Guidance Document and
Technical Workshop Report

Anticipating Occupational Hazards of Cleanup Technologies:

REMEMBERING THE WORKER

Sponsored by:

The National Institute of Environmental Health Sciences
Worker Education and Training Program
in the Division of Extramural Research and Training

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The U.S. Department of Energy
Office of Worker Health and Safety
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PREFACE

According to the Office of Technology Assessment in a July 1995 report, "Environmental Technology: Analysis of Selected Federal R&D Programs," billions of dollars — estimated at $2.5 to $3.5 billion — were spent in 1994 by Federal Agencies involved in research, development, and demonstration of new environmental remediation technologies. The Department of Energy (DOE), the Department of Defense, and the Environmental Protection Agency (EPA) all had major programs focusing on this area.

Recent reviews have established that these programs do not address occupational safety and health hazard analysis and prevention and emergency response considerations. Instead, such issues are addressed after the technology is deployed — a time consuming, costly approach.

There have been several recent, notable Federal efforts to develop comprehensive approaches to dealing with new and innovative remediation technology. Among them are the following:

- Some 3 years ago the EPA-Labor Superfund Safety and Health Task Force began focusing on new technology issues, resulting in an expanding awareness among the several agencies represented on the Task Force, which included EPA, DOE, the National Institute of Environmental Health Sciences (NIEHS), the Army Corps of Engineers, the National Institute for Occupational Safety and Health, and the Occupational Safety and Health Administration (OSHA). OSHA, under a cooperative agreement with EPA, undertook an effort to assess safety and health issues associated with new technologies already deployed and in operation at some EPA Superfund sites. The result was a unique program and product that provided a field-based safety and health guideline for hazardous waste site incinerator operations.

- EPA undertook the development of "Best Management Practices" for soils treatment technologies, which did not address safety and health issues.

- The Presidential Review Findings pursuant to Section 112 (r) (10) of the Clean Air Act prompted a multiple-agency effort to focus on the development of an Integrated Contingency Plan Guidance intended to be used by facilities to prepare emergency response plans.

These events show the emergence of interagency cooperation and coordination of effort. This spirit and their common interest and expertise brought DOE and NIEHS together in 1995 as joint sponsors of two technical workshops that addressed occupational safety and health and emergency response hazards associated with new and innovative environmental remediation technology.

Both agencies have large stakes in occupational safety and health and emergency response management. NIEHS has been, since the passage of the Superfund Amendments and Authorization Act of 1986, the administrator of the Federal hazardous waste operations and emergency response training grant program and, more recently, has administered the similar DOE training grant program. DOE has a well-funded and very active innovative environmental remediation technology development program, recently expanded to embrace occupational safety and health and emergency response issues through a partnership with the DOE Office of Worker Health and Safety. Concurrently, the DOE Office of Worker Health and Safety's new personal protective technology development program has begun to emerge.

The first technical workshop, held March 23 and 24, 1995, was an initial effort at developing a framework encompassing the occupational safety and health/new technology area. The second, on November 30 through December 1, using the first workshop product as a foundation, focused on the development of guidelines to aid those engaged in all aspects of new environmental technology in addressing and eliminating or mitigating occupational hazards and in providing the information essential to the development of effective emergency response programs at sites where the technology is deployed.

This report includes in the "Introduction" an overview of the technology life-cycle continuum in light of safety and health considerations. Part I, "Applying Process Safety Management Techniques and Technology Safety Data Sheets to the Development of New Cleanup Technologies," presents guidance on methods for the identification and mitigation of safety and health hazards during the technology life cycle. "Emergency Response Considerations for New Technology," Part II of the guidance, includes a framework for addressing emergency response planning that focuses on the hazards unique to a new technology. Appendix A presents the report from the March workshop and Appendix B the report of the November-December workshop. Finally, Appendix C discusses safety and health considerations during development, deployment, and implementation of new technologies.

It is the collective hope of the workshops' sponsors and participants that the guidance developed in the workshops and presented in this document will be used by and benefit the various organizations responsible for the development, implementation, and application of new technologies and that, as a result, the overall safety and health of workers and the public will be strengthened. We solicit comments on the usefulness of the material described here and any suggestions for changes that would further improve the remediation technology development process. The sponsors of the workshops will serve as the focal points for dissemination of any changes or revisions.

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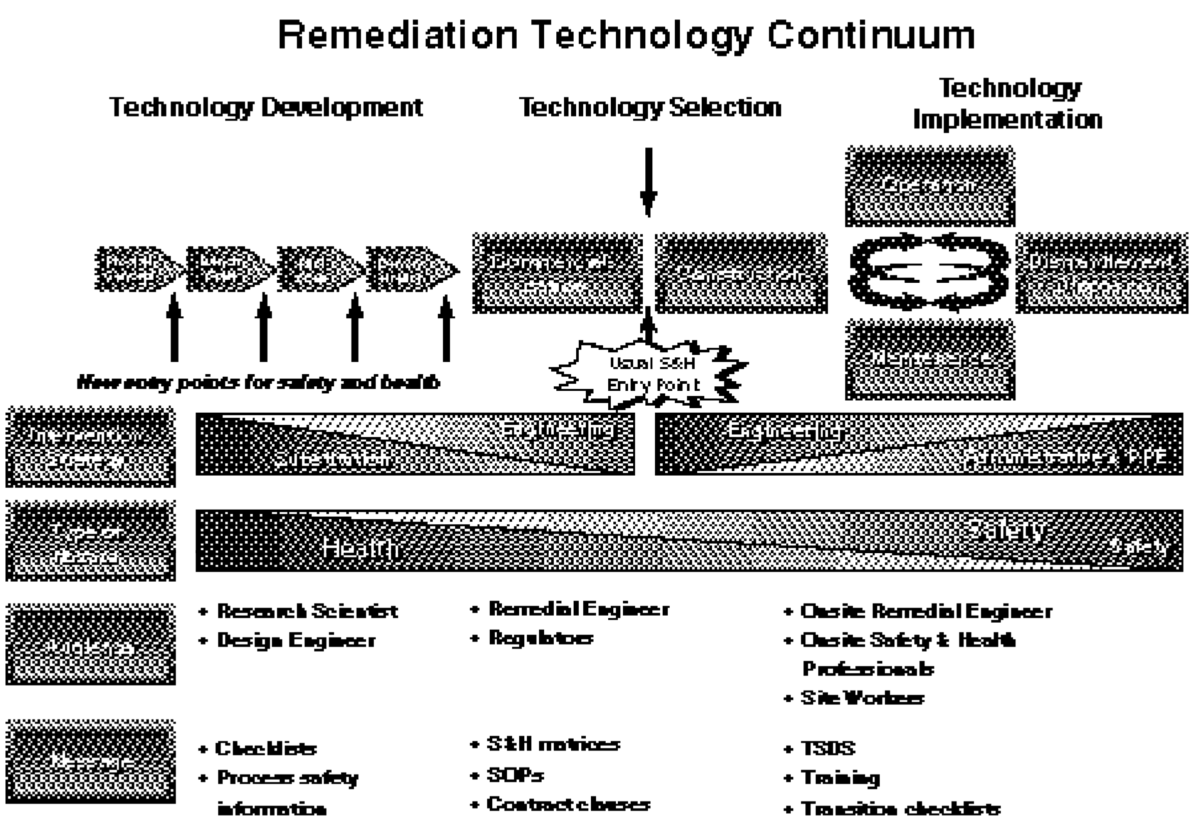
INTRODUCTION

Injecting Safety and Health Considerations Into the Technology Life-Cycle Continuum

In considering the life cycle of an environmental remediation technology — from idea through research and development, testing, implementation, operation, decommissioning, and dismantlement — it is clear that many opportunities exist to inject safety and health considerations into the technology life-cycle continuum (see illustration below). By recognizing risks as early as possible in the development and testing process, technologies that prove to be commercially viable can be constructed, operated, maintained, and dismantled with a minimum of health and safety hazards to workers at acceptable costs.



The technology continuum, highlighting new entry points.

To accomplish this objective, a process is needed to systematically identify and remove, wherever possible, safety and health hazards from environmental remediation technologies. This document is intended to provide guidance to people interested in contributing to the development of such a process that can be applied across a broad spectrum of technologies. Innovative strategies for hazard communication are also an important focus. Where hazards cannot be avoided in the research and development phase of an emerging technology, the goal is to reduce the safety and health hazards as much as practicable. The residual health and safety risks then must be communicated to field personnel actually using the technologies and performing the cleanup activities.

The protocols developed in the course of defining this process will be useful to research scientists, design engineers, site remediation engineers, safety professionals and, ultimately and perhaps most importantly, to workers. These groups or audiences have different perspectives and needs.

Research Scientists and Design Engineers: Because these individuals can influence the nature of a technology from the initial concept all the way through to demonstration, they are well positioned to mitigate its associated hazards. Such individuals must be encouraged to anticipate and consider hazards that may be new to them and to actively look for hazards in practical applications that were unforeseen in the conceptual stage.

Remedial Design Engineers: These engineers are responsible for selecting which technology will be used to clean up a particular site. Documentation aimed at these individuals will allow them to easily compare one technology with another in terms of safety and health hazards, and will be developed from the guidance supplied to senior safety professionals.

