Published in final edited form as:
J Emerg Manag. 2015 ; 13(4): 359–380. doi:10.5055/jem.2015.0248.

A decision support framework for characterizing and managing dermal exposures to chemicals during Emergency Management and Operations

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Abstract

Emergency Management and Operations (EMO) personnel are in need of resources and tools to assist in understanding the health risks associated with dermal exposures during chemical incidents. This article reviews available resources and presents a conceptual framework for a decision support system (DSS) that assists in characterizing and managing risk during chemical emergencies involving dermal exposures. The framework merges principles of three decision-making techniques: 1) scenario planning, 2) risk analysis, and 3) multicriteria decision analysis (MCDA). This DSS facilitates dynamic decision making during each of the distinct life cycle phases of an emergency incident (ie, preparedness, response, or recovery) and identifies EMO needs. A checklist tool provides key questions intended to guide users through the complexities of conducting a dermal risk assessment. The questions define the scope of the framework for resource identification and application to support decision-making needs. The framework consists of three primary modules: 1) resource compilation, 2) prioritization, and 3) decision. The modules systematically identify, organize, and rank relevant information resources relating to the hazards of dermal exposures to chemicals and risk management strategies. Each module is subdivided into critical elements designed to further delineate the resources based on relevant incident phase and type of information. The DSS framework provides a much needed structure based on contemporary decision analysis principles for 1) documenting key questions for EMO problem formulation and 2) a method for systematically organizing, screening, and prioritizing information resources on dermal hazards, exposures, risk characterization, and management.

Disclaimer: The findings and conclusions of this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

Conflict of interest: The authors declare no conflict of interest.

Keywords

chemicals; decision analysis; dermal; Emergency Management and Operations; risk analysis; hazards

INTRODUCTION

Recent world events demonstrate the need for high-quality resources specifically designed to assist Emergency Management and Operations (EMO) personnel in making informed decisions during both natural (eg, hurricanes and tsunamis) and human-caused disasters (eg, terrorist events and transportation accidents). Numerous efforts are underway to develop resources that address both the broader topic of EMO, in addition to specific scenarios or hazards. For instance, the Federal Emergency Management Agency (FEMA) created the National Incident Management System (NIMS) to provide a comprehensive national approach to incident management.[1] Additionally, a collaborative effort between the National Library of Medicine (NLM), the Office of the Assistant Secretary for Preparedness and Response (ASPR) of the US Department of Health and Human Services (US HHS) and US Department of Homeland Security (US DHS) is actively developing multiple web-based decision-making resources, such as Wireless Information System for Emergency Responders (WISER) and Chemical Hazards Emergency Medical Management (CHEMM).[2,3] These integrative web-based resources provide critical data, facts, and guidance during mass casualty events involving hazardous materials during each of the life cycle phases of an emergency incident.[2,3]

Despite the availability of numerous high-quality resources designed to guide EMO, data gaps continue to exist for specific hazards or scenarios. Dermal contact is an important exposure pathway and may present significant health risks during chemical incidents.[4,5] Chemicals, such as nerve agents, cyanides, vesicants, acids, and bases, cause numerous adverse health effects ranging from mild Skin irritation to paralysis and death following acute dermal contact,[5] but there are few information resources that provide guidance related to dermal exposures. For example, the US DRS had identified several data gaps in patient decontamination planning guidance and research associated with dermal exposures.[5]

Limited data are available on the characterization or management of dermal hazards. Table 1 identifies chemicals commonly involved in both fixed facility and transportation incidents,[6] along with their associated Skin hazard classifications based on the Globally Harmonized System of Classification and Labeling of Chemicals (GHS).[7] While the data captured by the National Toxic Substance Incident Program (NTSIP) describe fixed facility and transportation events and collect information on the incident, health effects, and contributing factors to the incident, the surveillance system does not collect route-specific data.[6] As such, it is difficult to determine how many of the injured or ill persons experienced health effects due to dermal exposure, as health effects may also include neurological, gastrointestinal, and other systemic effects.[4,5] A review of published studies revealed several investigations describing adverse health outcomes associated with dermal exposures to various chemicals. These studies provide supplemental evidence of the consequences of dermal exposures during chemical emergencies that included Skin damage (ie, irritation and corrosion) and dermal absorption of a recognized carcinogenic agent (ie, polycyclic aromatic hydrocarbons) released as pyrolysis products.[6,8,9] Additionally, the US Occupational Safety and Health Administration (US OSHA) identifies dermal exposures as a significant workplace health hazard and reports that both the number of cases and the rate of Skin disease in the United States exceeded recordable respiratory illnesses.[10]

Despite the absence of EMO resources pertaining to dermal exposures to chemicals, informed decisions need to be made to successfully manage and respond to chemical emergencies. A thorough examination of all aspects of dermal risk is very complex and rarely conducted during the response phase of an incident. This typically results in the use of general guidelines instead of substance-specific guidance (eg, chemical protective clothing [CPC] requirements for initial response and decontamination procedures)[11] or quick guides for a selected range of release scenarios.[12–14] These general procedures can be protective, but failure to provide dermal-specific technical guidance can place responders at increased risk. For example, wearing an inappropriate CPC ensemble may provide a false sense of security by providing an inadequate barrier to chemical penetration or may increase heat loads that enhance dermal absorption and result in elevated physiological burden (eg, heat stress).[15,16] Furthermore, inadequate decontamination procedures may lead to increased exposure to a chemical. The use of an aqueous solution consisting of soap and water may be ideal for decontamination of water-soluble chemicals; however, for more lipophilic (non-water) soluble chemicals (eg, organic solvents and some pesticides), potential for dermal exposure may increase by spreading the chemical over a larger surface area to potentially “wash in” the chemical.[15,16] Efforts underway in the federal government provides supplemental evidence of the complexities associated with dermal exposures to chemicals with an emphasis on the decontamination following mass casualty events.[6]

Purpose

A conceptual framework is presented for a decision support system (DSS) to assist EMO personnel during chemical incidents involving dermal exposures. The framework incorporates scenario planning, risk analysis, and decision analysis as the basis of the DSS. Several key issues are addressed, including 1) the complexities of dermal risk assessment, 2) the critical criteria and primary assumptions that govern the decision process, and 3) the identification, integration, and prioritization of relevant information resources.

FRAMING THE PROBLEM: DECISION MAKING IN EMERGENCY MANAGEMENT AND OPERATIONS

Effective decision making and problem solving are critically important for the management of chemical emergencies. The decision process should consider potential risks and magnitude of uncertainty in an interactive process of developing an incident management strategy. The successful development of these strategies relies on the availability of appropriate information resources. Tools and resources exist to guide decision making that governs the overall incident; however, information is often limited for aspects of the incident requiring special expertise. Thus, a specific issue, such as dermal exposures, may be overlooked because of the absence of readily available information that addresses all dimensions of dermal risk. To illustrate this, approximately 300 resources (see Appendix table) were identified that contained information that could be useful for addressing dermal exposure during chemical incidents. However, the current suite of available resources on dermal risk issues lacks a system, such as the CHEMM and WISER resources, to link disparate resources in a way that facilitates decision making.[2,3]

An effective dermal risk management strategy requires a decision process that addresses key risk assessment and management questions. As the process for answering these questions relies on complex data from numerous sources, a DSS can be a valuable aid to the incident command structure. Numerous examples of decision approaches used in EMO context to identify, organize, and integrate complex data in all emergency phases exist and support the development of a similar process for dermal risks.[17–20]

Risk analysis and decision making

Problems associated with dermal exposures during a chemical emergency can be framed using risk analysis, which is a systematic approach used to assess and manage the risk associated with a specific hazard, event, or situation and guide decision making related to potential risk management outcomes.[21] It consists of two distinct components: 1) risk assessment and 2) risk management. Risk assessment is concerned with the characterization of risks associated with a specified hazard.[21] Risk management focuses on the application of these findings to make decisions and policies to control the risk.[21] Both of these steps are also refined through iterative risk communication processes that include stakeholder involvement. For dermal exposures, risk analysis would aid in identifying the hazards and risks, and assist EMO personnel in formulating control strategies ranging from selection of CPC, medical management, and decontamination.

An initial step in risk analysis is problem formulation. In EMO, this is often accomplished via scenario planning, which is a strategic approach used to characterize potential threats or events to determine the level of readiness, vulnerabilities, and needs.[22,24] In the context of this article, dynamic scenario planning allows for the identification and integration of the key questions related to dermal exposures. This form of scenario planning allows for the construction of scenarios designed for preparedness planning that incorporate factors and variables that are readily adjustable to actual response conditions. The inclusion of such factors and variables results in flexible models that ensure that preparedness efforts parallel response activities more precisely. For issues like CPC selection during an actual response, this helps to mitigate the natural tendency to recommend defaults in the absence of information that are “over-protective” and may create a more hazardous situation for engaged EMO personnel. The key questions identified as a component of the dynamic scenario planning serve as the first stage of a dermal DSS. Table 2 provides a list of recommended key questions that can serve as a dermal checklist tool to guide resource review and data evaluation. The checklist is the first component of a dermal DSS by systematically organizing information using the primary principles of risk analysis with specific data divided between risk assessment (ie, hazard characterization, exposure assessment, and risk characterization) and risk management (ie, exposure control approaches, decontamination, and medical surveillance).

