nsf/vwResourcesByFilename/RMP-2004User-Manual-Final.pdf/$File/RMP-2004User-Manual-Final.pdf. This document contains a full list of the information items, on reportable process accidents, facility demographics, risk assessment and risk management processes that regulated facilities must submit to EPA and update at least every 5 years.

[22] Our conclusion will therefore be more positive than the summary assessment of Kirchsteiger (2001) who concluded that "the information currently available at a European level is not sufficient to come to reliable conclusions regarding the frequency of such events."

6. Overview of the Remainder of this Report

The results of this research study will be presented in five subsequent chapters which are briefly summarized in this overview.

Chapter 2: "RMP Accident History Database and Demographics of Reporting Facilities" begins with an expanded introduction to the structure of the RMP Rule and the key elements of the Rule that are particularly pertinent to this study, and then reviews the data screening and data quality procedures undertaken to screen the data and to cope with the data quality problems that were encountered. It then presents the basic descriptive data for the first wave of RMP data (RMP filings under RMP*Submit that were received by EPA between January 1, 1999 and December 31, 2000) and the second wave of RMP data (RMP filings under RMP*Submit that were received by EPA between January 1, 2004 and December 31, 2005) and discusses the similarities and differences in the findings on these two waves of filing data. In particular, a significant decrease in the number of facilities filing under RMP is noted between the two waves, with 15,145 facilities filing in the first wave and 12,065 in the second wave. A discussion of de-registration and other issues underlying this decrease in the number of filers is presented.

Chapter 3: This chapter reports the accident rates and severities for RMP facilities, for both the 1999-2000 data as well as the 2004-2005 data. We note, *inter alia*, that the number of facilities subject to threshold reporting requirements seems to have decreased from the first filing period to the second. This may reflect a decrease in the overall hazardousness of the industry (assuming that the primary reason for the decrease is that facilities have either closed or reduced inventories below threshold quantities). This chapter also summarizes research on several analytic models estimated for the 1999-2000 wave of RMP data. These models are concerned with the statistical association between accident rates and hazardousness of facilities, financial structure of parent companies of these facilities, and the demographics of the surrounding community. These results indicate some of the important research and policy results available through the RMP data.

Chapter 4: Among the most interesting 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. This chapter considers the nature of these scenarios for both waves of RMP data (1999-2000 and 2004-2005). We first describe the nature of the OCA data required to be reported under the RMP Rule and the models used to estimate OCA consequences (the data suggest that the types of models used for OCA assessment have not changed very much between the first and second wave of filings). Thereafter, we consider the results using two basic metrics on the magnitude of the worst-case scenarios considered: (1) end-point distances over which chemicals have the ability to cause serious injury, and (2) population closer to the facility than the end-point distance of the facility. Results for both waves of data are presented in graphical and tabular form.

Chapter 5: This chapter reports on trends in accident rates and consequences for an important subset of the facilities filing under the RMP Rule, namely for those that filed during both the initial wave of filings in 1999-2000 and the five-year anniversary filings in 2004-2005. There were 15,145 facilities that filed in 1999-2000 and 12,065 that filed in 2004-2005. Of these facilities, we selected a cohort of 10,446 that filed in both waves of RMP reporting and that had not de-registered by December 31, 2005. We report a number of key findings for this cohort. First and foremost, RMP reported accident rates significantly declined between Waves 1 and 2 of RMP filings for both accidents with reportable consequences and for all accidents. The principal cause for this drop is a decrease in the sub-category "injuries to employees and contractors" which are in essence reportable under OSHA OII. Second, except for employee and contractor injuries and medical treatment, differences in rates of accidents with particular types of impact were not statistically different across the two waves at the 0.05 significance level. Third, concerning accident severity, the severity of the 5-year consequences for RMP reported accidents for our cohort facilities was not substantially or statistically different between the two waves of filings for any of the reportable categories of specific impacts. Fourth, there was a significant increase in the hazardousness of the cohort facilities between the two waves. However, this increase in hazardousness did not lead to an increase in either the frequency or severity of impacts from RMP reported accidents. Finally, there were some small changes in the worst-case footprints of cohort facilities, with toxic worst-case scenarios decreasing slightly between Wave 1 and Wave 2. This chapter presents the above basic findings and provides a detailed discussion of alternative explanations for these findings, including a discussion of possible changes in the criteria used by facilities to report accidents.

Chapter 6: The final chapter in this study summarizes the results of previous chapters and then provides a summary assessment of the costs and benefits of the RMP Rule as a means of regulating chemical accident risks and of communicating these to the public. We conclude from this discussion that the Rule has not met the expectations embodied in the original benefit/cost study (U.S. EPA, 1996b) concerning the magnitude of benefits and costs. This was due in part to the fact that EPA's initial estimates of benefits and costs were overly optimistic, a point we discuss in some detail, noting that more recent policy documents suggest that EPA's current expectations for the RMP Rule are more in line with its observed effects. The actual reduction in accident rates was slightly in excess of 20% for the period covered by the trend analysis reported in Chapter 5. Even if we neglect the possibility that criteria for reporting accidents changed between the two waves of filing, as discussed in Chapter 5, a fair assessment would be that the rate of RMP reported accidents has declined significantly but not at the rate anticipated in the original U.S. EPA (1996b) benefit/cost study. While the Rule does not seem to have lived up to expectations formulated at the time of its initiation, it may have still resulted in significant benefits in terms of accident reduction. Further, it is important to keep two other potential impacts of the Rule in mind in evaluating its effectiveness – its informational impacts and its impacts on improved management systems for managing environmental, health and safety impacts of operations. These additional potential benefits are discussed in detail. Chapter 6 ends with a commentary on the limitations of this study and on some of the open research questions which may be fruitful in the future using the RMP data.

APPENDIX 1

TABLE 1.A-1:
SOME Major "Watershed" Accidents

Location of Accident	Date	Type of Event	Some Resulting Consequences	Regulatory Response
Flixborough, UK	1974	Explosion and fire	28 killed, over 100 injured	COMAH 1984
Seveso, Italy	1976	Runaway reaction	Large Dioxin environment contamination massive evacuations, Large animal kill	Initial Seveso Directive
Bhopal, India	1984	Runaway MIC reaction	≈ 2500 people killed and 100,000 injured, high litigation costs	USA EPCRA & Community Right-to-Know Act - CMA CAER Program
Basel, Switzerland	1986	Warehouse fire	Massive contamination of Rhine and very large fish kill	Triggered start of revisions of Seveso Directive which led to Seveso II Directive in 1996
Pasadena, TX, USA	1989	Explosion and fire	23 deaths, ≈ 100 injured Over $1 billion in losses	USA 1990 CAA amendments requiring OSHA 1992 PSM rule and EPA 1996 RMP Rule
Exxon Longford Australia	1998	Explosions and fires	2 deaths & gas supply to Melbourne cut off for 19 days. Losses over $1.3 Billion	Process safety regulatory initiatives in Australia
Enschede Netherlands	2000	Explosion and fire	22 deaths, ≈ 1000 injured, 350 houses and factories destroyed	Triggered changes in Seveso II Directive
Toulouse, France	2001	Explosion and fire	30 deaths, ≈ 2000 injured, 600 homes destroyed, 2 schools demolished	Triggered changes in Seveso II Directive

APPENDIX 2

Accidental Release Prevention Program Requirements of RMP Rule

§ 68.175 Prevention Program/Program 3

(a) For each Program 3 process, the owner or operator shall provide the information indicated in paragraphs (b) through (p) of this section. If the same information applies to more than one covered process, the owner or operator may provide the information only once, but shall indicate to which processes the information applies.

(b) The SIC code for the process.

(c) The name(s) of the substance(s) covered.

(d) The date on which the safety information was last reviewed or revised.

(e) The date of completion of the most recent PHA or update and the technique used.

(1) The expected date of completion of any changes resulting from the PHA;

(2) Major hazards identified;

(3) Process controls in use;

(4) Mitigation systems in use;

(5) Monitoring and detection systems in use; and

(6) Changes since the last PHA.

(f) The date of the most recent review or revision of operating procedures.

(g) The date of the most recent review or revision of training programs;

(1) The type of training provided—classroom, classroom plus on-the-job, on-the-job;

(2) The type of competency testing used.

(h) The date of the most recent review or revision of maintenance procedures and the date of the most recent equipment inspection or test and the equipment inspected or tested.

(i) The date of the most recent change that triggered management of change procedures and the date of the most recent review or revision of management of change procedures.

(j) The date of the most recent pre-startup review.

(k) The date of the most recent compliance audit and the expected date of completion of any changes resulting from the compliance audit;

(l) The date of the most recent incident investigation and the expected date of completion of any changes resulting from the investigation;

(m) The date of the most recent review or revision of employee participation plans;

(n) The date of the most recent review or revision of hot work permit procedures;

(o) The date of the most recent review or revision of contractor safety procedures; and

(p) The date of the most recent evaluation of contractor safety performance.

§ 68.170 Prevention Program/Program 2

(a) For each Program 2 process, the owner or operator shall provide in the RMP the information indicated in paragraphs (b) through (k) of this section. If the same information applies owner or operator may provide the information only once, but shall indicate to which processes the information applies.

(b) The SIC code for the process.

(c) The name(s) of the chemical(s) covered.

(d) The date of the most recent review or revision of the safety information and a list of Federal or state regulations or industry-specific design codes and standards used to demonstrate compliance with the safety information requirement.

(e) The date of completion of the most recent hazard review or update.

- (1) The expected date of completion of any changes resulting from the hazard review;
- (2) Major hazards identified;
- (3) Process controls in use;
- (4) Mitigation systems in use;
- (5) Monitoring and detection systems in use; and
- (6) Changes since the last hazard review.

(f) The date of the most recent review or revision of operating procedures.

(g) The date of the most recent review or revision of training programs;

- (1) The type of training provided: classroom, classroom plus on-the-job, on-the-job
- (2) The type of competency testing used.

APPENDIX 3

RMP Report Requirements Regarding Facility "Registration" (Demographics) and Five-Year Accident History

§ 68.160 Registration

(a) The owner or operator shall complete a single registration form and include it in the RMP. The form shall cover all regulated substances handled in covered processes.

(b) The registration shall include the following data:

(1) Stationary source name, street, city, county, state, zip code, latitude, and longitude;

(2) The stationary source Dun and Bradstreet number;

(3) The name and Dun and Bradstreet number of the corporate parent company;

(4) The name, telephone number, and mailing address of the owner or operator;

(5) The name and title of the person or position with overall responsibility for RMP elements and implementation;

(6) The name, title, telephone number, and 24-hour telephone number of the emergency contact;

(7) For each covered process, the name and CAS number of each regulated substance held above the threshold quantity in the process, the maximum quantity of each regulated substance or mixture in the process (in pounds) to two significant digits, the SIC code, and the Program level of the process;

(8) The stationary source EPA identifier;

(9) The number of full-time employees at the stationary source;

(10) Whether the stationary source is subject to 29 CFR 1910.119;

(11) Whether the stationary source is subject to 40 CFR part 355;

(12) Whether the stationary source has a CAA Title V operating permit; and

(13) The date of the last safety inspection of the stationary source by a Federal, state, or local government agency and the identity of the inspecting entity.

§ 68.42 Five-Year Accident History

(a) The owner or operator shall include in the five-year accident history all accidental releases from covered processes 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.

(b) Data required. For each accidental release included, the owner or operator shall report the following information:

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

(2) Chemical(s) released;

(3) Estimated quantity released in pounds;

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

(5) Weather conditions, if known;

(6) On-site impacts;

(7) Known offsite impacts;

(8) Initiating event and contributing factors if known;

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

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

(c) Level of accuracy. Numerical estimates may be provided to two significant digits.

APPENDIX 4

Definition of Accidents Reportable Under the
EPA Risk Management Rule and the Seveso II Directive

1) Accidents Reportable under the EPA Risk Management Rule: EPA elaborated on what constituted a reportable accident under RMP Rule requirements in a Guidance document[1] as follows:

"**On-site impacts.** Complete the following about on-site effects.

Deaths: Indicate the number of on-site deaths that are attributed to the accident or mitigation activities. On-site deaths means number of employees, contract employees, offsite responders, or others (e.g., visitors) who were killed by direct exposure to toxic concentrations, radiant heat, or overpressures from accidental releases or from indirect consequences of a vapor cloud explosion from an accidental release (e.g., flying glass, debris, other projectiles). You should list employee/contractor, offsite responder, and other on-site deaths separately.

Injuries: An injury is any effect that results either from direct exposure to toxic concentrations, radiant heat, or overpressures from accidental releases or from indirect consequences of a vapor cloud explosion (e.g., flying glass, debris, other projectiles) from an accidental release and that requires medical treatment or hospitalization. You should list injuries to employees and contractors, offsite responders, and others separately.

Medical treatment: Treatment, other than first aid, administered by a physician or registered professional personnel under standing orders from a physician. Your Log of Work-Related Injuries and Illnesses (OSHA Form 300) and Injury and Illness Incident Report (OSHA Form 301) will help complete these items for employees.

Property damage: Estimate the value of the equipment or business structures (for your business alone) that were damaged by the accident or mitigation activities. Record the

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[1] U.S. EPA/CEPPO (2004a), "General Risk Management Program Guidance," (April 2004), Chapter 3. See http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/EPAguidance.htm

value in American dollars. Insurance claims may provide this information. Do **not** include any losses that you may have incurred as a result of business interruption.

Known offsite impacts. These are impacts that you know or could reasonably be expected to know of (e.g., from media reports or from reports to your facility) that occurred as a result of the accidental release. You are not required to conduct an additional investigation to determine offsite impacts.

Question and Answer Concerning Property Damage

Q. What level of offsite property damage triggers reporting?

A. Any level of known offsite property damage triggers inclusion of the accident in the five-year accident history. You are not required to conduct a survey to determine if such damage occurred, but if you know, or could reasonably be expected to know (e.g., because of reporting in the newspapers), that damage occurred, you must include the accident.

Deaths: Indicate the number of offsite deaths that are attributable to the accident or mitigation activities. Offsite deaths means the number of community members who were killed by direct exposure to toxic concentrations, radiant heat, or overpressures from accidental releases or from indirect consequences of a vapor cloud explosion from an accidental release (e.g., flying glass, debris, other projectiles).

Injuries: Indicate the number of injuries among community members. *Injury* means any effect that results either from direct exposure to toxic concentrations, radiant heat, or overpressures from accidental releases or from indirect consequences of a vapor cloud explosion from an accidental release (e.g., flying glass, debris, other projectiles) and that requires medical treatment or hospitalization.

Evacuated: Estimate the number of members of the community who were evacuated to prevent exposure that might have resulted from the accident. A total count of the number of people evacuated is preferable to the number of houses evacuated. People who were ordered to move simply to improve access to the site for emergency vehicles are not considered to have been evacuated.

<u>*Sheltered:*</u> Estimate the number of members of the community who were sheltered-in-place during the accident. Sheltering-in-place occurs when community members are ordered to remain inside their residence or place of work until the emergency is over to prevent exposure to the effects of the accidental release. Usually these orders are communicated by an emergency broadcast or similar method of mass notification by response agencies.

<u>*Environmental damage:*</u> Indicate whether any environmental damage occurred and specify the type. The damage to be reported is not limited to environmental receptors listed in the rule. Any damage to the environment (e.g., dead or injured animals, defoliation, water contamination) should be identified. You are **not**, however, required to conduct surveys to determine whether such impact occurred. Types of environmental damage include:

- Fish or animal kills.
- Lawn, shrub, or crop damage (minor defoliation).
- Lawn, shrub, or crop damage (major defoliation).
- Water contamination.
- Other (specify)."

2) Accidents Reportable under the Seveso II Directive[2]

Any accident covered by paragraph 1 or having at least one of the consequences described in paragraphs 2, 3, 4 and 5 must be notified to the Commission.

1. **Substances involved**

   Any fire or explosion or accidental discharge of a dangerous substance involving, a quantity of at least 5% of the qualifying quantity laid down in column 3 of Annex 1.

2. **Injury to persons and damage to real estate**

   An accident directly involving a dangerous substance and giving rise to one of the following events:

[2] Criteria for the notification of an accident to the commission as provided for in article 15(1). See Appendix 6 of the Seveso II directive, *ibid* Ref. 8.

— a death,

— six persons injured within the establishment and hospitalized for at least 24 hours,

— one person outside the establishment hospitalized for at least 24 hours,

— dwelling(s) outside the establishment damaged and unusable as a result of the accident,

— the evacuation or confinement of persons for more than 2 hours (persons x hours): the value is at least 500,

— the interruption of drinking water, electricity, gas or telephone services for more than 2 hours (persons x hours): the value is at least 1,000.

3. Immediate damage to the environment

— *permanent or long-term damage to terrestrial habitats:*

— 0,5 ha or more of a habitat of environmental or conservation importance protected by legislation,

— 10 or more hectares of more widespread habitat, including agricultural land,

— *significant or long-term damage to freshwater and marine habitats* (*)

— 10 km or more of river or canal,

— 1 ha or more of a lake or pond,

— 2 ha or more of delta,

— 2 ha or more of a coastline or open sea,

— *significant damage to an aquifer or underground water* (*)

— 1 ha or more.

4. Damage to property

— damage to property in the establishment at least ECU 2 million,

— damage to property outside the establishment; at least ECU O,5 million.

5. Cross-border damage

— any accident directly involving a dangerous substance giving rise to effects outside the territory of the Member State concerned.

APPENDIX 5:

Some Seveso and Japan Process Accident Data

1) Seveso Data from the EU: A summary of information regarding the incidence of process accidents during the period before 2004 was presented at and OECD workshop[3] in response to the question, "Have trends in chemical process accident incidence rates and losses experienced in various countries and industry segments over the last 10 to 20 years met expectations and projections?" In response to this, Pitblado (2004) concluded that the MARS Seveso accident data presented in a paper by Duffield (2003) (see the cumulative Figure below which shows the cumulative number of accidents increasing linearly at roughly the same rate in recent years) showed no evidence of a significant reduction in the rate of major accidents reported under the Seveso Directives over the last 10 to 20 years, and furthermore, that the MARS data also showed no change in average severity of reported accidents based on the 7 point MARS severity scale. Christou (2004) also concluded, based on an update of the data used by Duffield, that "There is a clear indication that the total number of major accidents is relatively constant."

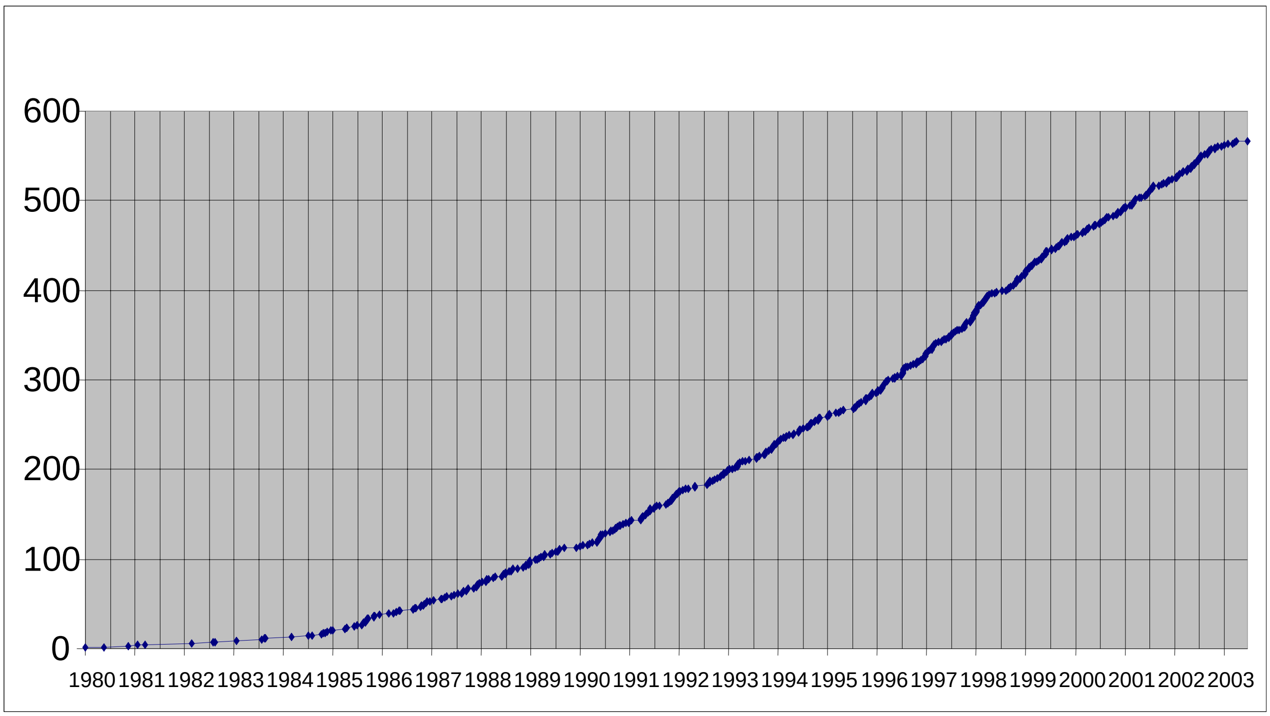

Figure 1.A-1
NUMBER OF INCIDENTS REPORTED IN MARS
Source: Christou (2004)

[3] See Rosenthal et al. (2004) for a detailed discussion of this issue.

The situation does not appear to have changed according to a recent EU report which presented the data shown in Table 1.A-2 below and made the following observation: "The absolute numbers of major Seveso II accidents, reported for the last 6 years, vary between 20 and 30 per year, and show no clear trend. In the same period, the number of sites covered, however increased slightly. A detailed analysis of past accidents recorded in the Commission's database will shortly be finalized."[4]

TABLE 1.A-2.
MAJOR ACCIDENTS

2000	2001	2002	2003	2004	2005
27	20	29	24	22	28

2) Data from Japan: Accident frequency data in Japan (Figure 1.2) also did not indicate the hoped for reduction in process accidents.[5] An interesting comment pertinent to this data was made by Noriko Hama, a professor of international economics at Doshisha University Business School pertinent to the Japan accident data shown in Figure 1.A-2 was reported in *The Japan Times* (March 12, 2004, p. 19) as follows:

[4] See European Commission (2005), "Report on the Application in the Member States of Directive 96/82/EC on the control of major-accident hazards involving dangerous substances for the period 2003-2005", Brussels. http://ec.europa.eu/environment/seveso/pdf/report_2003_2005_en.pdf The promised report examining these data was published in Sales et al. (2007), which draws a slightly different conclusion as follows (p. 24): "The number of major accidents reported since 1996 has been reduced in periods of three years. In each period the number of accidents was reduced progressively, followed by an abrupt increase of reported events every three years. This fact could suggest that there are cyclical variations in the management of safety of some process industries, probably due to an excessive relaxation in risk perception after periods with fewer accidents. Further analysis on the evolution of accidents during the future years will be needed in order to confirm this trend." The number of facilities regulated under the Seveso II Directive has been estimated by Kirchsteiger (2001) to be on the order of 10,000. But this has grown since this earlier estimate because of EU enlargement. Suffice it to note that even with the figure of 10,000 facilities, the average reported number of "major accidents" in the MARS system are on the order of one-tenth of the number reported for a similar sized population of facilities under the RMP Rule. As reported in Sales et al. (2007), the total number of fatalities reported in facilities reporting under the Seveso Directives over the period 1994-2004 was 153, which as we will see in Chapter 3 is greater than the number of fatalities in RMP reporting facilities (where total fatalities over the two reporting waves for the RMP Rule were 80). Even after taking into account the unusually high fatalities resulting from the Enschede accident in 2000 (22 deaths) and the Toulouse accident in 2001 (30 deaths), the severity of accidents in the EU that resulted in fatalities was of the same order or greater as those reporting under the RMP Rule. We can conclude from these basic statistics that the number and types of accidents reported under the Seveso Directives is far less encompassing than under the RMP Rule, with only "major accidents" reported under the former.

[5] See Hasegawa (2004).

"Another offshoot of deflation that is particularly worrying, she said, has manifested itself in a series of major accidents that have hit the plants of Japan's industrial giants in recent years. The examples cited by Hama included a fire that destroyed a tire factory of Bridgestone Corp. in Kuroiso, Tochigi Prefecture and a fire and explosion at Nippon Steel Corp.'s Nagoya ironworks, both of which happened last September.

In their bid to make profit under deflationary pressures, those companies have been restructuring their operations and trying to cut costs, and are compelled to continue using facilities and equipment that normally would have been replaced and renewed years ago, thereby raising the risk of accidents.

Also because of job cuts, the firms do not have sufficient numbers of workers who can repair and keep the old equipment in proper condition, she said. The operation of Japan's manufacturing industries was once looked upon as a global standard, but the fact that major companies that are supposed to symbolize that standard have been hit by serious accidents shows deflation has damaged the nation's industrial base."

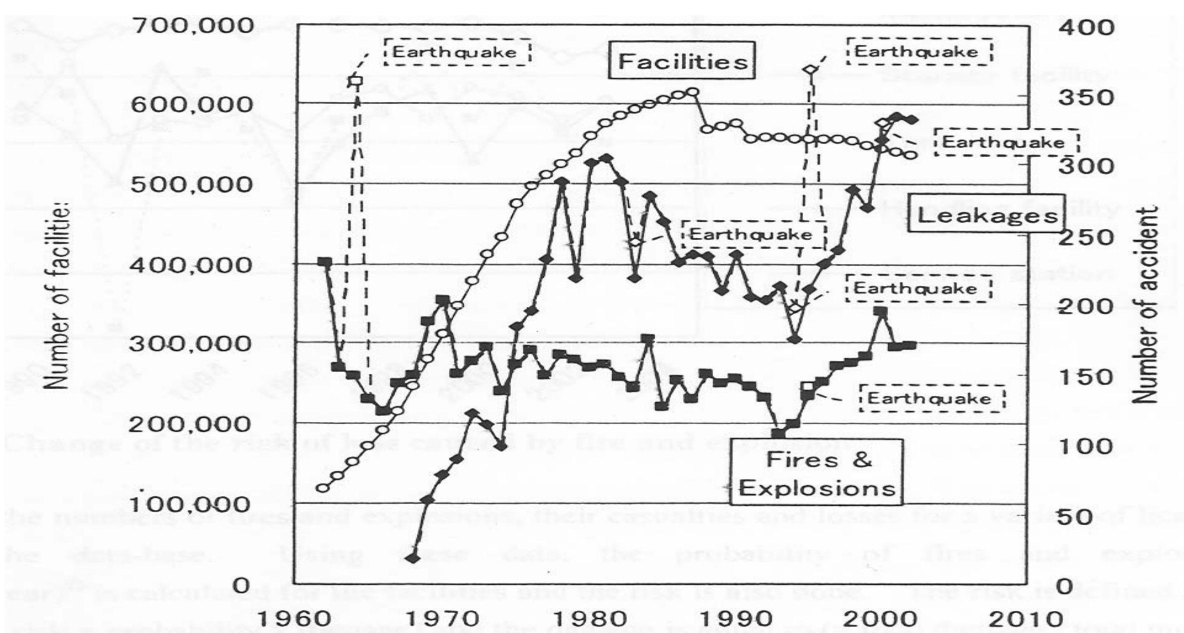

FIGURE 1.A-2.
ACCIDENT FREQUENCY DATA IN JAPAN

CHAPTER 2: RMP ACCIDENT HISTORY DATABASE AND DEMOGRAPHICS OF REPORTING FACILITIES

Outline of the Chapter

1. Introduction
2. RMP*Info and Data Quality Controls
3. Characteristics of Facilities Filing during 1999-2000 or 2004-2005
4. Concluding Comments

Appendix 2-A: Limitations of the RMP*Info Data Submission Process: Implications for Policy and Research

1. Introduction

This chapter reports the basic demographics of the facilities that filed under RMP*Info between 1994 and 2005. We also describe some aspects of the data quality assurance activities undertaken to screen data and to improve the understandability of the RMP process after the first filing.

Statistics on the nature of RMP facilities are important for several reasons. First, they provide an essential overview of which facilities and chemicals were affected by the RMP Rule. Second, changes in these demographics between the first filing and the second filing present an important aspect of the changing structure of the U.S. chemical industry.

A few words concerning terminology are important to note in reading this report. Data collected under the RMP Rule are obtained through a specific data acquisition protocol called RMP*Submit, and the data obtained are stored in an evolving database maintained at the EPA called RMP*Info. A partial version of RMP*Info (not including Offsite Consequence Analysis information) was available to the public via the Internet after August 1999 until shortly after September 11, 2001, when it was withdrawn from the Internet for security reasons.[1]

As explained below in more detail, the data reported under the RMP Rule arrive continuously, following various reporting requirements in the Rule. Nonetheless, two visible peaks of filings are apparent, the first around mid-year of 1999 and through calendar year 2000, and the second around mid-year 2004 and through calendar year 2005. We will refer

[1] Members of the public can still get access to the non-OCA version of the RMP*Info database by submitting a Freedom of Information Act request to EPA, and can get access to the full RMP data for a limited number individual facilities by visiting any of 50 Federal "reading rooms."

to the filings in these two sets of data, variously, as the first and second wave of filings, or as the 1999-2000 and 2004-2005 filings. We discuss in more detail below the nature of the data in these two filings.

2. RMP*Info and Data Quality Controls

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

- Executive Summary: This must cover the nature of the facility and its policies for accident prevention and emergency response, as well as a 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 regulations (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[2] 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.
- Sections 7 and 8: Prevention Program descriptions for Program 3 processes (Section 7) and Program 2 processes (Section 8),[3] 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.

[2] "Worst-Case" and "Alternative Release" scenarios encompass a number of factors, from meteorological to site-specific configurations, that are intended to describe the range of consequences, both on-site and off-site, arising from the sudden unplanned release of the greatest amount held in a single vessel (for worst-case scenarios) of the respective toxic or flammable substance associated with a process. As the terminology "worst-case" suggests, the consequences are intended to convey worst-case conditions. Alternative release scenarios capture the idea of a more likely accidental release scenario. Models and methods for computing worst-case and alternative release scenarios have been developed by EPA and others. We will have more to say about this matter when discussing worst-case footprints of facilities in Chapters 4 and 5.

[3] Under the RMP Rule, a process is subject to one of three specified program levels. Processes are eligible for Program 1 if the process has not had an accidental release with specified offsite consequences in the five years prior to the submission date of the RMP and has no public receptors within the distance to a specified toxic or flammable endpoint associated with a worst-case release scenario. Program 3 applies to processes not eligible for Program 1 that are either in one of ten specified North American Industrial Classification System codes or that are subject to the OSHA Process Safety Management standard (29 CFR 1910.119). A process is subject to Program 2 requirements if it is not eligible for Program 1 or subject to Program 3.

Reporting requirements under the RMP Rule are on-going. Facilities that operated a covered process in the interval between June 20, 1996 and June 20, 1999 were required to submit an initial Risk Management Plan (RMP) to EPA no later than June 21, 1999. After a facility submitted its RMP, it is required to revise and update its submission as follows:[4]

(1) At least once every five years from the date of its initial submission or most recent update required by paragraphs (b)(2) through (b)(7) of this section, whichever is later.
(2) No later than three years after a newly regulated substance is first listed by EPA;
(3) No later than the date on which a new regulated substance is first present in an already covered process above a threshold quantity;
(4) No later than the date on which a regulated substance is first present above a threshold quantity in a new process;
(5) Within six months of a change that requires a revised PHA or hazard review;
(6) Within six months of a change that requires a revised offsite consequence analysis as provided in §68.36; and
(7) Within six months of a change that alters the Program level that applied to any covered process.

[4] Quoted language taken from RMP Rule. The Rule also states that if a stationary source is no longer subject to part (b) requirements as noted below, then "the owner or operator shall submit a revised registration to EPA within six months indicating that the stationary source is no longer covered." A detailed discussion of de-registration of facilities is presented below.

In April 2004, EPA amended the reporting requirements associated with the Chemical Accident Prevention (RMP) Rule as follows:[5]

(1) To require that information on reportable chemical accidents be added to the RMP within six months of the date of the accident;
(2) To require that changes to emergency contact information be reported within one month;
(3) To remove the requirement to include a brief description of the off-site consequence analysis (OCA) in the RMP executive summary; and
(4) To add three RMP data elements to the RMP submission.
(5) To expand the list of possible accident causes to include uncontrolled chemical reactions.

As part of this 2004 rulemaking, EPA also clarified that the five-year deadline for updating RMPs that were originally filed early (i.e., submitted *before* June 21, 1999), was June 21, 2004. Facilities that filed early may have received correspondence indicating an earlier due date. However, EPA's interpretation of the regulations was that RMPs initially due on June 21, 1999 must be updated by June 21, 2004, not before.

The above requirements meant in practice that there was a natural peak in filings just before the June 21, 1999 deadline, with a second peak in filings in 2004 on the 5-year anniversary of the first filing peak. Most facilities reporting in 1999-2000 did file their RMP data by the initial deadline of June 21, 1999, with additions of new filers or exemptions of existing filers continuing through the end of 2000. The primary reason for the second group

[5] See U.S. EPA (2004a, b) for details on the new reporting requirements. The three new required data elements include: the facility's emergency contact e-mail address (if an email address exists); The purpose and type of any submission that revises or otherwise affects previously filed RMPs; and the name, address, and telephone number of the contractor/consultant who prepared the RMP (if any).

of filings in late 1999 and 2000 was that certain facilities distributing 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. Indeed, many of these facilities were eventually excluded from the Rule under the Chemical Safety Information, Site Security and Fuels Regulatory Relief Act (P.L. 106-40) passed in August 1999. In January 2000, the judicial stay was lifted and an additional 930 facilities, primarily propane producing facilities and fuel wholesalers (i.e., flammable fuel facilities not exempted by PL 106-40), began filing risk management plans under the Rule. These congressional and judicial rulings, occurring as they did after June 1999, gave rise to initial filings throughout 1999-2000 coming in several groups, with corrections to original filings occurring over time as well. Moreover, at a facility's request, the EPA/OEM also adjusted the RMP*Info database to withdraw RMP filings for facilities that had originally filed but were ultimately found not to be covered by the RMP 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. In addition, as noted above, 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. Given the five-year accident history requirement of the RMP Rule, the data from the 1999-2000 filing represents accident histories covering accidents from mid-1994 to the end of 2000, while the RMP reports made during the period 2004-2005 cover accident histories mid-1999 through the end of 2005. In the same manner as the first filing, these reports for 2004-2005 covered a variety of facilities, including new facilities that had not reported under the first filing, and a rolling set of renewal filings whose incoming date depended on when the facility had most recently filed an RMP accident history report.

From the above, it should be clear that the data in RMP*Info, including its associated accident histories, change over time as new and corrected filings arrive. The results reported here reflect a snapshot of this database as of February 21, 2006. These results capture both the data from the first filing in 1999-2000 and the second filing in 2004-2005. Our analysis is specifically concerned with the following two sets of accident history and RMP facility data:[6]

<u>First filing</u> (1999-2000):	RMP filings under RMP*Submit that were received between January 1, 1999 and December 31, 2000.
<u>Second filing</u> (2004-2005):	RMP filings under RMP*Submit that were received between January 1, 2004 and December 31, 2005.

Table 2.1 shows basic characteristics of the two sets of filing data of interest, indicating the numbers and percentages of reporting facilities, as well as the various state and federal regulatory programs covering process safety, notification requirements and emergency response regulations for these facilities. From Table 2.1, we see that 15,145 facilities filed in 1999-2000 and 12,065 reported in 2004-2005.

[6] A few facilities erroneously reported accidents reported in their initial filings that occurred prior to five years earlier than the filing date. These accidents were eliminated from the analysis to maintain uniformity across the database. These and other small changes and corrections undertaken by EPA/OEM over time mean that the results reported here are slightly different from the results reported in earlier analyses of this data, including Kleindorfer et al. (2003) and Elliott et al. (2003).

Table 2.1 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).[7] We note that 7,108 or 47% in the first filing (6055 or 50% in the second filing) of the reporting facilities had at least one process at level 3, therefore requiring a full Process Hazards Analysis to be undertaken and selected elements of it reported in the facility's RMP.

Data Quality Assurance

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 in the first set of filings and even less than that in the second set of filings.[8] Electronic submission is critical to data quality since the data submission system, called RMP*Submit, uses a standard data entry template and has a number of self-correcting and error checking mechanisms built into it to assure that the data submitted are in a standard format and meet other consistency checks (such as range checks).[9] Notwithstanding the significant

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[7] For definitions of Program Levels, see footnote 3 of this chapter.

[8] The U.S. EPA's responsible division, the Chemical Emergency Preparedness and Prevention Office (CEPPO), developed a data input and quality assurance program surrounding RMP*Submit for the initial wave of submissions. These procedures were continued in the second round within the EPA's Office of Emergency Management (OEM), which is the organizational successor of CEPPO.