Senior Safety Professionals: These individuals have an in-depth understanding of safety and health hazards and the skill to identify them. The documentation aimed at these professionals includes protocols for hazard identification, which are intended to enhance their already advanced identification skills and to ensure thoroughness in the process. In addition, several vehicles are presented for conveying hazard information downstream, including safety and health hazard matrices, hazard rating scales, checklists for transitions from one stage of operation to another, and Technology Safety Data Sheets (TSDSs).

Onsite Safety Professionals and Workers: These individuals will benefit from strategies that outline how to effectively use hazard information in terms of informational programs, training programs, new-technology programs, planning, and document use. Onsite personnel also are closely involved in pre-incident planning and emergency response.

Background

Promulgation of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980 created an impetus for development of new technologies to treat soil, surface water, groundwater, and air emissions contaminated with hazardous materials. As the demand continues for cleanup technologies that are better designed than existing ones as well as being faster and cheaper to operate, new developments continue to evolve. However, though these new technologies receive close scrutiny as they move from the bench-scale stage through pilot testing and into actual operation, little attention has been given to the hazards they might pose to worker health and safety. The databases on environmental remediation technologies maintained by government agencies, such as the Environmental Protection Agency (EPA), the Department of Energy (DOE), and the Air Force, reveal the virtual absence of information regarding safety and health hazards that might be associated with new and emerging technologies. This is because health and safety considerations seldom are included in assessments of these technologies. For example, in an environmental technology review document prepared by DOE's Office of Technology Development[1] in October 1993, only a handful of references to worker safety are made.

Remembering the Worker

In defining ways to inject health and safety considerations into the process of developing innovative cleanup technologies, a key strategy is to remember the worker when health and safety risks finally become the focus of attention. Far too often, even when the focus is brought to bear on health and safety, the risks addressed are those faced by the public, such as contaminated drinking water from a hazardous waste site. Remediation documents often refer to "risks to the public and to workers," but this combined reference tends to downplay the real risks that workers face cleaning up hazardous waste sites — risks that are significantly greater than those faced by the public.

It follows, then, that those charged with making decisions about environmental cleanup technologies must ask what the risk is to the worker. Furthermore, they

[1] FY 1993 Program Summary, Office of Demonstration, Testing, and Evaluation, U.S. Department of Energy, Office of Environmental Restoration and Waste Management, p.10, October 1993.

must be careful not to become so preoccupied with eliminating even the most insignificant environmental health risks to the public that they ignore or underappreciate occupational health practices that pose significant risks to workers.

Emerging environmental remediation technologies are developed in a well-defined procedure that begins with an idea, moves through proof of concept, laboratory trials, bench-scale analysis, and then on to a pilot demonstration. If proven successful in this multistage and rigorous process, a technology can be primed for commercialization. It is during this stage that the ultimate effectiveness of a technology must be demonstrated to compete in the marketplace.

Once it is available on the market, a technology may be selected and implemented to perform a site remediation operation. Many considerations go into selecting a remediation technology, including effectiveness, operating costs, maintenance requirements, production capacity, dependability, and acceptability to the surrounding population. To date, little information has been developed regarding the safety and health hazards associated with remediation technologies. Consequently, engineers tasked with technology selection often do not consider the safety and health implications of their decisions. This can be a costly mistake because of the costs associated with the use of personal protective equipment (PPE), operator training, and the planning required to ensure the safe operation of potentially hazardous cleanup technologies.

The next phase in the technology continuum is selection of a technology for use at a specific site. The technology moves through four distinct stages in this phase, cycling in and out of two of them. As the figure on the first page of this section illustrates, the first stage is construction, the second is operation, the third entails cycling from maintenance to operation and back again, and the fourth is dismantlement and disposition.

The usual entry point of safety and health professionals into the technology development/implementation continuum is after the remediation technology has been selected. As the technology moves through the continuum, several important parameters change.

First, the types of hazards that can be addressed become more limited. Hazards to human health are associated with exposure to certain chemicals, biological agents, and/or physical stressors — hazards that are more successfully addressed in the early design stages of a technology's development when substitution of hazardous chemicals or agents can be made and tested. Hazards to safety, on the other hand, usually are identified later, for example, somewhere between the demonstration stage and commercialization. There are, of course, exceptions to every rule and it is important to consider potential safety hazards early and health hazards late in the process, with an eye toward eliminating all potential hazards.

Just as the types of occupational hazard that can be addressed change over the course of technology development, so does the type of intervention strategy that can be employed. The classic safety approach dictates that controls be used in the following hierarchical order: substitution, engineering control, administrative control and — if, and only if, all other strategies fail or are impractical — PPE. In the early stages of technology development, substitution is a workable control. The research scientist or design engineer can experiment with substituting chemical and physical agents that are less hazardous than those originally planned. As the basic chemical processes that define the chemical treatment process are further defined, however, substitution becomes less of an option.

If substitutions for hazardous chemicals and physical stressors cannot be made, potential exposure scenarios should be engineered out of the remediation technology. This intervention strategy is most applicable during the demonstration and commercialization stages. As a technology is implemented onsite, engineering controls become the predominant intervention strategy. In the late stages of implementation — operation and maintenance — administrative controls and the use of PPE predominate.

Types of Remediation Technologies

Hundreds of remediation technologies currently are in use. Each involves a distinct process and poses its own set of occupational hazards. The technologies can be grouped by the type of environmental media they treat: groundwater, soil vapor, soil, debris, and buildings. An overview of each group of technologies is presented below.

Technologies for Treating Contaminated Groundwater

Volatile Organic Compounds and Fuels

The most commonly used treatment technologies for volatile organic compounds (VOCs) in groundwater and surface water include carbon adsorption and ultraviolet (UV) oxidation. *In situ* treatment technologies are not widely used. Groundwater and surface water concentrations of contaminants usually are not sufficiently high to support biological processes.

Liquid phase **carbon adsorption** is a technology in which groundwater is pumped through a series of vessels containing activated carbon to which dissolved contaminants are absorbed. When the concentration of contaminants in the effluent from the bed exceeds a certain level, the carbon can be regenerated in place, removed and regenerated at an offsite facility, or removed and disposed of. Carbon used for explosives- or metals-contaminated groundwater must be removed and properly disposed of. Adsorption by activated carbon has a long history of use in treating municipal, industrial, and hazardous wastes.

UV oxidation is a destruction process that oxidizes organic and explosive constituents in wastewaters by the addition of strong oxidizers and irradiation with intense UV light. The oxidation reactions are catalyzed by UV light, while ozone and/or hydrogen peroxide are commonly used as oxidizing agents. The final products of oxidation are carbon dioxide, water, and salts. The main advantage of UV oxidation is that organic contaminants can be converted to relatively harmless carbon dioxide and water during the process. UV oxidation processes can be configured in batch or continuous-flow modes. Catalyst addition may enhance the performance of the system.

Air stripping involves the mass transfer of volatile contaminants from water to air. For groundwater remediation, this process is typically conducted in a packed tower or an aeration tank. The packed tower includes a spray nozzle at the top to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect decontaminated water. Auxiliary equipment that can be added to the basic air stripper includes automated control systems with sump-level switches and safety features such as differential pressure monitors, high sump-level switches and explosion-proof components, and discharge air treatment systems such as activated carbon units, catalytic oxidizers, or thermal oxidizers. Packed-tower air strippers are installed either as permanent installations on concrete pads, on a skid, or on a trailer.

For **free-product recovery,** undissolved liquid-phase organics are removed from subsurface formations, either by active methods (e.g., pumping) or a passive collection system. The free product is generally drawn up to the surface by a pumping system. Following recovery, it can be disposed of, reused directly in an operation not requiring high-purity materials, or purified prior to reuse. Systems may be designed to recover only product, mixed product and water, or separate streams of product and water (i.e., dual pump or dual well systems).

Inorganic Chemicals

Precipitation, filtration, and ion exchange are widely used *ex situ* treatment technologies for inorganics in groundwater and are discussed in the following paragraphs. *In situ* treatment technologies are used less frequently.

The combination of **precipitation/flocculation** and sedimentation is a well-established technology for removal of metals and radionuclides from groundwater. This technology pumps groundwater through extraction wells and then treats it to precipitate heavy metals. Typically, removal of metals involves precipitation with hydroxides, carbonates, or sulfides. Hydroxide precipitation with lime or sodium hydroxide is the most common choice. Generally, the precipitating agent is added to water in a rapid-mixing tank along with flocculating agents such as alum, lime, and/or various iron salts. This mixture then flows to a flocculation chamber that agglomerates particles, which are then separated from the liquid phase in a sedimentation chamber. Other physical processes, such as filtration, may follow.

Filtration isolates solid particles by running a fluid stream through a porous medium. The driving force is either gravity or a pressure differential across the filtration medium. Pressure-differentiated filtration techniques include separation by centrifugal force, vacuum, or positive pressure. The chemicals are not destroyed; they are merely concentrated, making reclamation possible. Parallel installation of double filters is recommended so groundwater extraction or injection pumps do not have to stop operating when filters backwash.

Ion exchange is a process whereby the toxic ions are removed from the aqueous phase in an exchange with relatively innocuous ions (e.g., sodium chloride) held by the ion exchange material. Modern ion exchange resins consist of synthetic organic materials containing ionic functional groups to which exchangeable ions are attached. These synthetic resins are structurally stable and exhibit a high exchange capacity. They can be tailored to show selectivity toward specific ions. The exchange reaction is reversible and concentration-dependent; the exchange resins are regenerable for reuse. The regeneration step creates a wastestream that must be treated separately. All metallic elements present as soluble species can be removed by ion exchange. A practical influent upper concentration limit for ion exchange is about 2,000 mg/L. A higher concentration results in rapid exhaustion of the resin and high regeneration costs.

