

Physical and Chemical Hazards

INTRODUCTION

Hazard assessment (or analysis) includes the identification, evaluation, and mitigation (or control) of hazards.

The process of hazard identification involves the identification of (a) potential sources of hazards and (b) types (categories, classes) of hazards. Sources of hazards are inclusive of a wide range of structures, materials, operations, activities, circumstances, and phenomena, including (but not limited to) such sources as those included in Table 5.1 and Fig. 5.1. Types of hazards include specific physical, chemical, and biological agents (Fig. 5.2) that, regardless of their source or the circumstance in which they are encountered, present specific categories of safety and health risk.

Throughout the world, industrial facilities are under increasing regulatory control regarding the types of hazards that are typically associated with particular types of industrial activities, such as the hazards associated with the industrial use of chemicals. Agencies and organizations having responsibility for responding to emergencies also give particular attention to the types of hazards they are likely to encounter in their role as responders. In some instances, the range of hazards likely to be encountered is extremely comprehensive, as in the case of a fire fighting company; in others, the range may be considerably more narrow, as in the case of a specialized water rescue team. The range of hazards to be associated with either a particular industrial facility or the typical activities of an emergency response organizations does not, in itself, determine the actual risk presented to employees, response personnel, or the general public. Rather, the wider the range of potential hazards, the more comprehensive must be the planning effort devoted to maximizing both the day-to-day control of those hazards and, in the event of an incident, an efficient and effective emergency response. This is particularly the case at the municipal level which, after all, is typically the level that

TABLE 5.1 Typical Examples of Community Hazards (Adapted from U.S. Fire Administration, 1995: Technical Rescue Program Development Manual [FA-159])

Source of Risk	Potential Hazards
Sewers	Confined spaces; toxic gases; oxygen deficiency
Rivers/flood ducts, flood-prone areas	Swift water rescue; calm water rescue; toxic water environments; surface and underwater rescue; ice rescue
Industrial facilities	Hazardous materials; toxic gas emissions; confined spaces; machinery entrapment
Cliffs/gorges/ravines/mountains	Above grade and below grade rescue
Agricultural facilities	Dust explosions; confined spaces, hazardous materials; fertilizers; machinery entrapment
Cesspools/tanks	Toxic gases; oxygen deficiency; confined spaces
New construction	Structural collapse; trench rescue; machinery entrapment
Old buildings	Structural collapse
Wells/caves	Confined spaces; hazardous environments
High-rises	High angle rescue; elevator rescue
Earthquakes/hurricanes/tornadoes	Collapse rescue; extrication; disaster response
Transfer facilities	Hazardous materials; toxic gas emissions; confined spaces; machinery entrapment
Transportation centers	Hazardous materials; toxic gas emissions; confined spaces; machinery entrapment; derailment

is inclusive of all the diverse hazards associated with different industries, the diverse needs of local response services that must meet all contingencies, and, in addition, all nonindustrial hazards that put the public as well as response personnel at risk.

Given the diversity of hazard sources as well as types of physical, chemical, and biological hazards, there can be no question that the comprehensive identification of hazards, which is the first step toward the effective control of those hazards, must be achieved through a partnership of facility owners and operators, emergency response authorities, and municipal authorities. In the United States, such a partnership (Chapter 1) is the basic objective of the Federal Emergency and Community Right-to-Know Act of 1986 (EPCRA; SARA Title III).

STRUCTURAL, MATERIAL, AND OPERATIONAL SOURCES OF HAZARDS

Whether at a facility or municipal level, it is useful to approach hazard identification by focusing first on particular structures, materials, and operations that may present specific types of risks in a variety of different circumstances.