[9] 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/OEM at their

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 steps were undertaken by the research team:

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. 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 a sample of 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.

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 or empirical distributions were reviewed to look for unusual or unexpected values ("outliers"). Where appropriate, cross-tabulations were performed to

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website http://www.epa.gov/oem/. The Appendix to this Chapter describes data quality research undertaken by the Wharton Risk Center and the lessons from this for policy and research based on the RMP Rule.

look for internal inconsistencies in the data. Outliers were discussed with EPA staff, who reviewed these cases to determine their validity.[10]

A number of activities between the first and second wave of filings were undertaken to improve the data quality in the RMP*Submit process. Thus, in the summer of 2003, members of the project team made detailed site visits to a number of small and large firms located in three different states to obtain their input on ambiguities in the RMP*Submit process. Input on the same issue was obtained from a consultant who had assisted over 20 small firms in completing the RMP*Info process in the first filing period. This process uncovered several concerns about the quality of the data obtained through the RMP*Submit process.[11]

- Respondents reported problems answering questions about facility location for large facilities, which might span 2 counties – or in the case of one facility that was visited, 2 states. If a facility reported its location based on the county in which its entrance or administrative office was located and if the hazardous

[10] 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: "Co-ops 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.

[11] Details of this investigation are included in Appendix 2-A.

substances was in an adjacent county, community members who queried RMP*Info for facilities in their county might not have learned of the hazard.

- Ambiguities concerning questions about "full-time equivalent employees (FTEs)" led to inconsistent responses to this question.
- Some smaller facilities were not familiar with the specific requirements that led to their facility being covered by the RMP Rule. Because the Rule only applies to the specified substances when present above threshold quantities, personnel at some facilities may have been confused as to whether or not their facility was required to report under the Rule.
- There were similar challenges to the validity of data about chemicals on-site. Interviewees reported that they were not clear, when filing in 1999-2000, about how to calculate the maximum amount of chemical held on-site in a covered process (e.g., they were unclear as to whether to include the amount in interconnected vessels, including railroad tank cars in calculating on-site inventories).
- Some interviewees expressed the opinion that the "worst-case scenarios" in the off-site consequence analyses were not credible.
- Interviewees took different, and inconsistent, approaches to deciding which accidents were reportable. Some facilities reported all accidents. Other facilities more precisely followed the RMP guideline, "You must complete an Accident History for every accidental release, within the last 5 years (as of the date of submission of the RMP), involving a regulated substance held above a threshold

quantity in a covered process if that release resulted in deaths, injuries, property damage onsite, or known offsite deaths, injuries, property damage, or environmental damage, evacuations, or shelterings-in-place." Other facilities set explicit standards for what was considered to be an appropriate threshold for "significant" on-site property damage. For example, one company set a threshold for on-site property damage – below which they did not consider the damage significant enough to trigger a report – at $250,000 per accident. Finally, some interviewees reported that some of the specified consequences were difficult to verify – creating the possibility of under-reporting.

The Risk Center also conducted a Roundtable at Wharton on March 4, 2003, involving 34 representatives from government, industry and NGOs. These discussions all focused on data quality issues related to the RMP*Info process. The results of this field research and Roundtable were provided to EPA. Based on these inputs and others from industry and their own studies, EPA/CEPPO/OEM undertook a revision of the RMP*Submit process in late 2003 and early 2004, and corrected or revised a number of potential ambiguities in the existing RMP*Submit process. Thus, the data submitted in the second set of filings in 2004-2005 was arguably cleaner to begin with than the original filing in 1999-2000. After obtaining the data, additional standard cleaning and data quality procedures were then also applied to the second set of data.

Because the number of reported deaths is such an important data element, for the initial data set extensive checking was done of each accident in which non-employee deaths occurred. This led to the final result for the 1999-2000 data (reported 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.[12] We have incorporated these corrections on deaths to public responders and other non-employees into our analysis. It is believed that the primary reason for these misreported "public deaths" was because of an ambiguity in the wording of the original RMP*Submit protocol, which was corrected between the first and second filings. However, there may be further corrections and revisions to RMP*Info at any time via the submission of a corrected RMP by any facility. Thus, in interpreting results from RMP*Info, it is always important to know the date of the last update incorporated in the analysis and any notable revisions, such as those noted above for the 1999-2000 data, undertaken to the data.

3. Characteristics of Facilities Filing during 1999-2000 or 2004-2005

There were 15,145 facilities that filed with RMP*Info in 1999-2000 and 12,065 facilities that filed in 2004-2005. However, the sample size for various analyses conducted below will not remain constant at 15,145 and 12,065, since some sites have multiple processes and some processes use multiple listed chemicals. We will also be conducting a trend analysis in Chapter 5 on the subset of 10,466 facilities that filed in both waves of RMP filings. In this section, we wish to review the characteristics of the facilities that filed, analyze the continuity of such filings between the two waves, and discuss the nature of those facilities that de-registered between the two filing waves.

[12] Breeda Reilly at EPA/CEPPO confirmed such errors. Four facilities reported a total 45 public responders fatalities in the 1999-2000 filings but these were all reporting errors. There were no public responder deaths in the reported accidents covered in the first wave of filings. In addition, two facilities reported a total of 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. As subsequent study showed, these errors may have been caused by the form of the question about public responder deaths, and the format of this question was revised in promulgating the updated RMP*Submit protocol for the 2004-2005 filing period.

Characteristics of Facilities that Filed in 1999-2000 or 2004-2005

Tables 2.1 to 2.3 list various characteristics of filers in both waves under the Rule. Table 2.1 lists the numbers and percentages of reporting facilities, indicating the various state and federal regulatory programs to which these facilities were subject. Tables 2.2A and 2.2B list the 20 most commonly reported chemicals, along with the number of facilities using each chemical and the number of full-time equivalent (FTE) employees at these facilities. Also listed are the total numbers of facilities reporting use of at least one listed toxic or flammable chemical.

The average facility reporting in the 1999-2000 filing had 155 FTE, ranging from facilities with less than 0.5 FTE (recorded as 0 FTE in RMP*Info) to 48,000 FTE. Half of reporting facilities had 10 FTEs or fewer. Patterns were very similar in the 2004-2005 filings, when the average facility reporting had 154 FTE (range from less than 0.5 to 48,000 FTE) and half of facilities had 11 FTEs or fewer. Of the top 20 chemicals in terms of reporting facilities, 11 in 1999-2000 and 10 in 2004-2005 were toxics and 9 in 1999-2000 versus 10 in 2004-2005 were flammables.

Table 2.3 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. Subject to a minor change, discussed further below, in the definition of the NAICS code 42291 (farm supplies wholesalers) to 42491 (farm supplies merchant wholesalers), the top three reporting sectors, accounting for approximately 50% of total filers, were the same in both 1999-2000 and 2004-2005.

The most common sector reported is farm supplies wholesalers (4,309 or 28% of facilities in 1999-2000 vs. 3,039 or 25% of facilities in 2004-2005), followed by water treatment and irrigation systems (1,984 or 13 % of facilities in 1999-2000 vs. 1,507 or 12% of facilities in 2004-2005) and sewage treatment (1,412 or 9% of facilities in 1999-2000 vs. 971 or 8% of facilities in 2004-2005).

Continuity of Facilities Filing in the 1999-2000 and 2004-2005 Waves

As noted above, there was a minor change in the name of the NAICS code that accounted for the largest number of filings in both 1999-2000 and 2004-2005, the NAICS code 42291 vs. 42491. The redefinition/renaming of this NAICS code itself is not consequential as there is a unique relationship between facilities classified under the former code (42291) and the latter code (42491).[13] What is interesting, however, is the substantial decline in the number of reporting facilities under 42291/42491. Indeed, of the 4,623 facilities that submitted RMPs with the 42291 NAICS code (in use until the revision of the NAICS codes was implemented in 2002), 1,022 (22%) of those facilities formally de-registered after their first RMP filing.[14] This example of 42291/42491 points to the general question of determining what became of the facilities that filed under the RMP Rule in

[13] There was a general NAICS Code redefinition between the two filings as part of the continuing efforts of the Office of Management and Budget to assure homogeneity of activity and technology within each NAICS code. This was announced in April, 2000 and formally implemented as of January, 2002. For the particular codes in question here, however, there is a unique relationship between the prior code and the latter code, so the case of 42291/42491 is simply a matter of a minor renaming of this NAICS Code. For details, see: http://www.census.gov/epcd/naics02/naifr02c.htm.

[14] These figures were provided by Kenneth Farris of Science Applications International Corporation (RMP Reporting Center) and Armando Santiago, EPA-OEM. They are consistent with the reduction in filers noted in Tables 2.3A-B, with NAICS Code filers 42291 accounting for 4,309 of facilities in 1999-2000 and NAICS Code 42491 accounting for 3,039 of facilities in 2004-2005), for a reduction of 4,309 – 3,039 = 1,270 facilities. Thus, the 1,022 de-registrations account for the vast majority of the decline in filers in the 42291/42491 NAICS Code. The difference in the number of total filers under 42291 in the first wave of filers recorded in Tables 2.3A-B (namely 4,309) and the number of filers who ever filed under 42291 (namely 4,623) is the result of the fact that the 1997 NAICS codes continued in use beyond the 1999-2000 filing time frame used for the data in Tables 2.3A-B.

1999-2000 in the ensuing 5 years. This question is answered by considering the following "balance equations" for any given NAICS Code (denoted abc):

Facilities Filing in Wave 1 under NAICS Code (abc) = (BA1-NAICS)

(S1) Facilities Filing in Wave 2 under NAICS Code (abc)

\+ (S2) Facilities Filing in Wave 2 not using NAICS Code (abc) and not de-registered as of 12/31/05

\+ (S3) Facilities Filing in Wave 1 that de-registered by 12/31/05 (abc)

\+ (S4) Facilities Filing in Wave 1 under NAICS Code (abc) not accounted for in the above three subsets S1, S2, S3.

Facilities Filing in Wave 2 under NAICS Code (abc) = (BA2-NAICS)

(T1) Facilities Filing in Wave 1 under NAICS Code (abc)

\+ (T2) Facilities Filing in Wave 1 under NAICS Code (abc) not accounted for in the subset (T1)

We show the result of the above two balance equations in Table 2.4. The first five columns in Table 2.4 are the results for BA1-NAICS and the last three columns are the results for BA2-NAICS. (Because of the renaming of NAICS code 42291, we combine codes 42291 and 42491 in row 1 of the table.)

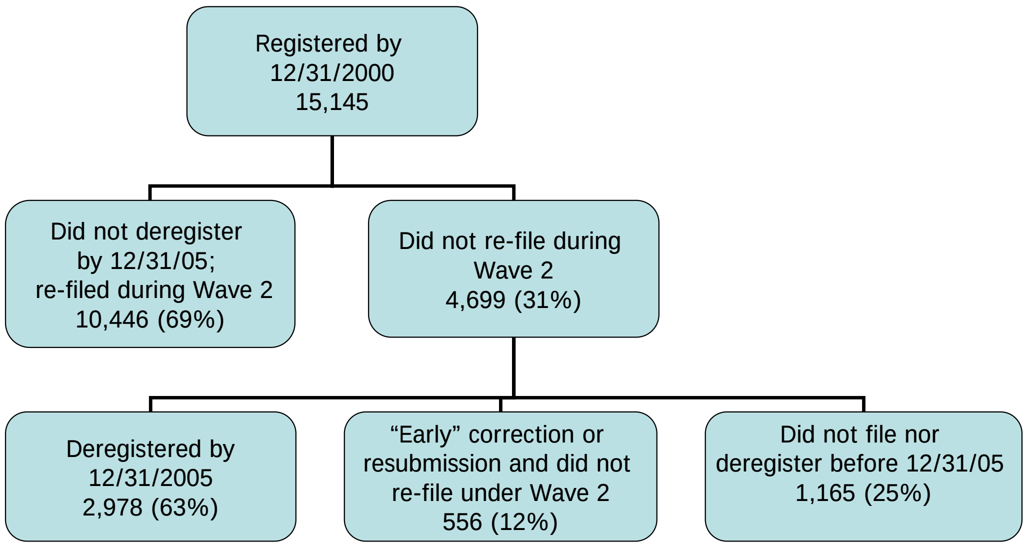
Corresponding results for the top 20 chemicals are provided in Table 2.5. We note for both Tables 2.4 and 2.5 that the definition of the NAICS Code and on-site chemicals were inclusive in the sense that any facility that named a particular NAICS code as one of possibly several NAICS codes for that facility was included in the set of facilities for that NAICS code (so that some facilities occur in more than one row of Table 2.4). Similarly, a facility was considered to belong to the group of facilities in Table 2.5 if it had the listed chemical on-site (as well as possibly other listed chemicals).

The overall balance equations for all Wave 1 and Wave 2 filers (not just the top 20 NAICS codes and chemicals reported in Tables 2.4 and 2.5) are themselves interesting and are given in the following balancing equations.

All together, there are 15,145 facilities that registered and filed a Wave 1-RMP filing by 12/31/2000, and among these 15,145 facilities:

> 10,446 were not de-registered by 12/31/2005 and filed during Wave 2 (which is defined as filings received between 1/1/04 and 12/31/05)
>
> 2,978 de-registered by 12/31/2005
>
> 556 had an "early" correction or resubmission of their Wave 1-RMP filing, which was received between 1/1/2001 and 12/31/2003, and did not file under Wave 2. These 556 facilities did not de-register as of 12/31/2005, nor did they file during the second filing. Those facilities that resubmitted (versus those who only corrected) their RMP between 1/1/2001 and 12/31/2003 were not be required to refile between 1/1/2004- 12/31/2005 if they did not have a reportable accident, as this time window would be within five years from their last submission.
>
> 1,165 facilities did not file before 12/31/2005 nor did they de-register as of 12/31/2005 though it is possible they de-registered after 12/31/2005, or filed after 12/31/2005.
>
> The above numbers give rise to the following balance equation for Wave 1 filers as depicted in Figure 2.1 below:

Figure 2.1:
Patterns of Filing and Re-Filing for Wave 1



Overall Balance Equation for Wave 1 Filers
15,145 = 10,446 + 2,978 + 556 + 1,165

For the second filing, we have 12,065 facilities. Among these 12,065 facilities:

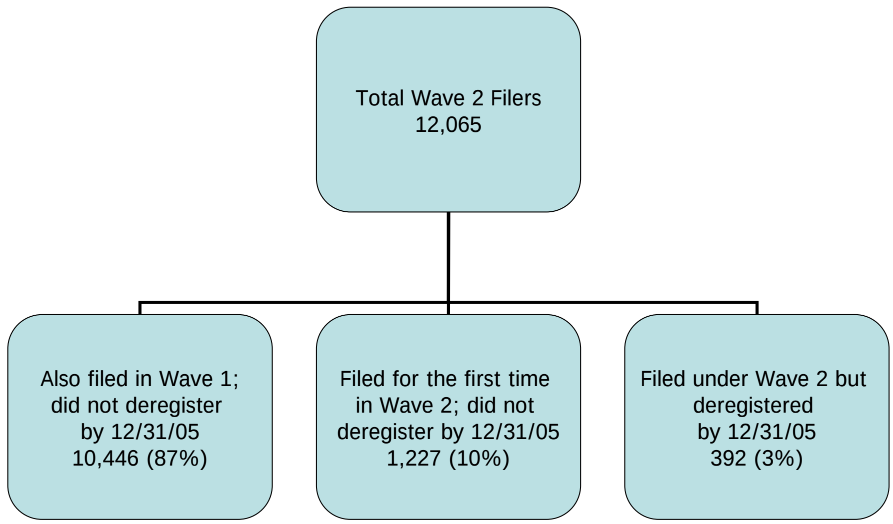
10,446 filed under both Wave 1 and Wave 2, and did not de-register by 12/31/2005 and filed during the second filing (and the first filing).

392 filed under Wave 2, but de-registered by 12/31/2005. These facilities filed in both waves but de-registered by 12/31/2005.

1,227 facilities filed for the first time in Wave 2 and did not de-register by 12/31/05

The above numbers give rise to the following balance equation shown in Figure 2.2 for Wave 2 filers.

Figure 2.2:
Patterns of Filing and Re-Filing for Wave 2



Overall Balance Equation for Wave 2 Filers
12,065 = 10,446 + 392 + 1,227

From these calculations, we see that 1,165 (or 7.6%) of the 15,145 Wave 1 filers were unaccounted for as of 12/31/05 (i.e., they had neither filed in Wave 2 nor had they de-registered by 12/31/05). New facility registrations accounted for 1,227 (or 10.2%) of the 12,065 RMPs filed under Wave 2.

<u>De-registration: Statistics and Reasons</u>

There is obviously a substantial difference between the number of facilities that filed in 1999-2000 (15,145) and 2004-2005 (12,065). Indeed, if one accounts for the fact that 1,227 of the 12,065 facilities in Wave 2 were new registrations, then there are 4,307 facilities that filed in Wave 1 but not in Wave 2. However, we see that nearly 70% of this total of 4,307 is accounted for by the 2,978 facilities that de-registered by 12/31/05 (and given the efforts of EPA, de-registrations continued thereafter). The reasons for de-registration are potentially interesting. At a general level, we would expect that such de-registrations would result from a shift to inherently safer chemicals (e.g., sodium hypochlorite solutions versus chlorine gas), a consolidation of various sectors,[15] as well as the redesign or changing the operation of processes to reduce facility inventories below the specified threshold limits required for reporting. Also, despite the EPA's diligence in its compliance and enforcement activities and the assistance of trade associations in helping members comply with the RMP Rule, non-compliance (including failure to properly de-register facilities that are no longer subject to the RMP Rule) is always a possible explanation for the decrease in filing activity.

To understand the nature of the facilities that de-registered, we analyzed the de-registrations that 2,978 facilities filed prior to 12/31/05.[16] When de-registering after May 24, 2004, a facility was asked to report its reason for de-registration under 1 of 4 categories (these categories are listed in Table 2.6). Prior to May 24, 2004, this information was not collected.

For the structure of NAICS codes and chemicals associated with these de-registrations, the reader is referred to Tables 2.4 and 2.5 (see the columns corresponding to subset 1-3 in these Tables). The major NAICS codes accounting for de-registration are shown in Table 2.7A, with the reasons given for their de-registration shown in Table 2.7B.

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[15] Note that consolidation typically takes the form of acquiring customers, while streamlining or closing facilities. This both adds to top-line revenue growth for the acquiring company as well as rationalizing the capital assets across the acquired and target company. It would be interesting to understand the relationship between the level of M&A activity in various chemical sectors and its relationship to sectoral EH&S performance. However, this is beyond the scope of the present study.

[16] Almost all of these de-registrations occurred after 01/01/2001. Only 52 facilities filed in Wave 1 but de-registered on or before 12/31/2000. Most of these early de-registrations were propane facilities that were no longer covered after PL 106-40 (the Chemical Safety Information, Site Security, and Fuels Regulatory Relief Act), exempted facilities that hold flammable substances for retail sale or on-site use as fuel.

Focusing just on the top three NAICS codes, whose major chemical usage was anhydrous ammonia and chlorine, we see that the major reasons for de-registration (for those facilities de-registering after 5/24/04 and indicating their reason) was the elimination of the regulated substances or the reduction of the substances below threshold quantities. This reflects, in part, the incentives in the RMP Rule to reduce the underlying hazards of on-site chemicals, a point we return to in Chapter 6 in our discussion of the overall effectiveness of the RMP Rule as a risk regulation.

The 201 facilities reported in Table 2.6 that filed their de-registration after May 24, 2004 and gave their reason for de-registering as “other” all included some explanatory text. Table 2.8 examines the textual reasons given for a relatively random sample of de-registrations filed under the category “other.” It is clear that many, if not most, of these facilities could have classified their de-registration under one of the categories available to define the facility’s reason for de-registering, as shown in Table 2.6, namely: (i) source terminated operations; (ii) source reduced inventory of all regulated substances below Threshold Quantities; or (iii) source no longer uses any regulated substance.

We draw two important conclusions from this discussion of de-registrations. First, RMP filings reflect the dynamics of the industry sectors covered by the Rule, and while there is considerable stability in the nature of the chemicals and processes used, there are also on-going changes in the industry and the associated RMP filings reflect this. Second, de-registration itself is a reflection of the positive impact of the RMP Rule. Indeed, from Table 2.6 we see that 803 (58%) of the 1,387 facilities that provided a reason for de-registration (which they could only do after the changes to RMP*Submit were implemented on May 24,

2004) indicated their reason for de-registration as moving to non-listed chemicals or reducing their inventories below threshold quantities.

Concluding Comments

The RMP Rule has now undergone two waves of filings since the implementing regulation for the Rule was first promulgated in June, 1996. The first wave occurred in 1999-2000 and the second in 2004-2005. The reader will note from Tables 2.1 to 2.3 that facilities filing in the two waves were similar in terms of regulatory programs, chemicals and sector covered. The changes in the pattern of registrations between the two waves of filings suggest that the reductions in the number of filers is in line with what one would expect from the initial introduction of a major regulation and is explained in good measure by de-registrations resulting from the natural motivations by facility owners across the industry to reduce regulatory burdens by holding inventories below threshold reporting requirements and shifting to alternative intrinsically safer raw materials that were not subject to the RMP Rule (e.g., alternative disinfection technologies in place of chlorine gas for water and wastewater treatment and alternatives to the use of anhydrous ammonia as a refrigerant). This reduction in the inventories of hazardous chemicals and movement to less hazardous substitutes can both be interpreted as steps towards accomplishing the second of the RMP Rule's three major objectives:[17]

[17] However, one must also be mindful of the findings of our data quality investigations (see Appendix 2-A) that facilities reported substantial variability in how they interpreted questions about quantities of hazardous chemicals. Therefore, we must be cautious in interpreting the findings of reduced registration numbers as representing an actual reduction in hazardous chemicals in U.S. chemical facilities. In fact, we will see in our analysis in Chapter 5, that inventories of chemicals have actually increased, on average, in the cohort of facilities that filed in both 1999-2000 and 2004-2005.

1) Prevent accidental chemical releases to the air;
2) Reduce the severity of chemical accidents that do occur;
3) Provide the public with information about the chemical hazards in their communities in order to promote a dialogue with industry to reduce facility risks.

The infrastructure to support the filing requirements of the Rule has been established and can be expected to continue to provide the basis for communication about facility risks between facility owners and the public that initially was, as noted above, one of the three major objectives that motivated the establishment of the RMP Rule in the first place. However, while this communication and information task is promoted by the required elements that make up the risk management plan, and the data required to be filed under the RMP Rule has been accumulated, actual dissemination of risk information has been curtailed because of security concerns around terrorist attacks.[18] It will be interesting to see if the first two of the Rule's three key objectives – prevention of chemical releases and reduction in the severity of those that did occur – were also enhanced. To that end, we now turn to the analysis of the accident history data reported in the two waves of RMP filings.

[18] Initial concern about terrorist and other purposeful releases of RMP regulated substances led to provisions in the *Chemical Safety Information, Site Security and Fuels Regulatory Relief Act (CSISSFRA)* of 1999 (PL 106-40) which among other things restricted public access to Offsite Consequence Analysis information. Increased concerns about purposeful releases by terrorists following the World Trade Center attack led to further reductions in the release of RMP information to the public. In 2004, the RMP rule was amended to "immediately remove the regulatory requirement for covered facilities to include in the executive summaries of their risk management plans (RMPs) a brief description of the off-site consequence analysis (OCA) for their facilities" see Environmental Protection Agency, 40 CFR Part 68, [Oar-2003-0044; Frl-7643-6] Rin 2050-Af09. See also US EPA (2004 a,b).

TABLE 2.1.
REPORTING FACILITIES COVERED BY VARIOUS REGULATORY PROGRAMS

Name of Regulatory Program	1999-2000 Filing		2004-2005 Filing	
	Number of Facilities Covered (from a Total of 15,145 Reporting)	Percent of Total Facilities Reporting under the Rule Covered by Each Specific Program	Number of Facilities Covered (from a Total of 12,065 Reporting)	Percent of Total Facilities Reporting under the Rule Covered by Each Specific Program
Process safety and hazards permitting programs				
OSHA-PSM	7,482	49%	6,278	52%
CAA-TITLE V	2,207	15%	1,985	16%
EPCRA-302	12,503	83%	10,209	85%
Emergency response programs				
OSHA 1910.38	12,732	84%	10,416	86%
OSHA 1910.120	9,041	60%	6,776	56%
RCRA (40 CFR 264, 265, 279.52)	3,100	20%	2,468	20%
OPA 90 (40 CFR 112, 33 CFR 1,424 9 154, 49 CFR 194, 30 CFR 254)	1,403	9%	1,201	10%
State EPCRA rules/law	11,000	73%	9,472	79%
Prevention program level				
Level 1	628	4%	407	3%
Level 2	7,409	49%	5,603	46%
Level 3	7,108	47%	6,055	50%

TABLE 2.2A
TWENTY MOST COMMONLY REPORTED CHEMICALS AND CHARACTERISTICS OF THE FACILITIES REPORTING THEM IN 1999-2000

Chemical Name	**Chemical type**	**Number of Filers**	**Mean FTEs of Filing Facilities**
Ammonia (anhydrous)	toxic	8,113	120
Chlorine	toxic	4,437	228
Propane	flammable	1,207	191
Flammable Mixture	flammable	807	138
Sulfur dioxide (anhydrous)	toxic	758	181
Ammonia (concentration 20% or greater)	toxic	508	141
Butane	flammable	317	229
Formaldehyde (solution)	toxic	280	275
Hydrogen fluoride/Hydrofluoric acid (concentration 50% or greater) [Hydrofluoric acid]	toxic	265	310
Isobutane [Propane, 2-methyl]	flammable	240	242
Pentane	flammable	168	244
Propylene [1-Propene]	flammable	161	485
Toluene diisocyanate (unspecified isomer) [Benzene, 1,3-diisocyanatomethyl-]	toxic	157	273
Methane	flammable	153	389
Vinyl acetate monomer [Acetic acid ethenyl ester]	toxic	150	245
Hydrogen	flammable	135	570
Isopentane [Butane, 2-methyl-]	flammable	115	277
Acrylonitrile [2-Propenenitrile]	toxic	113	308
Ethylene oxide [Oxirane]	toxic	107	359
Propylene oxide [Oxirane, methyl-]	toxic	104	324
Total facilities reporting		**15,145**	**155**
Total facilities reporting at least one toxic chemical		**13,570**	**159**
Total facilities reporting at least one flammable chemical		**2,502**	**208**

TABLE 2.2B
TWENTY MOST COMMONLY REPORTED CHEMICALS AND
CHARACTERISTICS OF THE FACILITIES REPORTING THEM IN 2004-2005

Chemical Name	Chemical type	Number of Filers	Mean FTEs of Filing Facilities
Ammonia (anhydrous)	toxic	6,876	136
Chlorine	toxic	3,193	212
Flammable Mixture	flammable	713	134
Sulfur dioxide (anhydrous)	toxic	598	135
Propane	flammable	596	180
Ammonia (concentration 20% or greater)	toxic	459	122
Butane	flammable	288	214
Isobutane [Propane, 2-methyl]	flammable	210	295
Formaldehyde (solution)	toxic	188	233
Hydrogen fluoride/Hydrofluoric acid (concentration 50% or greater) [Hydrofluoric acid]	toxic	181	346
Pentane	flammable	164	219
Propylene [1-Propene]	flammable	136	467
Toluene diisocyanate (unspecified isomer) [Benzene, 1,3-diisocyanatomethyl-]	toxic	132	190
Vinyl acetate monomer [Acetic acid ethenyl ester]	toxic	127	181
Isopentane [Butane, 2-methyl-]	flammable	126	271
Hydrogen	flammable	110	482
Acrylonitrile [2-Propenenitrile]	toxic	100	283
Ethylene oxide [Oxirane]	toxic	86	335
Ethylene [Ethene]	flammable	83	478
Methane	flammable	83	461
Total facilities reporting		**12,065**	**154**
Total facilities reporting at least one toxic chemical		**10,911**	**159**
Total facilities reporting at least one flammable chemical		**1,708**	**192**

TABLE 2.3A
TWENTY MOST COMMONLY REPORTED NAICS CODES AND
CHARACTERISTICS OF THE FACILITIES REPORTING THEM IN 1999-2000

NAICS DESCRIPTION	NAICS Code	Number of Filers	Mean FTEs of Filing Facilities
Farm Supplies Wholesalers	42291	4,309	7
Water Supply and Irrigation Systems	22131	1,984	205
Sewage Treatment Facilities	22132	1,412	217
Refrigerated Warehousing and Storage	49312	564	197
Natural Gas Liquid Extraction	211112	473	15
Other Chemical and Allied Products Wholesalers	42269	366	26
Farm Product Warehousing and Storage	49313	337	5
Support Activities for Crop Production	11511	304	7
Plastics Material and Resin Manufacturing	325211	256	266
All Other Basic Organic Chemical Manufacturing	325199	250	249
Poultry Processing	311615	226	804
Liquefied Petroleum Gas (Bottled Gas) Dealers	454312	205	17
All Other Basic Inorganic Chemical Manufacturing	325188	192	244
Soil Preparation, Planting, and Cultivating	115112	189	10
Petroleum Refineries	32411	167	371
Industrial Gas Manufacturing	32512	135	58
General Warehousing and Storage	49311	130	604
Fossil Fuel Electric Power Generation	221112	128	86
Meat Processed from Carcasses	311612	120	416
Nitrogenous Fertilizer Manufacturing	325311	119	91

TABLE 2.3B
TWENTY MOST COMMONLY REPORTED NAICS CODES AND CHARACTERISTICS OF THE FACILITIES REPORTING THEM IN 2004-2005

NAICS DESCRIPTION	NAICS Code	Number of Filers	Mean FTEs of Filing Facilities
Farm Supplies Merchant Wholesalers	42491	3,039	6
Water Supply and Irrigation Systems	22131	1,507	190
Sewage Treatment Facilities	22132	971	219
Refrigerated Warehousing and Storage	49312	626	218
Other Chemical and Allied Products Merchant Wholesalers	42469	393	21
Natural Gas Liquid Extraction	211112	391	16
Farm Product Warehousing and Storage	49313	284	3
Support Activities for Crop Production	11511	276	7
Poultry Processing	311615	231	821
All Other Basic Organic Chemical Manufacturing	325199	224	235
Plastics Material and Resin Manufacturing	325211	215	235
Other Farm Product Raw Material Merchant Wholesalers	42459	194	10
All Other Basic Inorganic Chemical Manufacturing	325188	168	210
Fossil Fuel Electric Power Generation	221112	149	99
Petroleum Refineries	32411	146	375
Industrial Gas Manufacturing	32512	122	46
Urethane and Other Foam Product (except Polystyrene) Manufacturing	32615	121	123
Meat Processed from Carcasses	311612	115	487
Petroleum Bulk Stations and Terminals	42471	114	17
Corn Farming	11115	104	7

TABLE 2.4.
REGISTRATIONS AND DE-REGISTRATIONS FOR WAVE 1 AND WAVE 2 FOR TOP 20 NAICS CODES

Rank	NAICS Code	NAICS DESCRIPTION	Total Wave 1 Filings	Filed under same NAICS code both waves (1_1)	Filed both waves but changed NAICS code (1_2)	Filed Wave 1, de-registered by 12/31/05 (1_3)	Filed Wave 1, not accounted for by columns 1_1, 1_2, or 1_3 (1_4)	Total Wave 2 Filings	Filed under same NAICS code both waves (2_1)	Filed Wave 2, did not file under same NAICS in Wave 1 (2_2)
1	42291 or 42491 *	Farm Supplies Wholesalers	4,309	2,516	543	811	449	2,516	2,516	0
2	22131	Water Supply and Irrigation Systems	1,984	1,326	57	383	218	1,507	1,326	181
3	22132	Sewage Treatment Facilities	1,412	824	38	386	164	971	824	147
4	49312	Refrigerated Warehousing and Storage	564	432	38	50	44	626	432	194
5	211112	Natural Gas Liquid Extraction	473	314	10	87	62	391	314	77
6	42269	Other Chemical and Allied Products Wholesalers	366	2	229	93	42	5	2	3
7	49313	Farm Product Warehousing and Storage	337	191	56	66	24	284	191	93
8	11511	Support Activities for Crop Production	304	125	92	53	34	276	125	151
9	325211	Plastics Material and Resin Manufacturing	256	191	18	22	25	215	191	24
10	325199	All Other Basic Organic Chemical Manufacturing	250	178	17	34	21	224	178	46
11	311615	Poultry Processing	226	193	7	22	4	231	193	38

Rank	NAICS Code	NAICS DESCRIPTION	Total Wave 1 Filings	Filed under same NAICS code both waves (1_1)	Filed both waves but changed NAICS code (1_2)	Filed Wave 1, de-registered by 12/31/05 (1_3)	Filed Wave 1, not accounted for by columns 1_1, 1_2, or 1_3 (1_4)	Total Wave 2 Filings	Filed under same NAICS code both waves (2_1)	Filed Wave 2, did not file under same NAICS in Wave 1 (2_2)
12	454312	Liquefied Petroleum Gas (Bottled Gas) Dealers	205	13	78	59	55	18	13	5
13	325188	All Other Basic Inorganic Chemical Manufacturing	192	131	24	20	17	168	131	37
14	115112	Soil Preparation, Planting, and Cultivating	189	7	98	53	31	51	7	44
15	32411	Petroleum Refineries	167	140	6	14	7	146	140	6
16	32512	Industrial Gas Manufacturing	135	90	10	29	6	122	90	32
17	49311	General Warehousing and Storage	130	53	17	40	20	76	53	23
18	221112	Fossil Fuel Electric Power Generation	128	79	3	37	9	149	79	70
19	311612	Meat Processed from Carcasses	120	81	17	10	12	115	81	34
20	325311	Nitrogenous Fertilizer Manufacturing	119	60	27	22	10	86	60	26

* In Row 1, 42291 and 42491 are combined, for reasons described in the text.

TABLE 2.5.
REGISTRATIONS AND DE-REGISTRATIONS FOR WAVE 1 AND WAVE 2 FOR TOP 20 CHEMICALS

Rank	CHEMICALNAME	Total Wave 1 Filings	Filed under same NAICS code both waves (1_1)	Filed both waves but changed NAICS code (1_2)	Filed Wave 1, de-registered by 12/31/05 (1_3)	Filed Wave 1, not accounted for by columns 1_1, 1_2, or 1_3 (1_4)	Total Wave 2 Filings	Filed under same NAICS code both waves (2_1)	Filed Wave 2, did not file under same NAICS in Wave 1 (2_2)
1	Ammonia (anhydrous)	8,113	5,862	91	1,339	821	6,876	5,862	1,014
2	Chlorine	4,437	2,893	63	963	518	3,193	2,893	300
3	Propane	1,207	445	272	259	231	596	445	151
4	Flammable Mixture	807	555	28	139	85	713	555	158
5	Sulfur dioxide (anhydrous)	758	507	45	136	70	598	507	91
6	Ammonia (conc 20% or greater)	508	324	54	94	36	459	324	135
7	Butane	317	215	46	31	25	288	215	73
8	Formaldehyde (solution)	280	159	26	58	37	188	159	29
9	Hydrogen fluoride/Hydrofluoric acid (conc 50% or greater) [Hydrofluoric acid]	265	151	21	63	30	181	151	30
10	Isobutane [Propane, 2-methyl]	240	165	32	23	20	210	165	45
11	Pentane	168	97	40	16	15	164	97	67
12	Propylene [1-Propene]	161	113	19	20	9	136	113	23
13	Toluene diisocyanate (unspecified isomer) [Benzene, 1,3-diisocyanatomethyl-]	157	104	20	24	9	132	104	28
14	Methane	153	64	32	46	11	83	64	19
15	Vinyl acetate monomer [Acetic acid ethenyl ester]	150	115	4	16	15	127	115	12
16	Hydrogen	135	99	12	19	5	110	99	11
17	Isopentane [Butane, 2-methyl-]	115	84	19	6	6	126	84	42
18	Acrylonitrile [2-Propenenitrile]	113	89	7	13	4	100	89	11
19	Ethylene oxide [Oxirane]	107	84	5	10	8	86	84	2
20	Propylene oxide [Oxirane, methyl-]	104	77	6	12	9	83	77	6

TABLE 2.6.
REASONS FOR DE-REGISTRATION
(FACILITIES FILING IN WAVE 1 THAT DE-REGISTERED PRIOR TO 12/31/05)

Reason Given for De-Registration	Facilities De-Registering on or Before 5/23/2004	Facilities De-Registering Between 5/24/04 and 12/31/05
No reason for de-registration was collected	1,591	NA
Source no longer uses any regulated substance	NA	530
Source reduced inventory of all regulated substances below threshold quantities	NA	273
Source terminated operations	NA	383
Facilities De-registering between 5/24/2004 and 12/31/2005 and listing "other" as the reason	NA	201

TABLE 2.7A.
NUMBER OF FACILITIES THAT FILED IN WAVE 1 AND DE-REGISTERED PRIOR TO 12/31/2005
FOR THE 20 MOST FREQUENTLY REPORTED NAICS CODES OF SUCH FACILITIES*

Rank	NAICS CODE	NAICS DESCRIPTION	COUNT
1	42291	Farm Supplies Wholesalers	745
2	22132	Sewage Treatment Facilities	388
3	22131	Water Supply and Irrigation Systems	384
4	211112	Natural Gas Liquid Extraction	88
5	42269	Other Chemical and Allied Products Wholesalers	83
6	49313	Farm Product Warehousing and Storage	68
7	42491	Farm Supplies Merchant Wholesalers	65
8	454312	Liquefied Petroleum Gas (Bottled Gas) Dealers	55
9	11511	Support Activities for Crop Production	51
10	49312	Refrigerated Warehousing and Storage	50
11	115112	Soil Preparation, Planting, and Cultivating	46
12	221112	Fossil Fuel Electric Power Generation	39
13	49311	General Warehousing and Storage	39
14	325199	All Other Basic Organic Chemical Manufacturing	33
15	32512	Industrial Gas Manufacturing	29
16	325311	Nitrogenous Fertilizer Manufacturing	23
17	325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	23
18	325211	Plastics Material and Resin Manufacturing	22
19	311615	Poultry Processing	21
20	325188	All Other Basic Inorganic Chemical Manufacturing	19

*The total of all facilities that filed in wave 1 and de-registered between 08/19/1999 and 12/29/2005 was 2,978, of which the total accounted for in the top 20 NAICS codes of de-registering facilities was 2,247. Note that 24 of these de-registering facilities listed more than one of the top 20 NAICS codes and these facilities therefore appear more than once in the above table.