Technologies for Treating Contaminated Soils

Volatile Organic Compounds and Fuels

Common treatment technologies for VOCs in soil, sediment, and sludge include biodegradation, incineration, and excavation with offsite disposal.

Biodegradation uses a process in which indigenous or inoculated microorganisms (e.g., fungi, bacteria, and other microbes) degrade (i.e., metabolize) organic contaminants found in soil and/or groundwater. In the presence of sufficient oxygen (aerobic conditions), microorganisms ultimately will convert many organic contaminants to carbon dioxide, water, and microbial cell mass. In the absence of oxygen (anaerobic conditions), the contaminants ultimately will be metabolized to methane and carbon dioxide. Sometimes contaminants may not be completely degraded, but instead be transformed to intermediate products that may be less hazardous than, equally as hazardous as, or more hazardous than the original contaminant.

All types of biodegradation, both *in situ* and *ex situ*, can be evaluated for use in soil remediation: *in situ* bioremediation, bioventing, composting, controlled solid phase, or landfarming. Treatability studies should be conducted to optimize design parameters, such as degradation rates, supplemental organism addition, cleanup levels achievable, degradation intermediates, and nutrient/oxygen addition.

The *in situ* bioremediation of soil typically involves the percolation or injection of groundwater or uncontaminated water mixed with nutrients. *Ex situ* bioremediation typically uses tilling or continuously mixed slurries to apply oxygen and nutrients, and is performed in a prepared bed (liners and aeration) or reactor.

Incineration uses high temperatures, 870 to 1,200 ^oC (1,400 to 2,200 ^oF), to volatilize and combust (in the presence of oxygen) organic constituents in hazardous wastes. The destruction and removal efficiency (DRE) for properly operated incinerators exceeds the 99.99 percent requirement for hazardous waste and can be increased to meet the 99.9999 percent requirement for polychlorinated biphenyls (PCBs) and dioxins. Distinct incinerator designs available for solids are rotary kiln, fluidized bed, and infrared units.

Excavation and removal of contaminated soil (with or without stabilization) to a landfill have been performed extensively at many sites. **Landfilling** of hazardous materials, especially hazardous wastes, is becoming increasingly difficult as a result of growing regulatory control, and may be cost-prohibitive for sites with large volumes, greater depths, or complex hydrogeologic environments. Determining the feasibility of offsite disposal requires knowledge of land disposal restrictions and other regulations developed by State governments.

Soil vapor extraction (SVE) is an *in situ* unsaturated (vadose) zone technology in which a vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semivolatile contaminants from the soil. The gas leaving the soil may be treated to recover or destroy the contaminants, depending on local and State air discharge regulations. Explosion-proof equipment should be used for fuels. Vertical extraction vents are typically used at depths of 1.5 meters (5 feet) or greater and have been successfully applied as deep as 91 meters (300 feet). Horizontal extraction vents (installed in trenches or horizontal borings) can be used as warranted by contamination zone geometry, drill rig access, or other site-specific factors.

Groundwater extraction pumps may be used to reduce groundwater upwelling induced by the vacuum or to increase the depth of the vadose zone. Air injection may be effective for facilitating extraction of deep contamination, contamination in low-permeability soils, and contamination in the saturated zone.

Low-temperature thermal desorption (LTTD) systems are physical separation processes and are not designed to destroy organic chemicals. Wastes are heated to between 90 ^{o} and 315 ^{o}C (200 ^{o} to 600 ^{o}F) to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system. Groundwater treatment concentrates the collected contaminants (e.g., carbon adsorption or condensation). The bed temperatures and residence times designed into these systems will volatilize selected contaminants but will typically not oxidize them. Decontaminated soil retains its physical properties and ability to support biological activity.

Inorganic Chemicals

The most commonly used treatment technologies for inorganics in soil include solidification/stabilization (S/S), and excavation and offsite (landfill) disposal. Solidification/stabilization is described briefly below; excavation and landfill disposal has already been discussed.

Solidification processes produce monolithic blocks of waste with high structural integrity. The contaminants do not necessarily interact chemically with the solidification reagents (typically cement/ash) but are mechanically locked within the solidified matrix. Stabilization methods usually involve the addition of materials such as fly ash, which limit the solubility or mobility of waste constituents, even though the physical handling characteristics of the waste may not be changed or improved. Solidification/stabilization of contaminated soil can be conducted either *in situ* or *ex situ*.

Technologies for Decontamination and Decommissioning of Buildings

Decontamination

Decontamination is a major decommissioning activity that may be used to accomplish several goals, such as reducing occupational exposure, reducing the potential for the release and uptake of radioactive material, permitting the reuse of a component, and facilitating waste management.

There are two primary categories of decontamination equipment or techniques: chemical and mechanical. Chemical decontamination uses concentrated or dilute solvents in contact with the contaminated item to dissolve either the base metal or the contamination film covering the base metal. Dissolution of the film is intended to be nondestructive to the base metal and is generally used for operating facilities. Dissolution of the base metal should be considered only in a decommissioning program where the item will never be reused. Chemical flushing is recommended for remote decontamination of intact piping systems. Chemical decontamination has also proven to be effective in reducing the radioactivity of large surface areas such as floors and walls as an alternative to partial or complete removal.

Mechanical and manual decontamination employs physical techniques. More recently, mechanical decontamination has included washing, swabbing, using foaming agents, and applying latex-peelable coatings. Mechanical techniques may also include wet or dry abrasive blasting, grinding of surfaces, and removal of concrete by spalling. These techniques are most applicable to the decontamination of structural surfaces.

In recent years, many innovative decontamination techniques have been proposed. For the most part, these emerging technologies are hybrid technologies comprising one or more of the following methods: chemical, electrochemical, biological, mechanical, or sonic methodology.

Dismantling, Segmenting, and Demolition

The decommissioning of nuclear facilities largely involves the segmentation of metal components and the cutting and demolition of concrete structures. Various techniques have been used for segmenting and demolishing these components and structures, and new techniques are being developed continually. The dismantling/segmenting techniques may be grouped into three categories: mechanical (e.g., saws, shears, cutters, explosives), thermal (e.g., plasma arc, oxygen burning, flame cutting), and others (e.g., abrasive water jet, carbon dioxide blasting).

Mechanical cutting techniques use mechanical forces and/or motions to cut various components (e.g., structures, piping) that may be encountered during decommissioning. The mechanical motions (reciprocating, circular) and forces (shear) are usually driven electrically, pneumatically, or hydraulically, resulting in the cutting and/or breaking of the component.

There are two types of thermal cutters: flame producers and arc producers. The more common are the flame-producing techniques where a flame is established by igniting fuel gases. With arc-producing techniques, an electrical arc is established between the tool and the workpiece. In both methods the workpiece is literally melted away.

Environmental Remediation Technologies—Case Studies

To date, the only serious review of operating remediation technologies from the standpoint of safety and health has provided cause for alarm. In September 1993, the Occupational Safety and Health Administration (OSHA) reported its findings based on inspections conducted at the following Superfund incinerator sites, most of which are similar in setup, as shown in Figure 1:

- Old Midland Products in Ola, AR
- Rose Township in Oakland County, MI
- Sikes disposal pits in Crosby, TX
- Big D campground in Kingsville, OH
- Bridgeport Rental and Oil Services in Bridgeport, NJ

OSHA found numerous safety and health deficiencies, including inadequate procedures for Process Safety Management (PSM) and for responding to an emergency. OSHA recommends as a best management practice that PSM be used even though the standard may not specifically apply. The adequacy of the agency's own response mechanisms was called into question in one case, where an inspection of an incinerator indicated that there were no standard operating procedures (SOPs) for emergency shutdown of the unit. The operator of the incinerator received a citation as a consequence, but it was unclear what would constitute a situation serious enough to require the unit to shut down, and how that would be done efficiently.