Framing the problem using risk analysis and dynamic scenario planning enhances the decision-making process and serves as the basis of a DSS. A variety of decision-making tools are available that can be applied to EMO problems.[20,24,36,37] One such tool is multicriteria decision analysis (MCDA). This is a group of methods applied to understand complicated decisions and assist in choosing among alternatives via systematic analyses of risk levels, uncertainty, and valuation based on multiple criteria.[37–40] The MCDA approach has a successful history of application in the field with ongoing refinement based on incident review processes.[41]

CASE STUDY: APPLICATION OF THE DERMAL CHECKLIST TOOL

Each chemical incident presents numerous challenges based on scenario-specific factors, such as type of emergency, location, and chemical of concern. These distinctions affect the actions needed to both manage the incident and protect EMO personnel. To illustrate this point, case studies were developed that demonstrate the challenges and difficulties associated with conducting a dermal risk assessment during two distinct chemical emergencies. The first scenario involves a fixed facility release of sulfuric acid (CAS# 7664-93-9). The second scenario describes a transportation-related incident involving the release of benzene (CAS# 71-43-2). Table 2 applies the previously described checklist of recommended key questions to assist in characterizing and managing the scenario-specific hazards, exposures, and risk to the case studies.

The information in Table 2 demonstrates that the complexity of conducting rigorous dermal risk assessments for chemical emergencies varies based on the scenario and hazard. The use of standard operating procedures and generic risk management practices, which are “one size fits all” or designed to accommodate a wide range of issues, represents one approach applied to assist in the management of chemical incidents. These approaches are useful, but in many cases are not the most appropriate: that is they may result in risk management actions that generate unintended risks. For example, the hazard characterization presented in Table 2 demonstrates that the hazards of dermal contact with sulfuric acid and benzene are very different. Sulfuric acid is capable of causing immediate and severe corrosion with dermal absorption and targeted systematic effects of less concern.[30] In comparison, benzene has limited potential as a Skin irritant, but is capable of being dermally absorbed and contributing to the onset of acute and delayed systematic effects including blood cancers.[32] These chemicals represent unique health risks following dermal exposure scenarios resulting in the need for specialized risk management practices. Thus, generic guidance would indicate the need for CPC but would not guide the user to the specific recommendations for each of these two different exposure scenarios. Subsequent considerations address the characterization and validation of dermal contact through surface sampling, decontamination needs, and medical surveillance. EMO personnel are in need of a decision support tool to assist in making informed decisions regarding both broad and specific issues during chemical emergencies involving dermal exposures. The dermal checklist tool serves to identify in a systematic manner the questions that need to be addressed for the scenario under review.

CONCEPTUAL FRAMEWORK FOR THE DERMAL DSS

The conceptual framework intended to facilitate the development of a dermal DSS to provide resources to answer the resulting set of key dermal risk questions is outlined in this section. The framework consists of three primary modules: 1) Resource Compilation, 2) Prioritization, and 3) Decision. Figure 1 presents the overall flow of the framework.

Resource compilation

The foundation of any decision process is a robust database comprised of high-quality data collected from multiple sources. The primary objective of this module is to identify, collect, and organize relevant resources to facilitate the compilation of a searchable dataset. This task is challenging due to the large volume of resources that are available and relevant to EMO activities involving chemical incidents coupled with the lack of a coherent link among the resources. For this reason, a classification system to organize resources is critical. Three elements of the classification system should include 1) incident phase, 2) information categories, and 3) resource categories. Figure 2 illustrates the relationship of the core elements of the resource compilation module.

The incident phase element serves as a descriptor that captures objectives and critical questions relevant to specific scenarios. This takes into account that the resource needs will vary during each of the distinct life cycle phases of an emergency incident (ie, preparedness, response, or recovery) for a given scenario. The resources compiled need to exhibit duality that allows for their application in both broad terms for use in multiple situations, but be sufficiently narrow to provide guidance under specified conditions. For example, a train derailment and terrorist event involving an office building would require different information resources to guide EMO. The second element of the resource compilation module pertains to information categories. The categories illustrated in Figure 2 reflect that the data needs are not consistent among scenarios. The case studies in Table 2 vary in the nature of the presented hazard highlighting the need to identify specialized resources. Another benefit of categorizing data in the manner presented in Figure 2 is that it allows specialists to rapidly identify resources specific to their roles, such as exposure modeling or medical management. The final element of the resource compilation module is resource categories. This is particularly important based on the incident phase, which are often subject to time constraints. For example, less accessible resources that have a high depth of information are more appropriate for the preparedness phase than for the response phase. In essence, the resource compilation module provides a specialized resource library pertaining to dermal exposures to chemicals that allows for effective sorting consistent with EMO needs.

Prioritization

A further enhancement to the dermal DSS enables prioritization of resources on top of, or in addition to, a single compilation of resources. This enhancement is conceptually consistent with the MCDA approach. In the prioritization module, an approach is applied that captures for each information resource the value for addressing user-defined scenarios. The process incorporates a weighting of the impacts of an information resource for the assessment being conducted. One such approach is value of information (VOI) scoring, which facilitates the systematic prioritization of large volumes of resources to limit uncertainty in decision making.[42]Figure 3 demonstrates the relationship of the core elements of the prioritization module.

In the context of the dermal DSS, application of VOI scores ensures that information resources are prioritized based on the critical needs of EMO personnel. Two important criteria for EMO resources are accessibility and reliability. Accessibility is a critical criterion because of the time dependence of decision making that varies by incident phase. For example, during the early response, rapidly accessible information is crucial and therefore should be readily identifiable from a resource library. Multiple factors governing the accessibility criterion are 1) cost (paid vs free resources), 2) format (hard copy textbook vs online databases), and 3) usability and ease of finding the relevant information within the resource (searchable databases vs hard copy textbooks). One potential drawback to giving high weight to accessibility is that common or highly accessible resources may not include information to meet a specific need. This is illustrated in the recommendations for CPC selection for benzene summarized in Table 2. The *Emergency Response Guidebook*, which is a common high access resource, does not provide specific CPC recommendations for benzene.[14] In contrast, other resources that might have lower accessibility scores provide specific CPC recommendations for benzene.[43]

The second criterion for a VOI score is reliability, which reflects the level of confidence in the information resource and its relevance to EMO. Elements of reliability include 1) the source of the information (government document vs unpublished resources), 2) the publication date, 3) the level of scrutiny (ie, peer review), and 4) relevance to dermal risk in EMO settings. This criterion is important for selecting the most appropriate resource for the scenario and is of particular importance when existing resources provide conflicting recommendations. For example, in evaluating the decontamination procedures for benzene and sulfuric acid, different organizations provide varying guidance on decontamination (as seen in Table 2).

The overall prioritization process can be further refined to address specific user needs by customizing the weights of the different criteria and factors. Strategic combinations of the accessibility and reliability criteria and factors allow for further stratification of resources. In addition, modifying factors or new criteria can be used to customize the VOI to allow consideration of additional variables and provide dynamic range in the process to further refine resource prioritization. For example, additional weight could be placed on free and Internet-accessible resources in a chemical emergency response or history of use or familiarity among the user community. Techniques such as MCDA, as described earlier, provide a tool for applying different weights to individual decision criteria such that the final prioritization emphasizes the component factors that are most important. The flexibility afforded by this technique for different scenarios is helpful in the EMO arena. For example, factors related to accessibility might be weighted more highly for the response than the planning phase. This preference can be built into the scoring approach using the MCDA concept.[39–41] Although there are many potential structures for such VOI-score-based resource rankings, an example approach that captures several key elements is shown in Table 3.

In practice, once the definition of the assignment criteria (ie, scores or weights) are completed, implementing the VOI score concept for dermal risk resources pertinent to emergency response scenarios requires ongoing refinement to ensure that new developments in resource utility are captured. The initial assignment process can employ anyone of many expert elicitations or focus group methods.[44] The primary goal is to involve subject matter experts (SMEs) that represent the breadth of expertise of the key content as well as the needs of the end users of the resource. EMO is a dynamic field with a significant history of applying lessons learned to improve performance on future responses. The dermal DSS (or any such resource for EMO) should reflect this feature of continuous improvement. Thus, the resource prioritization derived based on inputs of small numbers of SMEs should be refined based on actual user experience and preference. Mechanisms to capture user feedback or real-time data updates are a critical design component of the dermal DSS. Relevant techniques for capturing such data include user feedback surveys or usage tracking techniques for electronic resource libraries (eg, number of downloads of a mobile application). More advanced methods that build in automatic features for prioritization based on user selection (eg, number of “hits”) would provide a mechanism to ensure the tool reflects user preferences. These feedback tools are critical because the EMO community is composed of hundreds of thousands of active members and the ability of a small expert group to capture the sentiments of such a large and dynamic community is limited.