2.7B
TABLE OF DE-REGISTRATION REASONS BY TOP-20 NAICS CODES

NAICS CODE	DE-REGISTRATION REASON Number (%)					
	No reason reported (prior to 5/23/04)	Source no longer uses any regulated substance	Source reduced inventory of all regulated substances below TQs	Source terminated operations	Other	Total
42291	467 (62.7)	105 (14.1)	25 (3.4)	120 (16.1)	28 (3.8)	745
22132	194 (50.0)	110 (28.4)	48 (12.4)	9 (2.3)	27 (7.0)	388
22131	195 (50.8)	104 (27.1)	56 (14.6)	10 (2.6)	19 (5.0)	384
211112	50 (56.8)	9 (10.2)	5 (5.7)	14 (15.9)	10 (11.4)	88
42269	48 (57.8)	10 (12.1)	13 (15.7)	9 (10.8)	3 (3.6)	83
49313	23 (33.8)	10 (14.7)	0 (0.0)	32 (47.1)	3 (4.4)	68
42491	0 (0.0)	25 (38.5)	3 (4.6)	31 (47.7)	6 (9.2)	65
454312	10 (18.2)	9 (16.4)	22 (40.0)	5 (9.1)	9 (16.4)	55
11511	27 (52.9)	5 (9.8)	1 (2.0)	16 (31.4)	2 (3.9)	51
49312	21 (42.0)	5 (10.0)	7 (14.0)	8 (16.0)	9 (18.0)	50
115112	23 (50.0)	10 (21.7)	0 (0.0)	5 (10.9)	8 (17.4)	46
221112	34 (87.2)	2 (5.1)	2 (5.1)	0 (0.0)	1 (2.6)	39
49311	26 (66.7)	1 (2.6)	5 (12.8)	5 (12.8)	2 (5.1)	39
325199	22 (66.7)	3 (9.1)	1 (3.0)	6 (18.2)	1 (3.0)	33
32512	21 (72.4)	2 (6.9)	3 (10.3)	2 (6.9)	1 (3.5)	29
325311	10 43.48	3 13.04	1 4.35	8 34.78	1 4.35	23
325998	12 52.17	3 13.04	4 17.39	3 13.04	1 4.35	23
325211	13 59.09	2 9.09	2 9.09	5 22.73	0 0.00	22
311615	11 52.38	5 23.81	2 9.52	2 9.52	1 4.76	21
325188	9 47.37	2 10.53	2 10.53	5 26.32	1 5.26	19

TABLE 2.8.
EXAMPLES OF TEXT ACCOMPANYING USE OF "OTHER"
AS THE REASON FOR DE-REGISTRATION

1	Propane is no longer covered by the regulation when held for retail fuel sales.
2	The facility is no longer covered by the RISK MANAGEMENT PLAN 40 CFR
3	Not Required..... Exempt from Rule
4	Does not have storage of extremely hazardous substances
5	Retail Propane filling operation
6	We leased facility to another owner/operator
7	Source exempt under CISSFRA
8	Substance no longer a listed chemical
9	Never had regulated products on site
10	Switched from gas chlorine to liquid chlorine
11	No longer utilizes chlorine gas in its water process
12	This facility is no longer operating, the storage tank was moved to ABC
13	Previous owner ABC removed ammonia and sold facility
14	Eliminated the use of chlorine and have changed to UV disinfection
15	Quit the anhydrous business
16	All regulated substances have been removed from plant grounds
17	Never actually used the regulated substances, as anticipated.
18	Not regulated per Chemical Safety Information, Site Security and Fuel Relief Act
19	Got out of the Anhydrous Ammonia business
20	Chemicals used for the disinfection of the plant will no longer be used
21	New ownership
22	Facility has merged RMP requirements with ABC Corporation
23	Kicked out by the County of ABC
24	This facility stopped selling anhydrous ammonia

Appendix 2-A[1]

Limitations of the RMP*Info Data Submission Process: Implications for Policy and Research

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Summary

The Environmental Protection Agency's "Risk Management Programs for Chemical Accidental Release Prevention" created RMP*Info, requiring that U.S. facilities meeting certain criteria file a report on hazardous chemicals on-site, on accidents involving these chemicals, and on elements of the facility's risk management plans. RMP*Info has been used for a series of research projects investigating the impact of facility, community, and economic factors on hazardousness. In conducting some of these analyses, our research group noted several data inconsistencies, which created some concern about the validity of RMP*Info data. The study described here used

[1] This paper was originally developed by Robert A. Lowe and presented at a workshop on May 5, 2005, at the Wharton School.

qualitative epidemiologic methods to assess potential barriers to validity of the RMP*Info data collected in the initial filing of RMP data in 1999-2000. Respondents reported varied interpretations of several key data elements. These varied interpretations could affect validity of data on the presence and quantities of hazardous chemicals, number of employees on site, and accident history. Drawing on concepts of epidemiologic methods and informational regulation, we discuss the implications of this finding for the ability of the RMP process to meet its goals of reducing the probability of accidents, mitigating the consequences of accidents, and providing valid data for research. Following the research reported here, many of the ambiguities in the original RMP*Submit process, which governed the initial RMP submissions in 1999-2000, were remedied by EPA prior to the second wave of submissions in 2004-2005. Nonetheless, this paper argues that data quality issues will continue to be central to achieving the full benefits of the RMP process.

1. Introduction

This paper adds to a line of research undertaken by the Wharton Risk Management and Decision Processes Center, in cooperation with the U.S. Environmental Protection Agency (Office of Emergency Management - OEM), on accidents in the United States chemical industry, using the RMP*Info database [1-5].

The RMP*Info process was designed with several goals in mind. Facilities with high-risk toxic and flammable agents in substantial quantities would partner with emergency responders in their communities to develop response plans to manage toxic releases, fires, and explosions. Emergency preparedness would mitigate the impact of an untoward event. Community members could query RMP*Info electronically to identify facilities in their communities that contained environmental hazards, along with the accident history of these facilities. Requiring facilities to generate and publish information might create community pressure to reduce the risks, in line with the concept of "informational regulation" [1],[6]. This concept is grounded in the notion that providing better information to those affected by risks can assist them to prepare for eventual emergencies and can also promote an informed citizenry that can exert pressure on facilities to reduce risks. This informational aspect of the RMP Rule remains one of its key elements.

2. Background and Motivation for the Present Data Quality Project

As part of our explorations into the RMP*Info database, we discovered some issues that stimulated our interest in the data collection process. For example, the original database covering the 1999-2000 wave of filings included reports of 45 deaths of public responders (firefighters, paramedics, etc.) and 11 other on-site deaths of non-employee civilians. Because we were surprised that these deaths would have occurred without media publicity, we asked EPA staff to investigate. EPA staff confirmed that none of these deaths occurred; all had been due to data entry errors by responding facilities. We also found 10 facilities in the 1999-2000 wave of filings that each reported 10 or more accidents and asked EPA staff to investigate these cases. Of the 131 accidents reported by these facilities, 116 were deemed probably not reportable after investigation by EPA staff. These problems continued in the 2004-2005 wave of filings, with reports of 25 public responder deaths in two separate accidents also being the result of data entry errors by facilities.

As we considered the cause of these reporting errors, we recognized an opportunity. Just as the analyses described above used the tools of quantitative epidemiology to analyze a large database, we could employ qualitative epidemiologic tools to understand the data collection process. Our goal was to explore whether limitations of the data collection process might bias the results of our quantitative analyses or compromise the original intent of the RMP Rule to reduce hazards from chemical facilities, improve emergency preparedness, and inform communities. The resulting project, described below, was undertaken in 2003 with the objective of contributing to revisions of the RMP*Info process in the second cycle of filings, which began in June 2004.

3. Methods

Overview of questionnaire development methods in epidemiology

Because epidemiologists often rely on data that they collect themselves, the discipline includes emphasis on data quality [7]. Epidemiological researchers take pains to ensure that data are valid – i.e., that the data collection instrument measures what it is intended to measure – and that the instrument is reliable – i.e., that repeated measurements of the same variable on the same study subject by different data collectors will lead to the same result (unless, of course, the study subject has changed with respect to the variable of interest). These principles apply whether the data collection instrument is a questionnaire, an observation of behavior, a component of the physical examination, or a laboratory test.

When the instrument is a questionnaire or survey, there are defined steps that are often taken to develop and validate the instrument [8]. Because RMP*Info is, in essence, a questionnaire, we considered the relevance of these steps to RMP*Info. Several components of questionnaire design seemed particularly relevant.

Epidemiologists often conduct focus groups as part of questionnaire design [9]. A small group of people (usually in the range of 6 to 10) is selected, who are similar to the anticipated respondents for the survey. A group leader asks a series of open-ended questions and facilitates a discussion of these questions. Focus groups do not give quantitative information about the proportion of people with a given characteristic; instead they help researchers understand what characteristics are relevant and how to measure them. For instance, a research team might want to study patients' "access to medical care." Before conducting focus groups, the researchers might assume that patients would share the researchers' understanding of what "access to medical care" meant, i.e. the ability to obtain an appointment with a primary care physician. The focus group leader might introduce the topic by saying, "We're here to learn how you feel about access to medical care. What comes to mind when I ask you about access to medical care?" The response may be surprising. Patients may interpret "medical care" as including medical specialists, chiropractors, massage therapists, or pharmacists. Researchers may discover that if they want to learn about access to primary care physicians, they must define "primary care physician" more clearly and avoid the more general term, "medical care." "Access" may include issues of transportation, appointments that do not conflict with the patients' work schedules, or other factors that the researchers did not anticipate. The focus groups assist the research team in two ways: (1) the researchers gain a clearer understanding of the issues as perceived by patients, which may lead the researchers to collect additional data and perform a richer analysis; and (2) the researchers learn that they need to re-word their questions in order to obtain the information they seek.

A related approach is the in-depth interview [9]. Like focus groups, in-depth interviews are open-ended conversations in which the researcher asks the participant about a short list topics, probing for elaboration as needed. Unlike focus groups, in-depth interviews are conducted with one respondent at a time. The settings in which researchers select focus groups versus interviews and vice-versa are beyond the scope of this paper; both techniques are valuable aids to questionnaire design. While focus groups and in-depth interviews are not the only means to obtain information about what questions will be meaningful to respondents and how respondents are likely to interpret questions, they are useful tools to help achieve these ends.

Once the researchers have sufficient information to design a questionnaire, they develop and test potential questions [8]. First, they list the variables that they wish to measure. Then, they search for existing measures of these variables, measures that have been shown in previous studies to be valid and reliable. Where existing instruments are not sufficient, the researchers must create and test their own questions – determining what choice of wording leads to responses that are valid, when compared with a "gold standard," on a small group of subjects. Developing a question actually has two components: (1) finding the best way to ask the question; and (2) developing a list of possible responses that lists all likely possibilities, without overlap between the answers. (The ideal list of responses is described as "exhaustive and mutually exclusive.") After assembling individual questions into a draft questionnaire, the researchers read the draft, attempting to answer the questions as if they were study subjects and trying to imagine how the questions could be misinterpreted. Finally, the researchers pilot test the questionnaire. A small group of subjects is asked to take the questionnaire; researchers observe these subjects while they complete the questionnaire and ask them for feedback about items that are unclear or difficult to answer. The researchers may also seek to validate the respondents' answers through alternative approaches, to assess the validity of the instrument. Pilot testing usually leads to information about questions that are difficult to interpret, about missing or unclear response options, and about the need to shorten the questionnaire. The instrument must be revised and pilot-tested repeatedly until it is satisfactory [8].

Application of questionnaire development tools to RMP*Info

We conducted this project in 2003, several years after the first round of RMP*Info data collection, in partnership with EPA staff. One goal of this collaboration was to use insights obtained from this investigation to enhance the validity of the second round of RMP*Info data collection in 2004.

We began the project by recognizing several constraints. First, the goal was to help revise a questionnaire rather than to develop one *de novo*. Second, some modifications of the data collection process might require substantial regulatory changes by the EPA or even legislative action. Third, the length and complexity of the questionnaire precluded our evaluating the entire instrument. We concluded that our group could best contribute by evaluating the current data collection instrument, rather than by pilot-testing revisions to it, because EPA staff could best assess the feasibility of such revisions given regulatory constraints. We also concluded that this evaluation should be limited to the data elements that we felt were most important, because pilot testing the entire instrument would take longer than most interviewees would be able to spend.

Developing a method to assess the RMP*Info questionnaire

Our first step was to list the variables from RMP*Info that we felt were most important. We selected variables that we thought would be of greatest use in achieving the Risk Management Plan goals of informing community members and facilitating emergency preparedness, supplementing this list with variables that we had found important for our research.

We began with the facility location for three reasons: (1) community members can only exert pressure to reduce risk if they know that the risk is located in their community; (2) communities need to know the location of a facility in order for emergency responders to prepare for toxic or flammable releases; and (3) location was an important variable for the research questions we analyzed. Next, we inquired about the number of full-time equivalent employees on site, because the number of employees should reflect the number of people at risk on site if an accident occurs and because we had found this variable to be associated with the probability of accidents occurring. We reviewed the questions about "process specific information." We felt that these questions were important because only those facilities that engaged in specified processes were required to file under RMP*Info; therefore, ambiguities about these questions might lead to ambiguities about which facilities needed to comply with RMP regulations. We reviewed questions about chemicals (regulated substances) and quantities on site because they were also central to deciding whether a facility needed to file, as well as to community preparedness. (This information was also central to our analyses of the relationship of facility hazardousness to accident severity and frequency [3].) We asked how the worst-case scenarios for release of toxics or flammable substances were developed and about alternative scenarios that were submitted. We asked about the five-year accident history, including how respondents decided which accidents to report, and for each reported accident, how they decided which chemicals were involved, the quantities released, and the impacts. Doubtless other researchers would have picked additional variables but we felt that understanding the validity of responses to these key variables would be a useful beginning.

After identifying the key variables, we searched for the questions in RMP*Info that solicited information about these facility characteristics. We reviewed the existing data collection tools, including the RMP*Submit User's Manual [10], the RMP*Info data form for paper submissions [11], supplemental paper instructions [11], and the RMP*Submit software provided by EPA to facilitate electronic submissions.

In reviewing the RMP*Info materials, we identified some possible ambiguities. Some of these are discussed in the Results section below. We also comment on findings from our quantitative analyses that suggest problems with the questionnaire.

In-depth interviews

We selected a sample of facilities for in-depth interviews. The facilities we visited were located in 3 states (2 eastern and 1 western). Sites included large and small facilities, publicly and privately owned, in a variety of industries. In addition, we interviewed a consultant who had assisted numerous small facilities in the filing process. In each facility, the study team scheduled an appointment with the person or group responsible for completing RMP*Info. Senior plant management personnel often joined in these meetings. Thus, the field interviews ranged from in-depth interviews with single respondents to small focus groups.

4. Results

Facility location

Facility location data that were requested by RMP*Info included street address, county, latitude and longitude. Our quantitative work indicated that 11% of facilities reported longitudes outside of the United States; a common (although far from the only) error was the omission of a minus sign from the longitude. Review of the data entry form and the RMP*Submit data entry screen confirmed that the space for a minus sign within the longitude and latitude fields was confusing. Respondents reported problems answering these questions for large facilities, which might span two counties, or in the case of one facility that we visited, two states. If a facility reports its location based on the county in which its entrance or administrative office is located and if the hazardous substances are in an adjacent county, community members who query RMP*Info for facilities in their county may not learn of the hazard.

Number of employees

The question regarding number of employees was worded, "number of full-time employees (FTEs) on site." Instructions from the guidance manual [10] are shown in Figure 1. The ambiguity of the abbreviation "FTE," meaning full-time <u>equivalents</u> or full-time <u>employees</u>, created confusion, as did the term "on site." Although these terms are clarified in the accompanying instructions, not all respondents read and understood those instructions. One respondent, who appeared to have answered this question based on the form itself without having read the instructions in the RMP*Submit Users Manual, commented, "I didn't think it was that important."

Site respondents commented that, as defined in the instructions, "full-time equivalent employees" excludes contract employees. Because some facilities have hundreds of contract employees on site every day, FTE as described in the instructions may not accurately capture the size of the facility or the number of workers at risk on-site.

Some site respondents indicated that they had interpreted this question to mean employees at risk from their involvement in the work process of the facility. With this understanding, administrative staff and research and development employees on the same site but not involved in manufacturing were excluded from the count.

Our interviews suggested that the optimal wording of questions about FTEs is affected by the purpose of asking the questions. For instance, if the goal is to ascertain the number of on-site personnel at risk from an accident, contract employees should be included. Furthermore, a facility with 90 FTEs but multiple shifts will not have the same number of employees at risk as a facility with 90 FTEs all on one shift; if there are three shifts, with 30 employees per shift, there are rarely more than 30 employees at risk from a catastrophic event, while if there is one shift with 90 employees, all are at risk from such an event.

Manufacturing processes and chemicals used

When we inquired about manufacturing processes, we also discovered issues that might compromise validity and reliability of the responses. RMP*Info asks respondents to use North American Industrial Classification System (NAICS) numeric codes to identify each covered process. NAICS codes are available on the web, as indicated in the RMP*Submit instructions. However, not all respondents at small facilities were familiar with NAICS codes. In one instance, a respondent initially failed to recognize that the facility was engaged in processes coded by two different NAICS codes, rather than a single one. Because the Risk Management Program only applies to the specified substances when used in covered processes [12], personnel at a facility cannot decide whether it was required to report under the Program unless they are able to determine the processes correctly.

There were similar challenges to the validity of data about chemicals on-site. Interviewees reported that they have come to understand that, when they report the maximum amount of chemical held on-site in a covered process, they are to include the amount in interconnected vessels. If they have one tank holding 100,000 pounds that is connected by piping to the production process, it must be included; if they have three railroad tank cars of the same chemical, each holding 180,000 pounds, these are not to be reported.

Respondents at one facility called the issue of whether to report contents of tank cars, "The single biggest problem in interpretation of the RMP process." This facility had decided to include the contents of tank cars in their reported inventories, despite their understanding that the EPA did not require these contents to be reported. Staff at this facility reported that EPA's decision that tank cars did not have to be included was made too late to allow them to change their reporting procedure. A city-owned facility decided to include rail cars because, "We are a public agency … with a different culture [than a for-profit company]." This facility's staff concluded that the intent of the RMP process was to identify the amount of covered chemical that might be released in a worst-case scenario and they felt that the chemical stored in a rail car was as much at risk as chemical stored elsewhere on site. Had this facility not included the chemical in rail cars, they might have dropped below the RMP reporting threshold, in which case they would not have been required to file.

In order to elicit frank responses, we asked respondents about strategies that could be used by sites to reduce the reportable amount of chemicals or, in some cases, to avoid the reporting requirement altogether, without specifically asking whether their facilities had employed these strategies. Respondents listed several strategies. Some of these strategies might actually contribute to the goal of reducing hazard, namely decreasing the inventory and reducing the concentration of a covered chemical below the reportable concentration threshold. Other possible strategies would not reduce hazard but might obviate the need for filing, namely leaving a covered chemical in rail cars or other non-connected storage facilities, or perhaps disconnecting pipes so that a fixed storage tank no longer fell under criterion of "interconnected vessels." It was also noted that if a chemical is used in two or more processes, the total amount on-site may exceed the reporting threshold for a single process but not trigger a filing under RMP*Info. Respondents mentioned that some processes involving covered substances are such that it is very difficult to ascertain the maximum amount of a chemical that will be on-site and that facilities might take advantage of the lack of verifiability to record amounts below the threshold quantity and avoid the requirements of RMP.

There were also concerns expressed about flammable mixtures. One facility reported their understanding that, if a mixture contained greater than one percent propane, the entire quantity of the mixture had to be reported as propane, even though as much as 99% of the mixture might be other substances. In pointing out the limitations of the data as submitted, one respondent from that facility stated, "We looked at the data we gave the EPA as data that we would not use ourselves."[2]

There were other challenges in reporting maximum quantities on-site. One facility reported what they referred to as, "normal maximum," reflecting the fact that

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[2] The RMP*Submit User's Manual [10] stated [Chapter 2, page 13], "If you have a NFPA-4 flammable mixture containing regulated flammables, you may list it as a 'flammable mixture.' List all of the regulated substances contained in the mixture; however, only report the quantity of the entire mixture, not the individual substances." Thus, the confusion described by respondents may reflect uncertainties in how RMP*Info would be implemented dating from before the final instructions were published.

they would never fill all the interconnected tanks to the top at the same time. However, in modeling off-site consequences for the worst-case scenario, they used a larger quantity, namely the amount that would exist if all tanks were filled to capacity.

Off-site consequence analysis

Regarding the worst-case scenarios for off-site consequences, many facilities reported using the EPA's publicly available tools to calculate the worst-case scenarios. However, a common observation was that these scenarios represented "bad science," i.e., that the worst-case scenario could never occur. Despite the lack of conviction in the usefulness of these scenarios to guide disaster preparedness, facilities used them because they felt it would have been politically difficult to explain to the community around the facility why they have not used the "official government method." Respondents expressed concern that using an alternative method, which respondents believed would be more valid, would engender distrust that the facility was attempting to hide the extent of the risk.

Accident history

Respondents also highlighted issues about the validity of data on accident history. The RMP*Info questionnaire asks, "Did your facility have any reportable accidents in the last 5 years?" without defining "reportable accident" [10]. However, other EPA instructions state, "You must complete an Accident History for every accidental release, within the last 5 years (as of the date of submission of the RMP), involving a regulated substance held above a threshold quantity in a covered process if that release resulted in deaths, injuries, property damage onsite, or known offsite deaths, injuries, property damage, or environmental damage, evacuations, or shelterings-in-place." Some respondents interpreted the instructions to mean that accidents had to be reported if over a certain amount of the covered chemical was released, regardless of whether there were consequences; other facilities understood that only accidents leading to the above-listed consequences were reportable.

Respondents reported other challenges to accurate reporting of accidents, because different regulations have different criteria for reporting, creating confusion even at large – presumably sophisticated – facilities. In some cases (i.e., the National Response Center database), site respondents stated that emissions must be reported in less than 15 minutes, potentially too little time to provide a valid estimate of the amount of substance released. Because of the sanctions for late reporting, some facilities described a very low threshold for reporting such releases. When later, more complete evaluation and calculation revealed that the release was below the threshold quantity, some respondents reported that it was difficult to remove the erroneous report from the National Response Center database. Although the RMP*Info process does not require such prompt reporting, respondents reported that the conflicting reporting criteria will lead to inconsistent data in different databases, as well as leading to confusion among covered facilities as to the definition of a "reportable accident" under different regulations.

Another facility described an approach to reporting that might result in smaller numbers of accidents being reported. Their understanding was that, if a part of their facility is covered under RMP*Info for Toxic A but not for Toxic B, and an accident involved Toxic B, the accident was not reportable. One staff member understood that, even if both A and B were present in quantities exceeding the reporting threshold, only accidents involving the chemical present in the larger quantity need be reported.

Several companies set explicit standards for what was considered to be an appropriate threshold for "significant" on-site property damage. For example, one company set a threshold for on-site property damage – below which they did not consider the damage significant enough to trigger a report – at $250,000 per accident.

5. Discussion

These interviews raise concerns about the quality of data obtained under RMP*Info in the initial submissions in 1999-2000. Questions about key data elements, such as location of facility, size of facility (as measured by FTEs), amount of covered chemicals, and accident history, could be interpreted in different ways, leading to under- or over-reporting of hazardousness. These inconsistencies could occur even among facilities that sought to comply with the intent of the legislation; facilities that sought to take advantage of ambiguities in the data collection instructions might be able to under-report even more substantially. While some facilities might have actually changed practices to reduce accident and injury risk by reducing chemical inventories below threshold levels, other facilities might avoid filing simply by making minor shifts in chemical storage practices or disconnecting pipes, without substantially changing the risk to the community nearby.

In this discussion, we begin by noting potential limitations of our research. We summarize responses by the EPA to our findings. Then, we address the major policy questions stemming from our results: (1) Do these concerns about data quality invalidate our earlier research findings? (2) What do these concerns suggest concerning improving the value of the RMP*Info process itself?

Potential limitations of this study

Researchers accustomed to quantitative methods may question this study because only seven groups were interviewed. However, the goals of in-depth interviews differ from the goals of quantitative studies. The sample need not be large enough to achieve statistical significance, nor need it be a random sample of the population of interest. In the words of one qualitative researcher, “The aim is not to generalize about the *distribution* of experiences or processes, but to generalize about the *nature* and interpretive processes involved in the experiences,” and, “The sampling is terminated when no new information is forthcoming from new sampled units; thus, *redundancy* is the primary criterion.”[9]. The themes reported here were expressed repeatedly by respondents, suggesting that we met the criteria of redundancy for at least some of the topics we addressed. Although further interviews would probably have elicited additional themes, we conclude that enough interviews were conducted to present the concerns described here as valid.

Response to these findings

EPA staff have been responsive to these issues within the constraints of their regulatory authority to revise the data collection instructions.[3] For instance, the instructions regarding location were clarified substantially. Added detail was provided about how to enter latitude and longitude, and the instructions were formatted to emphasize key points such as the need to enter facility address, not mailing address. Similarly, the instructions for the section on 5-year accident history now state, "A reportable accident involves a part 68 regulated substance in a covered process if the release resulted in deaths, injuries, property damage onsite, or known offsite deaths, injuries, property damage, or environmental damage, evacuations, or sheltering-in-place." Some, more substantial, changes could not be made because of the need for extensive administrative review prior to changes.

Do these concerns invalidate our earlier research findings?

Having found evidence that RMP data may not be uniformly valid, should we question our previous analyses of these data as reported in [1-4]? To answer this question, we must consider the potential impact of data errors on our analyses.

Data errors can be divided into two categories: random misclassification and systematic misclassification. Random misclassification occurs when the data errors are not associated with the other variables being studied. Statistical analyses using data

[3] For EPA's proposed steps to improve data quality for the second wave of submissions, see Environmental Protection Agency, "Accidental Release Prevention Requirements: Risk Management Program Requirements Under Clean Air Act Section 112(r)(7); Amendments to the Submission Schedule and Data Requirements; Proposed Rule," *Federal Register*, Washington, DC, July 31, 2003. For the actual revised RMP*Submit process for the 2004-2005 filings, see http://www.epa.gov/ceppo/rmp_submit/rmp_affd.pdf.

with random misclassification will under-estimate the association between variables; however, if an association is detected despite the presence of random misclassification, one can still trust the validity of the association.

In contrast, systematic misclassification occurs when the probability of misclassification of one variable is affected by the other variable(s) being studied. Systematic misclassification can create artifactual associations between variables. For instance, we found in [4] that facilities sited in counties with a higher proportion of African-Americans were more likely to have accidents. Systematic misclassification could cause this finding if facilities in counties with a lower proportion of African-Americans were more likely to under-report accidents or if facilities in counties with a higher proportion of African-Americans were more likely to report accidents that did not meet criteria for reporting. We cannot think of a plausible reason to expect such a pattern. Similarly, we found that facilities whose parent companies had higher sales reported fewer accidents and injuries. We cannot think of a plausible reason that companies with higher sales would under-report these events, compared to companies with lower sales.

Our confidence in the associations we detected remains strong. Systematic misclassification is an unlikely explanation for our findings. To the extent that our analyses were compromised by random misclassification, a more valid dataset would likely find stronger associations than we found.

On the other hand, random misclassification can still cause under- or over-estimates of the frequency of events. Our interviews provide reason to question the frequency and severity of accidents, the amount of hazardous chemicals at these facilities, and even the number of facilities that should have registered under RMP*Info. Although these inaccuracies could be in either direction, we suspect that hazards and adverse events would more likely be under-reported than over-reported. Further analysis of the data from the 2004-2005 wave would be useful in understanding these matters related to reporting accuracy.

How do these concerns affect the value of the RMP*Info process?

The motivation for "Risk Management Programs for Chemical Accidental Release Prevention" was to reduce the probability of accidental releases and to foster community preparedness that would mitigate the impact of such releases. If the data in RMP*Info contain inaccuracies, then community pressure to enhance safety and the community preparation for emergency responses may be adversely affected. Thus, it is important to continue to work on the data quality issues raised in this report. The opportunity to use informational regulation [1],[6] to promote safety is among the most promising approaches to integrating emergency response and community organizations with facility preparation and prevention activities. As illustrated in this manuscript, to the extent that facilities with well-intentioned staff are not providing valid information because of ambiguities in the RMP*Info questionnaire, the process can be remedied by using the same tools of questionnaire development that are used for most epidemiological surveys. To the extent that facilities are prevaricating in their responses, data verification and enforcement processes can emulate those used in other regulated processes.

6. Conclusion

The RMP*Info process remains a promising opportunity to enhance facility safety and promote community preparedness. In addition, RMP*Info provides valuable data for research that may enhance our ability to mitigate these risks. Modifications of the RMP*Info process have the potential to improve these benefits substantially. Some of these have been undertaken by EPA as part of its on-going activities to improve the RMP*Submit process. Further qualitative work could inform RMP*Info revisions by evaluating other parts of the questionnaire and by testing revised questionnaires prior to their implementation.

Figure 1
1999 Instructions on Full-Time Employees

1.11. Number of full-time employees on site. Enter the number of full-time equivalent employees who work at your facility. To determine the number of full-time equivalent employees at your facility, add together the fractions of full-time work performed by part-time or seasonal employees and round to the nearest whole number (see example below). Do not include contract employees. If your facility is unmanned or is only staffed by part-time employees, you should briefly explain these circumstances in the executive summary.

For example, suppose a facility has 10 regular full-time employees, two part-time employees that each work 30 hours per week, and seven seasonal employees that each work 40 hours per week for three months of the year. You should count the two part-time employees as 3/4 of an employee each because they work 3/4 that of a full-time employee and the seven seasonal employees as a 1/4 of a full-time employee each, for the same reason. As shown in the table below you get 13.25, which you should round to the nearest whole number. You should enter “13" for the number of full-time employees.

EXAMPLE 4

Type of Employee	Number of Employees Times the Fraction of a Full-Time Employee	Full-Time Equivalent Employees
Full-time (40 Hours)	10 x 1	10
Part-Time (30 hours)	2 x 0.75	1.5
Seasonal (3 months/year)	7 x 0.25	1.75
Total		**13.25 (rounded to 13)**

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CHAPTER 3: FREQUENCY AND SEVERITY OF ACCIDENTS AT RMP FACILITIES

Outline of the Chapter

1. Introduction
2. RMP Facility Accident Rates and Severities
3. Analytic Studies on Accident History Data for the 1999-2000 Filing
4. Concluding Comments

1. Introduction

This chapter reports the accident rates and severities for RMP facilities, for both the 1999-2000 data as well as the 2004-2005 data. We then consider several predictive models for the 1999-2000 results. These predictive models are concerned with the statistical association between accident rates and hazardousness of facilities, financial structure of parent companies of these facilities, and the demographics of the surrounding community.

Before we begin with our analysis, it is important to recall what a reportable accident is under the RMP Rule.[1] According to the RMP Rule, the criteria defining a "reportable accident" are as follows: §68.42(a) of the RMP Rule specifies that:

> "The owner or operator shall include in the five-year accident history all accidental releases from covered processes 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."

Note specifically that, whatever the regulatory intent was of RMP, the original instructions for the RMP Rule, issued in 1998, did not define reportable accidents on the basis of quantities released alone, relying instead on consequences. The instructions for defining "reportable accidents" were sharpened in the documentation on reporting requirements in the intervening period between 1999-2000 and 2004-2005, but still maintained that "reportable accidents" should be defined on the basis of consequences. Nonetheless, it should be noted that 441 (23.3%) of the 1,896 accidents in the 1999-

[1] See Appendix 4 to Chapter 1 of this Report for complete details on the definition of a reportable accident.

2000 dataset and 283 (23.3%) of 1,214 reported accidents in the 2004-2005 dataset are "no-consequence" accidents: they did NOT report injuries, deaths, environmental damage, evacuations, shelterings, medical treatment or onsite or offsite property damage associated with them.[2]

We will have more to say about the criteria for "reportable accidents" below when we examine trends in accident rates and severities between the 1999-2000 and the 2004-2005 data. For the moment, the reader should keep in mind that the basic building block of our analysis of accident frequency and severity is the "reported accident" in RMP, and not actual releases (which have been far more frequent than what EPA wished to cover in its definition of "reportable accidents"). In particular, some care must be exercised in comparing accident rates across the two filing periods 1999-2000 and 2004-2005 as the criteria that were used by facility managers and owners as the threshold to report accidents may have changed over time. The nature of processes, of maximum inventories at facilities, and many other characteristics of reporting facilities may also have changed between the two filing periods. We will study these matters of comparison and trends more rigorously in Chapter 5 using a sample of facilities that filed in both periods, thus controlling for some of the many factors that could affect accident rates over time.

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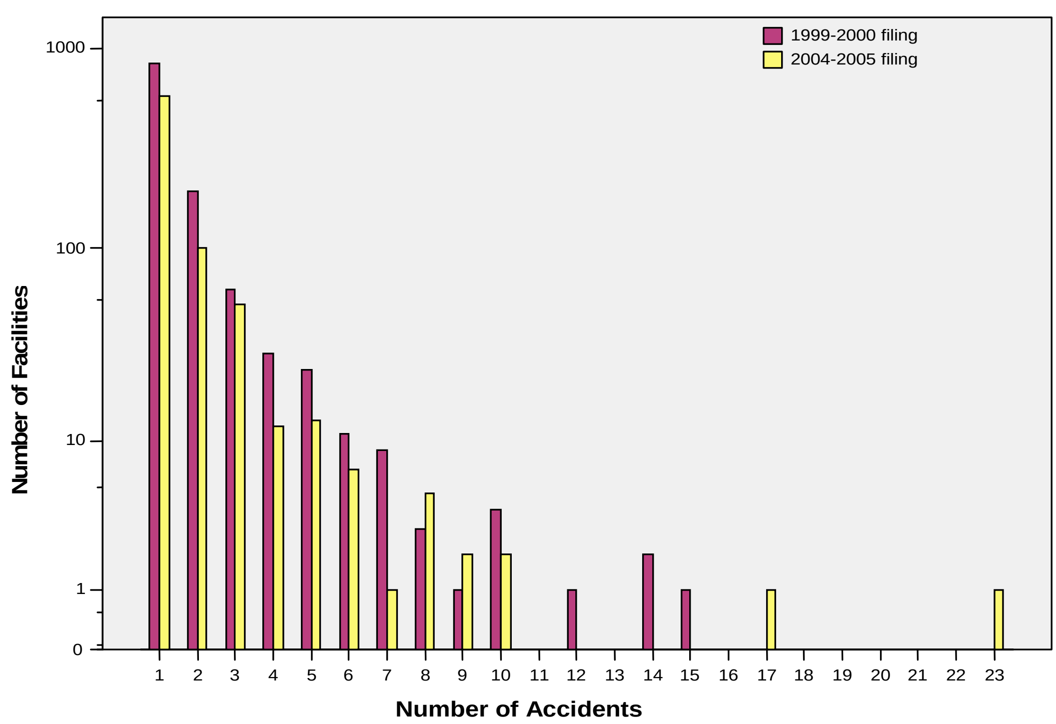
[2] Concerning data quality issues and our study of them, see Appendix 2-A. As we note there, some of these "no-consequence" accidents could have been reported to be assured that public responders would be notified properly, and without knowing at the time of reporting whether there were reportable consequences. Once reported, they stayed on the books as reported accidents even though subsequent investigation may have determined that there were no reportable consequences. Changes in approaches to reporting and recording such incidents may also have changed over time. These matters can only be surmised here, and would require very detailed follow-up studies to ascertain the nature of "no-consequence" reports in the RMP*Info database.

