Mary Kay O'Connor Process Safety Center

Defining Indicators and Metrics for Measuring Improvements in Chemical Safety

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The Mary Kay O’Connor Process Safety Center was established in 1995 with a goal to improve chemical safety in the chemical process industries. The Center is associated with the Texas Engineering Experiment Station, of The Texas A&M University System, Chemical Engineering Division.

The Center provides a uniquely neutral forum to address chemical process safety for all stakeholders, industry, government, labor, and the general public.

This document represents the collective work of the Mary Kay O’Connor Process Safety Center researchers and staff in support of the National Chemical Safety goals. The ongoing research efforts of the Center will be presented in similar documents as work is completed. Each research document serves as an individual step in achieving the national safety goals. These documents will become input into an overarching document pertaining to chemical safety in the United States.

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1.0 Introduction

A great body of information exists about the chemical industry. As a nation, we know what chemicals are manufactured, where they are manufactured, and how they are manufactured. As an informed community, we know the health and environmental risks associated with many chemicals. Because of past incidents, we know that catastrophic events can happen when chemicals are not handled properly or contained. But can we, as a nation, say that our chemical safety practices are better now than they were 20 years ago, or even five years ago? Has the promulgation of the U.S. Occupational Safety and Health Administration (OSHA) process safety management (PSM) standard or the U.S. Environmental Protection Agency (EPA) risk management program (RMP) rule had a positive effect on chemical safety? Do industry programs like Responsible Care® and Environmental Stewardship improve safety at facilities? Do Community Awareness efforts help citizens be more aware of their surroundings?

As a regulator or an industry professional, the intuitive answer is "Yes, the chemical industry is safer than it was 20 years ago." Experience suggests that PSM and RMP have had a positive effect on safety management at fixed facilities. However, stakeholders do not have the experience or the data that show this unequivocally.

There are many federal agencies that gather information about the chemical industry. Under statutory mandate, agencies gather data on releases of chemicals, and on injuries, illnesses, and fatalities caused by chemicals. These federal databases, some of which have received information for over three decades, may provide the information needed to develop trends of chemical-related incidents.

The Mary Kay O'Connor Process Safety Center (Center) conducted a review of seven federal databases to determine the information that would be useful for analyzing chemical incidents and establishing indicators on the status of chemical safety in the United States. In a recent report, *Feasibility of Using Incident Databases to Measure and Improve Chemical Safety*, the Center determined:

- The strengths and weaknesses of databases for the purposes of creating chemical safety metrics;
- The type of vetting process that must be used to produce accurate data;
- Which information in those databases can establish a baseline measurement of chemical safety;
- What other types of data can be gathered about chemical safety from the databases (i.e., causes and consequences); and
- Ways to improve databases and the Center's ability to measure progress in chemical safety.

From its analysis, the Center concluded that the federal databases could provide the information needed to measure chemical safety at fixed facilities. The next step is to define clearly what should be measured and how it is to be measured. This measurable element will become the indication of whether or not safety is improving. The Center undertook this analysis of indicators as part of the National Chemical Safety Program (NCSP). NCSP drew on the expertise and advice from a Roundtable, which was composed of a diverse group of stakeholders involved in chemical safety. The Roundtable established the following national goals for chemical safety:

- **Chemical incidents are zero;**
- **Chemical enterprises have earned the public's trust; and**
- **Public, government, and facility interactions improve safety and reduce risk.**

To realize this goal, an accurate measurement of chemical safety in the United States first must provide a benchmark against which to measure progress. Once a clear understanding of the current state of chemical safety is established, the stakeholders can work to achieve the goal.

At the 1999 Roundtable meeting, the stakeholders provided the Center with a preliminary analysis of chemical safety indicators to measure the status of chemical safety and, specifically, the movement toward the goal of "chemical incidents are zero." The potential measures and indicators were identified as:

- Trends in the total number of incidents
- Trends in the number of facilities reporting incidents, including the percent of facilities reporting
- Trends in publicizing near-misses
- Trends in the use of safety culture building programs
- Trends in the level of effort to install prevention programs
- Trends in public awareness and trust

These comments served as the starting point in identifying which indicators may provide the most valuable data currently available to measure chemical safety. In this report the Center will:

- Discuss the method used to determine indicators;
- Present the hypothesis of what can be measured (e.g., if, as believed, PSM improved safety, the data should support that conclusion);
- Establish the indicators that will present the data needed to measure chemical safety at fixed facilities.

2.0 Definitions

As determined in the *Feasibility of Using Federal Incident Databases to Measure and Improve Chemical Safety*, the federal incident databases reflect different statutory definitions and terms (e.g., spill, release, accident, incident), different chemical lists, and different impact concerns (e.g., death)."

Therefore, the Center established its own definitions by deriving common elements across all the federal definitions to arrive at the most consistent and inclusive definition for key terms, such as incident and hazardous substance.

Chemical safety is defined as:

> **The management principles and systems applied to the identification, understanding, and control of hazards involved in the manufacture or use of chemicals to prevent injuries and incidents.**

A ***fixed facility*** is defined as:

> **Any building, structure, piece of equipment or installation involved in the manufacture or use of a hazardous substance that is located at one location or belongs to the same industrial group or under the control of one person from which an incident could occur.**

A ***chemical incident*** is defined as:

> **The sudden unintended release of or exposure to a hazardous substance that results in or might reasonably have resulted in, deaths, injuries, significant property or environmental damage, evacuation, or sheltering-in-place.**

A ***hazardous substance*** is defined as:

> **Any chemical, including a petroleum product, that is toxic, reactive, flammable, asphyxiating, or that presents a potential hazard to people, the environment, or property because of pressure or temperature.**

3.0 Using Indicators

A large amount of information exists about the chemical industry, including extensive information gathered by federal, state, and local agencies. The information gathered includes data on the specifics and numbers of chemical releases, or injuries, illnesses, and deaths caused by chemicals. But are any of these accurate indicators of the state or effectiveness of chemical safety efforts? Do they tell us whether chemical safety is improving? How do we decide if one process or chemical is safer than another?