Decision

EMO reflects a demanding decision-making environment. The current state of the field is that the decision process occurs at the incident command level where judgments are made based on the weight of evidence. In many cases, the response requires the command structure to support numerous high impact decisions, often made in a rapid manner. The nature of the information needed is driven by the scenario. Because of the challenging demands in EMO decision making, the information inputs need to be optimized. The dermal DSS incorporates prioritized information as the input to the overall decision process as a basic step toward the goal of effective decision making. The decision process can be enhanced and facilitated with additional tools that integrate information, rather than just providing access to information. There are many examples of such decision tools that apply to dermal EMO needs. Most of the currently available tools take the form of hardcopy or online documents or databases that incorporate data with a decision logic component. Examples include the decision frameworks that weigh complex information datasets such as the NIOSH Skin Notation Methodology or databases that direct the user to a recommendation based on specific and limited inputs, such as the CPC selection guidance.[4,43] Decision tools are advancing to include probabilistic recommendations or other indications of likelihood based on user inputs. One example is CHEMM Intelligent Syndromes Tool (CHEMM-IST), which provides an indication of the likelihood for a particular toxidrome being present.[3] Overall, such decision tools are of significant value, and the demand for such products and the availability of technology to make them more available will increase their impact. Clearly, the nature of the decision tools is evolving from traditional methods (eg, from paper resources and decision logic documents) to electronic tools and computer-based applications that respond to user feedback and have learning features.

Although the amount and variety of resources are significant, EMO personnel often lack the data needed to answer important questions that may impact the health and lives of responders and the public. The case studies noted above highlight many opportunities for new data collection. Thus, the dermal DSS includes a practice to research loop as illustrated by the need to gather more information in Figure 1. This loop allows for the identification of important data for future use that were not available for decision support at a prior incident. As highlighted in Table 2, there is a need for dermal exposure guidance for both chemicals. This practice to research loop identifies this topic as a research need to ensure that the information is available for future emergencies involving benzene or sulfuric acid. Under ideal circumstances, the use of this component of the dermal DSS is during the planning phase of EMO, which allows new data collection to support an anticipated need (eg, a new dermal surface exposure limit). In the incident phase, documentation of data gaps can provide insights to prioritize new data development for future dermal DSS users and to support research agenda development.[45] As new data are collected or identified via this process linkage to the information resource, the compilation step will support access to the new data for future EMO needs.

DISCUSSION

Decision making in the context of the incident command structure for EMO is complex and integrates multiple health and safety hazards. The resulting complexity necessitates the use of simplifying assumptions and precautionary methods where information resources and decision tools are not immediately at hand. Dermal risks are one component of the EMO scenario in need of better decisions tools.

As an initial step to meet this need, the conceptual framework for a DSS is presented to provide an organization structure for EMO-related dermal risk information. To assist EMO, a dermal checklist tool was developed to guide users through critical considerations to ensure that dermal exposure and risk are fully considered during chemical incidents. This checklist provides a systematic process to identify dermal risk information resources needed for the scenario being evaluated. This checklist serves as the initial step in a dermal DSS strategy that is designed to identify key information needs for EMO by providing a structure for 1) documentation of key questions for EMO problem formulation and 2) the organization of information resources on dermal hazards, exposures, risk characterization, and management. The checklist and DSS provide practical guides to allow EMO personnel to develop and implement a customized preparedness and response plan to address an often overlooked risk during chemical incidents. The dermal DSS complements the suite of information resources often used in EMO but aims to provide a specific focus on dermal risk resources that might be overlooked by a superficial review of existing data. The dermal DSS was also organized for compatibility with existing EMO practices focusing on inputs that are made by health specialists at the level of the incident command structure.

An additional consideration that should be included in the management of any incident is the identification of potential hazards. In many cases, EMO personnel responding to an incident may not know what chemicals are present or which ones represent the greatest health hazard. The absence of this information may result in execution of critical decisions that are incorrect, such as the selection of an inappropriate CPC that is not protective and places EMO personnel at unacceptable health risks. To assist in overcoming this issue, EMO personnel and decision makers responsible for providing guidance on a chemical incident should use available tools to aid in chemical identification. For example, WISER and CHEMM-IST are capable of quickly assisting users in identifying a chemical based on numerous variables including physical proprieties, signs, and symptoms of exposure or National Fire Protection Association or DOT placards. Once identified, application of the DSS would allow EMO personnel make better informed decisions and risk to their lives and health.

Because EMO practice is continually improving, the dermal DSS is envisioned as an approach to be refined over time. Thus, it embeds feedback processes both to refine the prioritization of existing resources and to emphasize the ability to drive research from practical needs in the field. A case study approach was used to highlight many areas where chemical-specific guidance for EMO is not available from general guidance resources. For example, many common resources for EMO personnel denote the need for CPC but do not recommend specific products or materials that are found in specialized resources. Other areas that appear to be ready for new research include validated dermal exposure monitoring methods and dermal exposure limits.

CONCLUSION

The goal of the dermal DSS is to provide a systematic framework to identify and organize EMO resources to assist users in making informed decisions regarding the management of the risks of dermal exposures with chemicals. As outlined in this article, the DSS provides a platform for individual users to organize their own stock of resources. Future enhancements can include incorporation of the concept in venues for training and outreach regarding dermal risks for EMO. The increased access to Internet-based information or mobile device applications that function without Internet access opens the door to the development of shared information resource databases constructed on the principles provided in the dermal DSS. Resources from the US NLM, such as WISER and CHEMM, are potential sites for linkage to online or downloadable applications of the dermal DSS. Such a development would reflect the natural extension of current databases to create virtual libraries or electronic tools that harness smart search technologies and provide decision-making tools to protect EMO personnel from dermal risks.

Acknowledgments

The authors acknowledge the contributions of Dr. Erik Auf der Heide (Agency of Toxic Substance and Disease Registry, Division of Toxicology and Human Health Sciences), Dr. Pertti (Bert) Hakkinen (National Library of

Medicine, Office of Clinical Toxicology Specialized Information Services), John Koerner (Department of Health and Human Services, Office of Assistance Secretary for Preparedness and Response), Jennifer Hornsby-Myers (National Institute for Occupational Safety and Health [NIOSH], Office of Emergency Preparedness and Response), and Todd Niemeier (NIOSH, Education and Information Division (EID) through their critical reviews of the draft manuscript. They also thank Seleen Collins (NIOSH, EID) for her editorial review. Financial support for this study was provided via an intramural grant from the Centers for Disease Control and Prevention Office of Public Health Preparedness and Response.

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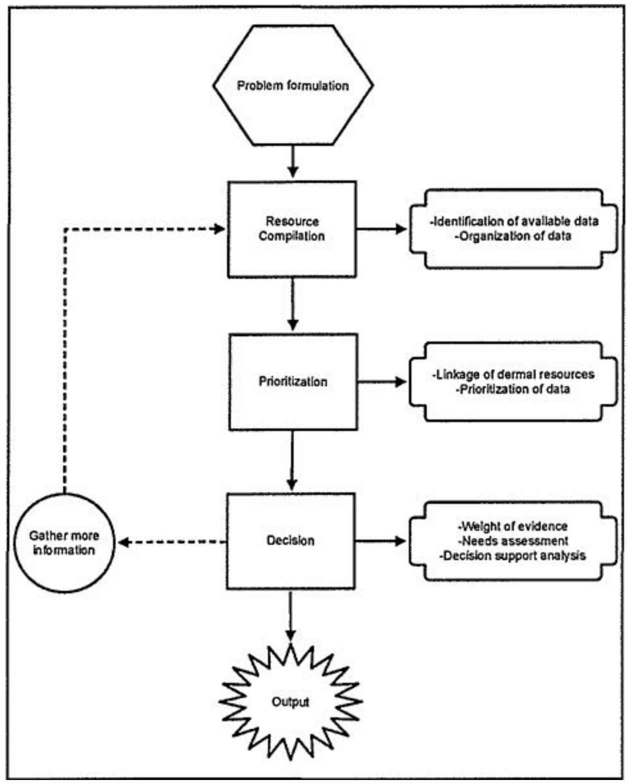

Figure 1.

Conceptual framework and relationship of the primary modules of the decision support system. The image illustrates the conceptual framework for a dermal decision support system. This framework consists of three primary modules: 1) resource compilation, 2) prioritization, and 3) decision. Each module represents a key function in the decision support system to ensure that critical information is available to users to aid in protecting emergency management and response personnel during chemical incidents involving dermal exposures.