2. RMP Facility Accident Rates and Severities

Table 3.1 provides data on the frequency of accidents at facilities in RMP*Info. In particular, we note that 1,173 facilities (7.7% of 15,145 facilities) had at least one accident during the (5-year) reporting period for the 1999-2000 filings, while 774 facilities (6.4% of 12,065 facilities) had at least one accident during the reporting period for the 2004-2005 filings. Note also that 338 facilities (2.2% of 15,145 facilities) had multiple accidents during the five-year reporting period preceding the 1999-2000 filings, while 196 facilities (1.6% of 12,065) reported multiple accidents in the 2004-2005 filings. The cumulative incidence of accidents, expressed as a fraction of total reporting facilities, was 1,896/15,145 (or 12.5%) in 1999-2000 and 1,214/12,065 (or 10.1%) in 2004-2005. Figure 3.1 below shows the data of Table 3.1 graphically on a logarithmic scale.

FIGURE 3.1.
FREQUENCY OF ACCIDENTS PER FACILITY FOR EACH REPORTING PERIOD



Tables 3.2A and 3.2B report the number of accidents by listed chemical involved in the accident for the 25 most frequently involved substances in the two filings. The three most frequently involved substances in both sets of filings were ammonia (anhydrous), chlorine, and flammable mixtures. Chemical frequencies ranged from 658 (respectively, 452) accidents for anhydrous ammonia facilities in 1999-2000 (resp., 2004-2005) to zero accidents for about half of the 140 chemicals listed under the Rule. Tables 3.3 A and 3.3B list the number of accidents by NAICS Code of the process involved in the reported accident for the top 25 processes.

Tables 3.4 and 3.5 report the number of injuries and deaths for employees/ contractors and non-employees, respectively. For 1999-2000 (resp., for 2004-2005), there were a total of 1,923 injuries (resp., 1,347 injuries) and 32 deaths (resp., 44 deaths) among workers/employees, and there were 153 injuries (resp., 140 injuries) and 0 deaths (resp., 4 deaths) among non-employees. There were 205 (resp., 101) total hospitalizations and 6,057 (resp., 898) individuals given other medical treatments. The major reason for the increase in employee deaths in the second wave of data was that one accident (the Texas City BP accident in 2005) had 15 employee deaths, while the highest number of employee deaths in any accident in the 1999-2000 data was 6. The difference in hospitalizations between the two waves is due almost entirely to one accident in the 1999-2000 data, with 4624 instances of medical treatment.[3] Given the

[3] This accident occurred on October 23, 1995, at the Gaylord Chemical Corporation plant in Bogalusa, Louisiana and involved release of poisonous and corrosive vapors from a railroad tank car. Some 3,000 people were evacuated from the area as a result of the vapor cloud and more than 4700 people were treated at local hospitals. Because of the nature and magnitude of this event, it was investigated by several federal agencies, including the National Transportation Safety Board, whose report on the incident is available at http://www.ntsb.gov/publictn/1998/HZB9801.pdf.

small number of accidents with deaths or hospitalizations, it is not possible to draw any statistical conclusions from these results.

Table 3.6 notes the damage to property and the non-medical off-site consequences resulting from accidents during the reporting period. Property damages alone were just shy of $1 billion in both filing periods, but these do not include business interruption costs, including losses in shareholder value and lost business associated with accidents.[4] In addition, large numbers of community residents were affected by accidents (over 220,000 involved in evacuations and shelter-in-place incidents in 1999-2000 and over 323,000 in 2004-2005). Note that 165 accidents (or 8.7% of 1,896 accidents) resulted in evacuations in 1999-2000 while 128 accidents (or 10.5% of 1,214 accidents) did so in 2004-2005. Similarly, 97 (or 5.1% of accidents) resulted in individuals being sheltered in place in 1999-2000 while 84 (or 6.9% of accidents) did so in 2004-2005. The environmental consequences of the accidents are also reported in Table 3.6.

3. Analytic Studies of Accident History Data for 1999-2000 Filing

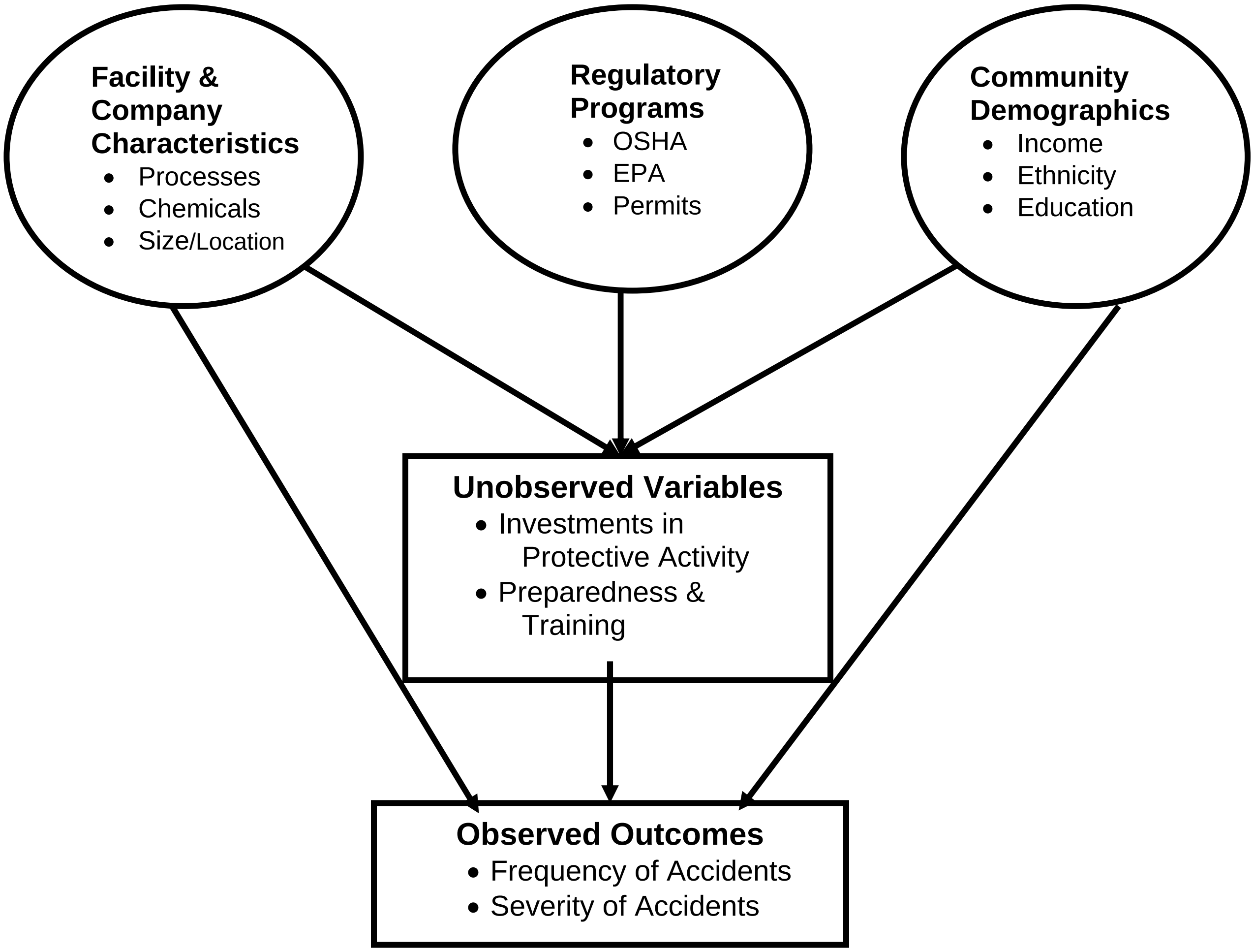
Analytic studies are concerned with establishing statistical associations between predictor variables such as facility characteristics and outcome variables such as frequency and severity of accidents of facilities having various characteristics. To date, such studies have only been accomplished for the 1999-2000 data, and we report a series of these studies here. In order to develop plausible hypotheses to test concerning predictors of facility safety, we first developed a conceptual model for predictors of

[4] 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).

frequency and severity of accidents (Figure 3.2). The following factors, evident in Figure 3.2, are proposed as potential predictors:

1. The characteristics of the facility itself, including facility location, size and the type of hazard present; as well as characteristics of the parent company/owner of the facility (capital structure, sales, management systems in place, etc.);
2. The nature of regulations in force that are applicable to this facility and the nature of enforcement activities associated with these regulations;
3. The socio-demographic characteristics of the host community for the facility, which characteristics may represent the level of pressure brought on the facility to operate safely and to inform the community of the hazards it faces. (The "community" may be defined in multiple ways here.)

FIGURE 3.2.
FRAMEWORK OF ANALYSIS



We review results on the statistical associations between accident frequency and severity and the above noted factors. These are summarized from earlier published papers (Elliott et al., 2003, 2004a; Kleindorfer et al., 2003; Kleindorfer et al., 2004).

Facility Characteristics and Regulatory Impacts

In Elliott et al. (2003), we tested the hypotheses that facility characteristics and regulatory programs are associated with a facility's accident history. The facility characteristics that we studied were the following: geographic region; size of facility; and chemicals used at facility. The information contained in RMP*Info database includes details about on-site chemicals and processes; regulatory program coverage; geographic location; and number of full-time employees (FTE).

For each regulated chemical, the EPA determined a "threshold quantity," such that facilities were required to comply with the regulation if they held quantities above the threshold in a process. The threshold quantity for each regulated chemical was determined by a consideration of its potential toxicity or flammability, its potential for dispersion in the event of an unintentional release, and the amount of the substance which in the event of an accidental release could cause death, injury, or serious adverse effects to human health. Regulated substances were grouped into hazard levels, with thresholds set to values of 500, 1000, 2500, 5000, 10000, 15000, and 20000 pounds. (Threshold levels are roughly inversely proportional to the per-weight hazardousness of the chemical.) The quantity and nature of chemicals used at each facility are summarized for our statistical analyses by a single "total hazard measure," defined roughly as a measure of the hazard of the chemicals on site and the number of covered processes at the facility.[5] The regulatory programs studied are OSHA-PSM; CAA Title V; and EPCRA-302. The direction of the statistical association between more stringent regulatory structures and accident rates is not clear *ex ante*. On the one hand, more stringent regulations might serve to reduce accident rates; however, more hazardous facilities might be the focus of more stringent regulations. The statistical associations identified here therefore reflect the combined effects of investments and regulatory oversight in preparedness/prevention activity and underlying factors driving accident propensity. Such hypotheses, if proven, could provide important insights on the impact of different regulatory programs for particular sectors and types of facilities.

Our results on facility characteristics and regulatory factors may be summarized under several headings (see Elliott et al., 2003 for more detailed discussion). We first consider the relationship between facility size (measured in FTEs) and facility hazard on accident consequences.

Figure 3.3 (from Elliott et al., 2003) plots the probability of accident, worker injury, and property damage versus number of full time employees. The probability of accident climbs from less than 3% for facilities with fewer than 10 employees to near 30% for firms with 1,000, then levels off for firms larger than 1,000. The probability of accident actually appears to decline for the very largest facilities (those with 5,000 or

[5] More precisely, the "total hazard" measure used is defined as the sum over all chemicals of $\log_2$(maximum quantity of inventory on site/threshold), or, alternatively, as the number of chemicals times $\log_2$ of the geometric mean of the maximum-to-threshold quantity ratio. Hence, a total hazard measure of 0 indicates that only threshold levels of chemicals are kept in inventory, a measure of 1 means 1 chemical is kept at up to twice threshold level, 2 means 2 chemicals kept at up to twice threshold level or 1 chemical at up to 4 times threshold level, and so forth; unit changes in this measure can thus be interpreted as either an doubling of volume inventoried of a single chemical or an addition of another twice-threshold chemical on-site.

more employees), but this decline is not statistically significant. Similar trends are seen for injury risk and property damage risk.

Figure 3.4 (from Elliott et al., 2003) plots the probability of accident, worker injury, and property damage versus the total hazard measure for the facility. The probability of any chemical accidents (for the reporting period 1995-2000 covered by the 1999-2000 filings) climbs from less than 4% for firms with a total hazard measure less than 5 (i.e., the equivalent of five chemicals at twice the threshold level, or one chemical at 32 times [i.e., 2^5 times] the threshold level) to approximately 40% for firms with a total hazard measure of 50-150. The probability of a chemical accident during the five-year period approaches 100% as the total hazard measure reaches the 300-400 range. Similarly the probability of worker injury climbs from about 3-4% for firms with a total hazard measure less than 5, then levels off around 30%, for firms with a total hazard measure of 50-150, then climbs to 50-60% as the total hazard measure reaches the 300-400 range, though the statistical significance declines appreciably at the high end of the total hazard range. The probability of property damage appears more linearly related to total hazard measure. Results are similar for the more serious outcomes.

Elliott et al. (2003) also study the geographic distribution of accidents. Facilities in the Mid-Atlantic, Southeast, and South Central had the highest risk of accident, injury, and property damage, and facilities in the Great Plains the lowest. Most of these regional differences are explained by the larger number of employees and greater total hazard measures at facilities in the Mid-Atlantic, Southeast, and South Central regions. However, the much higher rate of property damage in excess of $100,000 among facilities in Region VI (South Central) cannot be entirely explained by the number of employees or the total hazard measure.

Elliott et al. (2003) find for the 1999-2000 filings that that toxic chemicals were more strongly associated with worker injury, whereas flammables were more strongly associated with property damage, which makes sense because fire is obviously capable of causing a much greater degree of damage to property than release of acids or poisonous gases, which are either more contained or less damaging to property.

The statistical association of accident outcomes with regulation imposed on facilities has also been studied by Elliott et al (2003). Facilities regulated under the Right-to-Know Act had a modestly higher risk of accident, injury and property damage than other RMP*Info facilities, while facilities regulated under OSHA Process Safety Management and CAA Title V had a much higher risk. Nearly all of this excess risk for Right-to-Know and CAA Title V facilities could be explained by their larger size and greater total hazard measures, whereas only about one-half of the excess risk for OSHA-PSM facilities could be explained in this manner.

FIGURE 3.3.

Probability of having (a) any versus none or (d) 2 or more versus fewer than 2 accidents; (b) any versus none or (e) 2 or more versus fewer than 2 worker injuries; and (c) any versus no or (f) more than $100,000 versus less than $100,000 in facility property damage in 1995-1999, by number of full-time employee equivalents. Solid line represents mean estimates obtained from cubic spline model with knots at 5, 10, 100, 500, 1000, and 10000 employees; dotted line represents associated 95% confidence interval. Points are observed percentages for <10, 10-99, 100-199,…, 900-999, 1000-1999,…,9000-9999, and >10000 employees. Tick marks represent facility FTE measures (truncated at 10000).

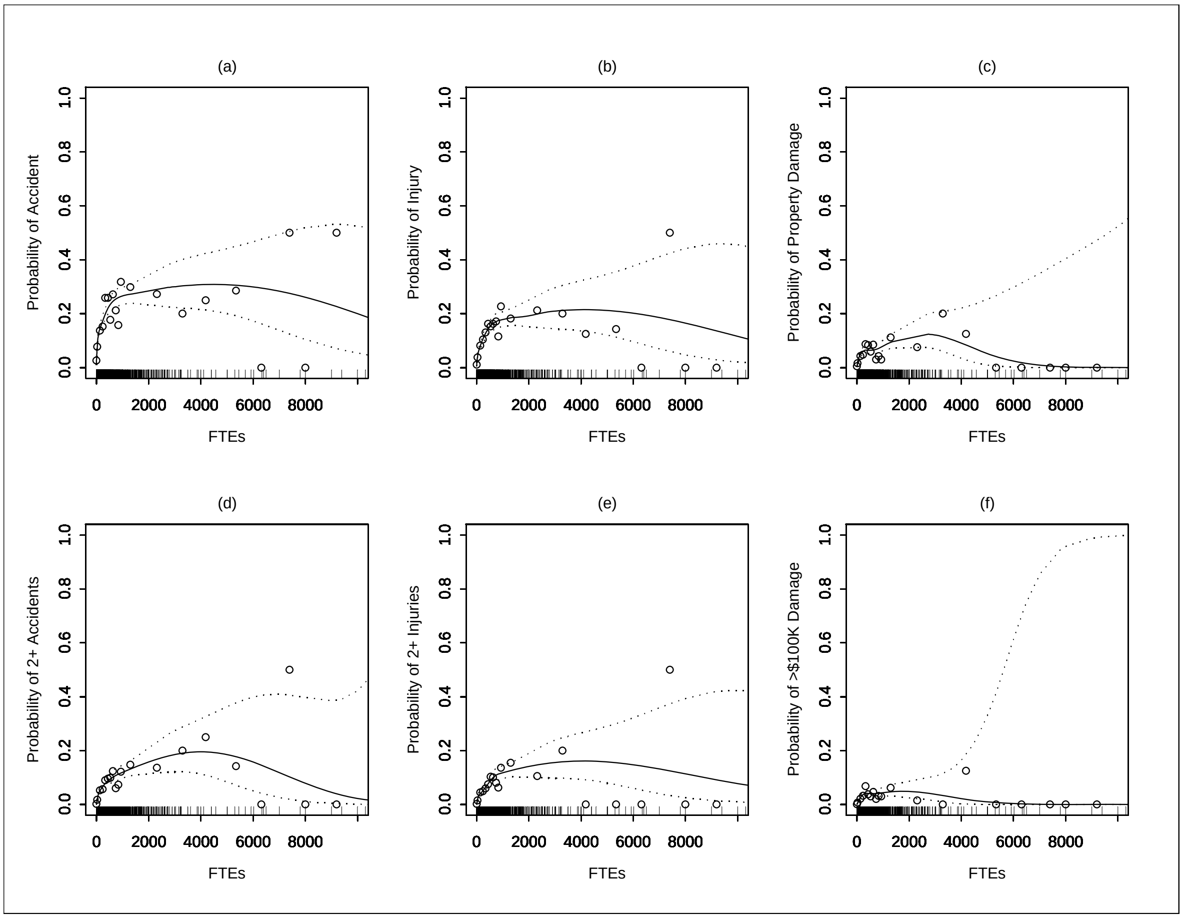
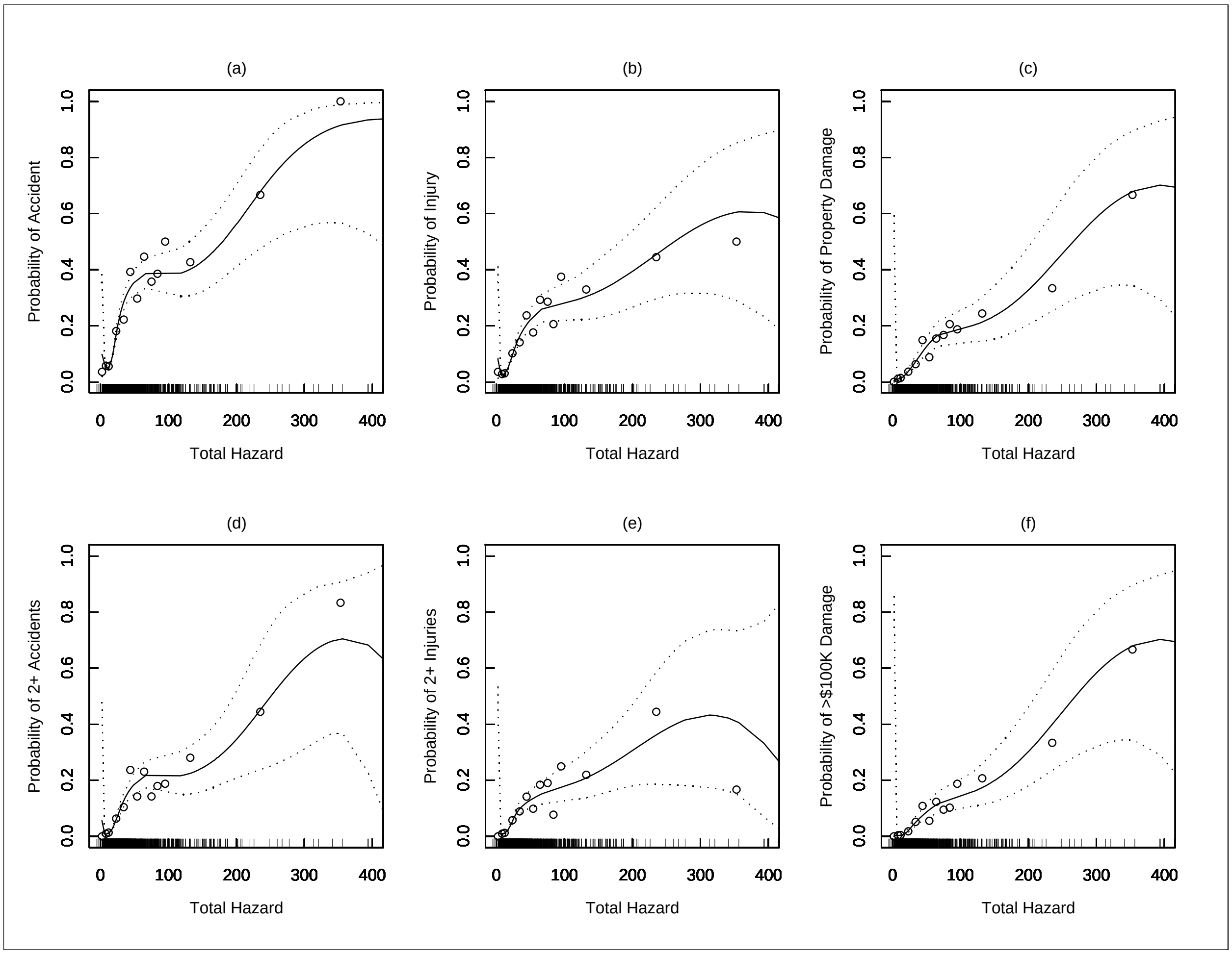


FIGURE 3.4.

Probability of having any versus none (a) or 2 or more versus fewer than 2 accidents (d); any versus none (b) or 2 or more versus fewer than 2 worker injuries (e); and any versus no (c) or more than $100,000 versus less than $100,000 in facility property damage (f) in 1995-1999, by total hazard measure. Solid line represents mean estimates obtained from cubic spline model with knots at total hazard measures of 5, 10, 20, 40, and 100; dotted line represents associated 95% confidence interval. Points are observed percentages for total hazard measures of <5, 5-10, 10-19,…, 90-99, and >100. Tick marks represent facility total hazard measures (truncated at 400).



<u>Association of Capital Structure and Sales on Accident Rates</u>

With an eye on Figure 3.2, let us now consider the influence of capital structure and financial variables, such as total sales, on the incentives that might affect companies in their decisions to take protective action against major accidents and, thereby, to influence the accident and injury rates observed in RMP. This analysis follows that first reported in Kleindorfer et al. (2004), which was based on a snapshot of the RMP*Info database as of December 11, 2000. At that time, the total number of filers in the initial implementation of 112(r) was 15,219. The analysis below of financial issues is restricted to the 2,023 facilities owned by 306 parent companies for which complete financial parent company data from 1994-2000 was publicly available. The accident-related information includes date and time of accident; number of associated injuries or deaths among workers, public responders, and the public at large; and other consequences such as property damage (on-site, offsite), evacuations, confinement indoors of nearby residents, and environmental damage. Our main outcomes of interest were frequency of accidents and severity of accidents, with the latter measured as total number of persons injured as a result of accidental releases.

We consider four main predictor variables of parent company financial performance: previous year debt/equity (D/E) ratio, total (net) sales, return on assets (ROA), and return on equity (ROE). Debt-equity ratio was determined as the ratio of the long-term debt to the common equity. Return on assets was defined as the ratio of income before extraordinary items divided by total assets minus depreciation and amortization. Return on equity was defined as income before earnings and interest divided by common equity.

To account for the fact that more "intrinsically" hazardous processes tend to involve capital-intensive infrastructure that might confound relationships between attention to safety and financial performance, we used two control variables as proxies for facility hazardousness: number of full-time-equivalent employees (FTEs), and a "total hazard" measure (as defined above).

Table 3.1 shows the descriptive statistics for the outcomes, financial predictors, size and hazard confounders, and percentage of facilities in key sectors of interest. One accident was observed for approximately each four fiscal years of parent company operations, while one injury was observed for approximately each three fiscal years of parent company operations (a single accident could result in multiple injuries).

Table 3.2A and 3.2B show the associations between the previous year's financial predictor and the risk of accident and injury respectively, adjusted for average facility size and intrinsic hazard measure. The associations were generally in the direction that economic theory would lead us to hypothesize. In particular, we see that each doubling in debt-equity ratio was associated with a statistically significant 12.2% increase in risk of injury at a parent company's facility (95% CI=3.5%-21.7%). Each billion-dollar increase in sales was associated with a 1.9% decrease in risk of accident at a parent company's facility (95% CI=0.4%-3.4%) and a 2.6% decrease in risk of injury (95% CI=0.7%-4.5%). Each 1% increase in return on equity was associated with a 0.8% decrease in risk of per-facility accident (95% CI=0.1%-1.4%). Return on assets was not associated with a statistically significant change in either risk of accident or risk of injury.

Summarizing our findings on the effects of financial variables, we note that these are in the direction that both intuition and theory would support. Companies that are more debt-ridden are likely to be less concerned with long-term cash flows, as most of the risk is borne by creditors who are not represented in the company's decision making about risk mitigating investments. Similarly, companies with large sales have greater cash flows at risk from disruptive accidents and this provides stronger incentive to undertake greater care, leading to the observed lower accident and injury rates. The RMP results are therefore consistent with normal economic expectations.

Community and Demographic Effects

In this section, we summarize the basic findings of Elliott et al. (2004a) on the statistical association between characteristics of the communities in which facilities are located and the frequency and severity of accidents of these facilities. This topic is generally addressed under the heading of "environmental justice." An extensive body of research in political economics, public policy, and public health has noted associations between environmental and health risks arising from industrial facilities and the socio-economic status (SES) of host communities. These associations could be caused by firms' preferring to locate hazardous facilities in lower-SES communities in which they anticipate lower levels of collective action and monitoring. These could also result from migration of groups of lower SES to sites where such facilities have located, since property values may be lower there.

Using the RMP data for 1999-2000 filings together with the 1990 census data, we looked for two potential impacts of community characteristics that reflect two essential sources of risk to surrounding populations: (1) risks associated with the decision about where to locate hazardous facilities, which we term "location risk"; and (2) risks associated with the methods of operation and standards of care that are used in existing facilities, which we term “operations risk.” Our analysis proceeds by first considering the association between community characteristics and “location risk” – the risk of an intrinsically hazardous facility, as reflected by the quantity of chemicals stored there and their potential for harm, being located in a community. The enumeration unit for the demographic studies is the county in which the facility is located. To measure location risk, we analyze whether there is a statistical association between the hazardousness of a facility and the characteristics of the surrounding county. A significant statistical relationship would indicate that more hazardous facilities tend to be located in counties with particular demographic characteristics.

We then consider “operations risk,” that is, the risk at a facility of an accident and resulting bad outcomes, including injuries and property damage. Two questions can be asked about operations risk: (1) whether the demographics of the communities surrounding facilities are associated with risk of an accident/injury; and (2) whether these community demographics are associated with accident/injury risk *after adjusting for location risk*. Our test for the effects of demographics on operations risk is simple. We analyze whether there is a statistical association between facility accident and injury rates and the demographics of the surrounding county, while controlling for the size of the facility and inherent hazardousness of it (see above for our definition of hazardousness). If it were hazardousness or size of the facility alone that determined accident/injury rates, and demographics were not a factor, then there would be no additional explanatory power associated with the inclusion of country demographics. However, if such demographic factors are themselves statistically significant, in addition to facility factors, this would support the hypothesis that operations risk is associated with demographic factors. In particular, we address the issue of whether facilities in low-SES and/or higher proportions of African-American population may exhibit higher accident rates than average, even if they have the same amount of hazardous chemicals on site.

Our findings regarding the relationship between accident propensity and community characteristics may be summarized as follows (see Table 3.9 below). First and foremost, the relationship between chemical facility risk and the demographics of the surrounding community is complex. The RMP data is strongly consistent with a finding that heavily African-American counties experience greater location risk and greater operations risk. Greater location risk here means more employees and more hazardous chemicals in use at facilities in these counties. Greater operations risk means that facilities in these counties had greater risks of an accidental chemical release, and of having injuries associated with the chemical release. The operations risk for the most heavily African-American counties persists even after accounting for location risk.

The impact of income and poverty is more complex. Larger facilities were more likely to be located in counties with higher median incomes and higher levels of income inequality, although part of this association is explained by the fact that larger facilities tend to also be located in counties with large populations and large manufacturing labor forces. Similarly, facilities in higher-income counties with higher levels of poverty, or at least without corresponding low poverty levels – again, high-income-inequality counties – were at greater operational risk as well. However, after adjusting for "hazardousness," income and income inequality were no longer associated with operations risk.

Thus, higher-risk facilities are more likely to be found in counties with sizeable poor and/or minority populations that disproportionately bear the collateral environmental, property, and health risks. An alternative, though related, perspective is that communities burdened by low SES and past or present discrimination may be willing to accept these risks in order to obtain the economic benefits of facility location, or that residents not willing to accept this risk move away. For facilities of a similar hazard level, those operated in counties with 10% or higher African-American populations appear to pose greater risk of accident than those in counties with less than 1% African-Americans.

<u>OSHA OII Data and RMP Data</u>

A further matter of great interest in analytic studies of the RMP data is whether the accidents reported there are statistically associated with day-to-day process safety, as captured by OSHA reported Occupational Illnesses and Injuries (OII). This matter has been investigated by Elliott et al. (2008). Their study links the RMP database of accident histories collected for the period 1996-2000 under the RMP Rule to OII's for the RMP facilities for the same period. They explore various statistical associations between OIIs and RMP-reported accidents. If one thinks of OIIs as reflecting everyday safety performance and RMP accidents as reflecting major accidents, then their analysis can be considered a test of whether good everyday safety performance is a foundation for preventing or mitigating relatively rare major accidents.

As discussed in Rosenthal et al. (2006), many practitioners continue to believe that an “effective” process safety management system is the key to prevention, both for OII incidents as well as for major accidents. Testing the validity of this belief requires the ability to define and identify the essential elements of ‘effective’ facility process safety management plans. Among other issues, it will be important to separate out the effects a given process safety management system has on everyday safety events from the effects, if any, that such a system might have in preventing or mitigating the consequences of larger events, including catastrophic failures. The main point of Elliott et al. (2008) is to examine whether there is any relationship between the performance of chemical facilities on everyday safety (defined in terms of regularly reported occupational illnesses and injuries—“OII rates”) and major accidents reported under the RMP rule in the U.S. for the first filing period of RMP, covering accidents during the period 1994-2000. The approach pursued by Elliott et al. was to link RMP*Info reporting facilities to OII reports provided to OSHA during the 1996-2000 RMP*Info reporting period where both types of data was clearly available for the same facility. Correlation between OII incidence and RMP accident incidence would suggest that a company culture or management team that is motivated and capable of creating effective OII management systems is also motivated and capable of generating practices that are effective in ensuring safe chemical process operations. Conversely, lack of correlation may indicate the existence of a positive safety culture but absence of capability, longer term focus and the know-how needed to design an chemical process safety system, or perhaps lack of the motivation to do so: good OII performance is relatively quickly reflected in significant reductions in workers' compensation costs, while the savings from avoiding process accidents are less tangible, certainly less predictable, and more long term, and this may reduce management motivation to act.

What Elliott and his colleagues found was that there are no strong positive correlations between OII reports and RMP*Info low-probability, high-consequence (LP-HC) events. Facilities with injuries, deaths, major property damage, or substantial off-site consequences from RMP*Info-reported events actually tended to have <u>lower</u> OII/Year/FTE than facilities without these types of RMP*Info-reported incidents. However, this negative correlation is a function of RMP-reporting facilities, with higher OIIs tending to have lower hazard measures and thus lower rates of RMP*Info-reported accidents. After adjusting for this confounding between OII rates and the underlying hazardousness of the process, no statistically significant associations were found between OII rates and either RMP*Info reported injuries or RMP*Info-reported major property damage and other consequence measures of severity of accidents. It appeared that facilities with high OII rates might pose a higher risk of an RMP*Info injury report, but this association did not reach statistical significance (p=.14). Thus, the Elliott et al. analysis provides no support for the hypothesis that low OII rates translate to low risk of RMP*Info reportable incidents, and only marginal support for the hypothesis that high OII rates might predict further LP-HC events. It would be interesting to extend this study to encompass the fuller 10-year RMP dataset now available. However, there is still no easy way to link the OII database with the RMP database.

Some Caveats on the RMP Data and Existing Analytic Studies

There are a number of caveats that attach to all of the above analyses. Selection bias remains a serious possibility, in that the sampling frame containing the RMP*Info facilities may not include all required facilities. It was originally estimated by EPA that over 66,000 facilities would be required to submit RMPs under 112(r); however, only slightly more than 15,000 ultimately did so in the 1999-2000 filing period. This lower than anticipated response is in part due to Congress exempting in 1999 from the reporting requirements any listed flammable substance when used as fuel or stored for retail sale as a fuel, effectively reducing the estimated population by about one-half. Also, many facilities responded to the RMP*Info requirement by reducing their inventories below the threshold limits required for reporting. The facilities that did reduce their inventories below the threshold limits required for reporting may have had a disproportionate number of management groups that did not believe deploying additional resources on process safety was justified, and reduced their inventories simply to avoid the added commitments to process safety that are required under the RMP Rule. Some facilities may have simply ignored the filing requirements. These non-responders may differ in significant ways from the responding facilities used in these analyses.

A further limitation involves facilities' interpreting accident reporting requirements differently and other uniformity and data quality issues associated with any large database of this sort, as analyzed earlier in Chapter 2 and Appendix 2-A.

A final limitation of these studies is that our analyses implicitly assume that all facilities were subject to RMP*Info reporting requirements throughout the previous five years. If facilities were either non-existent or off-line for substantial periods of time, then the resulting estimates of the associations of risk of accident and injury with parent company financial status could be biased toward or away from the null. For example, if parent companies with high D/E ratios tended to have facilities that operated for only a short period of time, that would tend to artificially strengthen the positive association between high D/E ratio and risk of accident in our financial analysis. However, facilities reporting to RMP*Info tend to have high capital costs; thus they tend to come on-line and go off-line rather slowly relative to the five-year reference period. We will reconsider these issues in Chapter 5 in comparing accident rates across both 1999-2000 data and 2004-2005 data for a subset of filers we refer to as the "Cohort of Joint Filers," i.e., those facilities that filed in both datasets.

4. Concluding Comments

Two waves of filings have now been received under the RMP Rule, the first for 1999-2000 and the second on the five-year anniversary of the first filing, namely in 2004-2005. These data provide an informative record of the accident histories of the U.S. chemical industry. The descriptive data reviewed here, and the studies undertaken thus far, suggest a complex set of interactions determining facility performance in terms of accident frequency and severity. First and foremost, they provide benchmark statistics on deaths, injuries and direct property damage at U.S. chemical facilities resulting from process accidents and accidental releases. They underline the expected interactions between regulatory oversight and level of hazard at facility (as graphically depicted in Figure 3.2). However, contrary to popular theorizing, it is not the small facilities per se that are the primary sources of accidents. Rather, it is the interaction of the underlying hazard at the facility with size and location that provides the explanatory power for accident and injury rates. In many ways, these results will appear intuitive to the EH&S policy and management community, but it is important to note that this is the first time in the history of the U.S. chemical industry that we have had the data to back up our intuition and to provide benchmark results for regulators, the insurance industry and the chemical industry as they attempt to assess the magnitude of the risks arising from chemical facilities.

It is tempting to use the raw data depicted in the Tables in this chapter to draw conclusions about trends in accidents over time. We have cautioned at several junctures in this chapter that this should be done only with great care, as reporting practices may have varied, the nature of facilities reporting may have varied, production levels, outputs and sales may have varied over time, and a number of other factors may have changed from the first filing period to the second, making straightforward comparisons difficult. From the results on decreased registrations analyzed in Chapter 2, it is reasonable to conclude that the number of facilities subject to reporting requirements seems to have decreased from the first filing period to the second, given that significant efforts by EPA to assure 100% reporting of covered processes. Perhaps because of this, as this chapter shows, the overall level of accidents reported and their consequences appear to have declined over time. However, because of the above complicating factors, we will need to undertake a more detailed analysis of trends in order to draw conclusions. We delay this analysis until Chapter 5.