An indicator is generally defined as an observed variable. Essentially, an indicator is presumed to reflect through a positive correlation a single underlying variable. The underlying variable considered here is the safety of chemical processes. It is impossible to observe or measure chemical safety as a positive measure. It can only be measured as a negative measure, or an observable variable that is defined when safety processes fail. The number of process failures is an indicator of chemical safety, when taken in the context of potential failures.

The indicator becomes more valuable when observed over a period of time or as a trend. Trend analysis analyzes an indicator or series of indicators over time to determine if there is a general sustained movement of the series upward, downward, or if there is no discernible pattern. Trend lines are used to display trends in data and to analyze problems of prediction. From regression analysis, one can extend a trend line in a chart beyond the data to predict future values. The specific techniques that are most commonly applied are linear model, exponential model, or a moving-averages model.

Trend analysis is commonly misapplied. For example, two or three data points do not indicate a trend, though with a simple glance it might appear so. In any trend and regression analysis, there always exists the assumption that a component of the underlying variable is generated through a random or stochastic process interacting with the data. Over a short period of time, the apparent impact of this random process can be much larger then over a longer time period, where it becomes the "white noise" part of the error term in a regression analysis.

It is often better to use a variety of time periods to perform a trend analysis. For example, weekly measures viewed over a period of a year may indicate an upward movement of injuries related to chemical releases.

When viewed over a five year period, the trend may be generally down, except for the current period, which could have been caused by an external variable such as a change in the definition of an injury, or a change in measurement techniques or methodologies.

From a larger perspective to compare a particular set of indicators, the indicators must be normalized so that the comparison is made of essentially equal sets. Normalization is a general process by which two or more indicators are divided by an equivalent denominator. For the above example, an equivalent denominator might be the amount of chemicals produced. It is not advisable to make a comparison across indicators that have not been normalized, as there is no common basis for comparison.

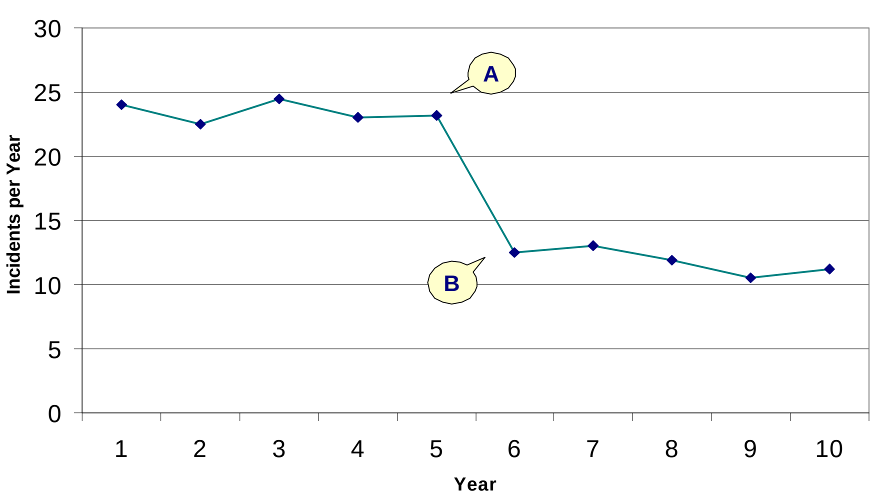
4.0 Policies Affecting Chemical Safety

It is as important to select the indicators properly, as it is to predict what type of information one might obtain. The affects of changes in government regulations covering the chemical industry should be identifiable from the data.

In December 1984, the release of 40 metric tons of methyl isocyanate from a pesticide manufacturing plant in Bhopal, India, caused the deaths of over 2,000 people and injuries to another 100,000. During the 17 years that have passed since this tragic accident, many organizations throughout the United States, and the world, have taken major steps to improve industrial chemical safety. These steps have included actions involving prevention, training, preparedness, and response. It is clear that there are a great many stakeholders concerned with chemical safety.

If a specific policy change or new regulation has an affect on chemical safety, then it is reasonable to conclude that graphic representations of the data recorded in the federal databases should be reflected in the metric of interest. For example, Figure 1 might illustrate the results of a governmental policy change. The performance in years one through five is relatively constant. During the fifth year (point A on the chart), a policy change is made and the resulting performance is shown by the value in year six (point B on the chart). It could be inferred that the change resulted in a 40 percent decrease in the number of incidents.

Figure 1: Measuring the Impact of Policy Change



Perhaps Figure 1 is a measure of the number of incidents at PSM-covered facilities. If the shift (A to B) occurred in 1996 when PSM programs were fully implemented, the shift in the curve would indicate that the PSM standard has had a positive affect on chemical safety by reducing incidents in PSM covered facilities. The amount of shift from the slope of the original curve describes the effectiveness of the PSM implementation. If the change is negative, then the result of the policy change can be viewed as detrimental.

This type of clear indication is one of the objectives for the NCSP project to measure chemical safety. This section reviews programs that the Center believes should have a positive effect on chemical safety. It provides a description of the type of data that the Center plans to provide.