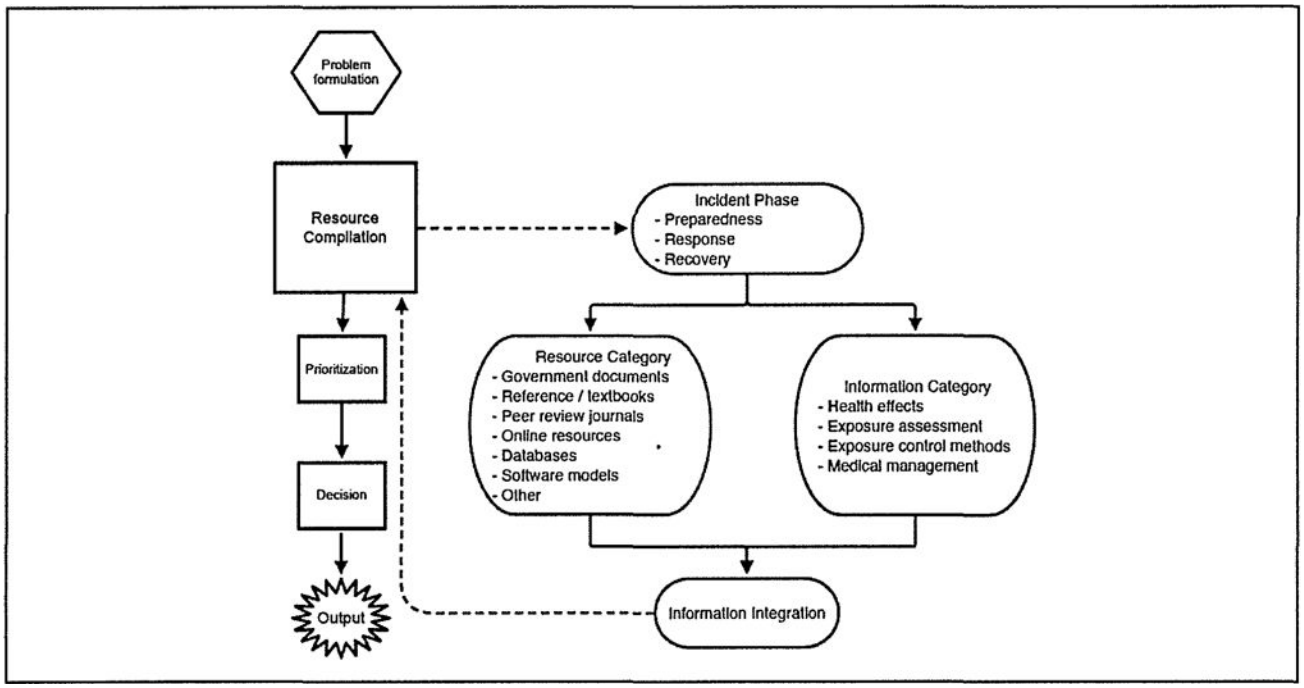

Figure 2.
Core elements of the resource compilation module of the decision support system. The image identifies the key elements included in the resource compilation module of the decision support system. These elements guide the classification and integration of relevant information resources according to 1) incident phase, 2) resource categories, and 3) information category. By classifying and integrating information resources, the resource compilation module provides a specialized resource library pertaining to dermal exposures to chemicals that effectively sorts data based on emergency management and response needs.

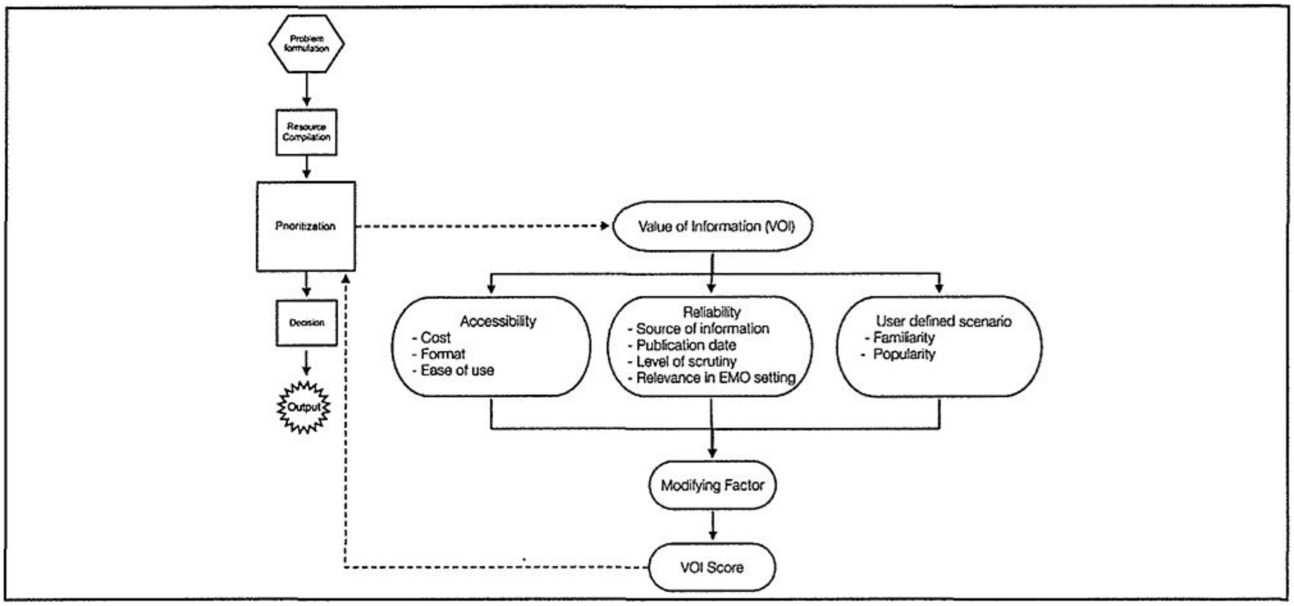

Figure 3.

Core elements of the prioritization module of the decision support system. The image illustrates the primary elements of the prioritization module of the decision support system. This module enhances the specialized resource library constructed during the resource compilation module by developing a relative ranking for each information resource. The relative rankings, also known as value of information (VOI) score, allow for key criteria, such as accessibility and reliability, to be incorporated into the prioritization of information resources based on the emergency phase and the associated need of involved personnel.

Table 1

Chemicals commonly involved in fixed facility and transportation incidents coupled with their Globally Harmonized System of Classification and Labeling of Chemicals (GHS) dermal hazard designations*

Chemicals	GHS designatlon†	GHS hazard statement
Ammonia	Acute Dermal Toxicity Category 3 skin Corrosion Category 1B	Toxic in contact with skin Causes severe skin burns
Sulfuric acid	Skin Corrosion Category 1A	Causes severe skin burns
Hydrochloric acid	Skin Corrosion Category 1B	Causes severe skin burns
Chlorine	Skin Irritation Category 2	Causes skin irritation
Sodium hydroxide	Skin Corrosion Category 1A	Causes severe skin burns
Potassium hydroxide	Skin Corrosion Category 1A	Causes severe skin burns
Benzene	Skin Irritation Category 2	Causes skin irritation
Sulfur dioxide	Acute Dermal Toxicity Category 3 Skin Corrosion Category 1B	Toxic in contact with skin Causes severe Skin burns

*List based on data retrieved from the National Toxic Substance Incident Program (NTSIP) Annual Report 2010.[6] These chemicals are located in both the top 20 most common chemicals in fixed facility events and in the top 10 of the most common chemicals in transportation events.

†European Union.[7]

Table 2

Case studies illustrating the complexities associated with assessing dermal risks during emergency response activities involving chemicals

Risk analysis activity		Case study 1	Case study 2
		Scenario description: Spill of sulfuric acid (CAS# 7664-93-9) from a drum puncture in a manufacturing facility warehouse	**Scenario description: Uncontrolled release of benzene (CAS# 71-43-2) from a tanker truck arising from a traffic accident**
Risk assessment	**Key questions**		
1. Hazard characterization	1a. Are chemicals present that represent a Skin hazard (direct or systemic effects)?	1a. Yes: Direct effects[*,†,‡,§,¶,**,††]	1a. Yes: Direct and systemic effects[*,†,‡,§,¶,**,‡‡,§§,¶¶]
	1b. Are the effects acute (ie, immediate), acute delayed, or chronic?	1b. Immediate: Skin irritation and corrosion[*,†,‡,§,¶,**,††]	1b. Immediate: Skin irritation; Delayed: Target organ toxicity (neurotoxicity, cancer, and noncancer effects on the blood)[*,†,‡,§,¶,**,‡‡,§§,¶¶]
	1c. Are other stressors present that may affect the hazard?	1c. Chemical reacts violently with water generating fumes and the potential for dermal absorption[†,¶,***]	1c. Hot environment may increase vapor exposure and the potential for dermal absorption[†,¶,***]
	1d. Can chemical be dermally absorbed following direct contact?	1d. No: Not expected to be readily absorbed[*,†]	1d. Yes: Dermal absorption may occur in sufficient amounts to cause adverse health outcome[*,†,‡,§,¶,***,§§]
	1e. Can dermal absorption occur following indirect contact (ie, vapors or aerosols)?	1e. Not expected; vapors may be irritating or corrosive[*,†,‡,§,¶,**,††]	1e. Yes.[*,†,‡,§,¶,***,‡‡,§§] *Note:* Vapor uptake via the skin is less than direct contact with liquid form[§§]
	1f. Is the chemical a systemic toxicant?	1f. No[*,†,‡,§,¶,***]	1f. Yes[*,†,‡,§,¶,‡‡,§§]
	1g. Are dermal absorption rates known?	1g. No	1g. Yes: Data indicate that dermal uptake may be significant: Quantified estimates available[‡‡,§§]
2. Exposure assessment	2a. Is dermal contact possible in immediate release zone?	2a. Yes: Dermal exposure may occur via contact with liquid following splashes or other pathways.[†,***]	2a. Yes: Dermal exposure may occur via contact with liquid following spills/ splashes or other pathways.[†,***]
	2b. Is dermal contact likely outside the immediate release zone?	2b. Yes: Reaction with water will generate heat and increase the concentration of fumes in the air,[†,††] therefore, it is likely that dermal contact may occur outside the immediate release zone	2b. Yes: Dermal exposure to benzene vapors may occur outside the immediate release zone as benzene may be encountered in liquid or vapor phases[†,¶,***,§§]
	2c. Can dermal exposures occur during the transport of potentially contaminated materials or patients?	2c. Yes: Be careful to avoid contact with contaminated objects and clothing[†]	2c. Yes: Be careful to avoid contact with contaminated objects and clothing[†]
	2d. Are sampling methods/ tools available to assess dermal exposures?	2d. No: No dermal methods identified; Multiple air sampling methods identified[*]	2d. No: No dermal methods identified; Analytical sampling methods for air, water, soil, and sediment identified[*,***]
	2e. Are dermal exposure estimation models available?	2e. No	2e. Yes: Numerous dermal exposure models; available to estimate dermal absorption[§§]
	2f. Do surface sampling techniques exist for the	2f. Skin SWYPEs may be used to determine if there is any Skin exposure[†††]	2f. No: None identified