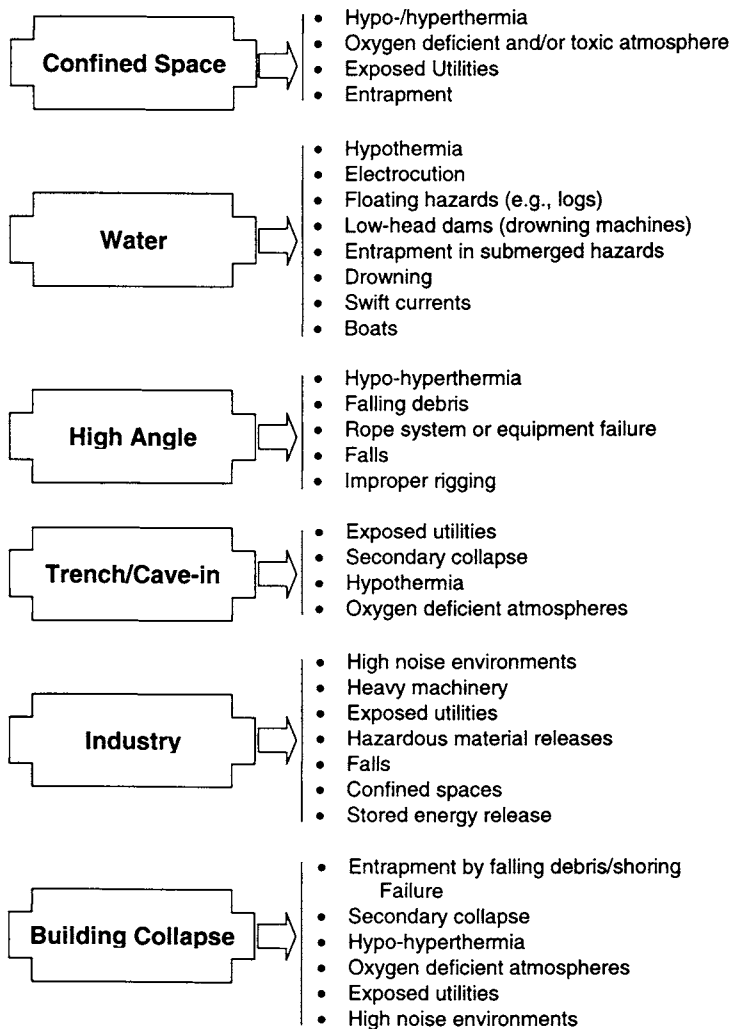


FIGURE 5.1 Sources of rescue hazards (adapted from U.S. Fire Administration, 1996: Technical Rescue Program Development Manual [FA-159, 2/96]).

Structural elements of any facility (e.g., general layout, floor plans, HVAC and sprinkler systems, construction materials, and engineering specifications) should be examined from the perspective of their becoming not only a source of hazard to persons who work or live inside the facility (employees, tenants), but also to emergency response personnel who may have to respond to an emergency in that facility. Just how structural elements may

Physical Agents

➔	Acoustic Radiation	Sonic and ultrasonic sound, including continuous and intermittent (impact) noise
➔	Temperature	Heat and cold stress
➔	Magnetic Radiation	Magnetic flux densities, including those having influence on implanted medical devices and ferromagnetic tools
➔	Electromagnetic Radiation	Visible light, lasers, radiofrequency/microwave radiation, ultraviolet radiation, and x-rays
➔	Radioactivity	Radionuclides and radiation (alpha, beta and gamma) associated with unstable atomic nuclei/nuclear reactions
➔	Ergonomic Stress	Stress associated with mechanical tensions in musculo-skeletal system
➔	Physical Impact	Mechanical impact that exerts physical force on the body

Chemical Agents

➔	Physical Risk	
	Asphyxiant	Vapors displace air and thereby cause suffocation
	Combustible	Burns when subjected to a temperature greater than 100°F and below 200°F
	Corrosive	Chemically burns living tissue on contact
	Explosive	Suddenly releases pressure, gas and heat when ignited
	Flammable	Burns when subjected to a temperature less than 100°F
	Irritant	A non-corrosive material that causes itching, soreness or inflammation of exposed skin, eyes or mucous membranes
	Pyrophoric	Ignites spontaneously in air at temperatures of 130°F or lower
	Organic Peroxide	Spontaneously explodes due to the formation of unstable peroxides
	Oxidizer	Promotes or initiates the burning of combustible or flammable materials
	Water Reactive	Reacts with water to form a flammable or toxic gas
	Unstable/Reactive	Spontaneously explodes with production of pressure, gas, heat and possibly toxic fumes

FIGURE 5.2 Physical, chemical, and biological agents presenting human risk.

Chemical Agents

➔ Health Risk

Carcinogen	Causes cancer
Mutagen	Causes changes in genetic information that is inherited from generation to generation
Poison	Causes life-threatening damage to tissues or internal organs in very small amounts (e.g., several teaspoons or less)
Sensitizer	Causes allergic reactions after repeated exposures, with possibly severe or even life-threatening consequences
Teratogen	Causes malformation of the developing fetus
Toxic	Causes life-threatening damage to tissues or internal organs, but in amounts greater than a poison

Biological Agents

➔ Bloodborne Pathogens	Disease causing organisms that may be transmitted through blood & other related body fluids of infected persons
➔ Other Pathogens	Infectious diseases that may be transmitted by means other than the body fluids of infected persons (e.g., air, food)

FIGURE 5.2—*continued*

contribute to an actual emergency depends, of course, on a variety of circumstances, including not only normal circumstances, but also floods, fire, earthquake, and terrorist attack.

For example, if a building is constructed downslope of unconsolidated (or unprotected) soils, design specifications may or may not be sufficient to prevent building collapse as a result of mud flow. If significant mud flow is not a possibility, may not heavy rainfall and subsequent flooding result in an explosion due to the location of non-flood-protected ground-level or subterranean storage areas used for storing water-reactive chemicals? If glass is a substantial component of structural design, does this not present clear categorical risks to employees during an explosion, as well as to fire fighters during fire fighting operations? Are stairwells kept at positive atmospheric pressure to ensure their effectiveness as smoke-free evacuation routes during fire? What state-of-the-art design and engineering features are employed to minimize catastrophic releases of hazardous fuels (e.g., natural gas, oil) during earthquake, or of other hazardous chemicals in even normal circumstances? How do design features make maximum use of fire- and toxic-rated materials to minimize the spread of fire and toxic fumes? In congested

industrial areas (e.g., seaports; industrial parks; mixed industrial, commercial, and residential areas), how do facility layout and transportation corridors (ground, water, and air) facilitate or prevent rapid access by community response authorities?

Several guidelines are well worth considering in the process of identifying potential hazards related to structures and their design features:

1. It is clearly not sufficient to disregard any potential hazard simply because a particular structural or design element meets the requirements of a particular legal building or construction code. After all, an appropriate code may be lacking or, if legally pertinent, not necessarily as effective as state-of-the-art practice and technology. The basic rule must be: regulatory compliance is always a *de minimus* requirement when it comes to health and safety.