TABLE 3.1.
FREQUENCY OF ACCIDENTS AT INDIVIDUAL FACILITIES

	1999-2000 filing 15,145 facilities reporting		2004-2005 filing 12,065 facilities reporting	
Number of Accidents at Facility	Number of Facilities in RMP*Info with the Indicated Number of Accidents in the Reporting Period	Total Accidents Represented	Number of Facilities in RMP*Info with the Indicated Number of Accidents in the Reporting Period	Total Accidents Represented
1	835	835	578	578
2	191	382	100	200
3	62	186	52	156
4	29	116	12	48
5	24	120	13	65
6	11	66	7	42
7	9	63	1	7
8	3	24	5	40
9	1	9	2	18
10	4	40	2	20
12	1	12	–	–
14	2	28	–	–
15	1	15	–	–
17	–	–	1	17
23	–	–	1	23
Total	**1,173**	**1,896**	**774**	**1,214**

TABLE 3.2-A
ACCIDENTS REPORTED IN RMP*INFO BY THE 25 MOST FREQUENTLY INVOLVED CHEMICALS
1999-2000

Chemical Name	Number of Accidents
Ammonia (anhydrous)	658
Chlorine	516
Flammable Mixture	98
Hydrogen fluoride/Hydrofluoric acid (conc 50% or greater) [Hydrofluoric acid]	96
Chlorine dioxide [Chlorine oxide (ClO2)]	56
Propane	49
Sulfur dioxide (anhydrous)	46
Ammonia (conc 20% or greater)	42
Hydrogen chloride (anhydrous) [Hydrochloric acid]	31
Hydrogen	29
Methane	25
Hydrogen sulfide	21
Butane	20
Ethylene oxide [Oxirane]	19
Formaldehyde (solution)	18
Pentane	16
Titanium tetrachloride [Titanium chloride (TiCl4) (T-4)-]	14
Isobutane [Propane, 2-methyl]	13
Phosgene [Carbonic dichloride]	12
Nitric acid (conc 80% or greater)	12
Oleum (Fuming Sulfuric acid) [Sulfuric acid, mixture with sulfur trioxide]	12
Ethane	12
Trichlorosilane [Silane, trichloro-]	12
Ethylene [Ethene]	11
Toluene diisocyanate (unspecified isomer) [Benzene, 1,3-diisocyanatomethyl-]	10

TABLE 3.2-B
ACCIDENTS REPORTED IN RMP*INFO BY THE 25 MOST FREQUENTLY INVOLVED CHEMICALS
2004-2005

Chemical Name	Number of Accidents
Ammonia (anhydrous)	452
Chlorine	270
Flammable Mixture	81
Hydrogen fluoride/Hydrofluoric acid (conc 50% or greater) [Hydrofluoric acid]	44
Chlorine dioxide [Chlorine oxide (ClO2)]	40
Propane	34
Sulfur dioxide (anhydrous)	29
Pentane	28
Hydrogen	22
Methane	21
Butane	21
Titanium tetrachloride [Titanium chloride (TiCl4) (T-4)-]	18
Hydrogen sulfide	18
Ammonia (conc 20% or greater)	17
1,3-Butadiene	17
Toluene diisocyanate (unspecified isomer) [Benzene, 1,3-diisocyanatomethyl-]	16
Ethane	15
Ethylene [Ethene]	15
Isobutane [Propane, 2-methyl]	14
Isopentane [Butane, 2-methyl-]	13
Propylene [1-Propene]	13
Hydrogen chloride (anhydrous) [Hydrochloric acid]	11
Formaldehyde (solution)	10
Ethylene oxide [Oxirane]	10
Ethylenediamine [1,2-Ethanediamine]	8

TABLE 3.3-A
ACCIDENTS REPORTED IN RMP*INFO BY THE 25 MOST FREQUENTLY INVOLVED NAICS CODE
1999-2000

NAICS Description	NAICS Code	Number of Accidents
Petroleum Refineries	32411	176
Water Supply and Irrigation Systems	22131	115
Sewage Treatment Facilities	22132	109
All Other Basic Inorganic Chemical Manufacturing	325188	92
Farm Supplies Wholesalers	42291	90
Other Chemical and Allied Products Wholesalers	42269	87
All Other Basic Organic Chemical Manufacturing	325199	81
Alkalies and Chlorine Manufacturing	325181	75
Nitrogenous Fertilizer Manufacturing	325311	68
Poultry Processing	311615	66
Pulp Mills	32211	56
Refrigerated Warehousing and Storage	49312	52
Petrochemical Manufacturing	32511	48
Natural Gas Liquid Extraction	211112	36
Animal (except Poultry) Slaughtering	311611	36
Plastics Material and Resin Manufacturing	325211	35
Meat Processed from Carcasses	311612	29
Frozen Fruit, Juice, and Vegetable Manufacturing	311411	28
Paper (except Newsprint) Mills	322121	27
Industrial Gas Manufacturing	32512	25
Other Basic Organic Chemical Manufacturing	32519	25
Other Basic Inorganic Chemical Manufacturing	32518	22
Pesticide and Other Agricultural Chemical Manufacturing	32532	21
Ice Cream and Frozen Dessert Manufacturing	31152	18
Paper Mills	32212	17

TABLE 3.3-B
ACCIDENTS REPORTED IN RMP*INFO BY THE 25 MOST FREQUENTLY INVOLVED NAICS CODE
2004-2005

NAICS Description	NAICS Code	Number of Accidents
Petroleum Refineries	32411	144
Farm Supplies Merchant Wholesalers	42491	99
All Other Basic Inorganic Chemical Manufacturing	325188	66
Sewage Treatment Facilities	22132	54
All Other Basic Organic Chemical Manufacturing	325199	53
Poultry Processing	311615	50
Other Chemical and Allied Products Merchant Wholesalers	42469	50
Water Supply and Irrigation Systems	22131	43
Alkalies and Chlorine Manufacturing	325181	42
Plastics Material and Resin Manufacturing	325211	37
Refrigerated Warehousing and Storage	49312	35
Pulp Mills	32211	33
Petrochemical Manufacturing	32511	27
Meat Processed from Carcasses	311612	26
Inorganic Dye and Pigment Manufacturing	325131	26
Primary Smelting and Refining of Nonferrous Metal (except Copper and Aluminum)	331419	21
Other Warehousing and Storage	49319	18
Natural Gas Liquid Extraction	211112	17
Industrial Gas Manufacturing	32512	17
Frozen Fruit, Juice, and Vegetable Manufacturing	311411	16
Nitrogenous Fertilizer Manufacturing	325311	16
Secondary Smelting and Alloying of Aluminum	331314	14
Fluid Milk Manufacturing	311511	13
Urethane and Other Foam Product (except Polystyrene) Manufacturing	32615	12
Perishable Prepared Food Manufacturing	311991	11

TABLE 3.4.
ON-SITE INJURIES AND DEATHS RESULTING FROM ACCIDENTS

	1999-2000 filing (1,896 accidents)			2004-2005 filing (1,214 accidents)		
	Mean or total	**Min**	**Max**	**Mean or total**	**Min**	**Max**
On-site injuries to workers/contractors						
Total on-site injuries	1,923			1,347		
Injuries per accident	1.0142	0	67	1.110	0	170
Injuries per FTE per accident*	0.0213	0	1	0.0210	0	1
On-site deaths to workers/contractors						
Total on-site deaths*	32			44		
Deaths per accident	0.0169	0	6	0.0362	0	15
Deaths per FTE per accident**	0.000323	0	0.25	0.000574	0	0.5

* Note that one of these deaths actually occurred off-site, although it was the result of an on-site injury and so is recorded here as an on-site death.
** Seventeen facilities with FTE listed as 0 are excluded, as is one with a missing value. Facilities with FTE=0 typically have one FTE employee for less than 6 months/year.

TABLE 3.5.
NON-EMPLOYEE INJURIES AND DEATHS RESULTING FROM ACCIDENTS

	1999-2000 filing (1,896 accidents)			2004-2005 filing (1,214 accidents)		
	Mean or total	Min	Max	Mean or total	Min	Max
Non-employee injuries						
Total injuries to public responders for all accidents	58			22		
Injuries to public responders per accident	0.0306	0	21	0.0181	0	3
Total on-site injuries to other members of the public for all accidents	95			118		
On-site injuries to other members of the public per accident	0.0501	0	59	0.0972	0	40
Total hospitalizations for all accidents	205			101		
Hospitalizations per accident	0.1081	0	80	0.0832	0	12
Total other medical treatment for all accidents	6,043			898		
Other medical treatment/accident	3.187	0	4624	0.7397	0	295
Non-employee deaths*						
Total public responder deaths	0			0		
Total on-site deaths by other members of the public	0			3		
Total off-site deaths to non-employees				1		
Overall non-employee deaths	0			4		

* Note that all 42 non-employee deaths originally reported in 1999-2000 were data errors, i.e. there were no actual deaths by public responders or other members of the public in the period covered by the 1999-2000 filings. Similarly, there were 25 public responder deaths reported in the 2004-2005 filings that were data errors. See Appendix 2-A for further details on the data quality procedures used to screen this data.

TABLE 3.6.
PROPERTY DAMAGE AND NON-MEDICAL OFF-SITE CONSEQUENCES OF ACCIDENTS
(ALL DOLLAR AMOUNTS IN THOUSANDS—NO INFLATION ADJUSTMENT)

	1999-2000 filing (1,896 accidents)			2004-2005 filing (1,214 accidents)		
	Mean or total	**Min**	**Max**	**Mean or total**	**Min**	**Max**
On-site property damage						
Total on-site damage	$976,773			$809,760		
Damage per accident	$515.2	$0	$219,000	$667	$0	$150,000
Off-site property damage						
Total off-site damage	$11,638			$8,296		
Damage per accident	$6.1	$0	$3,800	$6.1	$0	$2,000
Off-site consequences						
Total number of evacuations	165			128		
Total number of evacuees in all accidents	30,412			18,036		
Number of evacuees per accident	16.04	0	3,000	14.86	0	2,000
Total number of accidents involving shelter in place	97			84		
Total number of individuals confined to shelter in place in all accidents	190,039			305,189		
Number of individuals confined to shelter in place per instance	100	0	55,000	251	0	45,000
Number of accidents with effects on the ecosystem						
Fish or animal kills	18			8		
Minor defoliation	52			42		
Water contamination	28			36		
Soil contamination	22			18		
Any environmental damage	98			76		

TABLE 3.7.

SUMMARY STATISTICS FOR FINANCIAL ANALYSIS (1999-2000 FILING)

	N	Mean (SD)	Min	Max
Number of accidents per parent company	1642	.28 (.95)	0	13
Number of injuries per parent company	1642	.36 (2.01)	0	43
Previous year debt-equity ratio	1642	2.89 (4.01)	.04	20.00
Previous year sales ($ billions)	1642	$6.02 (14.90)	$2.6x10^{-4}$	168.74
Previous year return on assets (%)	1642	4.55 (9.61)	-126.65	132.78
Previous year return on equity (%)	1594	12.58 (43.30)	-639.52	451.88
Average number of FTEs	304	421 (1008)	<.5	14400
Average total hazard measure	306	12.46 (16.13)	3.87	228.76

TABLE 3.8.

PERCENT CHANGE IN RISK OF ACCIDENT PER FACILITY ASSOCIATED WITH PREVIOUS YEAR'S PARENT COMPANY FINANCIAL PERFORMANCE (1999-2000 FILING)

	Accidents			
	Debt-Equity Ratio	**Sales (Billions)**	**ROA**	**ROE**
All Combined*	6.3 (-.7, 12.8)	**-1.9 (-3.4,-.4)**	.3 (-2.6, 3.3)	**-.8 (-1.4, -.1)**
	Injuries			
All Combined**	**12.2 (3.5,21.7)**	**-2.6 (-4.5,-.7)**	.6 (-3.4,4.9)	-1.3 (-4.2,1.6)

*(100% debt-equity ratio, sales in 10^9 dollars, 100% return on assets [ROA], 100% return on equity [ROE]). Results adjusted for average size (in FTEs) and average total hazard measure across all facilities in the parent company; 95% confidence intervals in parentheses. Statistically significant results at α=.05 in **bold**.

(100% debt-equity ratio, sales in 10^9 dollars, 1% return on assets [ROA], 1% return on equity [ROE]). Results adjusted for average size (in FTEs) and average total hazard measure across all facilities in the parent company; 95% confidence intervals in parentheses. Statistically significant results at α=.05 in **bold. N/S=no significant difference.

TABLE 3.9.
"OPERATIONS RISK": ADJUSTED RELATIVE RISK (RR) FOR FACILITY ACCIDENTS IN 1995-2000.* FROM ELLIOTT ET AL. (2004A)

	Model 1****	Model 2****
1-10% African-American	**1.60(1.33-1.91)**	1.21(0.99-1.47)
10-20% African-American	**1.79(1.41-2.29)**	1.19(0.92-1.54)
>20% African-American	**3.03(2.40-3.83)**	**1.85(1.45-2.37)**
Median income $20-30K (vs.	**1.58(1.16-2.16)**	0.92(0.67-1.28)
Median income $30-40K	**2.05(1.44-2.94)**	0.99(0.68-1.44)
Median income $40K+	**2.34(1.42-3.89)**	1.00(0.60-1.67)
5-10% income below poverty (vs. <5%)	0.91(0.64-1.30)	0.80(0.57-1.13)
10-20% income below	1.01(0.68-1.49)	0.79(0.52-1.13)
>20% income below poverty	0.82(0.42-1.61)	0.54(0.28-1.04)
Income Inequality** .4-.45	1.24(.88-1.76)	1.21(.86-1.71)
Income Inequality .45-.55	**1.46(1.00-2.14)**	1.44(0.99-2.10)
Income Inequality >.55	**2.08(1.05-4.24)**	1.84(0.93-3.65)
10+% Manuf. (vs. <10%)	**1.57(1.29-1.91)**	**1.30(1.06-1.59)**
10-50K Total population (vs.		**1.61(1.16-2.26)**
50K+ population		**2.30(1.64-3.28)**
Number of FTEs (1000s)		**1.68(1.44-1.99)**
Total Hazard Measure***		**1.05(1.05-1.06)**

* 95% confidence intervals in parentheses; bold-face values significant at $p < 0.05$.
** Gini index of income inequality.
*** "Total hazard" is calculated as defined in Footnote 2.
**** "Model 1" is a multivariable regression model that simultaneously estimates the independent relationship between accident risk of a facility and the race, income, poverty, and labor force factors of the surrounding county; "Model 2" attempts to additionally adjust for "location risk" by also adjusting for the surrounding county's population, the number of FTEs in the facility, and the "total hazard" measure.

CHAPTER 4: ANALYSIS OF OFF-SITE CONSEQUENCES OF CHEMICAL ACCIDENTS

<u>Outline of the Chapter</u>

1. Introduction
2. Results for OCA Worst-Case Scenarios
3. Concluding Comments

1. Introduction

Among the most interesting information in the RMP*Info database is the Offsite Consequence Analysis (OCA) information.[1] 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. This chapter considers the nature of these scenarios for both waves of RMP data (1999-2000 and 2004-2005). We will not make any statistical comparisons between these two waves of data in this chapter, leaving that comparative analysis of the OCA data for Chapter 5.

We first describe the nature of the OCA data required to be reported under the RMP Rule. Thereafter, we consider the results using two basic metrics (defined more precisely below): (1) end-point distances over which chemicals have the ability to cause serious injury; and (2) affected population closer to the facility than the end-point distance of the facility. The reader should keep in mind that these results are "worst-case," and by definition therefore not likely to occur in practice. Nonetheless, using the worst-case footprints of chemical facilities is a useful metric on the maximum area of vulnerability from toxic and flammable chemicals, and is one informative metric for local communities and policy makers in evaluating the hazardousness of chemical facilities.

The OCA data required to be reported in the RMP include the following:

[1] Because of security concerns, the OCA data are not accessible to public in electronic format. In accordance with these restrictions, the statistical analysis reported here was either done completely internal to EPA or was encoded to hide the identity of individual facilities supplying the OCA data and to not permit statewide or national rankings derived from them.

- 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. Furthermore, 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.

Each facility using at least one regulated toxic chemical is required to provide a toxic worst-case and alternative release scenario in their RMP;[2] similarly each facility using at least one regulated flammable chemical is required to provide a flammable worst-case and alternative release scenario. Usually, each facility has a single worst-case scenario, but about 15% of reporting facilities 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-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. This means that the number of scenarios will exceed the number of facilities. For these reasons, as well as to provide an analysis of toxic and flammable scenarios separately, the unit of analysis in this chapter is the scenario, and not the facility.

2. Results for OCA 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

[2] Sections 2-5 are the relevant sections of the RMP for the worst-case and alternative release scenarios for toxic and flammable substances, respectively.

vessel or pipe in the process. 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.

In discussing OCA scenarios, it is important to note that two types of scenarios were required for each facility: a "worst-case scenario" and an "alternative release scenario." We will be concerned primarily with the former in this chapter, leaving to the next chapter the discussion of alternative release scenarios. The RMP regulation provides much greater flexibility in defining alternative release scenarios than worst-case scenarios. The result is that since there are no objective criteria for developing alternative release scenarios, the results can and do vary widely, even among similar facilities. In contrast, EPA placed numerous specifications on worst-case scenarios in order to simplify the analysis and to ensure comparability among facilities.

We first note that any changes between Wave 1 and Wave 2 in computed OCA effects for RMP facilities could be the result of changes in the models that were used to define these effects.[3] That is, some facilities might change the model used to calculate

[3] 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

distance to endpoint from one filing to the next. Because different models produce different results, a facility could reduce its reported endpoint distance or affected population by changing from one model to another, without making any change in the physical plant. To see whether such changes occurred, the research team examined the frequency of use of various models for computing worst-case OCA scenarios. Table 4.1 shows the results. It is important to keep in mind that some facilities have both toxic and flammable chemicals on site, so that the number of scenarios generated using these models will exceed the number of RMP facilities.

As seen in Table 4.1, a fairly low percentage of facilities changed their model between Wave 1 and Wave 2, and to the extent they did, a greater percentage used EPA OCA modeling in 2005 than 2000, for both toxics and flammables. This may seem a bit surprising at first glance since if a facility is motivated by a desire to reduce their endpoint distance, one might expect a trend away from using the EPA OCA guidance, as it is generally more conservative than other modeling approaches. However, the EPA OCA guidance is arguably more public and may be perceived to be more defensible with public stakeholders than "privately developed models," and this may well be the factor that underlies the noted shift. In any case, there does not appear to have been an appreciable change in the nature of the models used for OCA analysis between Wave 1 and Wave 2 of the RMP filings.

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. At http://yosemite.epa.gov/OSWER/Ceppoweb.nsf/content/EPAguidance.htm#OCA

TABLE 4.1.
MODELS USED BY RMP FACILITIES FOR OCA ANALYSIS

	Number of Facilities Using this Model in 1999-2000 Filings	Number of Facilities Using this Model in 2004-2005 Filings	% of Total Model Use for this Model in 1999-2000 Filings	% of Total Model Use for this Model in 2004-2005 Filings
Model Used for Toxic Worst-Case Scenario				
ALOHA	882	816	6.30	6.20
DEGADIS	3973	3404	28.39	25.88
EPA OCA	8421	8495	60.17	64.59
Other	310	149	2.21	1.13
PHAST	103	91	0.74	0.69
SLAB	307	197	2.19	1.50
Totals	13996	13152	100.00	100.00
Model Used for Flammable Worst-Case Scenario				
EPA OCA	2974	2497	93.49	95.02
PHAST	55	49	1.73	1.86
Other	152	82	4.78	3.12
Totals	3126	15731	198.27	100.00

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 4.1a-b and 4.2a-b are frequency histograms of endpoint distance for RMP toxic and flammable chemical process worst-case scenarios, respectively. Figures 4.1a and 4.2a are the results for the scenarios reported in the 1999-2000 wave of filings and Figure 4.1b and 4.2b are the corresponding results for the scenarios reported in the 2004-2005 wave of filings.[4] Each bar represents scenarios having endpoint distances in a particular distance interval. As explained earlier, the unit of analysis here is the "scenario" and not the "facility" since some (around 15%) facilities filed more than one scenario, usually because they had both toxic and flammable chemicals on site.

As we see from these figures, 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 (for both the first and second waves of RMP data), while the median endpoint distance for flammable worst-case scenarios is 0.4 miles (for both the first and second waves of RMP data). This reflects the differences in the physical nature of the two hazard classes and their worst-case scenarios, as described above.

[4] Tables 4.3 and 4.4 at the end of the chapter provide the data underlying Figures 4-1a-b and 4.2a-b.

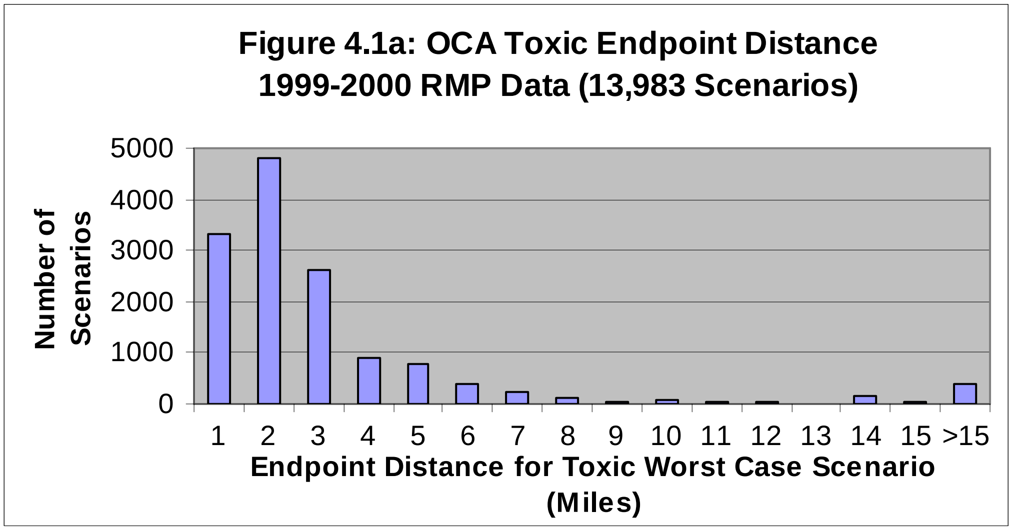


Figure 4.1a: OCA Toxic Endpoint Distance
1999-2000 RMP Data (13,983 Scenarios)
Number of Scenarios
5000
4000
3000
2000
1000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 >15
Endpoint Distance for Toxic Worst Case Scenario (Miles)

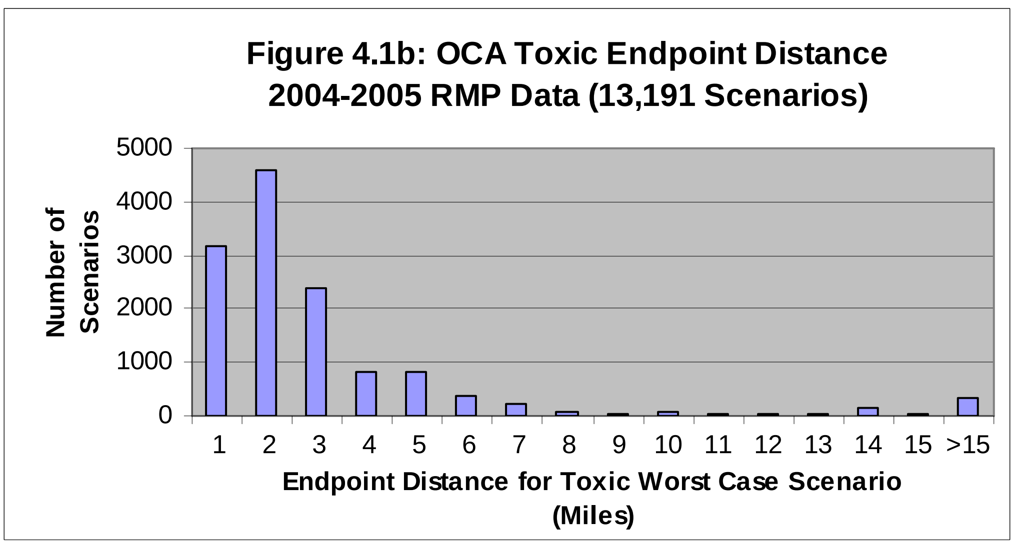
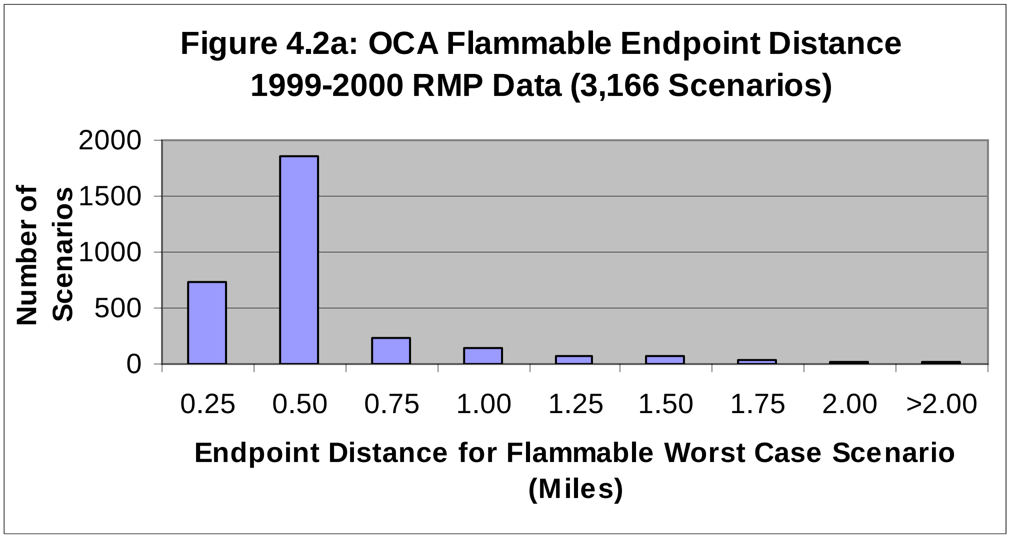
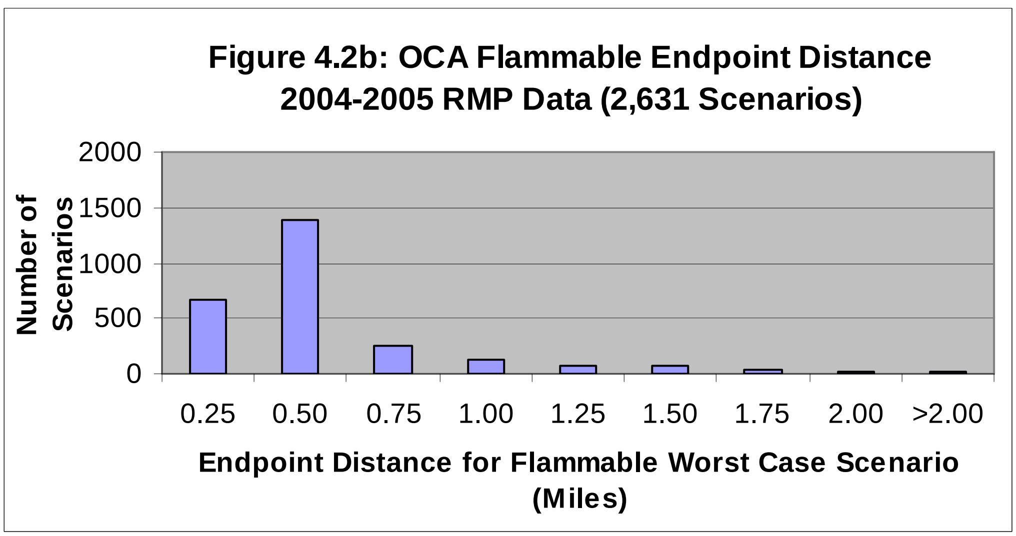


Figure 4.1b: OCA Toxic Endpoint Distance
2004-2005 RMP Data (13,191 Scenarios)
Number of Scenarios
5000
4000
3000
2000
1000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 >15
Endpoint Distance for Toxic Worst Case Scenario (Miles)

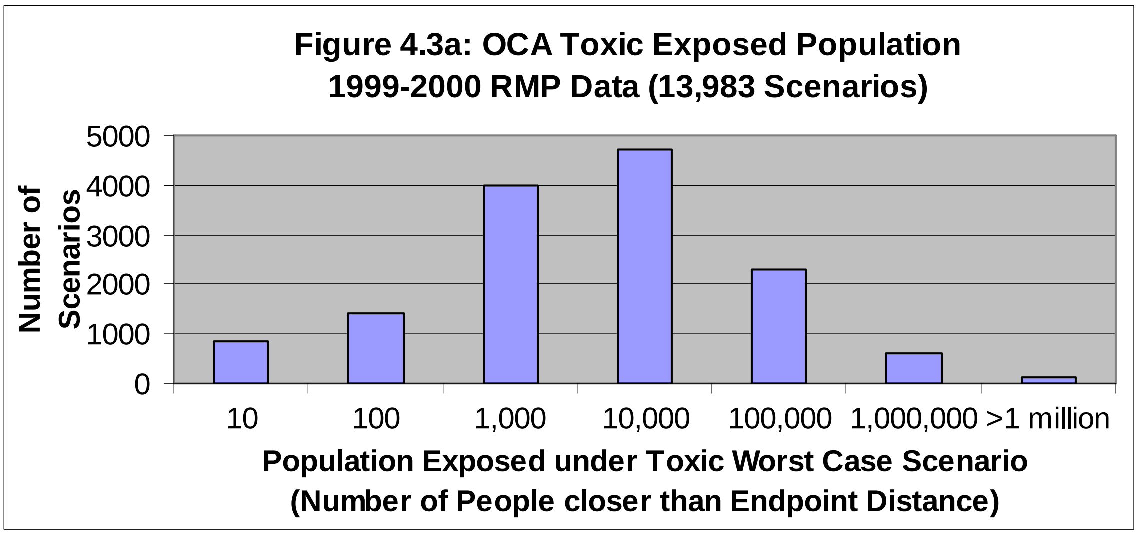


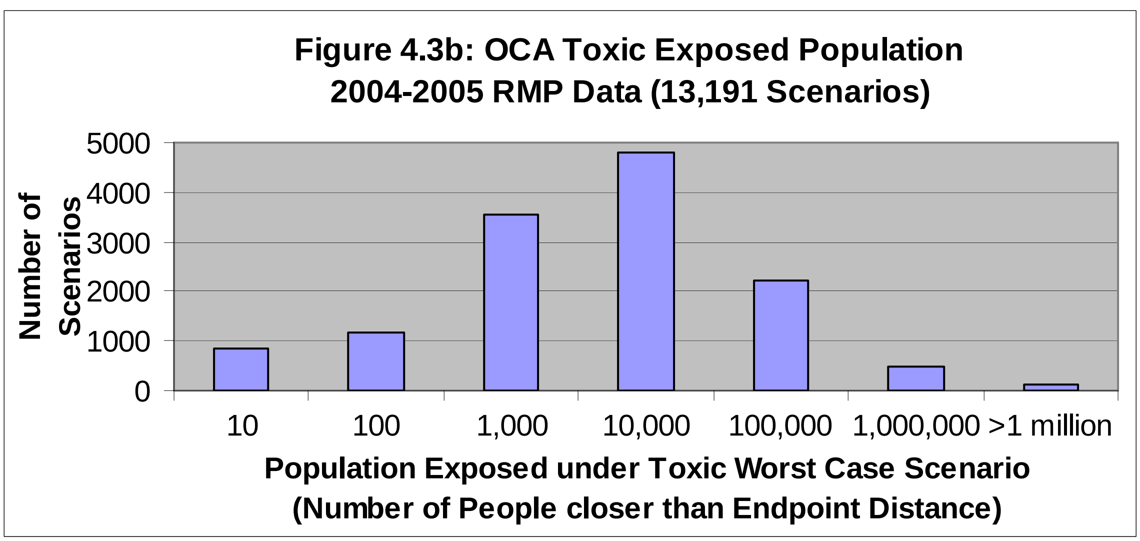


Potentially Affected Population

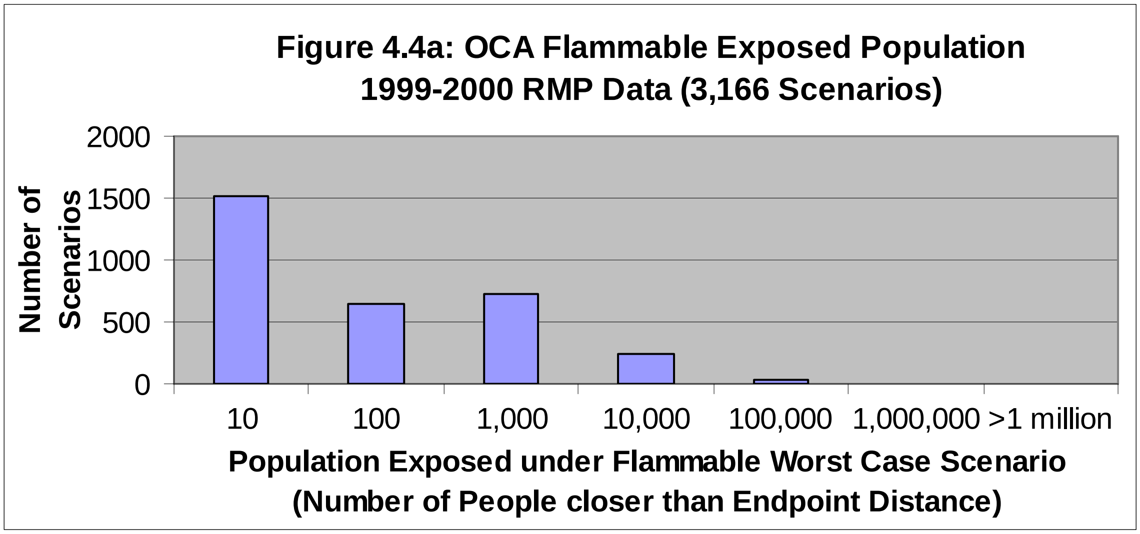
Under the RMP Rule, the population potentially affected by a release is defined as the residential population inside a circle with radius equal to the endpoint distance. Therefore, for a given population density, the population inside the "worst-case circle" will increase according to the area of the 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 the affected population increase as the square of endpoint distance.

Figures 4.3a-b and 4.4a-b are histograms of the potentially affected population for toxic and flammable worst-case scenarios for the respective first and second waves of RMP data.[5]





[5] Tables 4.5 and 4.6 at the end of the chapter provide the data underlying figures 4-3a-b and 4.4a-b.



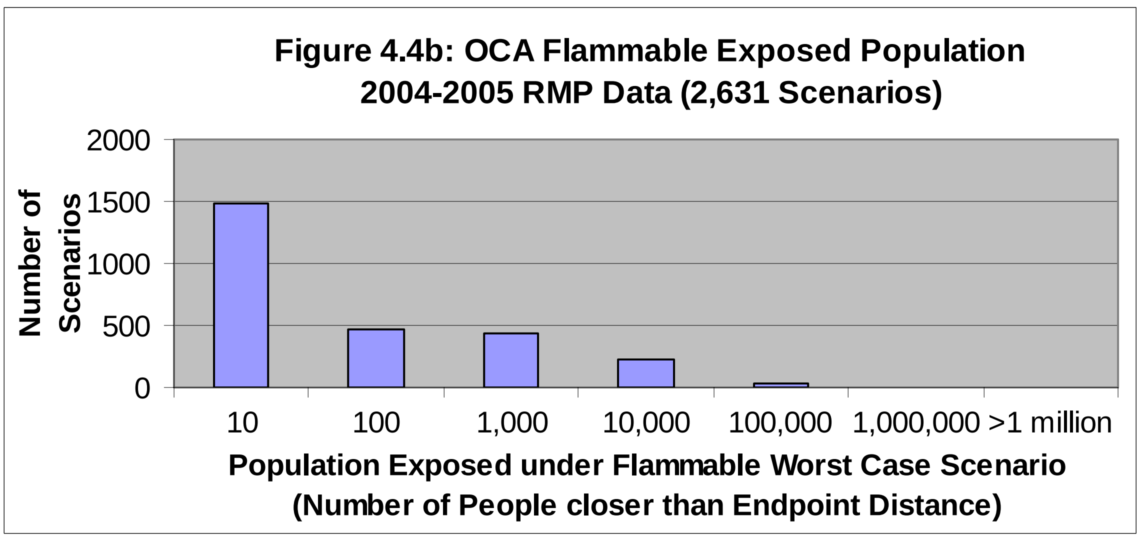


Table 4.2 summarizes the basic statistics for the above cases. We see from this Table that the distribution of the potentially affected population among the toxic worst-case scenarios is highly right-skewed: a mean of over 40,000 people would be affected per scenario in the first wave of filings (over 36,000 in the second wave), whereas the median scenario would affect 1,500 people in the 1999-2000 data (and 1,665 in the 2004-2005 data). The distribution of the potentially affected population among the flammable worst-scenarios is also highly right-skewed, although the estimated number affected is smaller: a mean of

668 and 752 per scenario in the first and second wave respectively, with the median scenarios affecting 15 and 4. 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.[6] 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. Thus, the OCA generally over-estimates the impact of a toxic release.