Risk analysis activity		Case study 1	Case study 2
		Scenario description: Spill of sulfuric acid (CAS# 7664-93-9) from a drum puncture in a manufacturing facility warehouse	**Scenario description: Uncontrolled release of benzene (CAS# 71-43-2) from a tanker truck arising from a traffic accident**
Risk assessment	**Key questions**		
	chemical of concern? If so, are they validated?		
	2g. Is biological monitoring an option?	2g. No	2g. Yes: Biological monitoring methods exist that rely on the measure metabolites in breath and biological samples (ie, blood, urine, and other tissues)[§§]
3. Risk characterization	3a. Are quantitative exposure limits for dermal exposures available?	3a. No: None identified	3a. Yes: A LOAEL was identified for acute exposure—mucous membrane and skin irritation[§§]
	3b. Is there a means to interpret or compare surface sampling results such as surface exposure limits?	3b. No: None identified	3b. No: None identified
	3c. Are other dermal-related exposure recommendations available?	3c. No: None identified	3c. No: None identified
	3d. Can exposures be compared to existing limits to support a risk characterization?	3d. No: None identified	3d. Yes: Concentrations of benzene in blood correspond to higher levels of exposure[§§]
4. Exposure mitigation	4a. What control techniques are needed to reduce the potential for direct dermal contact in the release zone?	4a. Water spray may be used to reduce fumes (*do not* allow the water to come in contact with the liquid sulfuric acid) or a *small* spill needs to be covered with dry sand or other noncombustible material[†,¶,***] Neutralization procedures are also recommended[†,¶,***]	4a. A vapor suppressing foam or water spray may be used to reduce vapors and liquids may be absorbed or covered with dry earth, sand, or other noncombustible material and transfer to containers[†,¶,***]
	4b. Are controls needed to reduce indirect dermal contact in the release zone?	4b. Yes: controls measures for fumes are needed to reduce dermal contact in the release zone[†,¶,***]	4b. Yes: Controls measures for vapors are needed to reduce dermal contact in the release zone[†,¶,***]
5. Protective equipment	5a. What chemical protection ensemble is needed?	5a. Follow ERG guidelines (137) [‡‡‡] or similar CPC guidance based on response zone, concentration and presence of fuming[§§§]	5a. Follow CPC guidance based on response zone[§§§,¶¶]
	5b. Are specific CPC selection guidelines available?	5b. Yes: Guidelines are available[§§§]	5b. Yes: Guidelines are available[§§§]
	5c. What barrier material is needed to prevent dermal contact during activities in each response zone?	5c. Protective clothing barriers are recommended to prevent dermal contact for sulfuric acid >70 percent, including Butyl rubber, Polyethylene (PE), Viton®, Viton®/Butyl Rubber®, Barrier (PE/PA/PE), Silver Shield/4H® (PE/EVAL/PE), Trellchem® HPS, Trellchem® VPS, Tychem® SL (Saranex®), Tychem® CPF3, Tychem® F, Tychem® BR/LV, Tychem® Responder®, Tychem® TK for 8 h and PE for >4 h[§§§]	5c. Protective clothing barriers are recommended to prevent dermal contact, including Polyvinylalcohol, Viton®, Barrier (PE/PA/PE), Silver Shield/4H® (PE/EVAL/PE), Tychem® CPF3, Tychem® F, Tychem® BR/LV, Tychem® Responder®, Tychem® TK for 8 h and Viton®/Butyl Rubber for>4 h[§§§]

Risk analysis activity		Case study 1	Case study 2
		Scenario description: Spill of sulfuric acid (CAS# 7664-93-9) from a drum puncture in a manufacturing facility warehouse	**Scenario description: Uncontrolled release of benzene (CAS# 71-43-2) from a tanker truck arising from a traffic accident**
Risk assessment	**Key questions**		
	5d. What metrics (eg, breakthrough time, compatibility data) are available to aid in selecting CPC?	5d. Breakthrough times are available to aid in CPC[‡‡‡,§§§]	5e. Breakthrough times are available to aid In CPC[§§§]
6. Decontamination	6a. what specific decontamination procedures are needed?	6a. Decontamination processes include removal from the area, removal of contaminated clothing, and washing any exposed skin thoroughly with soap and water[†] or flush with running water for at least 20min[‡‡‡]	6a. Decontamination processes include removal from the area, removal of contaminated clothing unless it is adhering to the skin, and washing any exposed skin thoroughly with soap and water.[†,¶¶] or flush with running water for at least 20 min[‡‡‡]
	6b. Are specific assays available to demonstrate the efficacy of decontamination?	6b. Skin SWYPEs may be used to determine if there is any of the chemical on the skin[†††]	6b. No: None identified
7. Medical surveillance	7. Are there specific medical surveillance requirements for exposed persons?	7. Medial surveillance for potentially exposed personnel is not recommended due to the immediate nature of the effects of dermal exposure to sulfuric acid	7. Persons with significant exposure to benzene should be followed for up to 72 h to monitor for the delayed effects, such as fluid in the lungs[¶¶]

[*] Ref. 25.

[†] Ref. 26.

[‡] Ref. 27.

[§] Ref. 7.

[¶] Ref. 28.

[**] Ref. 29.

[††] Ref. 30.

[‡‡] Ref. 31.

[§§] Ref. 32.

[¶¶] Ref. 13.

[***] Ref. 33.

[†††] Ref. 34.

[‡‡‡] Ref. 14.

[§§§] Ref. 35.

Table 3

Illustration of key steps in determining value of information (VOI)-score-based resource rankings

Key step	Overview	Example
1	Define primary criteria	(*Q*)=quality; (*A*)=accessibility; (*F*)=familiarity
2	Rate resources for each criterion	Assign a score from 1 to 5 (5 is most desirable)
3	Calculate the crude VOI score (*C*)	*C* determined by calculating the average of ratings for criteria *Q*, *A*, and *F* that can reflect multiple subject matter experts (SMEs) inputs
4	Application of a modifying factor (*M*) for anticipated overall utility of the resource; *M* is a multiplier included to raise or lower the crude VOI score in the ranking results	Assign a level of low, medium, or high (high is most desirable). For this results, low=−0.25, medium=0, and high=0.25.
5	Calculate the final VOI score (*V*)	[$V=C+(C\times(M)$]
6	Repeat for all candidate resources	Develop ranked list based on highest VOI score.

APPENDIX

Dermal-related resources for use during chemical incidents with potential for dermal exposure