2. Structural and design elements should be planned and implemented only after consideration of appropriately defined worst-case circumstances that, at a minimum, include fire, flood, storm, power-outage, earthquake, and terrorist attack.

3. Owners, operators, and other parties having legal responsibility for a facility should understand that, regardless of any regulatory rule, there can be no excuse for failing to coordinate with and seek the advice of local emergency response authorities regarding the structural design of that facility, including both original plans and any subsequent modifications.

Materials to be considered in any comprehensive identification of potential hazards typically include (beyond structural materials considered above) materials serving as feedstock to industrial and commercial processes, by-products of operational processes, and final process wastes.

Increasingly, global attention has begun to focus on what is commonly called the *product-cycle*, which is the totality of material and energy transformations that take place over the production, use, and final disposal of manufactured goods. It should therefore be no surprise that the comprehensive identification of hazards is increasingly presumed to be inclusive of those hazards associated not only with process feedstock, process by-products, and process wastes, but also with so-called “finished goods” as well as any material resultant from the use and environmental degradation of those goods. The assessment of new pharmaceutical products in the United States under the National Environmental Policy Act (NEPA), for example, specifically requires such a comprehensive evaluation of potential hazards.

Given the fact that a technologically developed society depends upon the daily industrial and commercial use of roughly 60,000 chemicals, the identification of hazards related to these individual chemicals and to the multitude of their combinations is certainly a daunting and demanding task—but it is a task that is nonetheless required under a constantly expanding number of laws, regulations, and standards implemented not only by national and local governments, but also by international organizations.

It is a mistake for municipal managers and community response services to assume that manufacturing industries are the only potential source of hazardous chemicals. For example, hazardous chemicals may be released into the community during various phases of new development or urban renewal projects, including property management phases prior to construction (e.g., demolition of existing structures that may contain hazardous chemicals as structural components), construction (e.g., on-site storage and preparation of materials and supplies, placement of contaminated fill, fugitive dusts that contain chemical contaminants), and operational and maintenance phases (e.g., runoff from operational site, application of pesticides).

Given the variety of potential sources of hazardous chemicals and materials, it is necessary to collate data and information from a variety of sources, including:

- Chemical inventories of industrial and commercial facilities (including feedstock, process, and waste chemicals)
- Records of previous land use that might be used to indicate chemical contaminants in soils or downstream wetland and lentic muds
- Records of previous incidents involving chemical releases in specific areas (including records maintained by regulatory agencies and/or community response services)
- Data and information that may be available through scientific surveys of local or regional resources (including surveys conducted by corporations and other land buyers to identify potential contamination of on-the-market parcels)

Operations that must be considered in any assessment of potential hazards include all on- and off-site operations (whether industrial or commercial) that involve the transportation, delivery, storage, handling, processing, or disposal of hazardous chemicals and materials.

While chemicals and materials are typically described as being hazardous by different regulatory agencies using diverse criteria and standards (and having different jurisdictional objectives), it is important to understand that all chemicals are intrinsically hazardous, and that the actual degree of risk presented by any hazard depends on a number of factors, including (but not limited to) the magnitude of exposure (i.e., *dose*), the route by which the chemical enters the body (i.e., *route of entry*), and the sensitivity of the person who becomes exposed (e.g., *hypersensitive*, *hyposensitive*). For purposes of identifying hazards that might trigger an emergency response, it is therefore inexcusable to dismiss as unimportant any chemical or material simply because it does not have a regulation-based designation (e.g., a *hazardous material* [under U.S. Department of Transportation regulations pursuant to the Hazardous Material Transportation Act]; a *hazardous waste* [under U.S. Environmental Protection Agency regulations pursuant to the Resource Conservation and Recovery Act]).

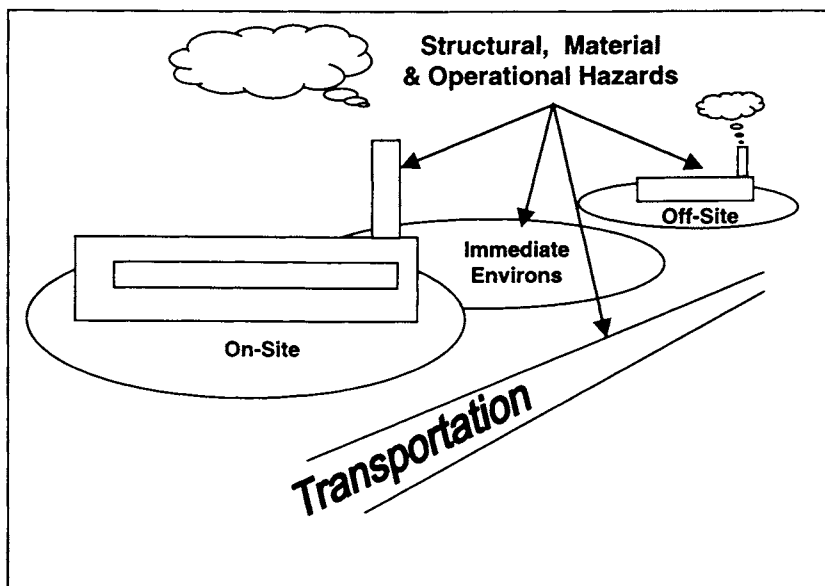


FIGURE 5.3 Holistic perspective of facility hazards is inclusive of all on- and off-site facilities, materials, and operations.