4.1 Governmental Programs

The history of safety regulations in the United States can be traced back to 1899, when the United States government issued the River and Harbor Act, which prohibited the creation of obstructions to the navigable waterways and was intended to protect the nation's waterways from excessive dumping. Since its promulgation, federal, state, and local governmental organizations have promulgated numerous regulations related to chemical safety and protection of the public and the environment from chemical releases.

However, major steps to regulate the industry did not occur until 1970, when the U.S. Occupational Safety and Health Administration (OSHA) and the U.S. Environmental Protection Agency (EPA) were formed. Each of these agencies have performed a significant role in chemical safety. Several regulations were passed during the 1970s to protect human health and the environment, including the Clean Water Act and the Toxic Substances Control Act.

During the early 1980s, the United States developed an emergency management system focusing on chemical releases, which resulted in the establishment of the National Response Center and the promulgation of the EPA Comprehensive Environmental Response Compensation and Liability Act (CERCLA). In the late 1980s, the focus shifted to preparing for releases and saw the promulgation of community-focused regulations like the EPA Emergency Planning and Community Right-to-Know Act.

However, in the 1990s, after witnessing the catastrophic results of Bhopal, the direction of federal regulations was shifted towards managing hazards. Specifically, the Clean Air Act Amendments of 1990 gave additional authority to both OSHA and EPA in the area of chemical process safety. This resulted in the promulgation of the OSHA *Process Safety Management of Highly Hazardous Chemicals* (PSM Standard, 29 CFR 1910.119) and the EPA *Accidental Release Prevention Requirements: Risk Management Program* (RMP Rule, 40 CFR 68). The Amendments also established the U.S. Chemical Safety and Hazard Investigation Board (CSB), with the primary responsibility for investigating major chemical accidents at fixed facilities.

4.1.1 OSHA PSM Standard

The Process Safety Management (PSM) standard, promulgated in 1992, is intended to prevent or minimize the consequences of a catastrophic release of toxic, reactive, flammable, or explosive highly hazardous chemicals from a process. A process is any activity or combination of activities including any use, storage, manufacturing, handling, or the onsite movement of highly hazardous chemicals. A process includes any group of vessels, which are interconnected and separate vessels that are located such that a highly hazardous chemical could potentially be released.

The standard applies to processes that contain a threshold quantity, or greater amount, of a regulated toxic or reactive highly hazardous chemical. It applies to 10,000 pounds or greater amounts of flammable liquids and gases as well as to the process activity of manufacturing explosives and pyrotechnics.

The standard does not apply to retail facilities, normally unoccupied remote facilities, and oil or gas well drilling or servicing activities. Hydrocarbon fuels used solely for workplace consumption as a fuel are not covered, if such fuels are not part of a process containing another highly hazardous chemical covered by the standard. Atmospheric tank storage and associated transfer of flammable liquids that are kept below their normal boiling point without benefit of chilling or refrigeration are not covered by the PSM standard.

4.1.2 EPA RMP Rule

In 1996, EPA promulgated the RMP Rule, which was mandated by Section 112(r) of the Clean Air Act Amendments of 1990. The regulation requires regulated facilities to develop and implement appropriate risk management programs to minimize the frequency and severity of chemical plant incidents. In keeping with regulatory trends, EPA required a performance-based approach towards compliance with the risk management program regulation.

The EPA regulation also requires regulated facilities to develop a Risk Management Plan (RMP). The RMP includes a description of the hazard assessment, prevention program, and the emergency response program. Facilities submit the RMP to the EPA, which subsequently is made available to governmental agencies, the state emergency response commission, the local emergency planning committees, and the public.

The risk management program regulation defines the worst-case release as the release of the largest quantity of a regulated substance from a vessel or process line failure, including administrative controls and passive mitigation that limit the total quantity involved or release rate. For gases, the worst-case release scenario assumes the quantity is released within 10 minutes. For liquids, the scenario assumes an instantaneous spill and that the release rate to the air is the volatilization rate from a pool 1 cm deep unless passive mitigation systems contain the substance in a smaller area. For flammables, the scenario assumes an instantaneous release and a vapor cloud explosion using a 10 percent yield factor. For alternative scenarios (note: EPA used the term *alternative scenario* as compared to the term *more-likely scenario* used earlier in the proposed regulation), facilities may take credit for both passive and active mitigation systems.

The final regulation lists endpoints for toxic substances to be used in worst-case and alternative scenario assessments. The toxic endpoints are based on ERPG-2 (Emergency Response Planning Guidelines – Level 2) or level of concern data compiled by EPA. The flammable endpoints represent vapor cloud explosion distances based on overpressure of 1 psi or radiant heat distances based on exposure to 5 KW/m^2 for 40 seconds.

4.1.3 Other Federal Agencies

While OSHA and EPA, through their respective regulations, have the most direct effect on the chemical industry, many other Federal agencies have oversight of the chemical industry and have promulgated their own rules to regulate the industry, including:

- Consumer Product Safety Commission
- U.S. Department of Transportation
- U.S. Coast Guard
- U.S. Department of Interior Minerals Management Service
- U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry

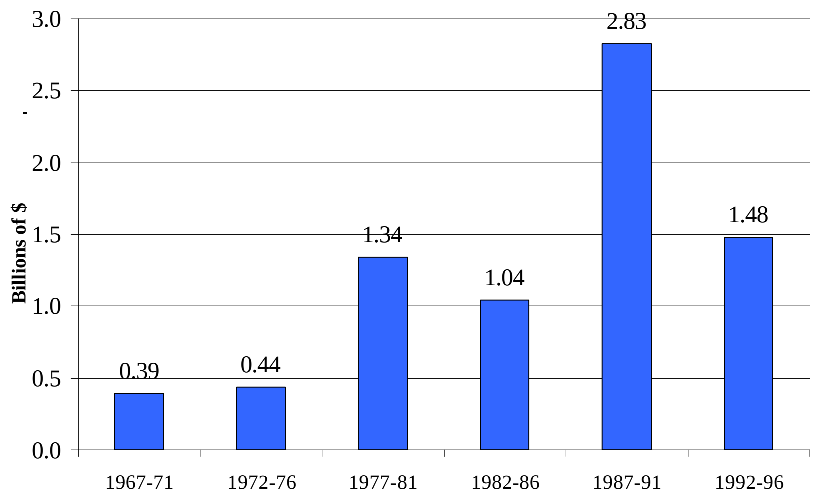
Further analysis of the data and interpretation of the results should represent the regulations and agencies that are making an impact.

4.1.4 Center's Analysis of Governmental Programs

The OSHA PSM standard requires covered facilities to implement a very detailed and thorough performance-based management program that, when adhered to, will improve safety. The Center believes the implementation of several key elements, e.g. Management of Change, Process Hazard Analysis, and Mechanical Integrity, have had an impact on safety in the covered processes. It is important to realize that no one element alone begets a significant change; a combination of the elements shows measurable results in chemical safety. Many companies view their compliance efforts not only as responsible corporate leadership, but also as a competitive edge.

The eighteenth edition, published in 1998, of the J&H Marsh & McLennan report of the "Large Property Damage Losses in the Hydrocarbon-Chemical Industries, A Thirty-year Review" illustrates that policy changes have had an impact on chemical safety. Changes in technology, plant size and layout, and management attitudes and programs are the primary drivers for the sharp drop in the number of losses and dollar amounts of each loss from 1992 through 1996. The implementation of Process Safety Management programs has likely contributed to the decrease in both the number and dollar amount of these losses. Using their data, Figure 2 represents the losses over several 5-year intervals.

Figure 2: Loss Distribution at 5-year Intervals



The EPA RMP rule requires covered-facilities to implement a program similar to the OSHA PSM standard. The main difference between the two standards is OSHA's concentration on worker protection and EPA's focus on the public and the environment. RMP implementation has had a positive impact on chemical safety. Many facilities have either reduced or eliminated onsite inventory of regulated substances. The requirement to develop "worst-case" scenarios has opened the dialogue to the potential impact of a chemical release into the community.

The Center contends that the information in the EPA RMP 5-Year Accident History and Accidental Release Information Program databases can be used to show improvements in chemical safety. These databases represent a large and potentially useful sources of information; however, because PSM and RMP went into effect while the data were being collected, the Center may not be able to demonstrate the full, independent impact of each of these regulations. Analysis of the usefulness of the databases can be found in *Feasibility of Using Federal Incident Databases to Measure and Improve Chemical Safety.*

4.2 Industry Programs

Government programs are not necessarily the only effort impacting chemical safety. Industry has taken a proactive role in safety since the 1984 incident in Bhopal, India. Several industry-led programs have been designed and launched to improve chemical safety. This section discusses only two of these programs.

4.2.1 Responsible Care®

In 1988, the American Chemistry Council (formerly known as the Chemical Manufacturers Association) launched Responsible Care® to respond to public concerns about the manufacture and use of chemicals.

Through Responsible Care®, member companies are committed to support a continuing program to improve the industry's responsible management of chemicals. Specifically, member companies are required to:

- Continually improve their health, safety, and environmental performance;
- Listen and respond to public concerns;
- Assist each other to achieve optimum performance; and
- Report their goals and progress to the public.

Responsible Care® is comprised of a set of guiding principles and six codes of management practice:

Guiding Principles — Outlines the principles expected of participating members. While creating its products, participants should make continuous progress toward the vision of no accidents, injuries, or harm to the environment.

Codes of Management Practices — At the heart of the Responsible Care® initiative are the six Codes of Management Practices:

- *The Community Awareness and Emergency Response (CAER) Code* promotes emergency response planning and calls for ongoing dialogue with local communities;
- *The Pollution Prevention Code* commits industry to the safe management and reduction of wastes;
- *The Process Safety Code* is designed to prevent fires, explosions, and accidental chemical releases;
- *The Distribution Code* focuses on reducing employee and public risks from the shipment of chemicals and applies to the transportation, storage, handling, transfer, and repackaging of chemicals;
- *The Employee Health and Safety Code* protects employees and visitors at company sites and operates plants and facilities in a manner that protects the environment and the health and safety of employees and the public; and
- *The Product Stewardship Code* makes health, safety, and environmental protection an integral part of designing, manufacturing, marketing, distributing, using, recycling, and disposing of products.

4.2.2 Environmental Stewardship

The American Petroleum Institute (API) Environmental Stewardship evolved out of what had previously been called the Strategies for Today's Environmental Partnership or STEP Program, which was sunset in June of 1999. The Environmental Stewardship Program facilitates information sharing and fosters continuous improvement. Environmental Stewardship activities can be grouped into these areas:

Guiding Principles— Outlines the pledge that members must be dedicated to improve the compatibility of operations with the environment while economically developing energy resources and supplying high quality products and services to consumers.

Sharing Information & Technology Transfer—One of API's many functions is to provide opportunities for company representatives and others to meet and share information on activities to improve industry operations and its environmental performance.

Operating Practices—To ensure safe operations for employees and for nearby communities and to make operations as efficient as possible, API develops and issues over 400 technical and operational standards, of which over 125 have direct environmental, health, and safety benefits. These standards guide the design, construction, and operation of oil and gas equipment, which covers operations ranging from exploration and production platforms, through pipelines and refinery processing units, to installation and operation of underground storage tanks at local fuel retailers.