In addition to the specific safety hazards documented at the incinerator sites, epidemiological studies indicate the presence of general health hazards at such sites. A Swedish study of 176 male workers employed for at least 1 year at a municipal waste incinerator found excess deaths from lung cancer and ischemic heart disease.[2]

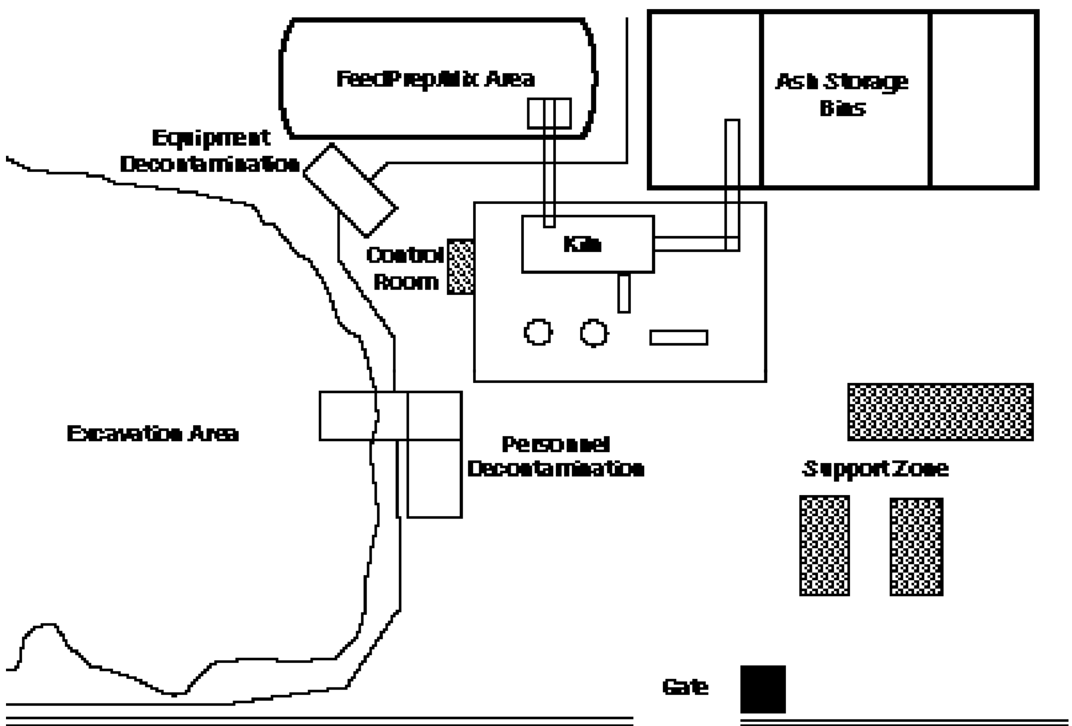


Figure 1. Generic incinerator.

[2] P. Gustavsson. "Mortality among Workers at a Municipal Waste Incinerator," *American Journal of Industrial Medicine*, 15:245-253, 1989.

Investigation and Identification of Hazards

It has been estimated that in some cases as much as 40 percent of the cost of remediation has been spent on controlling associated safety and health hazards through procedures, equipment, and training. Despite the large investment, safety and health procedures often are not considered at the outset during the development of new remediation technologies. Safety and health experts should be consulted routinely during the design phase to identify and investigate safety and health hazards.

Figure 2 illustrates a process for identifying hazards. Figure 3 shows the use of a site health and safety plan (HASP) as the medium through which hazards can be minimized. Specific health and safety hazards must be addressed through the HASP as well as the program requirements of the Hazardous Waste Operations and Emergency Response (HAZWOPER) Standard (see 29 CFR 1910.120).

The result of this effort is the development of component programs that address particular hazards identified through the analysis. Safety and health professionals familiar with a given site can use these component programs as guidance in developing a site-specific program.

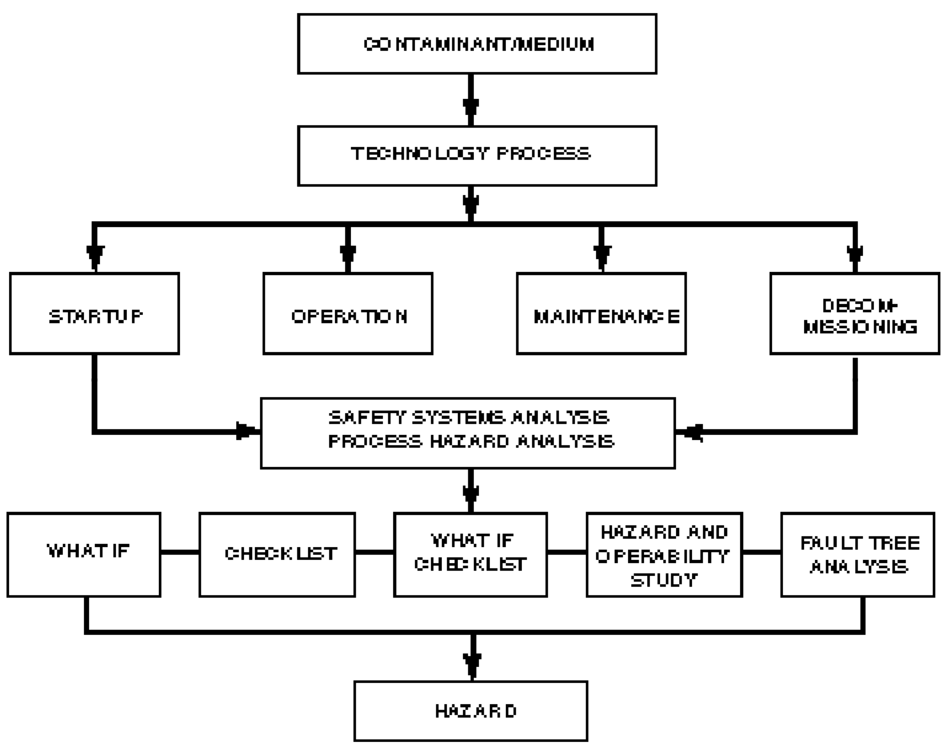


Figure 2. Technology hazard identification process.

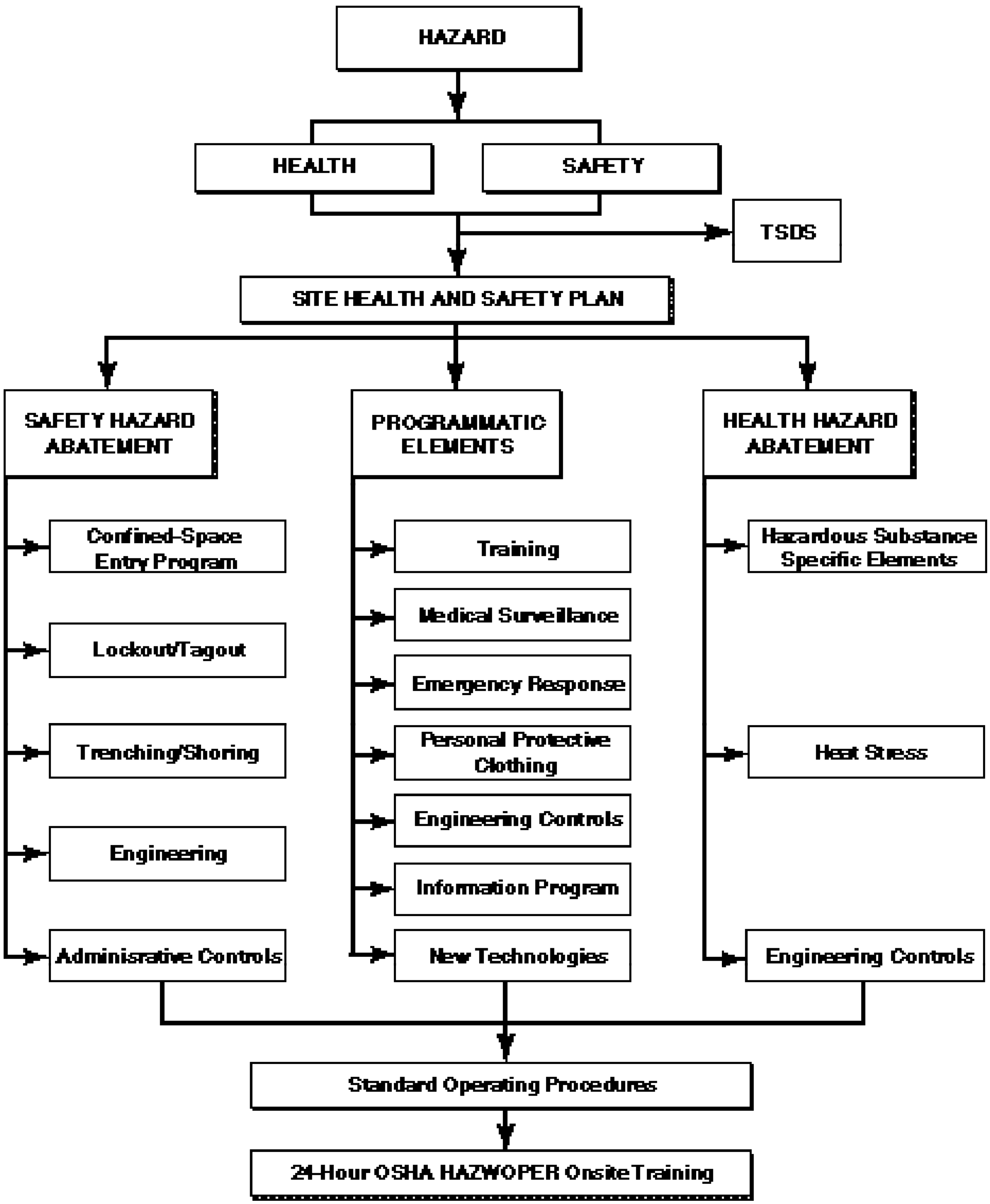


Figure 3. Technology hazard mitigation process.

Checklists for Safe Transitions

The transition from one phase of technology implementation to another can be extremely hazardous, such as when a technology moves from construction through startup to operation, or from operation through shutdown to maintenance, or as the result of decommissioning operations. A transition may be the result of an emergency in which the technology involved moves out of operation into shutdown mode. Because such transitions usually are inherently dangerous, SOPs should be developed to minimize potential consequences. These checklists are designed to remind operators of all the procedures required to move a technology safely from one phase of operation to another.