In light of these considerations, the assessment of structural, material, and operational hazards for the purpose of identifying potential hazards that may result in an emergency must be holistic—inclusive of not only industrial and commercial facilities, but also any activity (e.g., land clearing, delivery of feedstock chemicals) or circumstance (e.g., flood) that can trigger or otherwise exacerbate any emergency involving either or all; inclusive also of not only on-site features of any particular facility or activity, but also all off-site subsidiary or complementary activities and services related (directly or indirectly) to that facility, whether in the immediate environs or distantly located (Fig. 5.3).

HAZARD EVALUATION AND MITIGATION

As discussed in Chapter 2, standard procedures for conducting the appropriate analysis of hazards include Preliminary Hazard Analysis (PHA), What-if Analysis, Hazard and Operability Analysis (HAZOP), Failure Modes and Effects Analysis, Fault- and Event-Tree Analysis, and Human Reliability Analysis. These and additional techniques are included in Figs. 5.4 and 5.5, which summarize some of their basic attributes. It must be

Procedure	Analysis	Hazards	Mitigation
Safety Review	■	■	■
Checklist Analysis	■	■	■
Relative Ranking	■	■	■
Preliminary Hazard Analysis	■	■	■
What-if Analysis	■	■	■
What-if /Checklist Analysis	■	■	■
Hazard and Operability Study	■	■	■
Failure Modes and Effects Analysis	■	■	■
Fault -Tree Analysis	■	■	■
Event-Tree Analysis	■	■	■
Cause-Consequence Analysis	■	■	■
Human Reliability Analysis	■	■	■

FIGURE 5.4 Comparison of common process safety assessment techniques: basic type of analysis and usefulness for prioritizing and mitigating hazards.

emphasized that the indicated procedures are only representative of many techniques in common use in both private and public sectors; new procedures are continually under development. Moreover, because some are more demanding than others (in terms of time, skills of personnel, required data and information bases, and the complexity of protocols), there continues to be very active development of commercially available software (especially for Failure Modes and Effects Analysis, and Fault- and Event-Tree Analysis) to facilitate their use.

The early development of most (if not all) of these procedures was greatly influenced in the United States by the Chemical Process Regulations (29 CFR 1910.119). Such hazard analysis procedures are therefore sometimes referred to as *process hazard analysis* procedures. As this name implies, the primary focus of these procedures is *to assess and minimize the potential for a catastrophic release of known hazardous chemicals*, such as occurred at the Union Carbide pesticide plant in Bhopal, India.

While the achievement of this objective is vital to the proactive phase of emergency response planning, *it must be made clear that analytical*

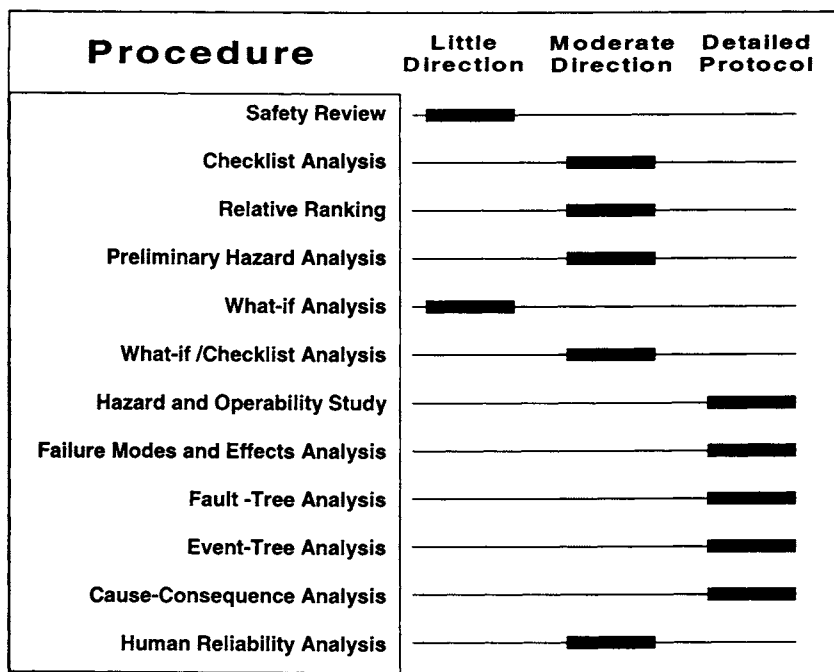


FIGURE 5.5 Comparison of common process safety assessment techniques: relative degree of direction provided by assessment protocols.

techniques used to assess the potential for catastrophic releases in the chemical industry are not sufficient to provide all the types of hazard assessment required by emergency response planning. For example, process hazard analysis typically does not define just what the health and safety hazards of a released chemical are but, rather, the sequence of events in the processing of chemicals that may lead to release. They do not define the actual health and safety probabilities attendant to chemical exposures (i.e., human risk) but, rather, the process-related probabilities of equipment or human failure (i.e., process risk) that will result in human exposure.