Resource name	Resource type	Source	URL
12th report on carcinogens	Government document	National Toxicology Program (NTP)	http://ntp.niehs.nih.gov/ntp/roc/twelfth/roc12.pdf
2012 Emergency Response Guidebook	Online	US Department of Transportation	http://phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Hazmat/ERC2012.pdf
A Guide to the Globally Harmonized System of Classification and Labeling of Chemicals (GHS)	Online	Occupational Safety and Health Administration (OSHA)	https://www.osha.gov/dsg/hazcom/ghs.html
AEGL Chemicals	Online	Environmental Protection Agency (EPA)	http://www.epa.gov/oppt/aegl/pubs/chemllst.htm
AIHA 2011 Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook	Reference/text book	American Industrial Hygiene Association (AIHA)	http://www.alha.org/get-Involved/AIHAGuidelineFoundation/EmergencyResponsePlanningGuidelines/Pages/default.aspx
Air International Regulations for shippers of dangerous goods	Reference/text book	AIR Shipper (Labelmaster)	http://www./abelmaster.com/shop/books/air-transport/a-i-r-shipper
American Industrial Hygiene Association Industrial Hyglenlsts' Role and Responsibilities in Emergency Preparedness and Response white Paper	Online	AIHA	https://www.alha.org/get-involved/VolunteerGroups/Documents/IPRWG-EPRWhitePaper_Final.pdf
AOAC: Official Methods of Analysis (19th ed.) and Supplements	Reference/text book	Association of Official Analytical Chemists (AOAC)	http://www.aoac.org/lmls15_prod/AOAC/Publications/Official_Methods_of_Analysis/About/AOAC_Member/Publications/OMA/AOAC_Officlal_Methods_of_Analysis.aspx?hkey=ccc1fa5c-3eOf-4f76-87ab-1604b266f9df
Areal Location of Hazardous Atmospheres (ALOHA)	Online	EPA/NOAA	http://www.epa.gov/osweroe1/content/cameo/aloha.htm
Ashford's Dictionary of Industrial Chemicals	Reference/text book	R.D. Ashford	http://www.Industrialchemistry.org/100pagesAddict3.pdf
Ashgate Handbook of Pesticides and Agricultural Chemicals	Reference/text book	G.W.A. Milne, ed.	http://www.waterstones.com/waterstonesweb/products/g-+w-+a-+milne/ashgate+handbook+of+pesticides+and+agricultural+chemicals/5928867/
Best Practices for protecting EMS Responders During Treatment and Transport of Victims of Hazardous Substance Releases	Online	OSHA	https://www.osha.gov/Publications/OSHA3370-protecting-EMS-respondersSM.pdf
Biological Monitoring Methods for Industrial Chemicals (2nd ed.)	Reference/text book	R.C. Baselt	http://www.clinchem.org/content/27/3/516.full.pdf
Biological Monitoring: An Introduction	Reference/text book	S. Que Hee, ed.	http://www.amazon.com/Biologlcal-Monitoring-Introduction-Shane-Oue/dp/0471290331/ref=sr_1_1?s=books&le=UTF8&qid=1382993441&sr=1-1
CAMEO chemicals	Online	National Oceanic and Atmospheric Administration (NOAA)	http://www.epa.gov/osweroe1/content/cameo/cameo.htm
CAMEO chemicals: mobile site	Online	NOAA	http://m.cameochemicals.noaa.gov/search/simple
CAMEO Chemicals: online version	Online	NOAA	http://www.cameochemicals.noaa.gov/
Cargo Decoder Mobile App	Online	Strategies In Software	http://www.strateglesinsoftware.com/current-projects/cargo-decoder
Casarett and Doull's Toxicology: The Basic Science of Poisons (8th ed.)	Reference/text book	C.D. Klaassen, ed.	http://www.amazon.com/Casarett-amp-Doulls-Toxicology-Science/dp/0071769234
Catalog of Teratogenic Agents (13th ed.)	Reference/text book	T.H. Shepard	http://www.amazon.com/catalog-Teratogenic-Agents-Thomas-Shepard/dp/080189784X
CG ICS Site Safety Plan (SSP) checklists	Online	OSHA	https://www.osha.gov/SLTC/etools/lcs/pdf/ics_uscg_ssp_checklists.pdf
Chemcyclopedia	Reference/text book	J.H. Kuney, ed. (American Chemical Society)	http://books.google.com/books/about/Chemcyclopedia_1992.html?Id=cv4UQwAACAAJ
Chemical Properties Handbook: Physical, Thermo dynamic, Environmental, Transport, Safety and Health Related Properties for Organic and inorganic Chemicals	Reference/text book	C.L Yaws	https://www.alha.org/marketplace/Pages/Product-Detall.aspx?productid=%7B453AFACe-092E-E411-B502-005056B20848%7D
Chemical Protective Clothing (2nd ed.)	Reference/text book	D.H. Anna (AIHA)	https://webportal/.alha.org/Purchase/ProductDetall.aspx?Product_code=ab99f67d-4778-de11-96b0-0050568361fd
Chemical Reactivity Worksheet	Online	NOAA	http://response.restoration.noaa.gov/reactivityworksheet
Chemical Warfare Agents: Toxicity at Low Levels	Reference/text book	S.M. Somanl, J.S. Romano Jr, eds.	http://www.amazon.com/Chemical-Warfare-Agents-Toxicity-Levels-ebook/dp/B001AOO9RA
Chemical Warfare Agents: Toxicology and Treatment (2nd ed.)	Reference/text book	T.C. Marrs, R.L Maynard, F.R. Sidell	http://books.google.com/books?hl=en&lr=&ld=nzVF04525ukC&ol=fnd&pg=PR5&dq=%22Chemical+warfare+agents:+toxicology+and+treatment%22&ots=FVbQCCvXrf&slg=VA_GJ5_Ks6vmjreUO6VJg1YaxmE#v=onepage&q=%22Chemical%20warfare%20agents%3A%20toxicology%20and%20treatment%22&f=false
Chemical Hazards Emergency Medical Management (CHEMM)	Online	US Department of Health and Human Services (HHS)	http://www.chemm.nlm.nih.gov/
Chemical protective Clothing Performance Index	Reference/text book	Krister Forsberg and Lawrence H. Keith	http://www.amazon.com/chemical-protectlve-clothing-Performance-Index/dp/0471328448/ref=sr_1_1?s=books&le=UTF8&qid=1429196112&sr=1-1&keywords=chemical+protective+clothing+performance
CHEMM: Decontamination Procedures	Online	US HHS	http://chemm.nlm.nih.gov/decontamlnatlon.htm
CHEMM: Information for Incident Preparedness	Online	US HHS	http://chemm.nlm.nih.gov/incidentpreparedness.htm
CHEMM: Information for the First Responders	Online	US HHS	http://chemm.nlm.nih.gov/firstresponders.htm
CHEMM: Intelligent Syndromes Tools (CHEMM-IST)	Online	US HHS	http://chemm.nlm.nih.gov/chemmist.htm
CHEMM: On-site Activities	Online	US HHS	http://chemm.nlm.nih.gov/onsite.htm
CHEMM: PPE	Online	US HHS	http://chemm.nlm.nih.gov/ppe.htm
CHEMM: Strategy for Developing a community Chemical Response Plan	Online	US HHS	http://chemm.nlm.nih.gov/responseplanstrategy.htm
CHEMM: Triage Guidelines	Online	US HHS	http://chemm.nlm.nih.gov/triage.htm
CHEMM: Types and Categories of Hazardous Chemicals	Online	US HHS	http://chemm.nlm.nih.gov/agentcategories.htm
CHEMM: What Kind of Emergency?	Online	US HHS	http://chemm.nlm.nih.gov/typesofevents.htm
CHEMTREC Operations Center	Online	CHEMTREC	http://www.chemtrec.com/responder/services/Pages/OpCen.aspx
Contact and Occupational Dermatology (3rd ed.)	Reference/text book	J.G. Marks Jr. V.A. DeLeo	http://www.sclencedirect.com/science/book/9780323014731
Coping with an attack: A quick guide to dealing with biological, chemical and "dirty bomb" attacks	Online	National Defense University	http://dhhs.ne.gov/Documents/WMD_Poster.pdf
CRC Handbook of Chemistry and Physics (94th ed.)	Reference/text book	W.M. Haynes, ed.	http://www.crcpress.com/product/isbn/9781466571143
Critical Care Toxicology: Diagnosis and Management of the Critically Poisoned Patient	Reference/text book	J. Brent, et al., eds.	http://books.google.com/books?hl=en&lr&=&id=WuA4LsWXXWEC&ol=fnd&pg=PA70&dq=Crltical+care+toxicology:+diagnosis+and+management+of+the+critically+poisoned+patient&ots=ljKt8D3EJj&sig=1Uf5FDxdmUkrDAL7plhyxKCzHfw#v=onepage&q=Critical%20care%20toxicology%3A%20diagnosis%20and%20management%20of%20the%20critically%20poisoned%20patient&f=false

Dermal-related resources for use during chemical incidents with potential for dermal exposure