TABLE 4.2.
DESCRIPTIVE STATISTICS FOR TOXIC AND FLAMMABLE OCA SCENARIOS
DTE = DISTANCE TO ENDPOINT (IN MILES); POP = AFFECTED POPULATION

1999-2000 Toxic OCA Scenarios				**2004-2005 Toxic OCA Scenarios**		
Descriptive Statistics	**DTE**	**Pop**		Descriptive Statistics	**DTE**	**Pop**
Mean	2.9	40,253		Mean	2.8	36,516
Median	1.6	1,500		Median	1.6	1,665
Mode	1.3	0		Mode	1.3	0
Standard Deviation	4.2	289,569.2		Standard Deviation	3.9	245,673.9
Range	60.49	12,000,000		Range	26.81	12,000,000
Minimum	0.01	0		Minimum	0.01	0
Maximum	60.50	12,000,000		Maximum	26.82	12,000,000
Number of Scenarios	13,983	13,983		Number of Scenarios	13,191	13,191
1999-2000 Flammable OCA Scenarios				**2004-2005 Flammable OCA Scenarios**		
Descriptive Statistics	**DTE**	**Pop**		Descriptive Statistics	**DTE**	**Pop**
Mean	0.4	668		Mean	0.5	753
Median	0.4	15		Median	0.4	4
Mode	0.4	0.0		Mode	0.4	0.0
Standard Deviation	0.4	3,842.0		Standard Deviation	0.4	5,251.0
Range	6.9	115,000		Range	3.49	164,621
Minimum	0.0	0		Minimum	0.01	0
Maximum	6.9	115,000		Maximum	3.5	164,621
Number of Scenarios	3,166	3,166		Number of Scenarios	2,631	2,631

[6] 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.

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 4.1-4.4 and Table 4.2 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.

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.[7] Several reasons for this might be advanced. The first is the underlying differences in the way in which effects of the two types of chemicals manifest themselves, with worst-case effects from flammables clearly closer to the source of ignition of the vapor cloud. The difference may also be due partly to the fact that each distribution is actually a collection of underlying distributions, one for each different chemical represented in the database. It is also possible that facilities with toxic chemicals tend to be located in areas with different population densities than do facilities with flammable chemicals, thereby affecting the populations at risk. 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

[7] Due to the extremely wide range of residential populations (0 to 12 million for toxic worst-case scenarios) both distributions are plotted on a logarithmic scale.

used to obtain the remaining results probably induces some artificial variations in these distributions.[8]

3. Concluding Comments

This chapter has presented the OCA results for both waves of RMP data. We discussed only the worst-case scenarios, leaving the analysis of alternative release scenarios to the next chapter. Worst-case scenarios are valuable information for both host communities and policy makers, as they approximate the magnitude of the largest problem that might result from an accident at a chemical facility.

These worst-case scenarios underline the importance of a continuing emphasis on process safety. The population potentially affected by the worst-case scenarios varied greatly between facilities. Although the mean population affected across toxic worst-case scenarios was 40,253 in the 1999-2000 filings and 36,516 in the 2004-2005 filings, for half of these scenarios, fewer than 1,500 people resided in the vulnerable zone in 1999-2000 and fewer than 1,665 in 2004-2005. On the other hand, 5.1% (708) of the 13,983 toxic worst-case scenarios in 1999-2000 and 4.5% (600) of the 13,191 toxic worst-case scenarios in 2004-2005 potentially affected more than 100,000 people, with the maximum population reported for any scenario in both waves being 12,000,000. For flammable worst-case scenarios, mean vulnerable zone populations were 668 and 753 in the two time periods, while for half of the reported scenarios fewer than 15 people were potentially affected in 1999-2000 and fewer than 4 in 2004-2005. On the other hand, 1.3% (40) of the 3,166

[8] We delay until the next chapter a closer comparison of the different types of models that could be used, as this has a potential bearing also on the comparative analysis we undertake there on the two waves of RMP data.

flammable worst-case scenarios in 1999-2000 and 1.5% (39) of the 2,631 flammable worst-case scenarios in 2004-2005 potentially affected more than 10,000 people, with the maximum vulnerable zone population for any flammable scenario being 115,000 in 1999-2000 and 164,621 in 2004-2005. The data in Tables 4.5 and 4.6 appear to show that the characteristics of the OCA scenarios reported have not changed very significantly across the two waves of filings. However, the more detailed comparative analysis of the OCA data will be left to Chapter 5.

TABLE 4.3.
TOXIC WORST-CASE SCENARIOS
DTE = ENDPOINT DISTANCE (MILES)

	Number of Scenarios	
DTE in Miles	**1999-2000**	**2004-2005**
0 to 1	3320	3180
1 to 2	4789	4591
2 to 3	2621	2384
3 to 4	902	831
4 to 5	765	805
5 to 6	391	382
6 to 7	243	241
7 to 8	118	68
8 to 9	49	43
9 to10	97	75
10 to 11	50	42
11 to 12	42	33
12 to 13	19	19
13 to 14	153	149
14 to 15	35	23
> 15 miles	389	325
Total Scenarios	**13,983**	**13,191**

TABLE 4.4.
FLAMMABLE WORST-CASE SCENARIOS
DTE = ENDPOINT DISTANCE (MILES)

	Number of Scenarios	
DTE of Miles	**1999-2000**	**2004-2005**
0.0 to 0.25	740	658
0.25 to 0.5	1849	1389
0.5 to 0.75	236	250
0.75 to 1.0	137	133
1.0 to 1.25	67	66
1.25 to 1.5	69	72
1.5 to 1.75	33	36
1.75 to 2.0	13	10
> 2 miles	22	17
Total Scenarios	**3166**	**2631**

TABLE 4.5.
TOXIC WORST-CASE SCENARIOS
POP = EXPOSED POPULATION

	Number of Scenarios	
Pop Persons	**1999-2000**	**2004-2005**
0 to 10	854	835
11 to 100	1429	1178
101 to1 ,000	3973	3563
1,001 to 10,000	4713	4790
10,001 to 100,000	2306	2225
100,001 to 1,000,000	586	488
> 1 million	122	112
Total Scenarios	**13983**	**13191**

TABLE 4.6
FLAMMABLE WORST-CASE SCENARIOS
POP = EXPOSED POPULATION

	Number of Scenarios	
Pop Persons	**1999-2000**	**2004-2005**
0 to 10	1513	1483
11 to 100	647	460
101 to 1,000	718	430
1,001 to 10,000	248	219
10,001 to 100,000	39	36
100,001 to 1,000,000	1	3
> 1 million	0	0
Total Scenarios	**3166**	**2631**

CHAPTER 5: TREND ANALYSIS FOR COHORT OF DUAL FILERS

Outline of the Chapter

1. Introduction
2. Trends in Frequency and Severity of Accidents over the Period 1994-2005
3. Analysis of Cohort Accident Trends by Type of Impact
4. Reportable Accident Criteria and “No-Consequence” Accidents
5. OCA and Alternative Release Scenarios
6. Concluding Comments

1. Introduction

This chapter reports on trends in accident rates and consequences for an important subset of the facilities filing under the RMP Rule, namely for those that filed during both the initial wave of filings in 1999-2000 and the five-year anniversary filings in 2004-2005. Recall from Chapter 2 (see Figures 2.1-2.2) that there were 15,145 facilities that filed in 1999-2000 and 12,065 that filed in 2004-2005. Of these facilities, we selected a cohort of 10,446 that filed in both waves of RMP reporting and that had not de-registered by December 31, 2005.[1]

There are two benefits to following this cohort of filers over time, rather than comparing accident histories for all filers. First, focusing on facilities that had a continuing existence makes the notion of a "trend" in some underlying outcome intuitively clear. Second, following a cohort of filers over time ensures that any observed change in accident patterns reflects a change in accidents at these facilities – rather than a change in which facilities are being studied. Were we to compare accident rates in all facilities (not just the cohort), we would not be able to distinguish between an improvement in safety among the reporting facilities versus a pattern of the more accident-prone facilities dropping out of the RMP*Info database. This latter explanation could occur if accident-prone facilities tended to close or if they were less likely to comply with the requirement to re-file in Wave 2.

The results reported in this chapter complement those presented earlier in this report. Policy makers interested in whether the Rule has improved safety of individual facilities will be most interested in the changes in accident pattern among the cohort of

[1] As we noted in Chapter 2, 392 facilities filed in both waves, but nonetheless de-registered after filing in the second wave. There were an additional 556 facilities that filed a correction or resubmission of their first filing sometime prior to 2004, and these facilities were then not required to file during the window of 2004-2005 defining our second wave. Both these groups of 392 and 556 facilities are excluded from our Cohort.

facilities described in this chapter. On the other hand, those interested in whether the Rule has improved safety of the industry as a whole – either through changes in practices at individual facilities or through elimination of higher-risk facilities – will be more interested in comparing accident patterns in the entire population of facilities as reported in Chapter 3. Both of these chapters are to be read with the obvious caveat in mind that the changes reported here may be the result of many other influences than just the implementation of the RMP Rule.

The chapter proceeds as follows. In the next section, we present the basic statistics on accident frequency and severity over the 10-year period. These show that frequency of reported accidents has decreased over the initial 10-year period covered by the RMP Rule. In Section 3, we then consider in more detail trends in accident rates for various types of accidents, such as those involving on-site consequences of various types, off-site consequences and so forth. Both the overall rate of reported accidents (for accidents with and without reportable consequences) as well as the rate for reported accidents that involved injuries to employees or contractors appear to have declined significantly over the 10-year period for our cohort of joint filers. This leads to a discussion in Section 4 of some possible explanations for this, including changes in the criteria used by facility managers to determine whether to report an incident as an accident in their RMP. In section 5, we present the offsite consequence analysis (OCA) data for our cohort, including a discussion of these results. We note there that there have been only small changes in the worst-case OCA footprints of cohort facilities in the two waves of RMP filing studied. Section 6 summarizes key findings for this chapter.

2. Trends in Frequency and Severity of Accidents over the Period 1994-2005

Let us begin with a bar chart that indicates the nature of the "hypothesis" that we will be dealing with throughout this chapter. Figure 5.1 shows for our cohort of joint filers the frequency of accidents over the period of January 1, 1994 to December 31, 2005 – covering the time period during which accidents could have been represented in the RMP database (RMP*Info).[2] The earliest accident reported in our cohort database bears the date 06/14/1994 and the latest accident reported bears the date 12/08/2005.

Before interpreting this figure, let us note two important elements, which we refer to as "truncation" and "no-consequence accidents."

On "truncation," note that we have drawn an "X" through the years 1994, 2004 and 2005 to indicate that these are years in which incomplete data on accidents for our cohort were available. This "incompleteness" is to be understood as follows. Per the discussion of Chapter 2, a large number of facilities (the actual number was 6,925) in our cohort filed their first RMP report in June of 1999. These facilities would have reported accidents that occurred from June 1994 to June 1999, encompassing the required 5-year accident history reporting period. Thus, accidents for our cohort facilities that occurred in, say, May of 1994 would not show up in RMP*Info. Accidents (including those that occurred for our cohort of joint filers) that occurred in the year 1994 are therefore not completely represented in RMP*Info. For similar reasons, cohort filers that filed by June 2004 (the 5-year anniversary date of most original filers) would not report accidents in their second filing that occurred later in 2004 or 2005.

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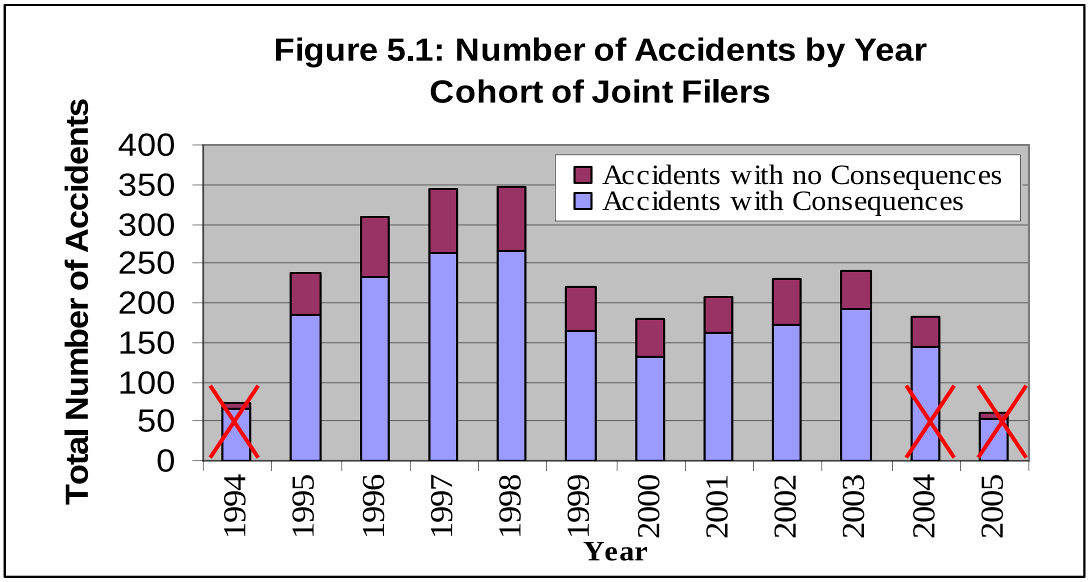
[2] The earliest RMP filed in our cohort database is 2/08/1999 and the latest RMP filing is dated 12/30/2005.

The above considerations related to "truncation" suggest the following caveat. While it is still meaningful to test accident rates across the first and second five-year accident histories for our cohort filers, it is important to note that the actual calendar time covered by a facility's 5-year accident history is a sliding scale which depends on the facility and its decision as to when to file.



We also note that we do not know when a facility actually began operations. Thus, some of the upward trend noted in Figure 5.1 in the period 1995-1998 may be due to facilities that began operations after 1995. For the same reason, the accident rates comparing the two waves of data, given this truncation, would tend to underestimate the actual five-year accident rates in the first wave of data since it would count every facility in the cohort as having been present for the entire five-year period 1994-1999, when some of the facilities will only have been in operation for part of this period. Notwithstanding the issue of truncation, and the potential underestimation of five-year accident rates per facility in the first wave of data, we will consider in what follows the first wave as representing the accident performance of the cohort in the five years preceding their first filing in the 1999-2000 wave of filings, and the second wave as representing (the) accident performance of the cohort for the subsequent five years, with the second RMP wave taking place in the 2004-2005 period.

Concerning "no-consequence" accidents, as explained in Chapter 3, facilities were required to report only accidents that had measurable consequences, though they might voluntarily report accidents that did not fulfill EPA's published criteria for required reporting. Thus, Figure 5.1 shows both the accidents with consequences and those without any reported consequences. Facilities might have reported "no-consequence accidents" because at the time of the accident it was not immediately clear what consequences would result and, once reported, the facility decided to keep the accident on the record. Furthermore, reporting practices may have changed over the period because of better measurement procedures. Thus, we must entertain the hypothesis that changes over time in facilities' decision-making as to which accidents needed to be reported may account for apparent reductions in accident rates. Therefore, it will be important to explore the consequences reported, in an attempt to distinguish between changes in reporting patterns and actual changes in accident patterns.

Noting the above two important elements, let us now consider trends in accident rates for our cohort. We first state a basic hypothesis which is graphically suggested by Figure 5.1.

> <u>Negative Accident Rate Trend Hypothesis</u>: Reported accident rates (for the cohort of filers) are higher in the first wave of data (the 1999-2000 RMP filings) than in the second wave of data (the 2004-2005 RMP filings), suggesting that a decrease in accident rates occurred when comparing the two 5-year reporting periods covered by the two waves of RMP filings.

Table 5.1 shows the results of statistical tests of this hypothesis for overall accident rates. There is a very significant decline in these accident rates between the first and second wave of filings for accidents with reported consequences and in total accidents ($P < 0.0001$). A decline in accident rate is also observed for accidents without reported consequences, but this decline is not significant ($P = 0.088$).[3] The "P-value" shown indicates the probability that the observed results of negative accident rate trends could have been the result of chance alone under the null hypothesis that there is no difference in accident rates between two filings. As can be seen from the very low P-values in Table 5.1, the observed results are very unlikely to have been the result of pure randomness. For our cohort, negative trends in reported accident frequency over the two 5-year reporting periods (Waves 1 and 2) of RMP data exist and these trends are statistically significant for two aggregate outcomes: (1) frequency of reported accidents with reportable consequences, and (2) frequency of reported accidents with or without reportable consequences.

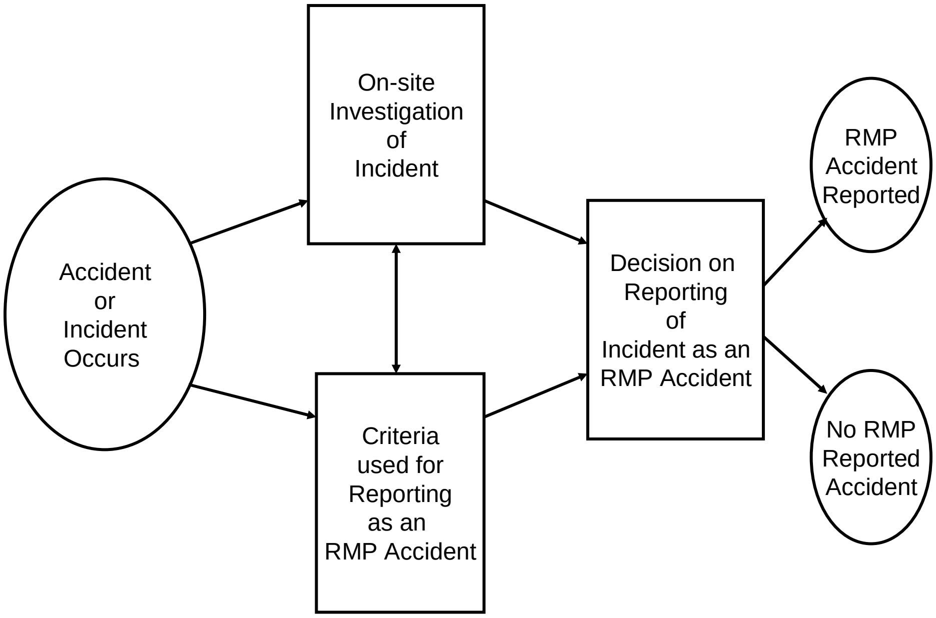
[3] A Poisson model is often used to compare rates for the number of accidents in a facility for a particular time period. However, for the present data the variance to mean ratio is larger than what is allowed by a Poisson model (over-dispersion) and there is also correlation between the number of accidents reported in the two filings for each facility. Therefore, a negative binomial generalized estimating equation (GEE) model was used to test the difference in accident rates between the two filings. The negative binomial model is a variant of the Poisson model and is used when there is over-dispersion in the data. The GEE approach takes into account the correlation between the numbers of accidents in the two filings for each facility (some facilities were more accident-prone than others, and their accident records were therefore correlated between the two five-year period covered by the two waves of filings).

In interpreting the findings of Figure 5.1, it is important to note that reported accidents are the result of (a) actual accidents/incidents, and (b) reporting practices used by facilities to decide whether or not to report any given accident/incident. Figure 5.2 illustrates this logic and gives rise to an additional hypothesis that we will consider in more detail below.

<u>Change in Reporting Practices Hypothesis</u>: Although the regulatory accident reporting thresholds were unchanged, facilities' interpretations of those thresholds, and their criteria and practices for reporting accidents (for the cohort of filers), changed from the first wave of data (the 1999-2000 RMP filings) to the second wave of data (the 2004-2005 RMP filings) in such a manner that part or all of the observed decrease in reported accident rates between these two waves is explained not by decreases in the frequency or severity of accidents that occurred but rather by the changes in the criteria and practices that were used by facilities to determine whether or not to report an incident as an RMP accident for the second wave of filings.

We consider both the "negative trend hypothesis" and the "change in reporting practices hypothesis" in the next two sections. In Section 3, we consider what can be said about the first hypothesis, focusing on accidents with consequences (on-site and off-site). In the process, we will sharpen the above negative trend hypothesis to account for different types of accidents with consequences, and their associated reported accident rates. In section 4, we consider the possibility that changes in reporting practices for accidents may have occurred for our cohort of joint filers over the initial 10-year period covered by the RMP Rule, so that part or all of the apparent reduction in accident rates evident in Figure 5.1 and Table 5.1 may have been due to changes in reporting practices used by facilities.

Figure 5.2: The Impact of Reporting Practices on RMP Data for Accident Rates



3. Analysis of Cohort Accident Trends by Type of Impact

Tables 5.1 through 5.3 show the details, for each on-site and off-site impact, of accident rates for the cohort of joint filers. As shown in Table 5.1, there is a difference of 245 (1,139 – 894) in the total number of cohort accidents with one or more EPA RMP reportable consequences between the 1999-2000 filing period (1,139 accidents) and the 2004-2005 filing period (894 accidents). As shown in Table 5.2, the difference in the number of cohort accidents with one or more reportable <u>on-site consequences</u> between the two filing periods is 212 (953 in 1999–2000 filing period, accidents and 741 in the 2004-2005 filing period), while the difference in the number of accidents with <u>off-site consequences</u> is 20 (325 in 1999-2000 filing period and 305 in the 2004-2005 filing period).

The difference in number of accidents with on-site impacts arises principally from a decrease of 221 in accidents involving worker injuries between the 1999-2000 and the 2004-2005 filing period (761 versus 540) and a decrease of 32 in accidents causing on-site property damage (311 versus 279), with the latter decrease not statistically significant.

For the different subgroups of onsite impacts, only accidents with one or more employees or contractors injured show a statistically significant difference between the two filings, with a significant decrease in the 2004-2005 filing period. There are no significant differences in rates of accidents with injuries for public responders, to other members of the public, or in rates of accidents with onsite property damage. There are not enough data to make meaningful statistical comparisons of accidents with deaths. When looking at accidents with <u>any</u> reportable onsite impact, there is also a significant decrease in the second filing period (Table 5.2).

For the different subgroups of off-site impacts including deaths, hospitalizations, other medical treatments, evacuations, shelter-in-place, property damage and environmental damages, there is no significant difference in accident rates between two filings at 0.05 significance level, except for other medical treatments, which has a P-value = 0.05.[4] When looking at the aggregate category of accidents with any reportable off-site impact, there is no significant difference between the two filing periods (Table 5.2).

In summary, when considering individual impacts of accidents, only counts of accidents with one or more employee or contractor injuries show a significant negative trend. The very significant finding of overall negative trends in Table 5.1 is driven mainly by

[4] When testing for differences in 10 different outcomes, there is a 40% chance of finding a P-value of 0.05 due to chance alone – making this finding of questionable significance.

the employee and contractor injuries, while other types of consequences show no substantial change.

We also considered the possibility that the number of people affected per accident, or the financial impact per accident, could change even when the number of accidents with that impact did not change. For instance, despite no significant change in the number of accidents with off-site victims requiring hospitalization, there might have been a decrease in the number of victims requiring hospitalization if there were fewer victims per accident. However, we did not find any such changes for any of the reportable outcomes (Table 5.3). Off-site hospitalizations occurred at a rate of 0.016 per facility in Wave 1, versus 0.0095 in Wave 2 (P=0.429).

Another interesting point related to changes in severity of reported accidents is the extent to which cohort facilities increased output or inventories of hazardous materials during the period in question.[5] We do not have a good measure of production output at the facility level, but we can measure hazardousness using the measure suggested in the Elliott et al. (2003) study. Recall from Chapter 3 that our hazardousness measure increases as the number of regulated chemicals at a facility increases and as the inventories of these chemicals increase relative to defined threshold quantities.[6] Table 5.4 shows relevant

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[5] We might also consider changes in regulation that applied to cohort facilities as a further measure of the hazardousness of these facilities. The statistics for the cohort in this regard are as follows. In summary, when comparing Wave 1 and Wave 2 filings, the percent covered by CAA Title V increased from 15.2% to 16.8%, the percent covered by EPCRA 302 increased from 84.3% to 85.7%. In contrast, the % covered by OSHA PSM as well as the maximum OSHA PSM program level at cohort facilities did not change in any substantial way between the two waves. We do not explore here the extent to which these changes are indicators of increased hazard, as we prefer to rely on the more direct measurement available through our hazardousness measure discussed below.

[6] Specifically, as defined in Elliott et al. (2003), the "hazardousness" measure used is defined as the sum over all RMP-listed chemicals at the facility of $\log_2$(maximum quantity of inventory/threshold), or, alternatively, as the number of chemicals times $\log_2$ of the geometric mean of the maximum-to-threshold quantity ratio. Hence a

results for the number of chemicals at cohort facilities and for our overall hazardousness measures. As can be seen, the number of chemicals did not change in cohort facilities, but the maximum inventories held did change, leading to significant increases in the average hazardousness of cohort facilities between the two waves of filings.[7]

Taking Tables 5.1 through 5.4 together, we may conclude the following. First, RMP reported accident rates significantly declined between Waves 1 and 2 of RMP filings in both accidents with reportable consequences and total accidents. Accidents with no reportable consequences also showed a decreasing trend though insignificant. Second, except for employee and contractor injuries and medical treatments, accident rates with particular types of impact were not statistically different across the two waves at the 0.05 level. The decrease between the two waves in reported accidents resulting in employee or contractor injuries is substantial. Third, the average severity per facility of the 5-year consequences for RMP reported accidents for our cohort was not statistically different between the two waves of filings for any of the reportable categories of specific impacts.[8] Thus, the number of

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total hazard measure of 0 indicates that only threshold levels of chemicals are kept in inventory, a measure of 1 means 1 chemical is kept at up to twice threshold level, 2 means 2 chemicals kept at up to twice threshold level or 1 chemical at up to 4 times threshold level, and so forth; unit changes in this measure can thus be interpreted as either an doubling of volume inventoried of a single chemical or an addition of another twice-threshold chemical on-site.

[7] We also examined whether there were any changes in the number of processes between the two waves for our cohort. There are 14,830 processes reported by 10,446 facilities in the 1999-2000 filing (mean number per facility = 1.42, SD = 1.94) and 14,556 process reported by 10,446 facilities in 2004-2005 filing (mean number per facility = 1.39, SD = 1.96). While this decrease is statistically significant, we will focus our discussion here on the hazardousness of facilities in terms of chemicals and maximum inventories rather than on the number of processes.

[8] It is to be emphasized that this consequence finding is on a "per facility" basis and not on the basis of "per dollar of output at a facility" or other normalization of accident consequences. If, for example, output or value added increased over the 10-year period for our cohort facilities, then some of the RMP impacts measured in these output-normalized measures might well exhibit significant declines. As noted, the research team did not have facility-level output information available to evaluate this question. However, total industry chemical industry production activity data from the Federal Reserve Board does show significant increases over the period covered in our analysis (see Table 5.8 Federal Reserve Board Chemical production data).

reported accidents involving worker injury declined between the two waves, and the number of reported workers injured per facility decreased as well, but the change in the latter was not statistically significant. Fourth, there was a significant increase in the hazardousness of the cohort facilities between the two waves (the hazardousness measure used reflects essentially the inventories of regulated substances onsite relative to regulatory thresholds). However, noting the other findings above, this increase in hazardousness did not lead to an increase in either the frequency or severity of impacts from RMP reported accidents.

It is worth considering some additional points related to the second and third findings above. We see from Table 5.2 that reported accidents involving worker or contractor injuries for our cohort decreased from 761 to 540 in Waves 1 and 2. We also see from Table 5.3 that average worker injury rates per facility (over the respective 5-year periods covered by the first and second filings) decreased from 0.152 to 0.125 between Waves 1 and 2, corresponding to total 5-year reported injuries across all cohort facilities of 1590 and 1310 in the two waves. The reader can see immediately that the average number of injuries reported per accident involving an injury was therefore 2.09 = 1590/761 and 2.43 = 1310/540. The contrast between the reduction in number of reported accidents with employee injuries, versus the apparent increase in injuries per accident (for those accidents involving injuries), emphasizes the need for clarity in defining appropriate metrics for measuring "improved worker safety."

Interestingly, there is what might be called a "Texas City effect" in these findings. This single accident on March 23, 2005 reported 170 injuries to workers and contractors.

Had the BP Texas City accident not occurred, the average number of injuries reported per accident involving an injury would have been 2.12 = (1310 – 170)/539 in the 2004-2005 filings, about the same average rate of reported injuries as in the first wave of filings (2.09). Of course, large accidents do happen in the low probability, high-consequence environment of chemical process safety, so that eliminating the Texas City event as an "outlier" is not appropriate. It is nonetheless interesting how significant an impact on the mean severity of accidents a single accident could have.[9] From a statistical point of view, these results lead to the conclusion that the frequency of RMP accidents involving worker or contractor injuries decreased significantly and substantially between the first and second waves (our second finding). For the same period, the severity of accidents, as measured by the number of workers and contractors injured per facility, also decreased, but the decrease was not statistically significant (consistent with our third finding). In fact, as we see from the discussion above, for those accidents involving worker injuries, the average number of workers injured was actually greater in the second wave than in the first.

[9] Various other results can be computed by eliminating the worst-case accidents in both filings. For example, eliminating the single accident in both filings that had the most injuries leads to eliminating the BP Texas City accident in the second filing (with 170 injuries) and the Point Comfort (Texas) Formosa Plastics Corporation accident of 12/04/98 in the first filing (which reported 67 injuries). This leads to average injuries per cohort facility in the first wave of 0.146 and in the second wave of 0.109. Eliminating the top two accidents with the most injuries in both waves leads to average injuries per cohort 0.143 in the first wave and 0.097 in the second filing. Eliminating "outliers" in low-probability, high-consequence event studies is quite misleading, however, since these major accidents provide realizations of the underlying random variables that are the very essence of the tail events of these random variables, i.e., they are fortunately rare but definitely a realistic part of the problem.

4. Reportable Accident Criteria and "No-Consequence" Accidents

As suggested by Figure 5.2, an important question in interpreting the above apparent significant decline in reported accident rates is whether this is partly the result of changes in facility reporting practices for accidents. It seems entirely plausible, for example, that as facility managers became more knowledgeable about RMP, they also became more aware about the criteria used by their peers to decide whether the level of damage or injury from an incident was sufficient to classify it as an RMP reportable accident. Certain classes of injury/damage are so unambiguous and have such public visibility, regulatory/legal oversight and clarity that they are difficult to ignore or misinterpret, e.g., deaths, public evacuations, public property damage. Others, such as OSHA reportable occupational injuries and illnesses (OII) are relatively more difficult to classify and less verifiable by the public or the authorities. Moreover, the definition of what constitutes an OII and recent OSHA enforcement patterns have led Friedman and Forst (2007a)[10] and others to conclude that recent rapid decreases in OII can be ascribed to changes in OSHA record-keeping rules.

Therefore, decreases in accident rates whose only impact is worker injuries or some other single on-site impact may possibly result from increased discretion in reporting. On the other hand, accidents with multiple impacts or with off-site consequences would present arguably less reporting discretion, so that a decrease in such accidents could be stronger

[10] See Friedman and Forst (2007a) for a discussion of OSHA OII reporting issues. They note that substantial declines in the number of injuries and illnesses correspond directly to changes in OSHA recordkeeping rules. "Changes in employment, productivity, OSHA enforcement activity and sampling error do not explain the large decline. Based on the baseline slope (joinpoint regression analysis, 1992-1994), we expected a decline of 407,964 injuries and illnesses during the period of follow-up if no intervention occurred. But in fact we observed a decline of 2.4 million injuries and illnesses of which 2 million or 83% of the decline can be attributed to the change in the OSHA recordkeeping rules."

evidence for a change in actual accident patterns and not changes in the criteria used by facilities for reporting.

In this light, consider Table 5.5 which classifies accident types in various ways, replicating some of the data of Table 5.2.

The strongest evidence for a possible change in reporting criteria is seen in comparing rows (ii) and (iii) of Table 5.5, where we see that accidents with on-site impacts track very closely the overall change in accident rates, whereas accidents with any off-site consequences have a lower ratio of decline, suggesting that these latter could have been subject to more rigorous reporting criteria. Intuitively, accidents with off-site consequences arguably involve less discretion in reporting and for these we see no significant change. The major observed changes are in accidents with reported on-site consequences.

However, it should also be noted that accidents in which worker injuries were the only reported impact decreased more than overall accident rates or than accidents involving other impacts. For example, comparing accidents of type (iv) whose consequences included worker or contractor injuries (and possibly some other consequences) with accidents of type (vii) where the only consequence was worker or contractor injury, we see that the difference in the decrease in these accident types is quite similar.

Similarly, comparing accidents of type (v) whose consequences included property damage (and possibly some other consequences) and accidents of type (ix) involving only property damage, we see similar outcomes, even though facility managers are given considerable discretion to define what they consider to be "reportable property damage."[11]

[11] On the issue of discretion related to on-site property damage, see our discussion in Chapter 2.

In this case, the evidence here runs counter to the notion that reporting criteria, where these were discretionary or less observable, were changed to be less demanding in Wave 2 than in Wave 1. All together, the results reported in Table 5.5 provide mixed support for the hypothesis that changes in accident reporting criteria occurred, with the primary evidence in support of the hypothesis deriving from the differences in the trends between accidents with on-site versus off-site consequences.

A further area that was considered in detail by the research team concerned “no-consequence” accidents, a topic that has surfaced repeatedly in this chapter in our discussions of the overall results of our cohort comparison. We note right away (see Table 5.1) that the decrease in “no-consequence” accidents is generally consistent with the overall decrease in reported accidents between Wave 1 and Wave 2. To check further on the nature of “no-consequence” accidents over the 10-year period of RMP filings, the research team identified 887 accidents in the database that had no identified consequences in the "Accident History" detail table. From these, we sampled 97, stratifying on year and EPA region in order to get a representative sample across time and space. We reviewed this sample in detail in order to determine if any pattern could be discerned over time in the nature of “no-consequence” accidents reported. When this sample of 97 accidents included more than one accident from a facility, we reviewed only one of the accidents, leading to a review of 85 accidents. These sampled “no-consequence” accidents were classified as follows:

YES: The accident should have been reported as an accident with consequences, so the fact that the facility's accident history did not report any impacts was likely erroneous. In this category, we found 3 of the 85 "no-consequence" accidents. Based on review of the text descriptions of the accidents, two cases involved accidents where roads were closed off-site, raising the question of whether these closures should have been reported as consequences. One case involved damage to a storage tank but no property damage was reported under the detailed impacts of the accident. Given the wide discretion in terms of the ability of facilities to set internal thresholds for how much property damage had to occur before they would report it (see Chapter 2), it is reasonable to assume that the facility chose not to report the damaged tank as "significant."

NO: The accident was probably reported correctly as an accident with no consequences, so that the facility's accident history report was likely correct. In this category, we found 58 of the 85 "no-consequence" accidents.

UNCLEAR: It was not clear from the accident information given as to whether or not the accident could have been reported as an accident with or without consequences. In this category, we classified 24 of the 85 "no-consequence" accidents.

What we conclude from this analysis of reporting criteria is the following: In terms of reporting for impacts which may allow for some discretion in reporting, such as off-site versus on-site consequences, worker injuries and property damage, the evidence available provides support for the hypothesis that there have been changes in accident reporting criteria over the 10-year period in question. We also examined a sample of "no-consequence accidents" across the 10-year period. What we found was that accidents classified as "no-consequence" did exhibit some "noise" and errors in the data, but no systematic biases were detected. Noise occurs with any dataset, and especially when the data is the result of a discretionary or judgmental process, as in RMP. The noise in the data does suggest that continuing attention to data quality, including communication with facility owners about the criteria for reportable accidents, remains a very important issue for the RMP Rule going forward.

5. OCA and Alternative Release Scenarios

As noted in Chapter 4, an off-site consequence analysis (OCA) is required of RMP facilities. Facilities comply with this requirement by using a computational model to calculate the distance to endpoint and potentially affected population of a worst-case scenario and an alternative release scenario. We wish to compare for our cohort any changes in the predicted outcomes of these models that may have occurred for cohort facilities between Wave 1 and Wave 2.[12]

Tables 5.6 and 5.7 provide a comparative summary of the OCA findings for the two waves of data. Table 5.6 shows that a few facilities in our cohort did not report the same type of OCA scenarios in both time periods. For instance, 23 facilities reported a toxic worst-

[12] The reader will recall that our analysis in Chapter 4 indicated that there does not appear to have been an appreciable change in the nature of the models used for OCA analysis between Wave 1 and Wave 2 of the RMP filings. Thus, the results reported here are not likely to have been influenced by changes in modeling methodology between the two waves of filings.

case scenario in 1999-2000 but did not report one in their 2004-2005 filing. (However, they still filed in both periods – the criterion for the cohort.)