Another common approach to hazard assessment, and one which is to be clearly distinguished from a “process hazard analysis,” is generally referred to as Job-Task Analysis. This type of analysis (Fig. 5.6), which was originally given major impetus in the United States by hazardous waste regulations under the RCRA and, more recently, by workplace health and safety regulations under OSHA, involves the resolution of each workplace job into specifically defined task requirements. Each task requirement is then assessed with respect to health and safety risks likely to be encountered, with subsequent identification and evaluation of alternative means of reducing risks.

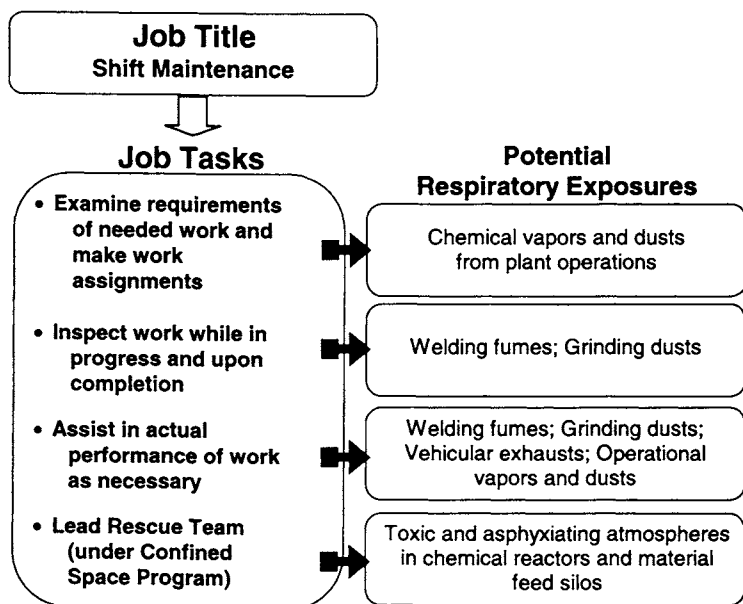


FIGURE 5.6 Example of a job-task (or job hazard) analysis.

The focus of Job-Task Analysis is clearly on (a) the manner in which the worker is exposed to hazard, (b) the risk to that specific worker as a consequence of exposure to the hazard, and (c) means for mitigating that risk. This approach to hazard assessment is a basic tool in any modern industrial program of occupational safety and health; it is also particularly relevant to corporate and municipal authorities having primary responsibility for emergency response planning because it requires that careful attention be given to each phase of hazard assessment (i.e., hazard identification, hazard evaluation, and mitigation) at the level of "human risk" rather than, as with process hazard assessment techniques, at the level of "process risk." This is not to say, of course, that process risk assessment is less important to emergency response planning than human risk assessment. Both are necessary. Neither alone is sufficient.

Scientific Basis of Chemical Hazard and Risk Assessment

As a potential harm or injury, any hazard associated with a chemical is intrinsic to that chemical and cannot be altered. Any chemical may be associated with several or more hazards.

Each of the roughly 60,000 chemicals in daily commercial use in technologically developed nations may be considered hazardous because, depending on the degree and nature of human exposure to it, each may result in harm or injury to an exposed person. Certainly some chemicals are more hazardous than others; the more hazardous are most often listed by regulatory agencies as requiring special attention regarding their handling, shipping, and storage.

As shown in Fig. 5.2, chemical hazards are often categorized as physical or health hazards. Physical hazards are those that result in physical injury to exposed persons; health hazards are those that result in physiological injury. Specific types of physical or health hazards are indicated by a chemical's *hazard class*.

Risk results from exposure to hazard. More specifically, risk is the statistical probability (or odds) that an organism will experience the specific harm or injury defined by hazard class. Generally, risk increases with exposure: the greater the exposure, the greater the risk. However, it is important to distinguish between physical and health risks.

Essentially a statistical concept, the risk of experiencing injury or harm to health reflects the fact that individuals within a population demonstrate a range of tolerance with respect to chemical exposure. Some individuals are very sensitive (hypersensitive) to certain chemicals, whereas others are relatively insensitive (hyposensitive). Contrarily, the risk of experiencing physical harm or injury as a result of exposure, for example, to a very strong acid or alkali, does not reflect a range of biological tolerance to chemical burns among humans but, rather, to the statistics of accidents.

Figure 5.7 depicts an example of a *dose-effect* (or *dose-response*) *relationship* between the *dose* of a toxic chemical (expressed as weight of the chemical per unit of body weight; e.g., mg/kg) and the probability of a particular effect (e.g., lethality). Dose-effect relationships may be established on the basis of laboratory experiments with animals and may also be inferred on the basis of epidemiological studies of humans. In laboratory studies, the experimenter controls the exposure of the test organisms to the toxic chemical. In epidemiological studies, exposures are inferred from information about workplace and other exposures of humans to the chemical of interest; that is, exposures are not controlled by the experimenter but by the life experience of the persons included in the study.

As shown in Fig. 5.7, the LD_{50} (*lethal dose*) represents the dose at which 50% of the test organisms (of the same species) exposed to that dose are expected to die. This statistic essentially states that any one organism exposed to that dose has a 50/50 chance (or 0.5 probability) of dying. If some health effect of exposure other than lethality is of interest (e.g., loss of hair, rapid heart beat), an ED_{50} (*effective dose*) can be similarly determined.