Resource name	Resource type	Source	URL
Dangerous Goods Regulations (55th ed.)	Reference/text book	International Air Transport Association, Dangerous Goods Board (IATA)	http://www.lata.org/publications/dgr/Pages/index.aspx
Decontamination at health facilities	Online	World Health Organization (WHO)	http://www.who.lnt/environmental_health_emergencies/deliberate_events/decontamination_en.pdf
Dermal (Skin)	Online	Agency for Toxic Substances and Disease Registry (ATSDR)	http://www.atsdr.cdc.gov/substances/toxorganlisting.asp?sysid=2
Dermal Exposure	Online	OSHA	https://www.osha.gov/SLTC/dermalexposure/index.html
Dermal Exposure Assessment: Principles and Applications	Online	EPA	http://rais.ornl.gov/documents/DERM_EXP.PDF
Dermal Exposure Monitoring	Online	OSHA	https://www.osha.gov/SLTC/dermalexposure/exposuremonltoring.html
Dermatotoxicology (8th ed.)	Reference/text book	H.I. Maibach, K.P. Wilhelm, H. Zhai	http://www.amazon.com/Dermatotoxlcology-Eighth-Edition-Klaus-Peter-Wilhelm/dp/1841848557/ref=dp_ob_title_bk
Disaster Response and Recovery. (Wiley Pathways) (2nd ed.)	Reference/text book	D. McEntire	http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118673026.html
Ellenhorn's Medical Toxicology: Diagnosis and Treatment of Human Poisoning (2nd ed.)	Reference/text book	M.J. Ellenhorn, S. Schonwald, G. Ordog, J. Wasserberger	http://www.clinchem.org/content/44/2/366.full
Emergency Action for Chemical and Biological Warfare Agents	Reference/text book	D.H. Ellison	http://www.amazon.com/Emergency-Action-Chemical-Biological-Warfare/ap/0849302412
Emergency Care for Hazardous Materials Exposure (3rd ed.)	Reference/text book	A.C. Bronstein. P.L. Currance, eds.	http://www.cne.go.cr/CEDO-CRID/CEDO-CRID%20V4/pdf/eng/doc2972/doc2972-1a.pdf
Emergency Decontamination corridor System	Online	US Army	http://www.au.af.mil/au/awc/awcgate/army/firefighter_quick_ref.paf
Emergency Handling of Hazardous Materials in Surface Transportation	Reference/text book	Association of American Railroads (Bureau of Explosives)	http://www.boepublications.com/hazmat.html
Emergency Preparedness and Response	Online	OSHA	https://www.osha.gov/SLTC/emergencypreparedness/index.html
Emergency Response Guidebook	Government document	US Department of Transportation (PHMSA)	http://phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Hazmat/ERG2012.pdf
Emergency Response Guidebook Mobile App	Online	US Department of Transportation	http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.ebac7a8a7e39f2e55cf2031050248a0c/?vgnextold=f6ab5aaa0581d310VgnVCM1000001ecb7898RCRD&vgnextchannel=c8e71dec94973110VgnVCM1000009ed07898RCRD&vgnextfmt=print
Emergency Response Resources	Online	CDC	http://www.cac.gov/niosh/topics/emres/responders.html
Emergency Response Resources: Personal Protective Equipment	Online	CDC	http://www.cac.gov/niosh/topics/emres/ppe.html
Encyclopaedia of occupational health and safety	Government document	International Labour Office	http://www.llo.org/safework/lnfo/publications/WCMS_113329/lang-en/lndex.htm
Environmental and Occupational Medicine (5th ed.)	Reference/text book	W.N. Rom, ed.	http://www.amazon.com/Environmental-Occupational-Medicine-William-Rom/dp/0781762995
Evaluation Guidelines for Surface Sampling Methods	Online	OSHA	https://www.osha.gov/dts/sitc/methods/surfacesampling/surfacesampling.html
Field Management of Chemical Casualties Handbook	Online	USAMRICD	https://www.rke.vaems.org/wvems/Libraryfiles/Dis/E_04.pdf
Fire Protection Guide to Hazardous Materials (2010 ed.)	Reference/text book	National Fire Protection Association (NFPA)	http://catalog.nfpa.org/Fire-Protection-Guide-to-Hazardous-Materials-2010-Edition-P14118.aspx
Goldfrank's Toxicologic Emergencies (9th ed.)	Reference/text book	L.R. Goldfrank	http://goldfrankstoxicology.com/
Goodman and Gilman's the Pharmacological Basis of Therapeutics (12th ed.)	Reference/text book	L. Brunton, B. Chabner, B. Knollman	http://accessmedicine.com/resourceTOC.aspx?resourceID=651
Guidance Document on Dermal Absorption	Online	European Commission	http://ec.europa.eu/food/plant/protection/evaluation/guidance/wrkdoc20_rev_en.pdf
Guidance on Emergency Responder Personal Protective Equipment (PPE) for Response to CBRN Terrorism Incidents	Online	CDC	http://www.cac.gov/niosh/docs/2008-132/pdfs/2008-132.pdf
Guide for the selection of Personal Protective Equipment for Emergency First Responders	Online	National Institute of Justice	https://www.ncjrs.gov/paffiles1/nij/191518.pdf
Guide to Occupational Exposure values	Reference/text book	American Conference of Governmental Industrial Hygienists (ACGIH)	https://www.acgih.org/store/ProauctDetail.cfm?id=2332
Guidelines for Mass Casualty Decontamination During a Terrorist Chemical Agent Incident	Online	US Army Soldier and Biological Chemical Command (SBCCOM)	http://www.au.af.mil/au/awc/awcgate/army/sbccom_decon.pdf
Guidelines for Responding to a Chemical Weapons Incident	Online	US Army	http://www.au.af.mil/au/awc/awcgate/army/sbccom_chem_response.pdf
Haddad and Winchester's Clinical Management of Poisoning and Drug Overdose (4th ed.)	Reference/text book	S.W. Borron, M. Burns, M.W. Shannon	http://www.amazon.com/Winchesters-Clinical-Management-Polsoning-Overdose/dp/0721606938
Hamilton & Hardy's Industrial Toxicology (5th ed.)	Reference/text book	R.D. Harbison	http://www.amazon.com/Hamilton-Harays-Industrial-Toxicology-5e/dp/0815141815
Handbook of Chemistry and Physics (94th ed.)	Reference/text book	R.C. Weast, ed. (The Chemical Rubber Company)	http://www.hbcpnetbase.com/
Handbook of Environmental Data on Organic Chemicals (5th ed.)	Reference/text book	K. Verschueren	http://www.amazon.com/Hanabook-Environmental-Data-Organic-Chemicals/dp/0470171723
Handbook of Poisoning (13th ed.)	Reference/text book	R.H. Dreisbach	http://www.amazon.com/Drelsbachs-Handbook-Polsoning-Prevention-Thirteenth/dp/1850700389/ref=sr_1_1?s=books&ie=UTF8&qid=1381776580&sr=1-1
Handbook of Reactive Chemical Hazards (7th ed.)	Reference/text book	L. Bretherick, P. Urben	http://www.sciencedirect.com/science/book/9780123725639
Hawley's condensed Chemical Dictionary (15th ed.)	Reference/text book	R.J. Lewis Sr, ed.	http://www.scribd.com/doc/94910911/Hawley%E2%80%99s-Conaensed-Chemical-Dictionary-Fifteenth-Edition
Hayes' Handbook of Pesticide Toxicology	Reference/text book	R. Krieger, ed.	http://www.sclencedirect.com/science/book/9780123743671
HaZ-MAP	Online	National Library of Medicine (NLM)	http://hazmap.nlm.nih.gov/index.php
Hazardous Chemicals Data Book: 1986	Reference/text book	G. Weiss (Noyes Data Corporation)	http://www.osti.gov/scitech/bibllo/6051711
Hazardous Material Emergency Response: Incident Command	Online	National Institute of Environmental Health Sciences	http://www.niehs.nih.gov/health/assets/docs_f_o/incident_command_hazardous_material_response.pdf
Hazardous Substances Data Bank (HSDB)	Online	NLM	http://toxnet.nlm.nih.gov/cgi-bln/sis/htmlgen?HSDB
HazMatiQ Federal Resources: Videos	Online	HAZMAT IQ	http://www.hazmatiq.com/video/index.html
ICS Resource Center	Online	Federal Emergency Management Agency (FEMA)	http://www.training.fema.gov/EMIWeb/IS/ICSResource/Index.htm
INCHEM: Chemical Safety Information from Intergovernmental Organizations	Online	WHO	http://www.inchem.org/
Incident Command System	Online	FEMA	https://www.fema.gov/incident-command-system-resources

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Dermal-related resources for use during chemical incidents with potential for dermal exposure