Performance Measures—The results of the oil and natural gas industry's efforts to improve the safety of its operations and to reduce its impact on the environment have been dramatic over the past several decades. The result has been improvements in air and water quality, reduced impacts on habitats, species, and communities in areas where the industry operates, improvements in product quality, reductions in waste generation, and exceptional worker safety.

Communications—A key aspect of corporate transparency is the willingness and ability to share information about the impacts of oil and gas industry operations on the environment as well as about the steps being taken to minimize or eliminate these impacts.

Public Involvement and Community Outreach—The industry recognizes its responsibility to reach out to the communities in which it operates to share information about their operations and to address concerns raised by these communities.

Programs and Partnerships—API and its member companies participate in a broad range of environmental, health, and safety programs and partnerships.

Management Support—The oil and natural gas industry is committed to responsible use of the world's natural resources while continually striving to improve the safety of its operations and to protect the environment and the communities in which we operate. To ensure that these goals are achieved, the management of API member companies supports a range of environmental stewardship activities and spends on the average between $8 and $9 billion dollars each year to protect the environment.

4.2.3 Center's Analysis of Industry Programs

The Center believes that industry programs like API's Environmental Stewardship and ACC's Responsible Care® lead to an improvement of safety in the chemical process industries. Industry programs establish a code of acceptable practice for a particular industry with adherence being a condition of membership in many cases. The benefits of participation can be found in the reduction of employee injuries, chemical releases, and public exposure. These programs must challenge member companies to make continuous improvements in their health, safety, and environmental practices; listening to and responding to the concerns of the public; and to report openly their progress.

4.3 Public Interactions

A third area affecting chemical safety is the interaction of the general public with neighboring facilities and governmental agencies. Public interactions have had an impact of their own. Many local emergency planning committees expect industry and government to work together to improve chemical safety.

4.3.1 Local Emergency Planning Committees

The Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 required each state Governor to establish a State Emergency Response Commission (SERC). Under EPCRA, the SERC is charged with developing integrated plans for responding to chemical emergencies and making chemical information available to the public. SERCs, in turn, appoint the local emergency planning committees (LEPCs). LEPCs are to have broad-based membership whose primary work is to receive information from local facilities about chemicals in the community, use that information to develop a comprehensive emergency plan for the community, and respond to public inquiries about local chemical hazards and releases.

The LEPCs initial task is to develop an emergency plan to prepare for and respond to chemical emergencies. The plan was to be completed by Oct. 17, 1988. The plan is reviewed annually, tested, and updated. The emergency plan must include the identity and location of hazardous materials, procedures for immediate response to a chemical incident, ways to notify the public about actions they must take, names of coordinators at plants, and schedules and plans for testing the plan. Once the plan is written, the SERC must review it. The LEPC must publicize the plan through public meetings or newspaper announcements, obtain public comments, and periodically test the plan by conducting emergency drills.

The LEPC has other responsibilities besides an emergency response plan. It receives emergency releases and hazardous chemical inventory information submitted by local facilities, and it must make this information available to the public upon request. LEPCs have the authority to request additional information from facilities for their own planning purposes or on behalf of others. LEPCs may visit facilities in the community to find out what they are doing to reduce hazards, prepare for accidents, and reduce hazardous inventories and releases. LEPCs can take civil actions against facilities if they fail to provide the information required under EPCRA.

In addition to its formal responsibilities, the LEPC serves as a focal point in the community for information and discussions about hazardous substances, emergency planning, and health and environmental risks. An LEPC can most effectively carry out its responsibilities as a community forum by taking steps to educate the public about chemical risks and working with facilities to minimize those risks. There are now more than 3,500 LEPCs, and they reflect the diversity of our country. Most LEPCs are organized to serve a county; some are for a single large city; others cover most of a state.

The LEPCs have improved chemical safety because of their direct interaction between facilities and the local community. As noted in a 1999 George Washington University Study for the U.S. Environmental Protection Agency, over 75 percent of the active LEPCs reported have completed and submitted emergency response plans. Among the active LEPCs, one out of every seven informational requests were for RMP information, three out of seven were for EPCRA information, and three out of seven were for other types of information. LEPCs suggested that over 95 percent of the requests were responded to sufficiently. These information requests help communities and individuals educate themselves about the local industries.

According to the 1999 George Washington University Study, nearly half of the “active” LEPCs reported that they had made hazard reduction, accident prevention, or pollution prevention recommendations to industry or local governments. Over half indicated they have provided assistance to local businesses, citing information, planning, and training as the types of assistance most typically provided. Few LEPCs reported “high” involvement with large businesses and very few reported a “high” level of involvement with small businesses.

While the number of active LEPCs fell between 1994 and 1999, their mission remains constant. SERCs and LEPCs continue to need the support of the EPA, industry, and their local community to improve chemical safety.

4.3.2 Community Advisory Panels

Community Advisory Panels (CAPs) are important entities for improving the dialogue between facilities and neighbors. They serve as an important link between the chemical facilities and their local communities while building mutual respect and trust.

A CAP consists of a group of individuals living near or around a facility. Members may include environmental groups, civic leaders, business leaders, homemakers, hourly workers, and individuals who represent key elements of a community such as health care providers and emergency responders. CAP members make a commitment to meet with facility management on a regular basis to discuss issues of mutual interest in a forum for open and honest dialogue.