LD_{50} and ED_{50} data are based on studies in which the chemical is actually introduced into the organism (e.g., through inhalation, infection);

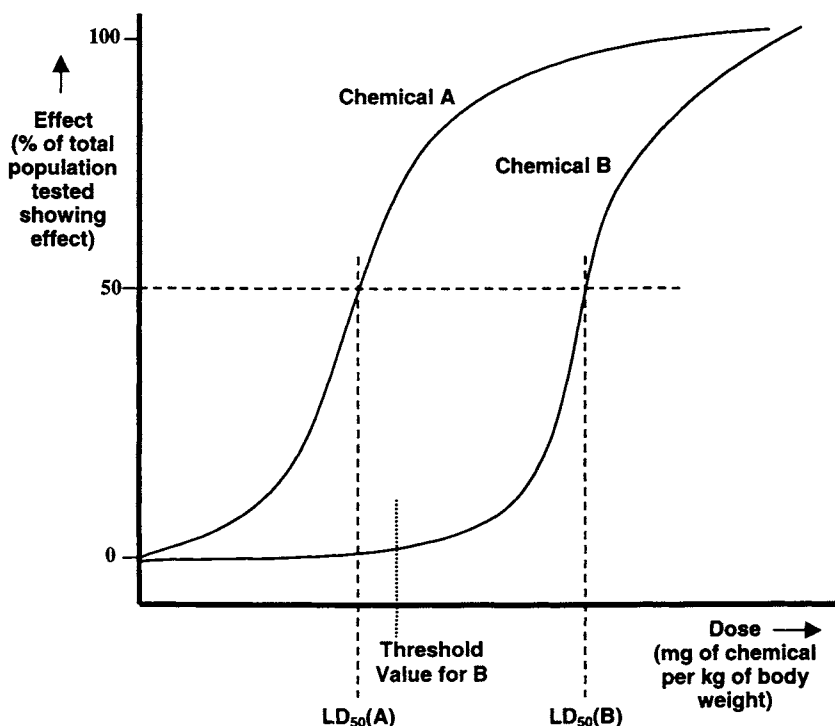


FIGURE 5.7 Dose-effect (response) relationships for two chemicals. Note that some effect (i.e., lethality) is seen for every incremental increase in dose of chemical A, whereas increase in dose of chemical B results in effect only after some threshold value of dose. Chemical A does not have a threshold value. The percentage of population showing lethal effects may also be read as the probability of death for an individual (e.g., 50% of the population is equivalent to a 0.5 probability for any individual).

the dose therefore defines that introduced amount. In many instances, the concentration of the toxic chemical in the atmosphere or water in which the test organism lives or functions (i.e., *ambient concentration*) is known, but the amount actually taken into the organism is unknown. In such cases, LC_{50} and EC_{50} are used to denote, respectively, the lethal concentration for a 0.5 probability of lethality and the effective concentration for a 0.5 probability of some other effect.

LD_{50} , LC_{50} , ED_{50} , and EC_{50} values are very useful for defining the relative toxicities of different chemicals. For example, Table 5.2 includes LD_{50} values and commonly used categories of relative toxicity. Although these terms are in general use, LD_{50} values do have important limitations when comparing the toxicity of two or more chemicals. For example, Fig. 5.8 shows the straight line portions of the dose-effect curves for two

TABLE 5.2 Commonly Used Terms and Criteria That Describe Relative Toxicity

Relative Toxicity	LD ₅₀ (mg/kg) ¹	Lethal Amount ²	Examples of Chemicals ³
Extremely Toxic (Poison)	< 1	< 7 drops	Dioxin Botulinus toxin Tetrodotoxin
Highly Toxic (Poison)	1 - 50	7 drops - 1 teaspoon	Hydrogen cyanide Nickel oxide Arsenic trioxide
Very Toxic	50 - 500	1 teaspoon - 1 ounce	Methylene chloride Phenol DDT
Moderately Toxic	500 - 5000	1 ounce - 1 pint	Benzene Chloroform Chromium chloride
Slightly Toxic	> 5000	> 1 pint	Acetone Ethyl alcohol Ferrous sulfate
1. As tested by the oral route in rats 2. Lethal amount for average adult human, based on liquid with density of water 3. As tested by various routes in several animal species			

different chemicals. Note that although both chemicals have equal LD₅₀s, increasing the dose of one chemical results in a smaller incremental increase in risk than does increasing the dose of the other.

The dose of a chemical received as a result of exposure is of paramount importance with respect to the health hazard of a chemical. However, it can be irrelevant in certain circumstances. For example, once allergic to a particular chemical, a person can experience a life-threatening episode upon even the most minuscule exposure to that chemical (i.e., an allergen). Also, no well-defined relationship exists between the dose of carcinogens, mutagens, and teratogens and the risk of experiencing their respective hazards.