Resource name	Resource type	Source	URL
Incident Command System eTool	Online	OSHA	https://www.osha.gov/SLTC/etools/ics/index.html
Incident Commanders Checklist: Emergency Response	Online	Wagner-Meinert, Inc.	http://www.wagner-meinert.com/Portals/0/Incident_Commanaers_Checklistpdf
International Cosmetic Ingredient Dictionary & Handbook (15th ed.)	Reference/text book	Personal Care Products Council (Formally CTFA)	https://access.personalcarecouncll.org/eweb/DynamicPage.aspx?Action=Add&ObjectKeyFrom=1A83491A-9853-4C87-86A4-F7D95601C2E2&WebCode=ProdDetailAdd&DoNotSave=yes&ParentObject=CentralizedOrderEntry&ParentDataObject=Invoice%20Detail&Ivd_formkey=69202792-63d7-4ba2-bf4e-a0da41270555&Ivd_CSt_key=00000000-0000-0000-0000-000000000000&Ivd_prc_pra_key=AD961222-3580-4D73-961F-68013ECCFE40
Jane's CBRN Response Handbook (4th ed.)	Reference/text book	A. Garcia, D. Rand, J.H. Rinard	http://www.lhs.com/products/janes/security/cbrn-response-handbook.aspx
Joint Information Center Model. Collaborative communications During Emergency Response	Online	National Response Team	http://www.au.af.mil/au/awc/awcgate/nrt/jic-model.pdf
Kirk-Othmer Encyclopedia of Chemical Technology, Vol 1 (4th ed.)	Reference/text book	Kirk-Othmer	http://onlinelibrary.wiley.com/book/10.1002/0471238961
Management of Terrorist Events Involving Radioactive Material (NCRP Report No. 13B)	Reference/text book	National Council on Radiation Protection and Measurements	http://www.ncrppubllcatlons.org/Reports/138
Managing Hazardous Materials Incidents (MHMIs)	Online	ATSDR	http://www.atsdr.cdc.gov/MHMI/index.asp
Managing Hazardous Materials Incidents (MHMIs) (PDF Version)	Online	ATSDR	http://www.atsdr.cdc.gov/MHMI/mhmi_v1_2_3.pdf
Mapping Applications for Response, Planning, and Local Operational Tasks (MARPLOT)	Online	EPA/NOAA	http://www.epa.gov/osweroe1/content/cameo/marplot_htm
Martindale: The Complete Drug Reference (37th ed.)	Reference/text book	S.C. Sweetman, ed.	http://www.amazon.com/Martlndale-Complete-Reference-Edition-Package/dp/085369933X/ref=pd_slm_sbs_b_1
Medical Aspects of Chemical and Biological Warfare. Chapter 15: Decontamination	Online	US Army	http://www.au.af.mil/au/awc/awcgate/medaspec/ch-15electrv699.pdf
Medical Aspects of Chemical Warfare	Online	US Army	http://www.cs.amedd.army.mil/borden/Portiet.aspx?ld=d3d11f5a-f2ef-4b4e-b75b-6ba4b64e4fb2
Medical Aspects of Chemical Warfare: Chapter 14. Field Management of Chemical Casualties	Online	US Army	http://www.hsdl.org/?vlew&dld=18081
Medical Aspects of Chemical Warfare: Chapter 15. Triage of Chemical Casualties	Online	US Army	http://www.hsdl.org/?vlew&dld=18076
Medical Aspects of Chemical Warfare: Chapter 16. Decontamination of Chemical Casualties	Online	US Army	http://www.hsdl.org/?vlew&dld=18072
Medical Management Guidelines (MMGs)	Online	ATSDR	http://www.atsdr.cdc.gov/mmg/index.asp
Medical Management Guidelines for Chemical Agents	online	CDC	http://www.btcdc.gov/chemical/mmg.asp
Medical Toxicology (3rd ed.)	Reference/text book	R.C. Dart, ed.	http://books.google.com/books?Id=BfdlghlyGiwC&pg=PA732&source=gbs_selected_pages&cad=2#v=onepage&q&f=false
Methodology for Developing Chemical Exposure Guidelines for Deployed Military Personnel (Reference Document 230)	Government document	US Army Public Health Command (USAPHC)	http://phc.amedd.army.mil/PHC%20Resource%20Library/RD230%20June%202010%20Revision.pdf
National Incident Management System	Online	FEMA	http://www.fema.gov/pdf/emergency/nlms/NIMS_core.pdf
National Incident Management System: Appendix B. Incident Command system	online	FEMA	http://www.fema.gov/pdf/emergency/nlms/NIMS_AppendixB.pdf
National Response Framework	Online	Homeland Security	http://www.fema.gov/media-library-data/20130726-1914-25045-12461/final_national/_response_framework_20130501.pdf
NCEA Exposure Factors Handbook. Chapter 6: Dermal.	online	EPA	http://www.epa.gov/ncea/pdfs/efh/front.pdf
NIOSH Emergency Response Safety and Health Database	Online	CDC	http://www.cdc.gov/nlosh/ershdb/default.html
NIOSH Manual of Analytical Methods (4th ed.)	Government document	National Institute for Occupational Safety and Health (NIOSH)	http://www.cdc.gov/niosh/docs/2003-154/
NIOSH pocket Guide (Full pdf)	Online	NIOSH	http://www.cdc.gov/niosh/does/2005-149/pdfs/2005-149.pdf
NIOSH pocket Guide search page	online	NIOSH	http://www.cdc.gov/niosh/npg/
OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response	Online	Organization for Economic Cooperation and Development (OECD)	http://www.oecd.org/env/ehs/chemical-accidents/Gulding-principles-chemical-accident.pdf
OSHA Occupational Chemical Database	Online	OSHA	https://www.osha.gov/chemicaldata/
OSHA Safety and Health Standards: 1910	Online	OSHA	https://www.osha.gov/pls/oshaweb/owastand.display_standard_group?p_toc_level=1&p_part_number=1910
OSHA Technical Manual Section II: Chapter 2. Occupational Skin Exposure	Online	OSHA	https://www.osha.gov/dts/osta/otm/otm_ll/otm_ll_2.html
OSHA/NIOSH interim Guidance. Chemical-Biological-Radiological-Nuclear (CBRN) Personal Protective Equipment Selection Matrix for Emergency Responders: Blister Agents	Online	OSHA	https://www.osha.gov/SLTC/emergencypreparedness/cbrnmatrlx/bllster.html
OSHA/NIOSH Interim Guidance. Chemical-Biological-Radiological-Nuclear (CBRN) Personal Protective Equipment Selection Matrix for Emergency Responders: Nerve Agents	Online	OSHA	https://www.osha.gov/SLTC/emergencypreparedness/cbrnmatrix/nerve.html
OSHA/NIOSH Interim Guidance. Chemical-Biological-Radiological-Nuclear (CBRN) Personal Protective Equipment Selection Matrix for Emergency Responders	Online	OSHA	https://www.osha.gov/SLTC/emergencypreparedness/cbrnmatrix/index.html
PAH Guidance Manual. Appendix G: Calculating Exposure Doses	Online	ATSDR	http://www.atsdr.cdc.gov/hac/PHAManual/appg.html
Patty's Toxicology Vols 1–9 (6th ed.)	Reference/text book	E. Bingham, B. Cohrssen, C.H. Powell	http://www.wlley.com/WlleyCDA/Section/id-811499.html
PDR Guide to Terrorism Response	Reference/text book	J.G. Bartlett, M.l. Greenberg, eds.	http://www.emergencystuff.com/product-p/156363550x.htm
Personal Protective Equipment	Online	EPA	http://www.epa.gov/osweroe1/content/hazsubs/equip.htm
Pesticide Manual (16th ed.)	Reference/text book	J. Turner (British Crop Protection Council)	http://bcpcdata.com/pesticide-manual.html
PHA Guidance Manual. Appendix F: Derivation of Comparison Values	Online	ATSDR	http://www.atsdr.cdc.gov/hac/PHAManual/appf.html
Physician's Drug Handbook (12th ed.)	Reference/text book	Springhouse: Lippincott Williams & Wilkins	http://www.amazon.com/Physicians-Drug-Handbook-Springhouse/dp/1582556806
Physicians' Desk Reference	Reference/text book	PDR Network LLC	http://www.pdr.net/
Poisindex	Online	Micromedex (Truven Health Analytics)	http://micromedex.com/Portais/1/Assets/Brochures/lnternational/lNTL_12339_0614_Poisindex_A4_WEB1.pdf
Poisoning and Drug Overdose (6th ed.)	Reference/text book	K.R. Olson, ed.	http://www.amazon.com/Poisoning-Drug-Overdose-Sixth-Edition/dp/0071668330
Prehospital management and medical Intervention after a chemical attack	Online	L. Kenar, T. Karayklanoglu (Emergency Medicine Journal)	http://emj.bmj.com/content/21/1/84.full.pdf

Dermal-related resources for use during chemical incidents with potential for dermal exposure

Resource name	Resource type	Source	URL
Principles of Clinical Toxicology (4th ed.)	Reference/text book	J.D. Bricker	http://www.abebooks.com/9780849353505/Principles-Clinical-Toxicology-Bricker-Douglas-0849353505/plp
Protective Clothing and Ensembles	Online	CDC	http://www.cdc.gov/niosh/topics/protciothing/
Reactive Skin Decontamination Lotion (RSDL)	Online	Bracco Diagnostics	http://www.rsdecon.com/PDFs/RSDL-MSDS_US.pdf
Recognition and Management of Pesticide Poisonings (6th ed.) (EPA 735K13001)	Government document	EPA	http://www2.epa.gov/sites/production/files/documents/rmpp_6thed_final_lowresopt.pdf
Registry of Toxic Effects of Chemical Substances, Vols 1 and 2	Government document	NIOSH	http://www.cdc.gov/niosh/docs/97-119/pdfs/97-119.pdf
Resource Guide for Disaster Medicine and Public Health	Online	NLM	http://disasterllt.nlm.nih.gov/
Sax's Dangerous Properties of Industrial Materials (12th ed.)	Reference/text book	RJ. Lewis Sr, ed.	https://archive.org/details/dangerousproper00saxn
Sittig's Handbook of Toxic and Hazardous Chemicals and Carcinogens (6th ed.)	Reference/text book	R.P. Pohanish, ed.	http://www.amazon.com/Sittigs-Handbook-Hazard-ous-Chemicals-Carcinogens/dp/1437778690
Skin Exposure and Effects	Online	CDC	http://www.cdc.gov/niosh/topics/skin/
Skin Notation Profiles	Online	NIOSH	http://www.cdc.gov/niosh/topics/skin/skin-notation_profiles.html
Surface Contamination	Online	OSHA	https://www.osha.gov/SLTC/surfacecontamination/index.html
Symptoms of exposure to highly toxic chemicals	Online	WHO	http://www.who.int/environmental_health_emergencies/deliberate_events/symptoms_en.pdf
Technical Support Document for Exposure Assessment and Stochastic Analysis: Dermal Exposure Assessment	Online	California Office of Environmental Health Hazard Assessment	http://oehha.ca.gov/air/hot_spots/pdf/chap6.pdf
The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals (15th ed.)	Reference/text book	Royal Society of Chemistry	http://www.rsc.org/Publishing/Merckindex/
The Pesticide Manual: World Compendium (16th ed.)	Reference/text book	C. MacBean, ed. (British Crop Protection Council)	http://www.amazon.com/The-Pesticide-Manual-world-compendium/dp/190139686X
The United States Pharmacopeia 37/The National Formulary 32	Reference/text book	United States Pharmacopelal Convention	http://www.uspnf.com/uspnf/login
The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009	Online	WHO	http://www.who.int/ipcs/publications/pesticides_hazard_2009.pdf
Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs)	Reference/text book	ACCIH	http://www.acgih.org/store/ProductDetail.cfm?id=2331
Toxicology of the Eye (4th ed.)	Reference/text book	W.M. Grant	http://www.amazon.com/Toxlcology-Eye-Chemicals-Minerals-Systemic/dp/0398058601
TOXNET	Online	NLM	http://toxnet.nlm.nih.gov/
Ullmann's Encyclopedia of Industrial Chemistry (7th ed.)	Reference/text book	F. Ullmann	http://onlinelibrary.wlley.com/book/10.1002/14356007
Unified Incident Command and Decision Support (UICDS)	Online	UICDS	http://www.uicds.us/index.php
WebWISER (Wireless Information System for Emergency Responders): Online version	Online	NLM	http://webwiser.nlm.nih.gov/getHomeData.do
WHO Manual: The Public Health Management of Chemical Incidents	Online	WHO	http://whqlibdoc.who.int/publications/2009/9789241598149_eng.pdf
WISER (Wireless Information System for Emergency Responders)	Online	NLM	http://wiser.nlm.nih.gov/
Workplace Safety and Health Topics: Chemicals	Online	NIOSH	http://www.cdc.gov/niosh/topics/chemical.html