Table 5.7 shows the changes in the outcomes of interest – distance to endpoint (DTE) and affected population (Population) – for Waves 1 and 2. Note that, just as in Chapter 4, the analysis of OCA scenarios here considers the numbers of scenarios, not the number of facilities.[13] For three of the four scenario types, there were statistically significant changes in average DTE. The largest change was a reduction of 0.072 miles (380 feet) in the average distance to endpoint for the toxic worst-case scenarios, which is statistically significant. The average distance to endpoint for flammable worst-case scenarios did not change significantly, nor did the population potentially affected by either toxic or flammable worst-case scenarios.

Mean, Median and Standard Deviation of DTE for the Toxic Worst-Case Scenarios have all decreased slightly. The flammable WCS distributional parameters show almost no change for the scenarios filed by cohort facilities. This may be a bit surprising. One might expect to see the same sort of thing in the flammable distributions as we see in the toxic distributions, namely a reduction in both mean and median effects due to reductions in the upper end of the distribution of DTE across scenarios. The fact that we do not see this may result from the fact that toxic scenarios, having the potential to result in very large scenarios that therefore have the potential to attract attention, are the type of scenarios that

[13] The number of scenarios is larger than the number of facilities, because some facilities have both toxic and flammable scenarios, and some even have more than one scenario for a given hazard class (there's a provision in the regulations for this where scenarios could affect significantly different populations).

inherently have greater power to motivate facilities to make some sort of change so as to reduce their endpoint distance.

In interpreting the results of Table 5.7, it is important to note the differences in Worst-case and 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 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 release scenarios are generally considered to be more representative of actual emergency scenarios that might occur.

With the above caveat in mind on the flexibility of facilities in defining alternative release scenarios, we note that the DTE for both toxic and flammable alternative release scenarios exhibits a statistically significant reduction between Wave 1 and Wave 2. As expected, alternative release scenarios for both toxic and flammable scenarios have, in general, shorter endpoint distances and 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 5.7 effectively highlights the much larger scale of toxic scenarios relative to flammable scenarios. All potential impacts from flammable scenarios are much 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 affect any members of the off-site public (i.e., the median population value for flammable alternative release scenarios is zero).

Summarizing the above, the OCA footprints for our cohort exhibit only small changes in the average effects (distance to endpoint and potentially affected population) between Waves 1 and 2. The most pronounced effects are reductions in the DTE for toxic worst-case and toxic alternative release scenarios. The results for the flammable OCA footprints are, if anything, in the direction of small increases in DTE (though these scenarios entail considerably lower impacts than the toxic scenarios, especially in terms of potentially affected population).

Given the increases in hazardousness for our cohort noted in Table 5.4, due to increased on-site inventories of RMP-listed chemicals, the relatively smaller increases seen in worst-case consequences of accidents, as reflected in Tables 5.6 and 5.7, may initially seem questionable. However, some care must be exercised in interpreting the relationship between the results in Table 5.4 and the OCA results reported above. First, it is possible that mitigation measures have been undertaken by cohort facilities to control any increase in worst-case scenario endpoint distance and population. However, other explanations can also give rise to these results. We note that the RMP reports the process quantity (in the registration information) and the release quantity (for worst-case and alternative release scenarios). The process quantity is not always the total quantity on site. This is important in and of itself, and it also suggests another possible explanation for the results of Table 5.4 and Tables 5.6 and 5.7. Indeed, process quantities can increase without worst-case scenario release quantities (and hence endpoint distances and populations) going up. For most regulated facilities, if facility managers want to increase the process quantity, they do not want or need to install a bigger tank; they will just manifold in a second (or third) equal-sized tank. For some types of chemicals, tanks comes in standard sizes, and if another same-sized tank is added, the worst-case scenario won't change, since the OCA analysis considers only the single largest vessel. Other explanations for the results of Tables 5.4, 5.6 and 5.7 are that if the scenario involves a liquid spill that is mitigated by containment dikes, the geometry of the dike (i.e., surface area of the evaporating pool) controls the release rate. If the dike is deep enough, it does not matter how big the vessel is, the scenario release rate (and hence endpoint distance) would not change. Lastly, due to the physics of vapor cloud dispersion, endpoint distances are not always highly sensitive to changes in release quantity (i.e., all other things being equal, an increase in release quantity will result in increased endpoint distance, but not in anything like a linear fashion). The bottom line to this discussion is that the increases in process inventories evident from Table 5.4 need not give rise to increases in computed worst-case scenario outcomes and the data here indicate, indeed, that they did not.

6. Concluding Comments

The above analysis covers the cohort of facilities that filed in both waves of RMP filings. Our analysis has focused our comparative assessment of accident trends and off-site consequence analysis on this cohort, so as to allow more straightforward statistical testing of trend results and for ease in interpreting the results intuitively. As noted, however, the overall assessment of the state of the hazards arising from chemical accidents at U.S.

chemical facilities should be based on the entire (and evolving) data collected under the RMP Rule. Nonetheless, the results for our cohort provide a useful benchmark for understanding trends in accident rates and worst-case footprints in the chemical industry over the past decade. What do we find in our comparison?

First, RMP reported accident rates significantly declined between Waves 1 and 2 of RMP filings for both accidents with reportable consequences and for all accidents. The principal cause for this drop is a decrease in the sub-category "injuries to employees and contractors" which are in essence reportable under OSHA OII. Second, except for employee and contractor injuries and medical treatment, differences in rates of accidents with particular types of impact were not statistically different across the two waves at the 0.05 significance level. Third, concerning accident severity, the severity of the 5-year actual consequences for RMP reported accidents for our cohort facilities was not substantially or statistically different between the two waves of filings for any of the reportable categories of specific impacts.[14] Fourth, there was a significant increase in the hazardousness of the cohort facilities between the two waves. However, this increase in hazardousness did not lead to an increase in either the frequency or severity of impacts from RMP reported accidents. Finally, there were some small changes in the worst-case footprints of cohort facilities.

There are several possible explanations for the above results on the decreases in accident rates between the two filing periods. First is the conclusion that the RMP Rule may

[14] It is to be emphasized that this finding is on a "per facility" basis and not on the basis of "per dollar of output" or other appropriate normalization of accident consequences. If, for example, output or value added increased over the 10-year period for our cohort facilities, then some of the RMP impacts measured in these output-normalized measures might well exhibit significant declines. As noted, the research team did not have facility-level output information available to evaluate this question.

have had its intended effect in lowering accidents and consequences for workers and the public. In this regard, it is useful to recall that the RMP Rule was first published in June, 1996, and the actual effective date of implementation of the RMP Rule was June 21, 1999.[15] Given the flurry of RMP submissions in 1999, it may be that the accident prevention outcomes expected from full compliance with the provisions of the RMP were not realized until well into 1999. If we assume this were the case, it could explain the 1999 and subsequent years drop in reported accident rates shown in Figure 5.1. An additional factor that could explain all or part of the decrease in reported accidents is that associated with Figure 5.2 and the possibility that facilities changed the criteria they use for reporting an incident as an "RMP accident."

To trace the argument on the change in reporting criteria hypothesis more fully, consider the following summary of our data.

From Table 5.1: there was a substantial and statistically significant (21.5% = (1477-1160)/1477) drop in total accidents reported and there was a substantial and statistically significant (21.5% = (1139 - 894)/1139) drop in accidents with consequences. There was also a substantial (21.3% = (338-266)/338) drop in no-consequence accidents but it was only of borderline statistical significance.

From Table 5.2: The only change that was substantial and significant was a 29% drop in accidents with injuries to employees/contractors. Earlier in this chapter, we cited evidence that reporting of OII has been subject to variations based on changes in reporting

[15] As noted in §68.10: "(a) An owner or operator of a stationary source that has more than a threshold quantity of a regulated substance in a process, as determined under §68.115, shall comply with the requirements of this part no later than the latest of the following dates: (1) June 21, 1999; (2) Three years after the date on which a regulated substance is first listed under §68.130; or (3) The date on which a regulated substance is first present above a threshold quantity in a process."

criteria.[16] Table 5.2 shows that the overall drop in accidents with on-site impacts was almost entirely driven by the drop in accidents with employee/contractor injuries, i.e., there was a drop of 221 in the accidents with employee/contractor injuries and a drop of 212 in the "any on-site impact" (including employee/contract injuries) count. Generally, we would expect that accidents that would show the most dramatic changes in response to changes in *de facto* reporting thresholds would be those involving worker/contractor injuries and on-site property damage. This is evident in Table 5.5. There was a decrease of 245 in the number of accidents with consequences between the two waves, of which 230 (798-568) or 94% represented accidents that had either only worker/contractor injury, only on-site property damage, or only those two consequences with no other consequences.

Summarizing, the data reported here suggest that the "changed *de facto* reporting criteria hypothesis" is a reasonable explanation for at least some of the reduction in reported RMP accidents and their consequences. An alternative explanation is that the observed decrease in RMP accidents involving worker injuries is due to a reduction in the number of employees working close to processes as a result of reductions in workforce or relocation of employees to better protected control rooms. Further study and data collection would be required to determine how much of the reduction in reported RMP accidents is "real" and how much of it is based on changes in reporting criteria.

While the above results provide some answers on the question of trends, we have also discussed a number of limitations and qualifications in interpreting the above findings.

[16] However, decreases in OII might also reflect reduction in employee and contractor presence close to operating units as a result of greater industry use of instrumentation operated from better protected control rooms.

Moreover, many fascinating questions remain open to further inquiry. To mention a few of the studies suggested by the above findings, we note the following:

1. What measures were undertaken by facilities to reduce worker injury rates, and how successful have specific measures been? Facilities may have taken special measures to avoid worker injuries, such as more protective control rooms. Such "new" control rooms would reduce worker injuries but not substantially affect property damage or off-site accident consequences. Also, some sectors (e.g., agriculture) have become more automated over the past decade and fewer employees and contractors are therefore exposed to process hazards in these sectors.
2. What reporting criteria are actually used at RMP facilities and how accurately are these implemented in practice?
3. It would be of considerable interest to determine if trends differed across particular industry sectors and why. The RMP Rule covers a very diverse set of industry sectors, which historically speaking have very different safety traditions, and investigating the differences among them could yield important insights.
4. Considering the fact that facility hazardousness was a powerful predictor of accident propensity in the analytic study of Wave 1 data reported in Elliott et al. (2003), it would be interesting to understand why the significant rise in hazardousness evident in Wave 2 data did not result in an increase in reported accident frequency or severity.

These questions can only be answered by continuing studies of the RMP data and related research. Perhaps the most important question raised by this comparative study is whether the RMP Rule itself has been worth its salt as an environmental and process safety regulation. This is the question to which we now turn.

TABLE 5.1.
CHANGES IN RMP REPORTABLE ACCIDENT RATES FOR COHORT OF JOINT FILERS OVER BOTH WAVES OF FILINGS

EPA RMP Reportable Accident Impact	**1999 - 2000 Filing # of Facilities: 10446**		**2004 - 2005 Filing # of Facilities: 10446**		**Change in Accident Rates (2nd -1st Filing)**	**P-value for Testing of Difference***
Nature of Reported Accident	# of Accidents with Impact	Accident Rate (per facility)	# of Accidents with Impact	Accident Rate (per facility)	Difference	
A. With Consequences	1,139	0.109	894	0.086	-0.023	<0.0001
B. Without Consequences	338	0.032	266	0.025	-0.007	0.088
C. With or without Consequences (All Reported Accidents)	1,477	0.141	1,160	0.111	-0.030	<0.0001

* The P-value was calculated by using a negative binomial generalized estimating equation (GEE) model.

TABLE 5.2.
RMP REPORTABLE ACCIDENTS WITH CONSEQUENCES FOR COHORT OF JOINT FILERS FOR BOTH WAVES OF FILINGS

RMP Reportable Accident Impact	**1999 - 2000 Filing** **# of Facilities: 10446** **# of Reported Accidents: 1477** **# of Accidents with Conseq: 1139**		**2004 - 2005 Filing** **# of Facilities: 10446** **# of Reported Accidents: 1160** **# of Accidents with Conseq: 894**		**Change in Accident Rates (2nd -1st Filing)**	**P-Value for Testing of Difference**
On-site Impacts	# of Accidents with Impact	Accident Rate (per Facility)	# of Accidents with Impact	Accident Rate (per facility)	Difference	
A. Deaths						
i. Employees or contractors	15	0.00144	22	0.00211	0.00067	/*
ii. Public responders	0	0	0	0	0	/*
iii. Public	0	0	3	0.00029	0.00029	/*
B. **Injuries**						
i. Employees or contractors	761	0.07285	540	0.05169	-0.02116	<0.001**
ii. Public responders	13	0.00124	10	0.00096	-0.00028	0.66
iii. Public	10	0.00096	17	0.00163	0.00067	0.25
C. On-site Property Damage	311	0.02977	279	0.02670	-0.00307	0.30**
Any On-site Impact(s)	953	0.09123	741	0.07094	-0.02029	<0.0001**
Off-site Impacts						
i. Deaths	0	0	0	0	0	/*
ii. Hospitalizations	39	0.00373	43	0.00412	0.00039	1.00
iii. Other medical treatments	98	0.00938	75	0.00718	-0.00220	0.05
iv. Evacuated	127	0.01216	123	0.01177	-0.00039	1.00
v. Sheltered-in-place	81	0.00775	85	0.00814	0.00039	1.00
vi. Property damage	38	0.00364	46	0.00440	0.00076	0.25
vii. Environmental damage						
a) Fish or animal kills	14	0.00134	8	0.00077	-0.00057	0.50
b) Tree, lawn, crop damage	37	0.00354	40	0.00383	0.00029	0.91
c) Water contamination	18	0.00172	17	0.00163	-0.00009	1.00
d) Soil contamination	22	0.00211	35	0.00335	0.00124	0.08
Any Off-site Impact(s)	325	0.03111	305	0.02920	-0.00191	0.47**

* Death outcomes are too rare to allow statistical testing.

**The P-value was calculated by using a negative binomial GEE model. Otherwise, a McNemar's test was used since most facilities only have one accident with the consequences in question. An exact test was used when the cell size was small.

TABLE 5.3.
ACTUAL CONSEQUENCES OF ACCIDENTS FOR COHORT OF JOINT FILERS IN THE TWO WAVES OF REPORTED RMP ACCIDENT DATA

RMP Reportable Accident Impact	1999 - 2000 Filing # of Facilities: 10446 # of Reported Accidents: 1477 # of Accidents with Conseq: 1139	2004 - 2005 Filing # of Facilities: 10446 # of Reported Accidents: 1160 # of Accidents with Conseq: 894	Change in Mean of Accidents (2^{nd} -1^{st} Filing)	P-Value for Testing of Difference
On-site Impacts	Mean (SD) per facility	Mean (SD) per facility	Mean Difference (SD)	
A. Deaths				
i. Employees or contractors	0.0026(0.093)	0.0042(0.165)	0.0016(0.190)	/*
ii. Public responders	0 (0)	0 (0)	0 (0)	/*
iii. Public	0 (0)	0.00029(0.0169)	0.00029(0.0169)	/*
B. Injuries				
i. Employees or contractors	0.152(1.368)	0.125(2.463)	-0.0268(2.698)	0.328**
ii. Public responders	0.00499(0.237)	0.0020(0.070	-0.0030(0.243)	0.213
iii. Public	0.0022(0.123)	0.0112(0.567)	0.0090(0.580)	0.113
C. On-site Property Damage	85,301(2,847,304)	78,942(2,538,004)	-6359.7(3751768)	0.863
Off-site impacts				
i. Deaths	0 (0)	0 (0)	0 (0)	/*
ii. Hospitalizations	0.0161(0.823)	0.0095(0.227)	-0.0066(0.853)	0.429
iii. Other medical treatments	0.539(45.29)	0.0852(3.432)	-0.453(45.40)	0.453**
iv. Evacuated	2.066(50.61)	1.617(38.79)	-0.449(63.55)	0.470
v. Sheltered-in-place	17.60(890.6)	28.44(2137.6)	10.84(2315.1)	0.632
vi. Property damage	742(40658.7)	796(27259.0)	53(48962.7)	0.911

* Death outcomes are too rare to allow statistical testing.

** P-value was calculated based on a bootstrap test since the assumption of normality is not satisfied. Otherwise, the P-value was calculated based on a two-sample paired t-test.

TABLE 5.4.
HAZARDOUSNESS OF COHORT FACILITIES (N = 10,466)

	1999-2000 Filing	2004-2005 Filing	P-Value of Difference*
Number of Regulated Chemicals at the Facility			
Mean	1.88	1.88	0.92
Median	1.00	1.00	
Hazardousness of the Facility**			
Mean	6.12	6.50	0.0006
Median	3.58	3.81	

* The P-value was calculated using paired t-test.

** Hazardousness is defined as in Elliott et al. (2003)

TABLE 5.5.
TYPES OF ACCIDENTS FOR COHORT OF JOINT FILERS

	1999-2000 Filing	2004-2005 Filing	Ratio of Wave 2 to Wave 1 Accidents
i. Number of accidents for our cohort that had any reportable consequences	1139	894	0.78
ii. Number of accident of type (i) that had any on-site impact(s)	953	741	0.78
iii. Number of accidents of type (i) that had any off-site impact(s)	325	305	0.94
iv. Number of accidents whose reported consequences included "worker or contractor injuries" (and possibly some other consequences)	761	540	0.71
v. Number of accidents whose reported consequences included "onsite property damage" (and possibly some other consequences)	311	279	0.90
vi. Number of accidents with a single reported consequence	849	629	0.74
vii. Number of accidents of type (vi) where the only consequence was "worker or contractor injury"	569	392	0.69
viii. Number of accidents of type (iv) whose reported consequences included “worker or contractor injuries” and at least one other consequence	192	148	0.77
ix. Number of accidents of type (vi) where the only consequence was "onsite property damage"	128	119	0.93
x. Number accidents of type (i) in which reported consequences included "worker or contractor injuries" & "onsite property damage" (& possibly other consequences)	132	88	0.67
xi. Number of accidents of type (i) in which reported consequences were the two consequences: "worker or contractor injuries" AND "onsite property damage" (and no others)	101	57	0.56

TABLE 5.6.
COHORT FACILITIES ADDING OR DROPPING FLAMMABLE AND TOXIC SCENARIOS

Scenario Type	Number of Facilities Reporting in 1999-2000*	Number of Facilities Reporting in 2004-2005*	Number Reporting in 1999-2000 but not in 2004-2005	Number Reporting in 2004-2005 but not in 1999-2000	Net Change between 1999-2000 and 2004-2005	P-Value†
Toxic Worst-Case	9,549	9,563	23	37	+ 14	0.07
Flammable Worst-Case	1,617	1,392	259	34	- 225	<0.001
Toxic Alternative Case	9,381	9,427	34	80	+ 46	<0.001
Flammable Alternative Case	1,383	1,172	263	52	- 211	<0.001

* Out of 10,446 facilities in the cohort that filed in both time periods
† McNemar's test

TABLE 5.7.
OFF-SITE CONSEQUENCE ANALYSIS REPORTS FOR COHORT

Scenario	Number of Scenarios Reporting in Both Time Periods	Mean (Median) [SD] 1999-2000 Filing	Mean (Median) [SD] 2004-2005 Filing	Difference (95% CI)	P-Value
Toxic Worst-Case					
Distance to Endpoint (miles)	9,526	3.05 (1.70) [4.28]	2.98 (1.63) [4.13]	-0.072 (-0.108, -0.036)	<.0001
Population	9,526	40,710 (1,400) [266,928]	42,894 (1,800) [275,736]	2,185 (-298, 4,667)	0.08
Flammable Worst-Case					
Distance to Endpoint (miles)	1,358	0.530 (0.40) [0.433]	0.533 (0.40) [0.427]	0.002 (-0.005, 0.009)	0.57
Population	1,357	986.1 (15.0) [5,328.3]	1,019.6 (10) [5,573.5]	33.5 (-61.4, 128.4)	0.49
Toxic Alternative Release					
Distance to Endpoint (miles)	9,347	0.48 (0.30) [0.70]	0.45 (0.26) [0.80]	-0.031 (-0.046, -0.015)	<.0001
Population	9,347	837 (47) [5,355]	1168 (30) [26,527]	331 (-62, 957)	0.3624*
Flammable Alternative Release					
Distance to Endpoint (miles)	1,120	0.139 (0.10) [0.115]	0.148 (0.10) [0.119]	0.009 (0.004, 0.014)	<.001
Population	1,120	51.3 (0) [397.0]	53.5 (0) [406. 2]	2.2 (-12.2, 16.5)	0.77

* This p-value is based on bootstrapping two-sample paired test and others are based on paired t-test.

TABLE 5.8.
U.S. PRODUCTION INDEX

PRODUCTION INDEX
1997 = 100

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	ANNUAL CHANGE 2005-06	1996-06
Total index	93.3	100	106.1	111.1	116.1	112.1	112.1	113.3	116.1	119.9	124.7	4.00%	2.90%
All manufacturing	92.2	100	106.9	112.9	118.5	113.7	114	115.4	118.9	123.7	129.9	5.0	3.5
Nondurable manufacturing	96.4	100	101.5	102.2	102.8	99.4	100.4	100.6	102.5	104.9	107.2	2.2	1.1
Chemicals	94.4	100	101.7	103.7	105.3	103.4	110.8	112.4	117.1	119.7	122.2	2.1	2.6
Basic chemicals	93	100	96.6	101.4	97.9	88.1	94.8	97.6	106.8	106.1	108.5	2.2	1.6
Basic inorganic chemicals	98	100	104.1	105.8	98.3	94.2	103.3	103.2	103	102	106.2	4.1	0.8
Alkalies & chlorine	109.3	100	98.8	129	119.2	100.3	159.7	150.3	173.9	181.4	181.0	-0.2	5.2
Synthetic dyes & pigments	95.5	100	98.7	95.3	98.2	91.1	103.8	103.1	98	102.4	116.6	13.8	2.0
Other basic inorganic chemicals	96.6	100	104.1	109.8	99.8	95.5	101.5	98.8	100.2	98.3	100.5	2.3	0.4
Organic chemicals	89.9	100	91.5	98.4	97.2	83.9	88.9	93.5	107.6	107.2	108.8	1.6	1.9
Synthetic materials (a)	94.1	100	104.3	105.2	103.3	93.2	95.9	94.3	98.9	102.6	103.1	0.5	0.9
Plastic materials & resins	90.8	100	108.2	112.3	111.4	101.1	106.5	102.6	110.3	115.2	117.3	1.8	2.6
Artificial & synthetic fibers	105.8	100	100.6	90.8	84.7	78.7	69.8	73.1	70.3	72.0	64.7	-10.2	-4.8
Chemical products	94.7	100	105	106.5	110.4	116.2	127	129	133	137.6	140.3	1.9	4
Pharmaceuticals & medicines	94.9	100	108.8	113.1	117.6	126.6	136.6	141.3	142.1	144.7	144.3	-0.3	4.3
Soap, cleaning compounds & toiletries	94.5	100	98.5	94.6	97.6	99.3	113	108.8	121.8	131.9	143.5	8.8	4.3
Paint & coatings	99.3	100	100.2	98.3	98.0	95.8	96.0	94.8	100.5	101.0	104.0	3.1	0.5
Pesticides, fertilizers & other agricultural chemicals	96.4	100	102.1	92	86.9	79.9	82.7	86.4	90.7	95.6	96.4	0.8	0.0

SOURCE: Federal Reserve Board
(a) Includes synthetic rubber.

CHAPTER 6: CONCLUDING COMMENTARY ON THE RMP RULE

Outline of the Chapter

1. Overview and Summary of Results Presented in this Report
2. Assessment of the RMP Rule as a Form of Risk Regulation
    a. Initial Assessment and Actual Performance Under the RMP Rule
    b. The RMP Rule as Informational Regulation
    c. The RMP Rule and Management System Regulation
3. Conclusions, Limitations and Open Questions for Future Research

1. Overview and Summary of Results Presented in this Report

This chapter reviews the results presented earlier in this Report based on the RMP data collected by EPA for the 10-year period from June 1995 through December, 2005. We then present an overall assessment of the RMP Rule in terms of its stated objectives. The final section of this chapter, and of this Report, notes some of the key limitations to our analysis of the data and our thoughts in regard to fruitful areas for future research. We begin with a summary of the main findings of the Report, chapter by chapter.

Chapter 1: Introduction and Background to Process Safety and the RMP Rule

Chapter 1 reviewed the background and objectives of the RMP Rule.[1] The Rule had three initial major objectives:

1) Prevent accidental chemical releases to the air;
2) Reduce the severity of chemical accidents that do occur;
3) Provide the public with information about the chemical hazards in their communities in order to promote a dialogue with industry to reduce facility risks.

This study has been focused on the first two objectives as the EPA reduced its emphasis on widely disseminating information about chemical hazards because of security concerns. Chapter 1 presented the rationale for the RMP Rule in terms of the Bhopal accident in 1984 and other major chemical accidents which drew considerable attention to the hazards of chemical facilities. Chapter 1 also provided an introduction to the structure of the RMP Rule, compared this structure with similar forms of risk regulation in Europe (Seveso Directive) and summarized the available data on the incidence of process accidents in Europe and Japan.

[1] CFR Part 68 Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act, Section 112(r)(7); § 68.10

<u>Chapter 2: RMP Accident History Database and Demographics of Reporting Facilities</u>

Chapter 2 described the accident history database of the RMP Rule and the nature of the facilities that reported under this Rule over the past 10 years. The chapter begins with an expanded introduction to the structure of the RMP Rule and the key elements of the Rule that are particularly pertinent to this study, and then reviews the data quality procedures undertaken to screen the data and to cope with the data quality problems that were encountered. The chapter then presents a description of the facilities reporting under the Rule. The Rule has undergone two major waves of filings since the implementing regulation for the Rule was first promulgated in June, 1996. The first wave occurred in 1999-2000 and the second in 2004-2005. Chapter 2 notes (e.g., Tables 2.1 to 2.3) that data generated by the Rule exhibit many similarities between these two waves in terms of the regulatory programs that applied to RMP covered firms, the regulated chemicals used by the covered firms and the type of business sectors covered.

A major finding of Chapter 2 is that there has been a significant decrease in the number of facilities filing in these two waves, with 15,145 filing in the 1999-2000 wave and 12,065 filing in the 2004-2005 wave. Chapter 2 examined the changes in the pattern of registrations between the two waves of filings and we concluded from this that the reduction in the number of filers is in line with what one would expect from the initial introduction of a major regulation, and is explained in good measure by de-registrations resulting from the natural motivation by facility owners across the industry to reduce regulatory burdens by holding inventories below threshold reporting requirements and shifting to alternative intrinsically safer raw materials that were not subject to the RMP Rule (e.g., alternative disinfection technologies in place of chlorine gas for water and wastewater treatment and alternatives to the use of anhydrous ammonia as a refrigerant).

This reported reduction in the inventories of hazardous chemicals and movement to less hazardous substitutes is arguably a step forward towards accomplishing the second of the RMP Rule's three major objectives noted above, namely reducing the consequences and severity of chemical accidents. However, notwithstanding EPA's enforcement efforts, there are still some gaps in observed registration and de-registration of facilities under the RMP Rule, so some facilities that should have reported under the Rule may not have done so. Moreover, research on data quality reported in Chapter 2 notes that facilities reported substantial variability in how they interpreted questions about a number of issues, including how to compute quantities of hazardous chemicals onsite. Therefore, we must be cautious in interpreting the decrease in the number of facilities filing under the RMP Rule as representing an actual reduction in the inventories of hazardous chemicals or in the inherent hazards of the chemical industry.

Chapter 3: Frequency and Severity of Accidents at RMP Facilities

Chapter 3 analyzes the frequency and severity of accidents separately for the two waves of filings that have now been received under the RMP Rule, the first for 1999-2000 and the second on the five-year anniversary of the first filing, namely in 2004-2005. These data provide an informative record of the accident histories of the U.S. chemical industry. The descriptive data reviewed here, and the studies undertaken thus far, suggest a complex set of interactions determining facility performance in terms of accident frequency and severity. First and foremost, these data provide benchmark statistics on deaths, injuries and direct property damage at U.S. chemical facilities resulting from process accidents and accidental releases over the 10-year period covered by the Rule. Second, these data enable a number of analytic studies to be undertaken to investigate facility, company, socio-demographic and regulatory factors that appear to be statistically associated with accident frequency or severity. The results of a number of such studies based on the 1999-2000 filing data are detailed in Chapter 3.

These studies and the underlying RMP data are consistent with the expected interactions between regulatory oversight and level of hazard at facilities and company characteristics and accident rates (as graphically depicted in Figure 3.2). For example, companies with larger sales revenue tend to have lower accident rates, other things being equal, and companies with larger debt burdens tend to have higher accident rates, perhaps reflecting the fact that higher debt burdens require relatively greater emphasis on current revenue flows as opposed to operational investments that may yield increased revenue or decreased process accident losses in the future. However, these studies run counter to other popular beliefs. For example, it is not the small facilities per se that are the primary sources of process accidents. Rather, it is the interaction of the underlying hazard at the facility with size and location that provides the explanatory power for accident and injury rates. In many ways, the results presented in this chapter will appear intuitive to the Environmental Health and Safety policy and management community, but it is important to note that this is the first time in the history of the U.S. chemical industry that we have had the data to provide benchmark results for regulators, the insurance industry and the chemical industry as they attempt to assess the magnitude of the risks arising from chemical facilities.

Chapter 4: Analysis of Off-site Consequences of Chemical Accidents

Analysis of worst-case consequences of potential chemical accidents is a necessary pre-condition for determining whether a major objective of the RMP Rule has been achieved, namely providing the public with information about the chemical hazards in their communities in order to promote a dialogue with industry to reduce facility risks. This chapter presented the results of study of the off-site consequence analysis (OCA) information reported by RMP facilities for both waves of RMP data. We discussed only the worst-case scenarios in Chapter 4, leaving the analysis of alternative release scenarios to Chapter 5, which focused only on the cohort of joint filers. These scenarios represent hypothetical estimates of the potential consequences of accidental chemical releases occurring under specified atmospheric and topographic conditions. Worst-case scenarios are valuable information for both host communities and policy makers, as they approximate the magnitude of the largest problem that might result from an accident at a chemical facility.

These worst-case scenarios underline the importance of a continuing emphasis on process safety. The population potentially affected by the worst-case scenarios varied greatly between facilities ("affected" here is defined in the EPA guidance discussed in Chapter 4). The average population affected across all toxic worst-case scenarios was 40,253 people in 1999-2000 filings, and 36,516 in 2004-2005 filings. However, for half of these scenarios, fewer than 1,500 people resided in the vulnerable zone in 1999-2000 and fewer than 1,665 in 2004-2005. On the other hand, 5.1% (708) of the 13,983 toxic worst-case scenarios in 1999-2000 and 4.5% (600) of the 13,191 toxic worst-case scenarios in 2004-2005 potentially affected more than 100,000 people, with the maximum population reported for any scenario in both waves being 12,000,000. For flammable worst-case scenarios, mean vulnerable zone populations were 668 and 753 in the two time periods, while for half of the reported scenarios fewer than 15 people were potentially affected in 1999-2000 and fewer than 4 in 2004-2005. On the other hand, 1.3% (40) of the 3,166 flammable worst-case scenarios in 1999-2000 and 1.5% (39) of the 2,631 flammable worst-case scenarios in 2004-2005 potentially affected more than 10,000 people, with the maximum vulnerable zone population for any flammable scenario being 115,000 in 1999-2000 and 164,621 in 2004-2005. The statistics in Tables 4.5 and 4.6 suggest that the characteristics of the OCA scenarios reported have not changed very substantially across the two waves of filings. However, the more detailed comparative analysis of the OCA analysis was left for Chapter 5.

<u>Chapter 5: Trend Analysis for Cohort of Dual Filers</u>

This chapter reported on trends in accident rates and consequences for an important subset of the facilities filing under the RMP Rule, namely those that filed during both the initial wave of filings in 1999-2000 and the five-year anniversary filings in 2004-2005. Recall from Chapter 2 (Table 2.1) that there were 15,145 facilities that filed in 1999-2000 and 12,065 that filed in 2004-2005. Of these facilities, we studied the cohort of 10,446 that filed in both waves of RMP reporting and that had not de-registered by December 31, 2005. A number of comparative findings are provided in Chapter 5.

RMP reported accident rates significantly declined between Waves 1 and 2 of RMP filings, both for all accidents and for accidents with reportable consequences. However, in contrast to this finding, we also found that there was no decrease in the total accidents with reportable off-site consequences, so that the major reason for the decline was a decrease in on-site consequence accidents. The principal cause for this drop in accidents with on-site consequences is a decrease in the sub-category "injuries to employees and contractors" which are in essence reportable under OSHA OII. Second, except for employee and contractor injuries and medical treatment, rates of accidents with particular types of impact were not statistically different across the two waves at the 0.05 significance level. Third, in contrast to accident rates, the severity of accidents, as evaluated by the 5-year actual consequences for RMP reported accidents for our cohort facilities, was not substantially or statistically different between the two waves of filings for any of the reportable categories of specific impacts. In this regard, the total number of reported accidents involving worker injury declined between the two waves, and the number of reported workers injured per facility decreased as well, but the change in the latter was not statistically significant. Fourth, there was a significant increase in the hazardousness of the cohort facilities between the two waves (the hazardousness measure used reflects essentially the inventories of regulated substances onsite relative to regulatory thresholds). However, notwithstanding this increase in hazardousness, there were only small changes in the worst-case "footprints" of cohort facilities, with the size of the geographic area affected by toxic worst-case scenarios decreasing slightly between Wave 1 and Wave 2.

There are several possible explanations for the above noted results on the decreases in accident rates between the two filing periods. First is the possibility that the RMP Rule may have had its intended effect in lowering accidents and consequences, at least for on-site employees and contractors. For example, the observed reduction in injuries to employees and contractors may have been the result of technical or management system improvements at facilities, such as more protective process control rooms, relocation of employees to such control rooms, and generally reducing the number of employees working in close proximity to process hazards, or improving maintenance or operating practices. An additional factor that could explain all or part of the decrease in reported accidents is the possibility that facility practices for reporting worker injuries changed, with different reporting criteria being used in the second wave than in the first wave. Questions have been raised regarding the reality of the changes (decreases) noted for OSHA OII rates in almost all industry areas, so there is at least some reason to question the decreases that appear to have occurred also with respect to RMP reporting.[2],[3] This matter was examined in Chapter 5 and we concluded that a change in facilities' *de facto* reporting criteria is a reasonable explanation for at least some of the reduction in reported RMP accidents and their consequences. Further studies on criteria used by facilities for reporting accidents, and on the relationship of OII reporting and RMP reporting of injuries would be useful in providing insights on this issue. We note some of these studies below under future research.

2. Assessment of the RMP Rule as a Form of Risk Regulation

The main objective in implementing the RMP Rule was to reduce the level of accidents and injuries from chemical facilities, and especially to surrounding community residents, and to inform affected communities of the nature of the hazards they faced in

[2] See Garrett Brown (2007). "Are declining workplace injury and illness rates too good to be true? *Occupational Hazards*, at http://www.occupationalhazards.com/Issue/Article/66378/Taking_a_closer_look.aspx.
[3] See Friedman and Forst (2007a, b). See also Wells et al. (1991, pp. 7-9) who note the following: "The degree to which EPA enforces the accident reporting regulation will also be very important as demonstrated by the apparent effect vigorous enforcement of the OII reporting requirement by OSHA had on that body of data. The OII rate for SIC 2869, Organic Chemicals, was 0.28 in 1983, and 0.27 in 1985. During 1985, OSHA started to more stringently enforce the employer OII record keeping requirements and subsequently levied the largest fines for this violation in the agency's history. In 1988, the OII rate rose to 0.40 and it was 0.39 in 1989. Similar jumps were noted for other Petrochemical SIC codes."

hosting chemical facilities. The logic of how this was to be accomplished was through both promoting improved management systems at the facility level as well as through the informational requirements of the Rule. The essentials of the regulation itself are worth recalling (see text box below).

Excerpt from Executive Summary of U.S. EPA (1996)

The chemical accident prevention regulations required under Section 112(r)(7) of the Clean Air Act must address, as appropriate, the use, operation, repair, and maintenance of equipment to monitor, detect, inspect, and control accidental releases, including training and maintenance of personnel. The regulations also include requirements for the development and implementation of risk management plans. Section 112(r)(7)(B)(ii) specifies that risk management plans must include, at a minimum:

- A hazard assessment to estimate the potential effects of an accidental release of a regulated substance. The owner or operator must consider how much of the substance could be released, and which populations a release would affect. The owner or operator also must prepare a five-year release history for the regulated substance.
- A program for preventing accidental releases of regulated substances, including safety precautions, maintenance, monitoring, and employee training.
- An emergency response program that lists the steps to be taken to respond to and mitigate a release. The plan must include procedures for notifying the public and local agencies when a release occurs.