Acute and Chronic Effects

The various effects of chemical exposure may be described as *acute* or *chronic* effects. Acute effects are those that occur very quickly (e.g., minutes, hours, days) after exposure to the causative chemical agent. As-

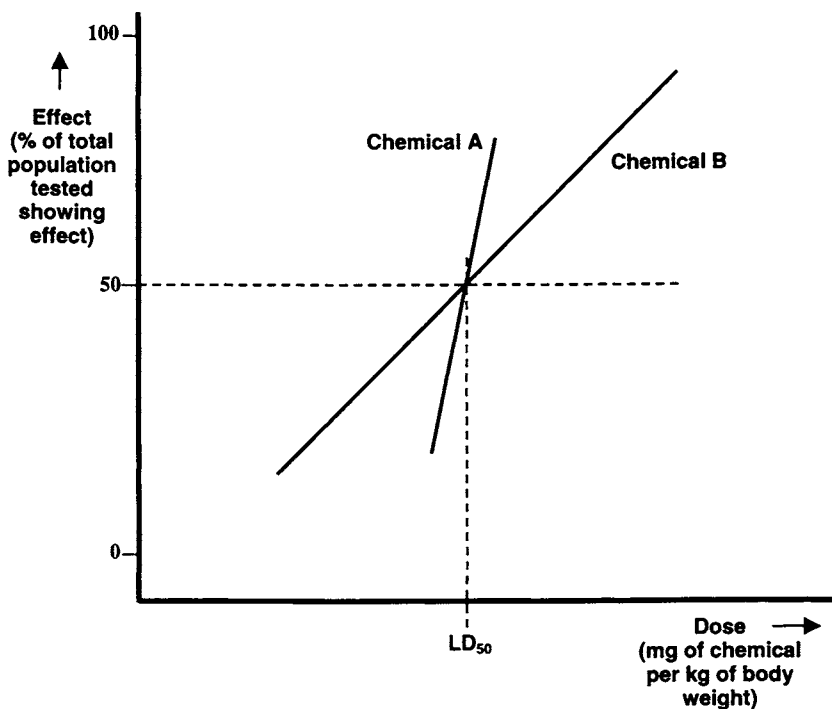


FIGURE 5.8 Dose–effect curves for two chemicals with the same LD_{50} . Note that incremental increases in dose result in greater increases in the percentage of population affected for chemical A than for chemical B. At doses less than the LD_{50} , chemical B is more potent than chemical A; at doses greater than the LD_{50} , chemical A is more potent than chemical B.

phyxiants, explosives, pyrophorics, organic peroxides, water reactive and unstable/reactive chemicals, corrosives, and poisons typically produce acute effects. Chronic effects are those that occur only after long periods of time postexposure (e.g., years, decades), including effects of sensitizers and carcinogens. Many lung cancers related to exposure to asbestos and cigarette smoke, for example, develop only after as long as 40 years.

Because chronic effects become apparent only over extended periods of time, they are particularly difficult to relate to a specific exposure to a particular chemical. As a result, our current state of knowledge regarding the potential effects of the more than 60,000 chemicals in daily commerce tends to be much more extensive with respect to their acute effects than their chronic effects. This state of affairs, however, reflects only the methodological difficulties involved in the scientific investigation of chronic effects, and does not imply that chronic effects should be of less concern. In fact, the paucity of scientific data regarding the chronic effects of exposure to

hazardous chemicals is sufficient reason to be particularly wary regarding the potential for chronic effects, especially with regard to periodic exposures experienced by community emergency response service personnel.

The phrase “target organ effects” is often used to specify the particular organs, tissues, cells, and physiologically important systems that are particularly affected by a specific hazardous chemical, regardless of whether the effects are acute or chronic. Target organs typically affected by a wide range of common commercial chemicals include the skin, eye, mucous membranes, respiratory tract, lungs, liver, kidney, reproductive system, and central nervous system.

Dimensions of Exposure

The term “exposure” denotes some measure of the amount of chemical to which a person may be subjected, either as a dose that enters the body or, as is often the case in emergency response, as a concentration in the ambient atmosphere. However, the risk of experiencing a health effect is not simply a function of dose or concentration. Other factors that influence risk include age, gender, general state of health, lifestyle, and any medications (or drugs) a person may use.

In some instances, one or more of these exposure-related factors may dramatically increase the risk of exposure to a hazardous chemical. For example, smoking cigarettes imparts a certain risk to a person of developing lung cancer; so does exposure to asbestos. However, the combination of these two factors results in a substantially greater risk than is imparted by either factor alone. The interaction of two or more chemicals to multiply the risks associated with any one chemical is an example of the phenomenon of *synergy*. Synergistic effects should be of particular concern to emergency response service personnel who, given the nature of their work, are likely to experience periodic exposures to a wide range of chemicals over a long period of time.

Another important factor that can directly influence risk is the particular means (*route of entry*) by which a chemical comes into contact with a person, including:

- Inhalation
- Ingestion (contamination of food and/or hands used to prepare or consume food, nasal drippings that have become contaminated through inhalation)
- Skin or eye contact (where the chemical action is at the surface)
- Absorption (through intact skin, eye, or mucous membranes; no physical lesions necessary)
- Puncture (or injection)

Not all chemicals can enter the body through all possible routes of entry. Most chemicals do, however, enter the body through two or more routes.

The toxicity of many chemicals is greater or lesser (i.e., in terms of the dose required to produce certain health effects) depending on the specific chemical and its specific route of entry. For example, a toxic chemical that is ingested will often have a higher LD_{50} (i.e., be less toxic on a per dose basis) than the same chemical injected directly into the bloodstream. Knowing the various routes of entry for different hazardous chemicals is important because by blocking those routes of entry through the appropriate use of personal protective clothing and equipment (e.g., impervious gloves, respirators), we can effectively prevent exposure and thereby minimize risk.