A Two-Part Approach to Addressing New Technology Hazards

In attempting to transition from general considerations of worker safety and health associated with new technologies, as presented in the preceding text, the Workshop participants sought to develop guidance approaches to addressing the hazards associated with the design, development, deployment, use, and unique emergency hazards specific to new technologies. Toward that objective, the Workshop participants focused attention on the development of two guidance documents:

I. Applying Process Safety Management Techniques and Technology Safety Data Sheets to the Development of New Cleanup Technologies.

II. Emergency Response Considerations for New Technology.

These two guidance documents are presented in the following as Parts I and II.

PART I

Guidance for Applying Process Safety Management Techniques and Technology Safety Data Sheets to the Development of New Cleanup Technologies

Introduction

The Occupational Safety and Health Administration's (OSHA) Standard, "Process Safety Management (PSM) of Highly Hazardous Chemicals," as promulgated in 29 CFR 1910.119, was established to prevent or minimize consequences from the catastrophic releases of toxic, reactive, flammable, or explosive chemicals that may result in fire or explosion hazards. Although the requirements of PSM apply only to specific processes, the principles and guidance in the Standard can be used as aids in addressing safety and health hazards and prevention actions for cleanup technologies. The goals of the PSM Standard are to build safety into the process up-front, and then keep the process operating safely for its entire life cycle.

The Process Safety Management Standard also introduces the concept of a Technology Safety Data Sheet (TSDS) as a tool to assist in managing safety throughout the technology development and implementation process. As discussed in the following pages, the TSDS can be used as a vehicle for collecting most of the safety, health, and emergency response information associated with a new technology. It is anticipated that the TSDS would first be prepared during the technology development process and that it would continue to be updated as the technology evolves throughout the commercialization and implementation phases of technology implementation. An example of a TSDS and a short case study are included here to illustrate how the data could be used in a practical situation. Finally, the TSDS is used to develop a list of standard operating procedures (SOPs) that can be used during construction, operation, maintenance, and decommissioning of a technology.

Getting Started

PSM requires compilation of process safety information that must be completed before any form of process hazard analysis (PrHA) is conducted. Appendix C-2 discusses the various PrHA techniques that can be used. Process safety information is used to conduct the PrHA, to support hazard communication requirements, and to document process design and configuration. Process safety information assists the employer and the employees in understanding processes and their hazards.

Knowledge and awareness begin the flow of information between management and employees. Employees are often the best suited to recognize potential or existing hazards; thus, their participation early in the assessment activity can be important. The following three tasks involve the collection of process safety information.

Task 1: Collect Hazard Information

The following chemical and physical hazard information should be collected:

1. Toxicity information (LD50/LC50 values, Immediately Dangerous to Life and Health [IDLH] values, Emergency Response Planning Guideline [ERPG] concentrations);
2. Permissible exposure limits (PELs) and Threshold Limit Values (TLVs);
3. Physical data (boiling point, freezing point, density, vapor pressure, vapor density, solubility, evaporation rate, appearance, and odor);
4. Reactivity data (polymerization and decomposition by-products);
5. Corrosivity data;
6. Thermal and chemical stability data (upper and lower flammable ranges);
7. Hazardous effects of inadvertently mixing different materials outside of normal operations;
8. Characteristics of any special physical or electrical hazards;
9. Noise levels;
10. Adequacy of machine guarding;
11. Temperature extremes;
12. Information on material handling;
13. Status of walking and working surfaces;
14. Status of pressure vessels;
15. Biohazards; and
16. Other information related to worker health and safety

Note: Material safety data sheets (MSDSs) meeting the requirements of 29 CFR 1910.1200(g) may be used as a source of data. This information should be summarized and may be used to help prepare a TSDS.

Task 2: Compile Technology Process Information

The following information pertaining to process technology should be developed:

1. A block flow diagram or simplified process flow diagram (Appendix B of 29 CFR 1910.119);
2. Process chemistry (e.g., flow rates, chemical equations, chemistry of intermediates, utility systems, and exothermic and endothermic reactions);
3. Maximum intended inventory for all tanks, reactors, and vessels;
4. Safe upper and lower limits for such factors as temperatures, pressures, flows, levels, phases, or compositions; and
5. An evaluation of the consequences of deviations, including those affecting the safety and health of employees.

Note: Where the original technical information no longer exists, such information may be developed in conjunction with the PrHA in sufficient detail to support the analysis.

Task 3: Collect Process Equipment Information

The following minimum information pertaining to the equipment in the process should be collected:

1. Materials of construction and the basis for selection, such as material compatibility or corrosion resistance;
2. Piping and instrumentation diagrams (P&IDs), which generally contain more detailed information than process flow diagrams;
3. Electrical classifications based on flammable materials located near the process;
4. Relief system design and design basis;
5. Ventilation system design, including airflow, and psychometric and sizing calculations;
6. Design codes and standards employed;

7. Material and energy balances for processes; the balances must properly show the mass flows and heat transfers sum; and
8. Safety systems (e.g., interlocks, depressurization, detection of suppression systems, containment and disposal, toxic and flammable material detection systems).

Note: Documentation that equipment complies with recognized and generally accepted good engineering practices should be maintained. For existing equipment designed and constructed in accordance with codes, standards, or practices that are no longer in general use, it should be determined and documented that the equipment is designed, maintained, inspected, tested, and operated safely.

After tasks 1 through 3 are completed, the PrHA phase can begin. The complexities of the process will determine how detailed the PrHA should be. At a minimum, the PrHA is expected to identify, evaluate, and control identified hazards. It is imperative to involve representatives of various disciplines in the process. All levels of employees should participate in the conduct and development of PrHAs and in the development of the other elements of PSM. Who better to help identify hazards than those involved in the various phases of assembly, dismantlement, operation, and maintenance of new technologies?

Process Hazard Analysis

The cornerstone of PSM rests on results obtained from performing a PrHA. Depending on the complexities of the process, an appropriate PrHA technique will be selected. The following techniques should be considered:

- What-if;
- Checklist;
- What-if/checklist;
- Hazards and Operability study;
- Failure Mode and Effects Analysis (FMEA);
- Fault Tree Analysis (FTA); and
- Other equivalent techniques.

PrHA techniques are used to identify the causes and consequences of potential accidents related to equipment, instrumentation, utilities, human performance, and external factors. PrHA allows hazards and excessive risks to be identified so they can be controlled or eliminated. The techniques can identify accident scenarios leading to worker injuries or fatalities, property damage, public exposure, environmental impacts, or adverse consequences.

PrHA techniques usually are implemented by a team of two to five individuals. The team should comprise a safety engineer, a process engineer, a maintenance supervisor, an operations supervisor, a facilities engineer, or other disciplines, as needed. At least one person familiar with the process should be involved in the analysis. The three-phase process includes the following activities:

Data Collection

- Work in multidisciplinary teams.
- Involve all levels of employees in the process.

Conduct the PrHA

- Identify process hazards.
- Prepare a process flow chart to include visual and verbal descriptions of each step.
- Evaluate hazardous substances used or generated in the process (e.g., raw materials, wastes).
- Evaluate equipment.
- Evaluate worker exposures.
- Evaluate unplanned events (fault tree analysis and FMEA).
- Review accident history to identify process hazards (accident and incident reports are required to be retained for at least 5 years).
- Look at accident precursors (Have emergency situations been considered? Have the local fire and rescue emergency responders been informed of the technology?)
- Consider lessons learned information.
- Evaluate trends.
- Consider the impacts of human factors (i.e., to what degree process safety depends on human performance). For example:
  - Can workers be reasonably expected to perform their assigned tasks?
  - Do the procedures and training appear adequate to guide the employees to do their tasks?
  - What are the human error causes of accidents?
  - Are safety instruments, alarms, and equipment provided in critical locations?
  - How close are covered processes to workers or high-traffic areas?
- Identify engineering and administrative control measures and their interrelationships.

- Determine the consequence(s) of failure of those control measures.
- Determine the qualitative range of safety and health effects on employees at the worksite.
- Consider the involvement of subtier contractor employees with oversight and coordination as factors for creating hazards.

Develop Recommendations and Resolutions

- Track issues raised by PrHA techniques to completion.
- Communicated and disseminate appropriately any necessary changes to processes or procedures.

Documentation of the PrHA is imperative. Revalidation should be dependent on the number(s) of modifications made and the operating cycle.

Operating Procedures

Written operating procedures are important for establishing a consistent approach for handling the various phases of a remediation technology. These procedures should provide clear instructions for safely conducting activities consistent with the process safety information. They should be easily accessible to all employees who work in or maintain a process or remediation technology. A review process should be implemented at regular intervals to ensure that procedures reflect current operating practice, including changes that result from changes in process chemicals, technology, and equipment, and from changes to facilities. The following elements may be applicable to procedures for cleanup technologies.

Steps for Startup and Operation

A. Delivery
B. Unloading and assembly
C. Initial startup
D. Normal operations
E. Temporary operations
F. Emergency shutdown, including the conditions under which it is required, and the assignment of shutdown responsibility to qualified operators to ensure that emergency shutdown is carried out safely and in a timely manner
G. Emergency operations
H. Maintenance
I. Normal shutdown

J. Startup following a turnaround, or after an emergency shutdown.

Operating Limits

A. Consequences of deviation
B. Steps required to correct or avoid deviation.

Safety and Health Considerations

A. Properties of, and hazards presented by, the chemicals used in the process
B. Precautions necessary to prevent exposure, including engineering controls, administrative controls, and personal protective equipment (PPE) (i.e., lockout/tagout procedures, confined-space entry program). A Job Safety Analysis (JSA) procedure could be used to facilitate and document this activity.
C. Control measures to be taken if physical contact or airborne exposure occurs
D. Quality control for raw materials and control of inventory levels of hazardous chemicals
E. Any special or unique hazards.