4.3.3 Center's Analysis of Public Interactions

The Center conducted a survey from mid-January through mid-February of 2001 on *Public Trust and Community Interaction in Areas Surrounding RMP Facilities*. The survey measured attitudes, knowledge, and experience of persons living near sites where chemical releases are possible. Based on the results of that survey, nearly half of the respondents were unaware of any companies in their community that manufacture, use, or distribute chemicals that may be hazardous. When this same group was asked about LEPCs, over 50 percent were unaware of the existence of an LEPC in their community. While only five percent of the respondents have participated in LEPC activities, over 60 percent felt that the existence of LEPCs makes the community safer.

These percentages reveal several areas for improvement in community programs. LEPCs and SERCs serve an important role in planning, training, and communicating information in their local communities. The Center believes that their level of activity and therefore their effectiveness is directly related to the support they receive from governmental agencies, industry, and the community. Public incentives have a significant role for improving chemical safety in the United States. Continued support should be a high priority among all stakeholders to ensure the continued existence of many community programs.

5.0 Proposed Indicators to Measure Chemical Safety

Considering the work done by government, industry, and the public to effect changes in chemical safety, it is anticipated that there will be measurable trends in the data. It is crucial to identify proper indicators that can accurately measure trends in chemical safety in the United States.

As described in the *Feasibility of Using Federal Incident Databases to Measure and Improve Chemical Safety*, there is much information about the chemical industry. The critical component for the mission of the National Chemical Safety Program is identification of data that are useful for determining the status of chemical safety. Since current data were collected for different purposes, the Center must clearly define what information is of value as indicators and how those indicators can produce the most accurate assessment of chemical safety in the United States.

This section discusses the indicators proposed by the Center to establish a baseline from which to measure performance in chemical safety. Initially, the Center proposes to use the following data elements because these are readily available throughout the federal databases and are clear indicators for the purposes of the NCSP.

> **Fatalities -** represent a clear and uncontestable indication that a chemical incident has occurred. By measuring fatalities resulting from a chemical incident, a better understanding of the most significant incidents is available. Additionally, mortality information has been collected for decades by governmental agencies.

Injuries – represents a clear indication of the significance of a chemical incident. By working to separate the onsite and off-site injuries, the Center can more fully describe the severity of the incident in terms of impact to company personnel and the general public. Measurement of injuries has been commonplace in general industry for many years.

Releases – represents a clear indication that a chemical incident has occurred. Counting the number of releases in combination with the types and amounts of chemicals released presents a clear indication of the magnitude of exposure.

Chemicals – represents the materials involved in the chemical incident. By combining the type and amount of chemical released with the number of releases, the magnitude of the exposure can be clearly described.

The databases reviewed contain information on many types of chemical incidents. The EPA ARIP and RMP databases concentrate on fixed facilities providing information on listed chemicals stored above a threshold quantity and releases resulting in significant consequences. The NRC IRIS database concentrates on chemicals, releases, injuries, and fatalities. It provides a listing of reported incidents from fixed facilities, marine and offshore facilities, pipelines, and transportation vehicles. Occupational fatalities and injuries from all industry are recorded in the OSHA/BLS system. Chemical related incidents could be sorted to provide not only a business segment but also a total manufacturing viewpoint. The ATSDR and CDC databases concentrate on human aspects of incidents. The CDC WONDER records all fatalities in the United States, while the ATSDR HSEES records incidents involving hazardous substances that might result in an adverse health effect.

Table 1 summarizes the indicators and the federal databases from which they can be obtained. By combining the information within the various data sources, a relatively complete picture of each incident can be created. Then by sorting the information based on the indicators, a baseline of performance can be established.

The Center proposes that the baseline initially be established for fixed facilities using the EPA RMP 5-year Accident History database as the central data source. Various modes of transportation will be the second business segment reviewed. Other business segments and the capability to sort by geographic area will be added as the data become available.

Table 1: Federal Databases and Potential Indicators

Agency - Databases	Chemicals Involved	Number of Incidents	Fatalities	Injuries
NRC – IRIS	Ö	Ö	Ö	Ö
EPA - ARIP	Ö	Ö	Ö	Ö
EPA - RMP	Ö	Ö	Ö	Ö
OSHA	Ö		Ö	Ö
ATSDR - HSEES	Ö	Ö	Ö	Ö
CDC - WONDER	Ö		Ö	Ö

For the measurement of chemical safety to be reproducible, two things must occur. First, the data gathered by the federal agencies must continue and the quality of the data reported must be improved. For more information, refer to the report entitled: *Feasibility of Using Federal Incident Databases to Measure and Improve Chemical Safety*. Second, a series of questions should be created such that the answers can be compared to determine trends.

The following questions are examples of how the data can be used to establish the status of chemical safety.

- What are the 5 most commonly produced chemicals by volume? (This question identifies the chemicals in commerce presenting the greatest potential for exposure.)
- What are the 5 chemicals with the most money spent to prevent accidents? (This question identifies those chemicals currently receiving the most attention due to their inherent hazards and potential significant adverse health or environmental effects.)
- What are the 5 most released chemicals by business segment and geographic area? (This question focuses on the chemicals that traditionally present problems within a business segment or geographic region.)
- What are the 5 chemicals with the largest consequences by business segment and geographic area? (This question represents the chemicals involved in significant incidents within the business segments or geographic area.)

6.0 Preliminary Application of the Indicators

To illustrate the potential application of the indicators for fixed facilities in measuring chemical safety, a series of simple queries were run against the EPA ARIP and RMP 5-year Accident History databases. The following Tables 2-4 exhibit the chemicals that are most frequently released with the resulting consequences.