In addition, risk management information, in the form of the risk management plan (RMP), must be registered with EPA and provided to the implementing agency and state and local officials responsible for emergency planning and response for the community.

The management system improvements associated with the RMP Rule derive from the requirements of paragraph *§ 68.15* of the RMP Rule.

Excerpt from the RMP Rule (§ 68.15) on Management Systems

(a) The owner or operator of a stationary source with processes subject to Program 2 or Program 3 shall develop a management system to oversee the implementation of the risk management program elements.

(b) The owner or operator shall assign a qualified person or position that has the overall responsibility for the development, implementation, and integration of the risk management program elements.

(c) When responsibility for implementing individual requirements of this part is assigned to persons other than the person identified under paragraph (b) of this section, the names or positions of these people shall be documented and the lines of authority defined through an organization chart or similar document.

In essence, unlike the OSHA PSM Rule, the RMP Rule explicitly required regulated facilities to set up a structured risk "Management System," with explicit responsibilities assigned to named persons. This management system was charged with the responsibility for implementing ***both*** the adopted OSHA PSM risk management program elements (e.g., Management of change, etc.) ***and*** the additional new elements of the RMP Rule, e.g. 5-year accident history, hazard assessment, emergency response, etc., which were explicit elements in the overall RMP risk management system.

Thus, the Rule arguably has important elements of "management system regulation" of the form argued by Coglianese and Nash (2001, 2006). Such management system regulation is based on the belief that requirements for specific management actions, such as those of the RMP Rule, will cause firms to improve their assessment and management of environmental and safety risks, including identifying and managing the factors underlying worst-case scenarios.

Concerning the information requirements of the RMP Rule, facilities are required to develop and file accident history and facility information which then becomes available to both regulators and the public. The logic of the RMP Rule, as a form of "informational regulation" is that requiring facilities to generate and publish information will promote facility managers' attention to the more severe problems that may exist in a facility.[4] It may also attract community and regulatory pressure to reduce the risks of chemical accidents in facilities hosted by the community. Of course, this will not happen merely through wishful thinking, but rather through changes in facility management systems that assure a stable framework for risk management planning and attention to mitigating risks and hazards that arise in implementing these plans. Thus, the two mechanisms for performance improvement, management-system based and informational, are linked.

The proof of the pudding, so to speak, is whether the stated objectives of the RMP Rule have actually been met. These objectives can be succinctly summarized as:

i) Prevent accidental chemical releases to the air;

ii) Reduce the severity of chemical accidents that do occur;

iii) Provide the public with information about the chemical hazards in their communities in order to promote a dialogue with industry to reduce facility risks.

We proceed as follows in our assessment. We first consider the target levels envisioned for objective (i) in the original benefit/cost analysis of the Rule contained in

[4] For an introduction to the concepts of "informational regulation," including those of the RMP Rule, see Kleindorfer and Orts (1998).

U.S. EPA (1996).[5] We then review the evidence from previous chapters on observable data related to objectives (i)-(ii) above. We then consider the broader objectives of RMP as a form of informational regulation [objective (iii)] and, finally, we consider the impact of the RMP Rule on covered facility's management system effectiveness.

Initial Assessment and Actual Performance under the RMP Rule

Table 6.1 shows the initial estimated benefits and costs reported in U.S. EPA (1996) as part of the necessary assessment provided to OMB. The methodology employed in the very detailed assessment leading to these numbers involved an estimation of the costs of fulfilling various obligations/tasks required to assure compliance with the Rule, both initially and in the periodic refiling required. These obligations were further evaluated as to whether they would already have been accomplished (e.g., because of prior OSHA requirements) and the magnitude of the task by industry sector. The key element to note is that this very detailed assessment was based first on predicting the number of covered facilities in each sector, then estimating the magnitude of the costs and benefits likely to arise from the implementation of the Rule for each facility in sector, and accumulating the results.

[5] No explicit targets were set for reducing the worst-case footprint of facilities, in part because the magnitude of this footprint only became known as a result of the RMP data.

TABLE 6.1.
TOTAL ANNUALIZED NET COSTS AND BENEFITS OF THE RMP RULE
AS ESTIMATED *EX ANTE* AND REPORTED IN U.S. EPA (1996; EXHIBIT ES-2)
(2007 DOLLARS DEFLATED BY 0.75706 TO OBTAIN 1996 DOLLARS USING GDP DEFLATOR)[6]

	Number of Sources By Program Level and Total	Estimated Annual Cost of RMP Program (in $ millions) a. 1996 Dollars b. 2007 Dollars	Estimated Annual Benefit of RMP Program (in $ millions) a. 1996 Dollars b. 2007 Dollars
1996 Estimates*	360 (Program 1) 40,200 (Program 2) 25,500 (Program 3) 66,060 (Total)	a. $ 97.0 b. $128.1	a. $174.0 b. $229.8
1999-2000 Wave of RMP Filings**	628 (Program 1) 7,409 (Program 2) 7,108 (Program 3) 15,145 (Total)	a. $22.2 b. $29.4	a. $39.9 b. $52.7
2004-2005 Wave of RMP Filings**	407 (Program 1) 5,603 (Program 2) 6,055 (Program 3) 12,065 (Total)	a. $17.7 b. $23.4	a. $31.8 b. $42.0

*** U.S. EPA (1996; Exhibit ES-2) **Wharton estimate (see text below)**

The research team did not have the resources to redo this detailed benefit/cost analysis based on the actual number of filers in each industrial segment for the two waves of filers in 1999-2000 and 2004-2005.[7] As can be seen in Table 6.1, there were significantly fewer facilities that actually filed than the number that formed the basis for the initial benefit/cost study (the reasons for this are discussed in detail in Chapter 2). One approach to adjusting the initial benefit/cost analysis to account for the reduction in the number of filers is to assume that there was a proportionate reduction in both the costs and benefits related to the number of actual filers relative to the number of filers that formed the basis

[6] See http://www.hm-treasury.gov.uk/media/2/F/gdpdeflators_290607.xls.
[7] As we note further below, redoing this benefit/cost study with the updated numbers of filers and the more accurate estimates of accident rates, and changes in these over time, would be an important future research topic.

for the initial EPA benefit/cost study. This is, in fact, the assumption underlying the results shown in Table 6.1.

Following this "proportionate reduction" assumption will, of course, yield only very rough estimates, both on the cost side as well as the benefit side. On the cost side, there were significant differences across the sectors in terms of the incremental burden of the RMP Rule. We know that the number of facilities that actually filed was substantially less than what had been projected in the 1996 estimates. Characteristics of the facilities that actually filed may have differed from those projected to file – in which case the associated costs of compliance may not have fallen proportionately to the decrease in the number of facilities filing. On the benefit side, the estimates reported in Table 6.1 are also based on the assumption that the reduction in benefits relative to the original assumptions underlying the U.S. EPA (2006) assessment would be proportional to the reduction in the number of filers. In actuality, both these costs and these benefits are likely to be underestimated by this "proportionality assumption" because more hazardous facilities are more likely to be overrepresented in the actual filers relative to the original estimates. Indeed, one notes in terms of pure percentages that level 3 programs made up roughly 50% of the reporting facilities in the two waves of RMP filings, while they represented less than 40% of the population of facilities originally estimated by EPA to be covered by the Rule. However, given that both costs and benefits are biased in the same direction, even fairly large deviations from the proportional cost assumption used in Table 6.1 would not change the net assessment of benefits and costs of the Rule. Thus, one can summarize EPA's *ex ante* assessment as saying that benefits of the Rule were generally thought to be nearly double the costs of the Rule, and these *ex ante* estimated benefits themselves did not even include a number of intangible benefits such as reducing worst-case hazards and improving the level of understanding of the public about the risks they faced from chemical facilities.

The original estimate of benefits by the EPA was understandably less informed by empirical estimates than the costs of compliance for which reasonable estimates could be obtained based on the costs of previously implemented regulations, cost surveys of facilities in various covered industry sectors, and labor cost data available from the Bureau of Labor Statistics. The actual benefits estimation process considered the frequency and severity of major accidents and their impacts, based on the some sketchy evidence available from OSHA and other sources at the time of the RMP benefit/cost study. To this baseline data, EPA first considered OSHA's estimate that PSM activities would reduce accidents by 80% within 5 years of the implementation of the PSM standard. EPA considered this estimate optimistic and reduced it to 50%. Then using the logic of decreasing marginal benefits of investments in risk reduction, and noting that the compliance costs for the RMP Rule were anticipated to be of the same relative magnitude as those for the OSHA PSM standard, EPA reasoned that the doubling of expenditures on process safety would lead to an additional 25% reduction over the assumed PSM effect of 50%.[8] In total, then, the anticipated reduction in accident frequencies and impacts based on the combined effects of the PSM standard and the RMP Rule was estimated to be 75% of the baseline accident/impact rates over the first 5 years of

[8] To quote U.S. EPA (1996, Section 6.5.2): "According to economic theory, a source would perform the more cost-effective activities before less cost-effective activities in order to maximize the returns on expended dollars. Consistent with this theory, EPA made the simple assumption that for sources already regulated under the OSHA PSM program, doubling their current level of spending on accident prevention activities would reduce remaining damages by 50 percent. Consequently, if twice as much money was spent on non-PSM and other activities than is currently spent to achieve a 50 percent reduction in damages, the program would reduce remaining damages by an additional 25 percent, for a total damage reduction of 75 percent."

implementation, one-third of which (25% of the baseline rates) was "credited" to the RMP Rule. Given the lack of data available at the time, this very rough estimate is understandable.[9] Revisiting our results from Chapter 5, we will see that the original estimate of 25% reduction in accident rates and on-site impacts was not far off from the actual rates in reported reductions achieved over the period 1994 to 2005 covered by RMP reporting. However, accidents with off-site consequences, and their off-site impacts, did not change in any significant manner. One might view the actual outcome as a failure against the predicted benchmark, or one might view this outcome as the result of an overly optimistic benchmark. Put simply, there was a statistically significant decrease in reported accidents, but not at the rate or to the degree predicted at the time the RMP Rule was implemented. Let us consider the evidence in more detail.

To estimate the benefits of the RMP Rule, we could use the total weighted sum of changes in impacts across the first wave and second wave of filings, with weights equal to the imputed or monetary value of each impact. To illustrate, let us assume the following. Suppose we take as the base period the results of the 1999-2000 wave and estimate the five-year benefits associated with changes in just three categories of on-site impacts, noted for the cohort of 10,446 facilities studied in Chapter 5, namely deaths, injuries and property damage. Suppose further that we use the estimates of the cost of a worker injury as

[9] To be noted, this estimate was also supported at the time by industry groups such as Organization Resource Counselors (ORC), so EPA was not alone in its predictions of the potential for significant decreases in process accidents. The reader should also note that the final PSM rule was published in 1992, and with the exception of the PHA element, was effective immediately. RMP was published in 1996 and effective in 1999. The accident history information goes back to mid-1994, but due to the fact that not all covered facilities present in 1994 were still present in 1999, the data do not necessarily encompass all facility accidents that would have otherwise met the criteria. This all complicates establishment of a baseline to compare against.

$19,000, the cost of a fatality at $5.4 million,[10] and total property damage in actual nominal dollars as reported. Then for our cohort of 10,446 facilities, we obtain the results shown in Table 6.2 from Table 5.3 for the five-year period between the two waves of filings. Table 6.2 provides only point estimates, and these clearly depend heavily on the assumed costs (or benefits) of (avoided) injuries and fatalities. The estimates used here for the cost of a worker injury and a fatality are the values in 1996 dollars that were used by the EPA (see U.S. EPA (1996, Chapter 6) in its original benefit/cost analysis. We used them here in order to assure comparability with Table 6.1. As an example of the entries in Table 6.2, the difference in total deaths between the two filings was +15 = 47 – 32. Assuming a value per death avoided of $5,400,000 (per the initial EPA study), this yields in thousands of 1996 dollars a net <u>decrease</u> in 5-year benefits from the Rule of $81,000.000 = 15*$5,400,000 (this is a <u>decrease</u> in net benefits since the change was an <u>increase</u> in deaths). This 5-year benefit figure can be annualized by dividing it by 5, and it can be converted to 2007 dollars by dividing by 0.75706, yielding a decrease in annual net benefits from deaths between Waves 1 and 2 of $21,399,000 of 2007 dollars, as shown.

[10] The estimates for injury costs and fatalities are those that were used in the original EPA benefit/cost study and the rationale for these is provided in that study—U.S. EPA (1996a)

TABLE 6.2.
ESTIMATING BENEFITS ON THE BASIS OF CHANGES IN REPORTED IMPACTS
FOR THE COHORT OF 10,446 JOINT FILERS ($ THOUSANDS)

	Deaths	On-Site Injuries	On-Site Property Damage
Number or Dollars Reported in 1999-2000 Wave	32	1667	$891,057
Number or Dollars Reported in 2004-2005 Wave	47	1447	$824,624
Change in Reported Number or Dollars [Delta]	+15	−220	−$66,433
Multiplier to Monetize the Change (M) ($ Thousands)	$5,400/death	$19/injury	1.00 $/$
$ Value of Benefit [−M*Delta] for Total 5-year Period (in '000 of 1996 $'s)	−$81,000	$4,180	$66,433
$ Value of Benefit Annualized ($ Thousands, 1996) = Total Benefit/5	−$16,200	$836	$13,287
$ Value of Benefit Annualized ($ Thousands, 2007)*	−$21,399	$1,104	$17,550

* From U.S. Treasury GDP Deflator, 1 2007 $ = .75706 1996 Dollars

While a number of refinements could be pursued with respect to the benefit/cost calculations illustrated in Table 6.2, we will not undertake these studies here. The reason is that these refinements would not materially affect the basic finding already clear in Tables 6.1 and 6.2. This finding is that, judged in explicitly monetized benefit/cost terms, the annualized benefits of the RMP Rule are close to zero when focusing only on deaths, injuries and property damage. For example, considering the results for 2007 dollars, we see that the annualized benefits from Table 6.2 are a negative $2.7 million (-$2,745,000 = -$21,399,000 + $1,104,000 + $17,550,000). Note that estimated annualized compliance costs for 2004-2005 from Table 6.1 are $23.4 million. Changing the cost of injury by significant amounts would not change this result. Adding off-site consequences to the analysis would not change the result, either, as there were no appreciable differences in off-site impacts between the waves of RMP filings (see Table 5.2 and 5.3 for details). As the reader will note, however, fatalities are the key factor in the benefit/cost calculus leading to the result captured in Table 6.2 that are benefits are near zero. Thus, a single accident, such as the BP Texas City accident in 2005, does account for a significant change in the benefit/cost difference. This point underlines the fact that evaluating the effects of the RMP Rule is a statistical evaluation process, and making inferences about the impact of a program based on one five-year trend estimate is inherently limited for this reason. Furthermore, the original estimate of benefits did not account explicitly for increases in production activity. Taking such increases into account, as is the case for example with auto accidents, where one uses the metric of deaths per miles driven, would result in an increase in the estimated prevention benefits of the RMP Rule because industrial production in the chemical industry increased significantly over the period (see Table 5.8).[11]

What we can conclude from this discussion is that the Rule has not met the expectations embodied in the original benefit/cost study (U.S. EPA, 1996b) concerning the magnitude of benefits and costs. Concerning expected reductions in accident rates, it is not clear whether to apply the 75% figure noted above for the anticipated effect of OSHA PSM plus the RMP Rule or the more modest 25% reduction in accident rates predicted as the

[11] However, because these increases were different for different sectors of the industry, incorporating these into the benefit calculations would require sector-specific or even facility-specific study to estimate the magnitude of this effect. Such an estimate was not within the scope of the present study.

incremental impact of the RMP Rule. Reproducing the figures from our earlier Table 5.1, we see in Table 6.3 that the actual reduction in reported accident rates was slightly in excess of 20% for the period (1994-2005) covered by the trend analysis reported in Chapter 5.

TABLE 6.3.
CHANGES IN RMP REPORTABLE ACCIDENT RATES FOR COHORT OF 10,466 JOINT FILERS OVER BOTH WAVES OF FILINGS

EPA RMP Reportable Accident Impact	1999-2000 Filing # of Accidents with Impact	2004-2005 Filing # of Accidents with Impact	Percent Change between 1999-2000 and 2004-2005 Filings
With Consequences	1,139	894	$21.5\% = \frac{1139-894}{1139}$
Without Consequences	338	266	$21.3\% = \frac{338-266}{338}$
With or without Consequences: (All Reported Accidents)	1,477	1,160	$21.5\% = \frac{1477-1160}{1477}$

Even if we neglect possible reporting threshold changes, as discussed in Chapter 5, a summary assessment from Table 6.3 would be that the rate of RMP reported accidents has declined, but not at the rate anticipated in the original U.S. EPA (1996b) benefit/cost study. However, due to a lack of data relating to the actual effect of process-safety regulations at the time of the Rule's formulation (i.e., OSHA PSM requires no data reporting) the original expectations were not well-grounded. Moreover, while these original estimates provide a benchmark for judging the effectiveness of the RMP Rule, the actual costs and benefits of the Rule are a more important measure of its impact. In terms of impacts of the Rule in practice, it is also important to keep two other potential impacts in mind: (1) the informational impacts of the Rule and (2) the Rule's impacts on improved management systems for managing environmental, health and safety impacts of operations. We now consider these two potential impacts in more detail.

The RMP Rule as Informational Regulation[12]

Informational regulation is easy enough to describe. Informational regulation (IR) is any regulation which provides to third parties information on company operations. IR can therefore complement either performance-based or specification-based regulation. For example, requiring the publication of certain information may provide a verified signal of regulatory compliance. Alternatively, IR can require that specified third parties or the public have access to certain information about a company's operations, without mandating a particular regulatory result or outcome.

Several examples may serve to illustrate the idea.[13] As a very common example, publicly traded companies are required to file audited accounting information according to Generally Accepted Accounting Practices. This information is a primary source of information for investors in their decision making on the value of stock and debt instruments issued by the company. A second example is that some county health authorities rate restaurants as to their cleanliness and their compliance with specific health standards. For example, Los Angeles county performs annual audits of licensed restaurants, and these restaurants are required to post their "grade" (on an A, B, C, D scale) associated with these audits in a visible place for the public to see.

[12] While mandatory disclosure has been a standard regulatory practice for some time, its use in environmental regulation is relatively recent. For a summary of the arguments supporting informational regulation in the environmental area, see Kleindorfer and Orts (1998).

[13] For a recent summary and evaluation of the effectiveness of various forms of informational regulation, see Weil et al. (2006). Weil and his coauthors conclude that for information disclosure policies to be effective, it is important that they be "embedded" in the decision making process of both disclosures and stakeholders affected by the information disclosed.

In the industrial environmental, health and safety area, some forms of information regulation are mandatory, such as the Toxic Release Inventory (TRI) data and the RMP Rules requirements to provide a five-year listing of the accident history at each facility. Some are voluntary, such as the ISO 14000 environmental management certification, which verifies that a facility has been audited within the past three years according to ISO 14001 standard and has passed that audit.[14]

In all of these cases, the key regulatory objective is "transparency." The general logic underpinning the benefits of such disclosure is to decrease the transactions costs for the involvement of regulators and affected stakeholders, such as local communities and public responders. A further indirect benefit is that if the information required is sufficiently standardized then benchmarking studies can be undertaken on an on-going basis to identify average outcomes, best practices and other comparative information. This latter is clearly a benefit of the RMP Rule, since without the accident history database and the ability to link this to other databases, such as in the studies reported in Chapter 3, reliable conclusions about the performance of the U.S. chemical industry in regard to process safety impacts would be much more difficult and costly to obtain. We also note that it is not just the research community that has profited from the RMP data. This data has also been of great interest in analyzing a number of policy questions at EPA and at the Department of Homeland Security.

[14] For a discussion of voluntary vs. mandatory disclosure in the context of environmental regulations such as the RMP Rule, see Chinander et al. (1998), who present a framework under which compliance itself may be audited by third parties, possibly on a voluntary basis. See also Kunreuther et al. (2002) for a discussion of the tradeoffs involved in such third party auditing arrangements. Kunreuther et al. (2002) report on a study that was undertaken as part of the Wharton Risk Center's research on the RMP Rule to assess the costs and benefits of third party audits of Compliance with the RMP Rule.

From an informational regulation perspective, one can note (in addition to the just noted research and policy benefits of more reliable and standardized information on accidental releases) the following two anticipated effects of the RMP Rule may be considered as being aspects of the Rule as informational regulation:

1) By requiring that risk management programs and key facility information be shared with public responders, the RMP Rule aimed to improve the level of communication and knowledge about chemical facilities with organizations responsible for responding to accidental releases at these facilities.
2) By making available off-site consequence information to the public, the RMP Rule aimed to inform the public about chemical hazards that could affect them.

The research team had only anecdotal evidence on which to judge whether either of these two effects were significantly impacted by the RMP Rule. In the data quality studies reported in Chapter 2, and in several Roundtables held at the Wharton School, it did appear that the first objective above was significantly and positively impacted by the RMP Rule. Facility emergency management teams at smaller facilities were formed, when they had only been ad hoc previously. Formal sharing of facility information with public responders was clearly in evidence at all the facilities we visited. In certain regions of the country (e.g., the Delaware Valley and Harris County in Houston) sharing of experience and expertise between large and small companies took place. Public and county fairs featured cooperative information sharing events between the public, emergency responders and facility owners, covering everything from the nature of the chemicals used at various facilities to emergency evacuation and crisis management plans. This activity generally can be interpreted as having achieved better communication between facilities and public responders, and more generally the local communities in which facilities were located. However, to our knowledge, no survey information was collected to reliably measure either the state of knowledge of various stakeholder groups or the change in that level of knowledge occasioned by the RMP Rule.

Turning to the off-site consequence (OCA) information, as reported earlier, access to this information was severely restricted after the events of September 11, 2001, in order to prevent access by terrorists to the RMP worst-case information. Nonetheless, the OCA information on specific facilities has remained accessible to the public in public reading rooms, though this is clearly a much less effective communication route for individual members of the public. One measure of the effectiveness of this information would be the potential pressure associated with this information to reduce the worst-case footprint of RMP facilities. This pressure could come from the public, but it also could come from other agencies such Department of Transportation and the Department of Homeland Security. In any case, the news is somewhat encouraging on this front. As we saw in Chapter 5, (Table 5.4), hazardousness of facilities has increased in the past five years, reflecting increased inventories on site. Notwithstanding this, the worst-case footprint, as measured by distance to endpoint (DTE) of facilities' OCA scenarios has not increased. In fact, for facilities with toxic chemicals on site, the DTE measure has actually exhibited a small but statistically significant decrease (although there was a marginally significant ($p=0.08$) increase in the population affected by that scenario, of 2,185 people). The fact that facility inventories of hazardous chemicals have increased, as has industry output, in the intervening years between the waves of RMP filings, without a corresponding increase in the average size of the worst-case footprint of facilities, suggests that facility managers have been responsive to the perceived pressures to control the magnitude of the worst-case hazard of their facilities. These results are consistent with what would be expected from the perspective of informational regulation.

Summarizing the basic point here, an informed public is a central tenet of American democracy. Motivated by the examples of Bhopal and Three Mile Island, the RMP Rule was clearly motivated to ensure that both the public and emergency response organizations were in working contact with chemical facilities in their jurisdiction and were knowledgeable about the nature of the hazards at these facilities. It is difficult to put a dollar value on the likely improvements achieved in this regard by the RMP Rule, but these are clearly important benefits of the Rule. Similarly, even though the public and research community have less access to the OCA data because of security threats, these data continue to serve as a foundation for studies and strategic initiatives at the EPA and the Department of Homeland Security. Moreover, the very requirement that this data be gathered by each facility will have continuing benefits in focusing the attention of facility managers on potentially catastrophic scenarios that could affect their facility and the communities in which they live. Here again, the counterfactual of what would have happened in the absence of such information or easier public access to this information is impossible to know. However, the logic of requiring the generation and assessment of this information seems as solid now as it did when the RMP Rule was first promulgated.

The RMP Rule and Management System Regulation

As discussed in Rosenthal et al. (2006), knowledgeable practitioners and regulators broadly share the belief that prevention of low-probability, high-consequence process accidents requires effective process safety management systems on top of appropriate technical practices, since deficiencies in management systems are the underlying (root) cause of most chemical process accidents. This "management system" paradigm was implicitly incorporated into the OSHA Process Safety Management standard (PSM) in 1992 and explicitly into both the European Union Seveso II Directive and the RMP Rule in 1996 (see the explicit requirements on Management Systems under the RMP Rule highlighted in the text box in Section 6.1).

As the following excerpt from the background discussion preceding EPA presentation of its RMP regulation shows, EPA intended to distinguish between its broader RMP management system requirements and OSHA risk management program requirements that were in essence focused on execution of the technical elements of its prevention program.

Excerpt from the Published RMP Rule on Prevention Programs[15]

EPA has retained the management system requirement proposed in the notice of proposed rulemaking, but only for Program 2 and 3 processes. EPA has moved the management system requirement from the prevention program section to the general requirements section because it should be designed to oversee the implementation of all elements of the risk management program." *(Emphasis added).*

At the time these regulatory initiatives were launched, there was optimism that these regulations would result in significant decreases in the incidence of process accidents. An example of such optimism is seen in the benefit/cost analysis noted in discussing

[15] Federal Register, June 20, 1996, Vol. 61, No 120, p. 3167.

Table 6.2 above that OSHA submitted to justify the significant costs of complying with its 1992 Process Safety Management Regulation (PSM). OSHA (1992, p. 6402) projected that:

> "In Years 6-10, a risk reduction of 80 percent is projected, with 264 fatalities and 1,534 injuries/illnesses (including 500 catastrophic lost-workday injuries) avoided, annually."

When EPA introduced the RMP Rule in 1996, it reduced this 80% estimate to a 50% estimate, and projected an additional 25% reduction in the accident rates experienced by OSHA processes that would now also be covered by the provisions of the EPA regulation. While the number of process accidents has declined since the promulgation of the Rule, the data we reviewed earlier in this Report and this chapter on the incidence of process accidents covered under the RMP Rule do not appear to support this early Agency optimism. Notably, more recent policy documents published by the Agency suggest that EPA's current expectations for the RMP rule are more in line with its observed effects as reported here.[16] In Europe, Pitblado (2004) concluded that the MARS data presented in a paper by Duffield (2003) showed no evidence of a significant reduction in the rate of major accidents reported under the Seveso Directives over the last 10 to 20 years, and preliminary data from the European Union for the period following the observations by Duffield and Pitblado (see Chapter 1) also shows no reduction. Furthermore, that the MARS data also showed no change in average severity of reported accidents based on the 7-point MARS severity scale.

One might conclude from these observations that either the "management system" paradigm is a weaker influence on facility accident propensity than previously believed, or

[16] The current EPA Strategic Plan (http://www.epa.gov/cfo/plan/plan.htm - page 84) sets out goals for reduction in the number of accidents, accident severity, and worst-case scenario vulnerable zone populations of 5% by 2011 (from a 2003 baseline).

that present process regulations did not achieve their goal of ensuring that facilities have effective process safety management systems in place. The authors of this Report and most practitioners (see Rosenthal et al. 2006) subscribe to the second explanation and hypothesize that many, if not most, firms that experience process accidents do not in fact have effective process safety management systems in operation.[17] That is the bad news. The better news is that, in our view, the observed decline in reported accident frequency of continuously-covered RMP facilities, while not meeting early Agency estimates, and keeping in mind the possibility that facility reporting criteria may affect these results, still offers significant support for the view that well-implemented management systems may indeed prevent accidents. Further, the accident epidemiologic approach that has been developed on the basis of the RMP data, and described in this Report, has the potential to test the validity of specific hypotheses regarding RMP accident causation and also to verify whether one or more of the specific survey instruments in use today, is able to predict whether a given management system is likely to be effective in reducing the incidence of RMP accidents.

Conventional statistical analyses of accident data, employee surveys and process audits, have been used to validate instruments for predicting and confirming the likely effectiveness of systems for managing the prevention of OII.[18] However, conventional statistical techniques are not able to robustly validate instruments with similar capabilities in

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[17] A recent review of a series of U.S. Chemical Safety Board accident investigations by Murphy (2007) also supports this conclusion.

[18] See Rosenthal et al. (2006) for details on these survey instruments. See also Elliott et al. (2008) for an initial study linking the RMP data to OII reports. This study suggests that good process safety management systems underlying everyday safety are a necessary condition for preventing major accidents, but not a sufficient condition. Studies of this sort illustrate the importance of having both aggregate accident data, as provided by the RMP Rule, and more detailed data on other elements of facility management (such as OII reports and culture surveys) to uncover the foundations of effective facility risk management systems.

regard to the LP process accidents that must be reported to EPA under their RMP regulation (Rosenthal et al. 2006). The evidence to date suggests that little systematic knowledge has yet become available and validated on the characteristics of process safety management systems likely to be important in reducing low-probability, high-consequence accidents. In fact, the problem is not likely to be with the nominal written contents of the management system but rather with the actual way it is implemented. There thus remains a significant potential for using the RMP data to ascertain the effectiveness of the content and implementation aspects of management system improvements, but this potential has not yet been realized.

3. Conclusions, Limitations and Open Questions for Future Research

By way of summary, we have noted along the way in this Report critical findings based on the data provided by the RMP Rule. The most important conclusion from our study is that this the RMP Rule provides, at a relatively modest cost, data that enhance our understanding of the actual outcomes of U.S. chemical facilities with respect to accidental releases. This understanding is a necessary basis for further improvement of process safety. In terms of the initial results of the first 10 years of data, we have noted the following basic conclusions: (1) the RMP data show a modest decline in reported accident frequency and worker injury rates over the two filings of data received thus far, in conjunction with no change in reported accident severity over a period when facility hazardousness and industry output were significantly increasing; (2) some or all of this decline may be due to changes in facility reporting criteria, and further studies on data quality going forward will therefore be important; (3) the initial regulatory benefit estimates on the RMP Rule appear to have been overly optimistic; and (4) there are additional, as yet unquantified, benefits associated with the Rule's information provisions and its potential impact on management systems.

The RMP data are of interest to regulators, policy makers (in the EPA and other state and Federal agencies), the affected public and facility managers. While this study reports some important initial findings based on these data, a number of limitations should be kept in mind in evaluating the results. We have already discussed limitations of these analyses due to limitations of the data. RMP*Info does not include information on when facilities began operation. Although it reports when facilities ceased operation, many facilities covered by the Rule are engaged in multiple covered processes and the database does not report start or end dates for individual processes. Therefore, comparing the number of accidents to a "denominator" of the number of facilities engaged in a specific process in a specific time period is not possible. We attempted to approximate this goal by tracking a "cohort" of facilities that filed reports in 1999-2000 and again in 2004-2005. Although this strategy identifies facilities that were in operation and covered by the Rule for at least the five years between filings, we cannot be sure that these facilities were in operation throughout the five years preceding the first filing, nor can we assign dates to initiation or termination of different manufacturing activities at facilities engaged in more than one covered process. These limitations impact our ability to convert counts of accidents to rates per facility at risk.

By tracking a cohort of facilities over time, we increase the probability that any observed changes in accident patterns are due to changes in the safety of the facilities rather than to a change in the manufacturing sectors, covered chemicals, or other characteristics of the facilities being studied. However, there may still have been changes in the characteristics of our cohort of facilities that we are unable to identify. Also, it is important to understand the difference between the policy implications of a reduction in accidents within the cohort (i.e., individual facilities becoming safer over time) versus a reduction in accidents among all reporting facilities (i.e., the covered industries' becoming safer as a whole – either due to individual facilities' becoming safer or to a reduction in the number of facilities). Both observations are important but the policy implications are different.

Throughout this report, we have emphasized the distinction between changes in the number of ***reported*** accidents and changes in the ***actual*** number of accidents. Given the perspective on the data in RMP*Info obtained from site visits to facilities, the analyses reported here do not allow us to distinguish with confidence between actual reductions in accidents and changes in facilities' perceptions of which accidents required reporting.

None of these limitations should be viewed as fundamental objections to the RMP process, nor as gainsaying its potential – both to provide valuable data for analyses such as those reported here and for additional analyses described below, as well as more directly to cause dramatic improvements in process safety and community preparedness. Rather, these limitations should be viewed as opportunities to further improve the RMP process, in particular the RMP*Info data collection process, in order to promote more effective implementation of process safety management systems over the coming years.

The incidence of reported RMP accidents after the RMP Rule was in force reflects the effectiveness of the RMP Rule as implemented, not as written, and good data on the degree or depth of implementation of the Rule's management system provisions by covered facilities, does not exist. Some insight into the issue might be obtainable by studying the results of audits or inspections by government officials responsible for overseeing implementation of the Rule's provisions, and comparing these to trends in accident incidence. Further, the fact that some States have elected to implement the RMP Rule (with some variants of the Rule's provisions) and have deployed varying degrees of inspection and enforcement of the Rule's provisions may offer additional insights (assuming the inspection data from these States are available).

In terms of open research questions, there are many that come immediately to mind. We mention only a few of these here.

<u>Completing the analytic epidemiologic studies</u> that were carried out for the 1999-2000 data for the entire data set of both waves of data. These studies could investigate the impact of the characteristics of parent companies on facilities they manage, the impact of socio-demographic factors on facility accident frequency and severity, as well as sectoral studies.

<u>Using the detailed facility data available in RMP*Info to elucidate the relationship between "macro" characteristics of facilities and accident rates</u>. To date, as reported in Chapter 3, we have studied the association between accident rates and characteristics such as facility size (reflected by full-time equivalent employees), economic characteristics of the parent companies, and population demographics of the communities in which the facilities are sited. The associations we have found are informative and have led to hypotheses and speculation as to why these associations exist. We have not yet examined other variables in the database, describing specific accident prevention and mitigation strategies implemented at the facilities. To the extent that these strategies (some of which are mandated by the Rule

or other regulations) are effective, they may be on the "causal chain" between the "macro" characteristics of facilities that we have studied and facility accident history.

Using accident epidemiology in connection with survey instruments to identify the characteristics of facility populations likely to experience defined low-probability incidents (e.g., reportable RMP accidents). Similarly, evaluating the degree to which specific postulated corrective measures remove or reduce the frequency or severity of the system disturbances (incidents) in question and their statistical association with constructs developed by the survey instruments. Responses to safety and culture survey instruments, audits, or other available data could be used to identify the presence of specific features of a firm's safety culture, and the relationship between a positive safety culture and safety management systems or any other aspect of its operation hypothesized to be positively or negatively related to the frequency of process accidents. Epidemiologic techniques would then be used to examine possible correlations between the RMP accident frequency of sub-populations with and without the specific factor being studied.[19] Similar survey instruments could be designed to collect information on site security and other risk characteristics of a facility, and their association with RMP accident frequency could be studied.

Data quality studies have been underlined at various junctures in this report. These include continuing research on how facility managers and their consultants understand the requirements of the Rule, the definition of reportable accidents, and other key elements that should inform the interpretation of RMP findings. They also include issues related to the

[19] As an example of this type of study, Elliott et al. (2008) conducted a study of this type, using OSHA OII data. This study tested correlations between a facility's effectiveness in reducing the incidence of relatively frequent occupational illnesses and injuries reportable to OSHA and its effectiveness in reducing the likelihood of an RMP reportable accident.

registration and de-registration process, and to the quality of this process (which determines in part whether all RMP-covered facilities actually fulfill their filing requirements).

Benefit/cost studies will remain important indicators of the efficacy of the RMP Rule as a risk regulation. At the least, it would be useful to revisit the methodology and assumptions of the initial benefit/cost study U.S. EPA (1996b) on the RMP Rule, using this as an *ex post* tool (inputting actual impacts of reported chemical accidents) to track costs and benefits of the Rule going forward. This would give rise not only to a deeper appreciation of the data collected under the Rule and to its policy relevance. It would also engender further debate on the regulatory compliance burden of the Rule and the benefits resulting from it. Beyond this "replication study," there are deeper issues of informational regulation and management system changes associated with the Rule. The impact and value of these for various stakeholders would be very interesting in their own right, beyond their possible implications for direct benefits and costs of the Rule.

Looking back on the first decade of the RMP Rule, the U.S. EPA and the U.S. chemical industry can point with pride to the relatively smooth implementation of this Rule with relatively low implementation resources and the value of the data and findings that have been generated as a result of it. As the RMP Rule goes into its second decade of applicability, a number of fascinating research and policy issues remain to be studied, none of which could be approached reliably without the data provided by the RMP Rule.

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