Worker Responsibilities

A. During normal operation
B. During emergency response
C. During oversight of contractor employees
D. During maintenance activities (scheduled and unscheduled).

Process Change Management

A. Field process modifications
B. Operating parameter changes outside established limits
C. Waste feed composition changes outside established limits
D. Revisions to worker protection programs and SOPs
E. Additional worker training.

Training

After operating procedures are developed, employees involved in their implementation must be trained. Each responsible person should receive appropriate training before initial assignment and after any change in or revision of the procedure.

The training should include an overview of the process, operating procedures, safety and health hazards, emergency operations including shutdown, and safe work practices applicable to the employee's job tasks, including technology maintenance/ repair tasks. The frequency of training should take into consideration changes in the technology. A written record should be required to document the date of training and to verify that the employee understood the training (e.g., testing).

It is important to recognize that worker training associated with set-up, operation, and maintenance of new technologies should occur at the site and be included in the site-specific training activity. The use of JSAs to identify hazards and the methods to manage them in combination with technology-specific SOPs provide benchmarks upon which appropriate learning objectives and technology-specific training modules can be developed. Where possible, such technology-specific training modules should be developed by the technology developer with careful review and revision specific to site application by the site contractor/user.

Inspections

Inspections and testing must be performed on the process and associated equipment. The frequency of these inspections and testings should be consistent with applicable manufacturers' recommendations and good engineering practices (more frequently if determined to be necessary by prior operating experience). Documentation of the inspections and tests must be maintained.

CASE STUDY

Idaho National Engineering Laboratory (INEL) Test Area North (TAN) has a groundwater contaminant problem that is being addressed through a pump and treatment technology. This factually based situation did not have a PrHA or TSDS developed. The SOPs and TSDS following this discussion are based on information available on the technology.

Background

Contamination was found in the drinking water of the community adjacent to the INEL TAN. The contamination was found to be caused by the Technical Support Facility's (TSF-05) Injection Well, which was installed in 1953 to dispose of process and sanitary waste from TAN operations. From 1955 until 1972, concentrated evaporator sludge from the processing of low-level radioactive and process wastes was pumped into the well. The well was drilled to a depth of 305 feet, which allowed waste to seep into the Snake River Plain Aquifer.

Contaminants in the groundwater were identified as TCE, perchloroethylene, dichloroethylene, lead, strontium-90, americium, uranium, and cesium-137. The

TCE was found to have traveled up to 1.5 miles with the groundwater flow. The local drinking water was contaminated above allowable levels and can not be consumed.

Remediation

The goal of this project is to collect sludge and groundwater from the TSF-05 Injection Well in order to remove cesium-137, strontium-90, and other radionuclides, as well as the identified hazardous chemicals. The process moves mixed waste through equipment and piping. This will be accomplished with a combination of filtration, air stripping, carbon absorption, ion exchange and disposal of treated water back into the aquifer. Containment and automatic controls are in place to prevent spills to the environment.

The technology was developed and delivered to INEL. After installation was complete, the system was energized and immediately experienced a major problem due to a pump failure. The pump and treatment technology was designed for a continuous pump flow rate of 30 gpm. Instead, the process began to pump at 130 gpm. This fourfold increase in flow caused the standing water in the well to be quickly withdrawn and a shock/stress put on the area surrounding the well pipe — a stress that pulled concentrations of contaminant that were greater than expected and greater than design limits, along with grease and oils. This concentrated mess clogged the filters and set off the automatic alarm, which shut down the system.

Once the system was repaired and the problems identified, the process could no longer be operated in a continuous mode. The facility was actually operated in a batch mode as necessitated by the concentrations of cesium-137 and volatile organic compounds (VOCs). The batch mode of operations created several specific problems. The influent tank is 20,000 gallons, while the effluent verification tank is 3,000 gallons. After 3,000 gallons had been processed, it could be released if the concentrations of the analytes were below acceptable levels. If not, then it would be circulated back to the influent tank. Because the sample plan called for time interval sampling, another sample would be drawn at the appropriate time regardless of the number of times the effluent had been recirculated. In this manner, partially processed batches (partially recirculated batches) would be sampled at different times from the same sample point, but would yield, as expected, different results.

Lessons Learned

The lack of a PrHA for this project contributed to the almost immediate failure of the technology. Many of the consequences described below could have been avoided if a PrHA had been completed. As a result of the stress/shock placed on the well, the following conditions were observed:

- The grease and oil clogged the resin beds and air strippers. This resulted in increased maintenance of the process, which resulted in increased exposure of the workers to radiation and VOCs.
- The influent had significantly higher suspended particulates than the process was designed to handle. Pre- and post-tank filters had to be retrofitted to the influent 20,000-gallon tank, as well as a larger pump. The particulates were so heavy that, at times, the filters had to be changed every 15 minutes. This resulted in engineering redesign, increased health risks to the workers, and increased waste generation.
- VOCs were found to be 10,000 times greater than the design levels for the process. This resulted in the carbon beds becoming filled sooner than anticipated. This in turn resulted in increased maintenance to change the beds and in increased amounts of waste generated. VOC concentrations needed to be evaluated with regard to flammability limits. Also, classifications of electrical systems had to be reviewed.

STANDARD OPERATING PROCEDURES

The following is a list of generalized SOPs addressing each of the technology phases described in TSDSs. This list is not all-encompassing or task-specific; it is presented as a typical representation of the areas that would need to be addressed with this technology. The SOPs will change depending on the technology and the phase.

Additional technology-specific information will be required to develop a list of SOPs that is directly applicable to workers who will be operating and maintaining the technology. Although clear and understandable SOPs are needed by workers, the PSM techniques and tools described previously may be too complex and cumbersome for workers on a jobsite to use.

One possibility is to use the job safety analysis (JSA) approach (or a focused portion of this approach) as a basis for developing SOPs for operation and maintenance of a technology. The JSA is already the most basic and widely used tool for identifying job hazards. A properly designed tool that uses JSA techniques might provide enough detail to allow technology-specific SOPs to be developed while not overwhelming users with excessive detail.

Construction Phase

1. To ensure the safety of construction-site workers and the public, the worksite shall be kept clean and orderly.
2. The minimum PPE for any worker or visitor to the construction site shall be safety-approved eye, head, and foot protection, generally referred to as safety

glasses, hard hat, and safety shoes or boots. Other safety protective devices or equipment may be required for specific jobs or operations and shall be worn or used as prescribed in the site-specific Health and Safety Plan (HASP).

3. Worksite lighting shall be sufficient and meet the minimum lighting requirements specified in 29 CFR 1926.56(a). Emergency lighting shall be provided in accordance with the National Fire Protection Association (NFPA) 101. If work areas contain a flammable atmosphere, only approved devices and lighting shall be used in accordance with 29 CFR 1926.407 and NFPA 70.

4. Backup alarms that are in working order shall be required on all heavy equipment. All personnel shall remain out of the immediate work zone.

5. Gas cylinders and gas system manifolds shall be used and stored in accordance with 29 CFR 1926.350. Welding and cutting shall comply with the applicable regulations in 29 CFR 1926.350-.354.

6. Temperature extremes will require monitoring of the environment as well as the employees. Excessive hot and cold temperatures combined with prevailing winds and/or humidity should be considered when work schedules are designed. Physiological monitoring of the employees shall be in accordance with National Institute for Occupational Safety and Health (NIOSH) Publication No. 85-115, "Standard Operating Safety Guides."

7. Medical attention and first aid shall be available to the workers. Before the start of the project, provisions should be made for prompt medical attention in the event of serious injury.

8. The Hazard Communication Program shall be made available to all workers and be established and implemented in accordance with 29 CFR 1926.59. MSDSs for chemicals used or anticipated to be encountered in the process technology must be provided.

9. Scaffolding shall not be erected, moved, dismantled, or altered except under the supervision of a competent person and in accordance with 29 CFR 1926.452.

10. Users of electricity, including general site workers, tradespeople, and electrical workers, shall be governed by the installation requirements, interpretations, and definitions in 29 CFR 1926.400-.499 and the National Electric Code (NFPA 70); other national, State, and local codes; and manufacturers' instructions attached to equipment. All appropriate requirements shall be followed. Before work begins, it shall be determined by inquiry, direct observation, or instrumentation if the electric power circuit, exposed or concealed, is located in a manner such that work may bring the employee into contact with the circuit. Deenergizing, lockout/tagout, signs, guarding and/or other grounding methods shall be in place and verified before any work begins.

11. Heavy equipment that is capable of hitting overhead electric lines must not work within 10 feet of energized lines (or the distance computed based on 29 CFR 1926.550). If work requires that equipment be closer than the prescribed distance, the power line must be deenergized and visibly grounded or insulating barriers installed.