Ammonia, chlorine, and sulfur dioxide top the two lists as the chemicals with the most number of releases, injuries, and hospitalizations. However, the similarities in the two data sources end there.

While the different answers can generally be rationalized by the different scope of the two databases, it is essential to have an understanding of the original intent for their development as well as the limitations of the various data sources.

Table 2: Data from the ARIP Database (1986 – 1992)

Chemical Name	Number of Releases	Deaths	Hospitalized	Injuries	Incidents with Injury
Ammonia	880	7	203	500	108
Chlorine	648	1	454	1793	187
Sulfur dioxide	370	0	66	199	24
Sulfuric acid	326	2	24	89	31
Hydrogen sulfide	186	1	41	149	17
Ethylene oxide	147	0	31	36	10
HCl Acid + vapor	144	0	31	221	26
Sodium hydroxide	143	1	9	21	18
Sodium hypochlorite	90	0	21	117	8
Benzene	84	1	5	8	3

The RMP 5-Year Accident History data can be further divided into subcategories such as: worker and public deaths, worker and public injuries, and medical treatment cases. In Table 3, "Deaths" is a summation of worker death plus public death. "Injuries" is reported as a combination of worker injuries and public injuries. "Medical Treatment" as reported in Table 3 indicates the number of people off-site requiring medical treatment.

The next step involves interpreting the information gained from the RMP 5-year Accident History database. The production volumes came from the National Petroleum Refiners Association and Bureau of the Census as presented in a June 26, 2000, article entitled *Production: Gains Beat Losses* published in Chemical and Engineering News.

The Center proposes to use the ten EPA regions as the geographic area breakdown. The RMP 5-Year Accident History database currently does not include the EPA regions and thus the field should be included in the final repository. However, the database does include a finer breakdown of information by using data fields such as City, State, and Zip. Applying the currently available information in the RMP 5-Year Accident History database to the Center's proposed questions produced the following responses:

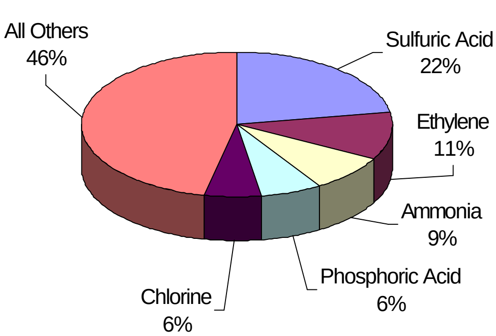
Table 3: Data from the RMP 5-Year Accident History Database (1994 – 1999)

Chemical Name	Number of Releases	Deaths	Hospitalizations	Injuries	Incidents with Injuries
Ammonia	666	7	48	688	277
Chlorine	505	0	47	623	330
Sulfur dioxide	45	1	2	26	16
Ethylene oxide	19	0	0	5	5
Hydrogen sulfide	17	0	6	33	8
Phosgene	12	3	0	24	10
Nitric acid	12	0	80	15	10
Trichlorosiliane	11	2	10	11	6
Vinyl acetate monomer	5	0	0	2	2
Propylene oxide	6	0	0	0	0
Silane	4	0	1	1	1

Table 4: Additional Data from the RMP 5-Year Accident History Database (1994 – 1999)

Chemical Name	Worker Deaths	Public Deaths	Worker Injuries	Public Injuries	Offsite Deaths	Medical Treatment
Ammonia	7	0	651	37	0	374
Chlorine	0	0	531	92	0	111
Sulfur dioxide	1	0	26	0	0	89
Ethylene oxide	0	0	5	0	0	0
Hydrogen sulfide	0	0	33	0	0	80
Phosgene	2	0	23	1	0	1
Nitric acid	0	0	14	1	0	127
Trichlorosiliane	2	0	11	0	0	2
Vinyl acetate monomer	0	0	2	0	0	0
Propylene oxide	0	0	0	0	0	0
Silane	0	0	1	0	0	4

Figure 3: 1998 Production Volumes



- What are the 5 most commonly produced chemicals by volume, as illustrated by Figure 3?
- What are the 5 chemicals with most money spent to prevent accidents?

Answering this question requires further research to identify an indicator and a metric. The Center believes the chemicals used to answer this question must come from commerce and not from the military. By excluding chemicals produced for military use, a better understanding of the industry's return on investment to prevent incidents can be reached.

- What are the 5 most released chemicals by business segment, as shown in Table 5 and 6?

Table 5: Summary of Chemical Releases by Pounds Released

Chemical	No. of Total Releases	Total Pounds Released	Pounds per Release
Ammonia	437	7,708,255	17,639
Flammable mixture	54	2,019,677	37,401
Formaldehyde	16	263,283	16,455
Propane	31	253,183	8,167
Chlorine	263	23,343	89

Table 6: Further Analysis by Business Segment

Chemical	No. of Total Releases	Total Pounds Released	Pounds per Release	Highest No. of Total Releases	Lowest No. of Total Releases	Largest Total Quantity Released	Lowest Total Quantity Released
Chemical Manufacturing - NAICS # 325XX							
Ammonia	132	7,697,481	58,293	X		X	
Formaldehyde	16	263,283	16,455				
Nitric acid	10	144,525	14,452				
Oleum	7	66,859	9,551		X (Tie)		X
Propane	7	191,587	27,367		X (Tie)		
Food Manufacturing - NAICS # 311XX							
Ammonia	292	1,726	1,591	X		X	
Chlorine	9	119	13				X
Hydrogen fluoride	1	360	360		X (Tie)		
Propane	1	200	200		X (Tie)		
Sulfur dioxide	2	901	451				
Utilities - NAICS #221XX							
Ammonia	12	9,047	753	X			
Chlorine	205	21,803	106			X	
Isopentane	1	10	10		X (Tie)		X (Tie)
Methane	1	10	10		X (Tie)		X (Tie)
Sulfur dioxide	9	1,096	121				
Paper Manufacturing - NAICS # 322XX							
Ammonia	1	1	1		X		X
Chlorine	49	10,807	220			X	
Chlorine dioxide	54	2,354	45	X			
Sulfur dioxide	4	1,421	355				
Petroleum Refining - NAICS # 32411							
Flammable mixture	54	2,019,677	37,401	X		X	
Butane	18	174,416	9,689				
Isobutane	10	540,185	54,018				
Propane	23	61,396	2,790				
Sulfur dioxide	3	27,128	9,042		X		X