Environmental Transport and Transformation

Once a chemical enters the environment it is subject to a variety of mechanisms that transport it from place to place and from one environmental medium to another (e.g., soil to air, air to water). During transport, a chemical may also undergo transformation because of dynamic physical, chemical, and biological processes (e.g., combustion). Some environmentally mediated transformations of chemicals can result in the production of a chemical (or chemical by-product) that is more toxic than the original chemical.

The environmental transport and transformation of a chemical is often referred to as the *environmental fate* of that chemical. Computerized multimedia environmental models describe the environmental fate of chemicals and are increasingly available commercially. These models are important for calculating the probable concentrations of different chemical species in different environmental media, as may be expected as a result of chemical release to the environment. Computerized models are also particularly useful to emergency response personnel insofar as they have the capacity to predict atmospheric flows of chemical plumes under a variety of ambient conditions. Such models are most often called *air (or water) dispersion models*.

CONSOLIDATION OF INFORMATION AND DATABASE

There is no question that there are vast amounts of information and data regarding hazard assessment that are readily available through governmental agencies (e.g., Nuclear Regulatory Commission, National Institute of Occupational Safety and Health, the U.S. Fire Administration), private organizations (e.g., CHEMTREC) and electronic network services (e.g., National Pesticide Telecommunications Network), corporate regulatory com-

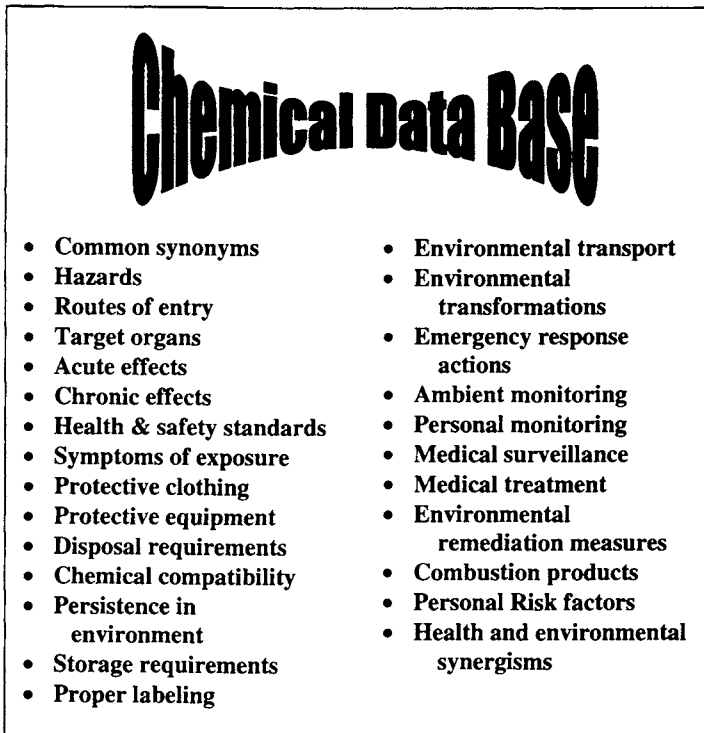


FIGURE 5.9 Example of contents of a computerized industrial chemical database used to inform and direct all decision making regarding personnel health and safety programs, including the emergency response program.

pliance plans (e.g., Hazard Communication Plan), chemical manufacturers (e.g., Material Safety Data Sheets), and, of course, commercial publications. However, the ready availability of printed or electronic information and data does not in any way guarantee the practical application of that information and data to the manifold needs of effective emergency response planning.

Whether at the national, regional, municipal, or corporate level, relevant data and information must not only be collected but, most importantly, organized into useful formats and translated into protocols that can be directly used to meet the urgent needs of site-specific emergency response. It is not, after all, the amount of information and data on hand that is important for preventing, planning for, or responding to an emergency; rather, what is important is precisely how specific information and data are consolidated into actual proactive and reactive practice.

For example, Fig. 5.9 is a summary of information related to the in-plant inventory of chemicals in a small manufacturing company. This infor-

**Use this
Table When
the Material
is NOT
on Fire**

Small Spills ← → **Large Spills**

ID No.	Name of Material	Small Spills		Large Spills	
		Feet	Miles	Feet	Miles
1051	Hydrocyanic Acid	600	2	600	2
1051	Hydrogen Cyanide (anhydrous, stabilized)	600	2	600	2
1052	Hydrofluoric Acid (anhydrous)	300	1	900	3
1052	Hydrofluoric Acid (anhydrous)	300	1	900	3
1053	Hydrogen Sulfide	1500	5	1500	5

FIGURE 5.10 Example of page entries on standard guide regarding the proper response to small and large spills of specific chemicals (adapted from U.S. Department Transportation [DOT], Guidebook for First Response to Hazardous Materials Incidents).

mation is consolidated into a computerized database (of roughly 1500 chemicals, including feedstock, by-products, and wastes) that serves as the basis of corporate policy, operational procedures, and all personnel training related to occupational health and safety, including both in-house and community emergency response services.

While there are many readily available, excellent guides that are very useful as generic tools (Fig. 5.10) for implementing effective emergency prevention, planning, and response programs, there can be no substitute for those tools specifically fashioned to meet facility-specific, place-specific, and circumstance-specific emergency response needs.