12. Material-handling injuries should be prevented through the use of proper lifting techniques, proper housekeeping, PPE, and mechanical aids.
13. Protruding objects must be adequately guarded/covered and flagged to ensure against inadvertent contact.
14. Ladders must be selected, maintained, and inspected in accordance with 20 CFR 1926.1051, .1053, and .1060.
15. Fire-suppression activities and equipment shall be in accordance with 29 CFR 1926.150 and NFPA 241, "Standards for Safeguarding Construction, Alteration, or Demolition." An appropriately sized hand-held extinguisher shall be available.
16. All components of the technology that represent a confined space according to 29 CFR 1910.146 must be identified and appropriately marked.

Operation Phase

1. Fire-protection equipment shall be provided, inspected, maintained, and conspicuously located, or a trained firefighting organization shall be provided.
2. Ionizing radiation shall be addressed through 10 CFR Part 20, 29 CFR 1910.96, and 29 CFR 1926.53. All employees who could be exposed to the radioactive waste derived from the groundwater shall be instructed in necessary safeguards. This should include all laboratory, maintenance, janitorial, and emergency response personnel.
3. A Hazard Communication Program shall be made available to all workers and shall be established and implemented in accordance with 29 CFR 1926.59. MSDSs for the chemicals used in the process technology and for those in the groundwater must be provided.
4. Hazardous concentrations of contaminants in the air shall be determined as specified in the "Threshold Limit Values of Toxic Chemicals of the American Conference of Governmental Industrial Hygienists" and in 29 CFR 1910.1000.
5. Oil spill and containment plans must be understood and available to operating employees.
6. Drills designed to practice a spill containment and/or cleanup should be held periodically.
7. Spills must be contained with absorbent material and by sealing floor drains.
8. Emergency Response and Emergency Action plans from the HASP should be posted and available to all site personnel. Offsite emergency response teams should be briefed on the plans and should participate in any drills or mock disaster preparedness.
9. Sampling of the groundwater and all other resultants from this process must be in accordance with 29 CFR 1910.1450.
10. If the technology has confined spaces as an element, a confined-space entry program that complies with 29 CFR 1910.1 and .6 must be developed and

referenced for operations, emergency, decommissioning, and maintenance activities.

Maintenance

1. Lockout/tagout procedures shall be established, implemented, and enforced during all maintenance procedures. Workers shall be protected from unplanned releases of energy or hazardous materials. Lockout/tagout procedures shall conform to 29 CFR 1910.147.
2. Oil spill and containment plans must be understood and available to maintenance employees. Drills designed to practice a spill containment and/or cleanup should be held periodically.
3. In case of a spill, all operations must be suspended and the spill stopped if possible. However, stopping the spill should not incur excessive personnel hazard.
4. Hazardous concentrations of contaminants in the air shall be determined as specified in the "Threshold Limit Values of Toxic Chemicals of the American Conference of Governmental Industrial Hygienists," in 29 CFR 1910.1000, and in applicable OSHA health standards.
5. Users of electricity, including general site workers, tradespeople, and electrical and/or maintenance workers, shall be governed by 29 CFR 1926.400-.499 and the National Electric Code (NFPA 70); other national, State, and local codes; and manufacturers' instructions attached to equipment. All appropriate requirements shall be followed. Before work begins, it shall be determined by inquiry, direct observation, or instrumentation if the electric power circuit, exposed or concealed, is located in a manner such that work may bring the employee in to contact with the circuit. Deenergizing, lockout/tagout, signs, guarding and/or other grounding methods shall be in place and verified before any work begins.
6. Protruding objects must be adequately guarded/covered and flagged to ensure against inadvertent contact.
7. Scaffolding shall not be erected, moved, dismantled, or altered except under the supervision of a competent person and in accordance with 29 CFR 1926.452.

Decommissioning

1. Before workers start operations, a competent person shall make an engineering survey of the structure/machinery to be demolished/disassembled to determine the condition of the structures and/or machinery. All work shall be in accordance with 29 CFR 1926.850.

2. Fire-suppression activities and equipment shall be in accordance with NFPA 241, “Standards for Safeguarding Construction, Alteration, or Demolition” and 29 CFR 1926.150. An appropriately sized hand-held extinguisher shall be available.
3. All power sources (gas, electrical, sewer, and others) shall be shut off, capped, or controlled outside the building line before work begins, in accordance with applicable lockout/tagout requirements. Utility companies should be notified in advance of any work activities.
4. Ladders must be provided, maintained, and inspected in accordance with 20 CFR 1926.851.
5. Decontamination requirements and procedures must be in accordance with the site-specific decontamination plans of the HASP.
6. Decommissioning plans and activities should be in accordance with the Department of Energy Office of Environmental Management “Decommissioning Resource Manual.”
7. Users of electricity, including general site workers, tradespeople, and electrical and/or maintenance workers, shall be governed by 29 CFR 1926.400-.499 and the National Electric Code (NFPA 70); other national, State, and local codes; and manufacturers’ instructions attached to equipment. All appropriate requirements shall be followed. Before work begins, it shall be determined by inquiry, direct observation, or instrumentation if the electric power circuit, exposed or concealed, is located in a manner such that work may bring the employee into contact with the circuit. Deenergizing, lockout/tagout, signs, guarding and/or other grounding methods shall be in place and verified before any work begins.

EXAMPLE

TECHNOLOGY SAFETY DATA SHEET:
Groundwater Pump and Treatment Technology

Section 1. Technology Identity

Manufacturer's Name	**Emergency Contact:** (800)-000-1234
Address	**Information Contact:** (410)-123-0000
	Date Prepared: 3 November 1995
Other Names	**Signature of Preparer**

Section 2. Process Description

The pumping and subsequent treatment of groundwater is an important technology that uses a series of filtering and chemical addition steps to render groundwater contaminants innocuous or to remove them from the source. In this application of the technology, groundwater containing trichloroethylene (TCE), perchloroethylene, dichloroethylene, lead, strontium-90, americium, uranium, and cesium-137 is processed. The primary processes involved in the pump and treatment groundwater technology are air stripping, vapor phase carbon adsorption, filtration, and ion exchange.

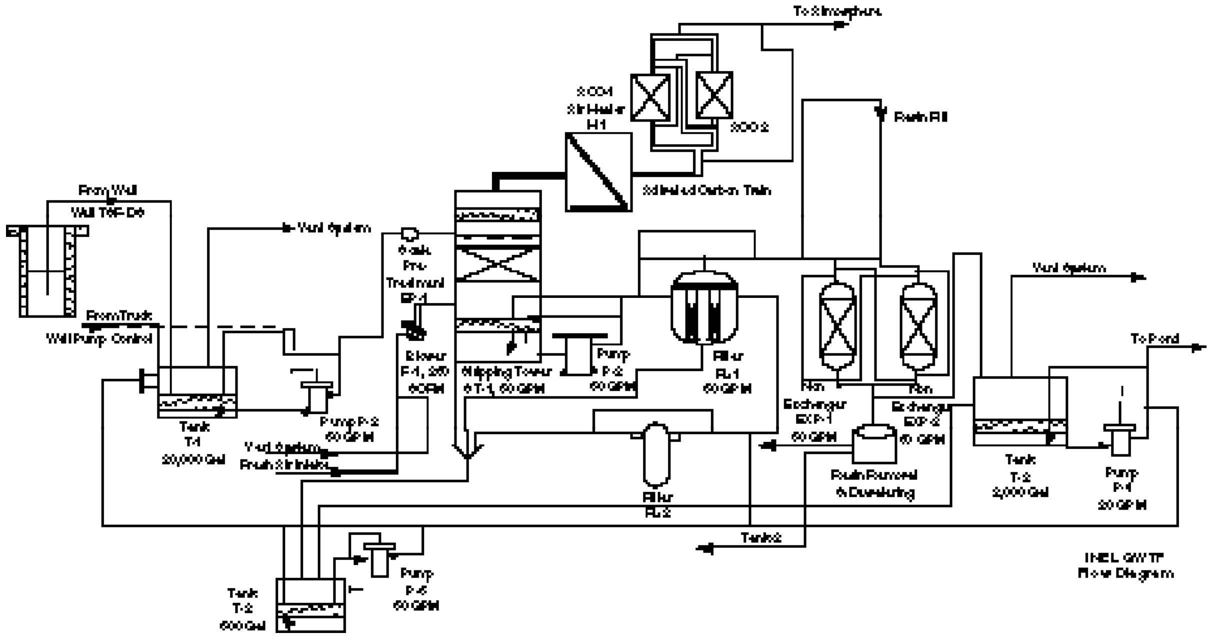
Contaminated groundwater is pumped from a well into a 20,000-gallon surge tank. The water is first treated with a scale inhibitor to reduce fouling of the air stripper. The scale inhibitor process also uses ozone to control bacterial growth. The water travels to the air stripper where the organic components are separated. The organic vapors, tritium, and noncondensable portion are piped to the two activated carbon beds operated in series. The activated carbon traps the organic vapors. As the carbon beds demonstrate breakthrough, they are replaced. The 55-gallon activated carbon beds, once saturated and removed from service, are labeled as hazardous waste.

The liquid phase of the waste stream travels to the multimedia filters, where the solid contaminants are removed. When the pressure differential across the filter increases by 10 PSI above normal, backwashing is required. The solid contaminants removed from the multimedia filters through backwashing are dewatered and sampled to determine if they are hazardous or radioactive waste.

The ion-exchange system consists of two ion-exchange vessels arranged in parallel. Each ion-exchange vessel contains a strong acid resin for removing the radioactive contaminants and lead. A secondary waste treatment system for resin removal and dewatering is in place to reduce the amount of waste that might otherwise be generated.