- What are the 5 chemicals with the largest consequences by business segment, as shown in Table 7 and 8?

Table 7: Summary of Chemical Releases by Consequence

Chemical	Total Property Damage (Single Release – Mixture)	Total Deaths (Single Release – Mixture)	Total Injuries (Single Release – Mixture)
Chlorine	$1,373,473 -- $202,000	9 -- 0	333 -- 1
Flammable Mixtures	$379,791,446 -- $71,058,000	7 -- 1	41 -- 29
Ammonia	$308,591,908 -- $580,000	7 -- 0	542 -- 0
Hydrogen	$4,005,000 -- $58,425,000	0 -- 2	6 -- 35
Propane	$10,999,984 -- $55,416,200	0 -- 7	10 -- 42

Table 8: Further Analysis by Consequence

Chemical	Property Damage (Single Release – Mixture)	Deaths (Single Release – Mixture)	Injuries (Single Release – Mixture)
Chemical Manufacturing - NAICS # 325XX			
Ammonia	$226,474,259 -- $580,000	4 -- 0	75 -- 0
Isobutane	$25,000 -- $38,000,000	0 -- 0	0 -- 12
Flammable mixtures	$168,598,500 -- $1,925,000	0 -- 1	18 -- 0
Hydrogen	$4,005,000 -- $58,425,000	0 -- 2	6 -- 35
Propane	$752,500 -- $40,850,100	0 -- 0	0 -- 30
Food Manufacturing - NAICS # 311XX			
Ammonia	$82,117,649 -- $0	3 -- 0	456 -- 0
Chlorine	$500 -- $0	0 -- 0	6 -- 0
Hydrogen fluoride	$1,585 -- $0	0 -- 0	0 -- 0
Sulfur dioxide	$0 -- $0	0 -- 0	1 -- 0
Propane	$0 -- $0	0 -- 0	0 -- 0
Utilities - NAICS #221XX			
Ammonia	$0 -- $0	0 -- 0	11 -- 0
Chlorine	$1,372,923 -- $0	9 -- 0	249 -- 0
Sulfur dioxide	$75,000 -- $0	0 -- 0	4 -- 0
Methane	$50,000 -- $0	0 -- 0	0 -- 0
Isopentane	$0 -- $0	0 -- 0	1 -- 0
Paper Manufacturing - NAICS # 322XX			
Chlorine	$50 - $202,000	0 -- 0	78 -- 1
Chlorine dioxide	$50 - $202,000	0 -- 0	93 -- 1
Sulfur dioxide	$0	0 -- 0	4 -- 0
Ammonia	$0	0 -- 0	0 -- 0
Petroleum Refining - NAICS # 32411			
Flammable mixtures	$211,192,946 -- $69,133,000	7 -- 0	23 -- 29
Butane	$61,750 -- $29,266,100	0 -- 6	2 -- 2
Propane	$10,247,484 -- $14,566,100	0 -- 7	10 -- 12
Methane	$2,600,000 -- $14,000,100	0 -- 7	0 -- 9
Isobutane	$1,048,000 -- $20,050,100	0 -- 0	0 -- 3

"Single Release" denotes release of a single chemical in one event.
"Mixture" denotes release of multiple chemicals in one event.

7.0 Forward Vision

To achieve the National Chemical Safety Goals, stakeholders require a baseline against which they can measure progress. To provide a meaningful measurement scheme for the status of chemical safety, it is important to select a uniformly acceptable series of indicators and metrics for interpretting the information. The Center's initial research supports the conclusion that existing federal databases can be useful in measuring chemical safety.

The Center proposes the following indicators for fixed facilities:

- Chemicals Involved
- Number of Releases
- Number of Fatalities
- Number of Injuries

The Center proposes the following examples for analysis of the data used to establish the status of chemical safety in the United States.

- What are the 5 most common used chemicals by volume?
- What are the 5 chemicals with the most money spent to prevent accidents?
- What are the 5 most released chemicals by business segment and geographic area?
- What are the 5 chemicals with the largest consequences by business segment and geographic area?

The proposed indicators are based on the Center's knowledge of existing data. They were chosen to represent means of measuring exposure and consequences to chemicals. As the measurement of chemical safety matures, these indicators will be reviewed and refined.

To continue, the Center will:

- **Seek stakeholder approval for the proposed indicators and metrics for fixed facilities.**
- **Establish a frequency for performing the trend analysis for the various business segments and geographic areas.**
- **Improve data quality throughout the seven federal databases.** Emphasis will be placed on working with the EPA 5-year Accident History database, as it will serve as the core data for trending fixed facilities.

The Center calls on all stakeholders to:

- **Seek ways to gain standardization in the key data elements, e.g., definition of an incident;**
- **Be active in promoting chemical process safety in local organizations, e.g., LEPCs; and**
- **Work to institutionalize measurement of chemical safety in the United States.**