Treated groundwater is held in a 3,000-gallon verification tank for sampling. At the conclusion of the treatment process, treated water is discharged to an evaporation pond where the water percolates into the ground.

Section 3. Process Diagram



Section 4. Contaminants and Media

The contaminants in the groundwater have been identified as TCE, perchloroethylene, dichloroethylene, lead, strontium-90, americium, uranium, and cesium-137. The media used in the collection systems, multimedia filters, charcoal beds, and acid resin, have the potential of becoming a hazardous, radioactive, or mixed waste during normal operation. The rate at which the media become contaminated or saturated to a point where maintenance is required will be dependent on the consistency of the contaminants in the groundwater. The process, when fully operational, will run continuously.

Section 5. Associated Safety Hazards

Hazard	Present	Comment
Electrical (lockout/tagout)	yes	The potential for electrical hazards exists during construction and all maintenance activities. Because water is involved, the potential for electric shock is heightened. For all electrical connections and maintenance activities, adhere to lockout/tagout procedure.

Section 5. Associated Safety Hazards (continued)

Hazard	Present	Comment
Fire and Explosion	no	During construction operations when compressed gases are required for welding, fire and explosion potential exists. During operation and specifically during maintenance activities, the carbon beds will be saturated with volatile organic compounds and the potential for fire and explosion hazards exists. Smoking is not permitted within the parameters of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site; signs are posted.
Confined-Space Entry	no	For this operation, the only confined spaces are the tanks. No work is expected inside the tanks, therefore no confined-space entry program is necessary. However, all entry points into confined spaces must be properly labeled in accordance with 29 CFR 1910.146.
Mechanical Hazards	yes	There are operating pumps and fan equipment that require guarding to comply with 29 CFR 1910.212.
Pressure Hazards	yes	Several tanks and process systems will be under pressure. Several operating and maintenance procedures will require access to these points. Tanks under pressure require special precautions and periodic inspection and testing.
Tripping and Falling	yes	Construction activities will cause the greatest tripping and falling hazards. There are several tight areas and pipes at low levels that have been labeled as hazards. There are several areas also marked with warning labels that are under 7 feet and can be bumped by a person's head. Work above 6 feet will require the use of a full-body harness and lanyard. All lanyard attachment points must be capable of supporting at least 5,000 pounds/employee.
Ladders and Platforms	yes	During the construction phase, there will be work on ladders and elevated platforms. All work above 6 feet requires the use of full-body harnesses attached to a 4-foot lanyard. Once construction activities are completed, the only ladder or elevated-platform work will be during maintenance activities and that is limited to replacing light bulbs.
Moving Vehicles	yes	The technology is surrounded by a fence and is under a waterproof sprung structure. Once delivery, unloading, and construction are completed, there will be no hazards from moving vehicles. All moving vehicles should remain outside the fenced-in area. Those vehicles required for delivery, unloading, and construction will be equipped with back-up alarms and an observer to warn persons of movement.

Section 5. Associated Safety Hazards (continued)

Hazard	Present	Comment
Buried Utilities, Drums, and Tanks	no	These hazards do not exist with this application of the technology. No digging or drilling will be required. The contaminated well already exists and electricity is the only utility being provided; it will be brought in from a pole.
Protruding Objects	yes	All bolts, brackets, hangers, and framing under 7 feet shall be properly capped and/or labeled.
Gas Cylinders	yes	During construction, welding is necessary. It is important that all compressed gases are used and stored in a manner that complies with 29 CFR 1910.101. During operation, an onsite laboratory will be functioning and compressed gases will be used for the analytical instruments. It is important that they be used and stored in accordance with 29 CFR 1910.101.
Trenching and Excavations	potential	All trenching must satisfy the requirements of OSHA 29 CFR 1926.650-652 before employees can enter. All excavations deeper than 5 feet must be sloped or have shoring installed. Excavations deeper than 4 feet must have ladders every 25 feet. Persons not entering trenching must remain 2 feet from edge at all times. Be alert for unknown buried drums, tanks, or utilities.
Overhead Lifts	yes	Hazards during construction and decommissioning. All high-consequence lifts will require a procedure approved by the project superintendent. Overhead lifts will be required during construction activities when placing equipment into place. A competent person is necessary to oversee the crane and load rigging. Overhead lifts will occur during maintenance activities when the carbon beds and ion-exchange vessels become saturated and require replacement. No employees are permitted under a load that is being or has been lifted.
Overhead Hazards	potential	Entry into the fenced-in CERCLA site requires, at a minimum, level D protection, even though there are fewer overhead hazards after the construction phase is completed. There are low-lying pipes and bolts that pose both eye and head hazards. Hardhats are required during the construction phase.

Section 6. Associated Health Hazards (continued)

Hazard	Present	Comment
Inhalation Hazard	potential	Because the entire operation is a closed system, a direct inhalation hazard is unlikely. The several instances where indirect inhalation hazards exist include: when a leak in the system develops, while water samples are being collected, when a pressure release valve blows, and during maintenance activities. There are controls in place for exhaust fans in the process areas and in the sprung structure to operate if exposures exceed the alert levels established in the site-specific health and safety plan. Prior to entering the interim waste storage facility, make sure the engineering controls have been activated. When an unexpected inhalation occurs, immediately notify the project superintendent. Call the emergency response staff when necessary.
Skin Absorption	potential	Because the entire operation is a closed system, a skin absorption hazard is unlikely. However, there are several instances where skin absorption hazards may exist, including: when a leak in the system develops and it must be controlled and cleaned, while water samples are collected, and during maintenance activities. The SOPs and maintenance procedures address the use of personal protective equipment (PPE) when performing these activities. When skin absorption occurs, immediately notify the project superintendent. Call the emergency response staff when necessary.
Heat Stress	potential	Only during the construction and assembly phase. Once these activities are complete, the two persons necessary to operate the technology will be performing sedentary to moderate activities for short periods. The sprung structure is equipped with an exhaust fan to control the temperatures during the summer months. Extended maintenance activities shall comply with the heat stress work/rest regimen identified in the site-specific health and safety plan.
Noise	potential	The operating equipment is housed in metal enclosed containers. The metal containers contain no noise absorption materials. Sound level meter measurements collected in accordance with a health and safety procedure found noise levels to be below the site-specific requirement of 85 dBA. Hearing protection is available for those persons requesting it, but is not required. During construction activities, hearing protection may be required for operators of powered tools and heavy equipment.

Section 6. Associated Health Hazards (continued)

Hazard	Present	Comment
Nonionizing Radiation	potential	The only known source of nonionizing radiation is welding operations. Once the construction and assembly activities have been completed, welding activities will stop. From then on, welding would not be necessary again unless modifications to the system occurred or part of the system failed and repairs were necessary.
Ionizing Radiation	yes	As the contaminated groundwater is treated and the collection media accumulate contaminants, ionizing radiation hazards become an issue. Based on the low-level radioactive materials in the groundwater, it is difficult to estimate potential radiation levels in the surge tank, ion-exchange vessels, air stripper, charcoal beds, or verification tank. It is important to routinely survey those areas expected to accumulate radioactive components. Post radiation levels where necessary. All maintenance activities will require protection from the radioactive components identified. The maintenance procedures identify what controls are necessary to work on the process equipment during normal "hot" operating conditions. Assume all spills or leaks contain radioactive materials.
Cold Stress	potential	Work during the winter months in cold climates must plan for potential cold stress hazards. The temperature extremes procedure provides essential working condition information, including work/rest regimens and recommended warm clothing for specific outside temperatures. Use the outdoor thermometer and wind sock to estimate wind chill factors. Use the buddy system if work requires prolonged exposures to temperatures exceeding those specified in the procedure.
Ergonomic Hazards	potential	Acute musculoskeletal injuries may occur during assembly, maintenance, and disassembly activities. Appropriate staffing and materials handling aids may mitigate potential hazards.
Other	yes	This technology application has built into the process a full-scale quality control laboratory. The hazards associated with quality control laboratory analysis inherent to both radiological and chemical analysis must be considered. Because the laboratory is solely for quality control, the requirements for a Chemical Hygiene Plan under 29 CFR 1910.1450 do not apply. However, all provisions under OSHA's Hazard Communication standard, 29 CFR 1910.1200, are necessary.

Section 7. Systems Safety Analysis (Process Hazard Analysis)

A Tier III analysis was not performed on this technology.

Section 8. Phase Analysis

The following hazards could potentially be encountered or are expected to be encountered during the various phases of the technology life cycle.

Construction/Startup
Electrical, fire and explosion, mechanical, pressure vessels, trips and falls, elevated work surfaces, vehicle and equipment traffic, overhead lifts, inhalation and skin chemical exposures, heat and cold stress, ionizing radiation, nonionizing radiation, noise, ergonomics.

Operation
Fire and explosion, mechanical, pressure vessels, trips and falls, ergonomics.

Maintenance
Electrical, mechanical, pressure vessels, trips and falls, elevated work surfaces, inhalation and skin chemical exposures, heat and cold stress, ionizing radiation, ergonomics.

Waste Handling
Waste-treatment by-products, incinerator ash contaminated with heavy metals.

Decommissioning
Electrical, mechanical, pressure vessels, trips and falls, elevated work surfaces, vehicle and equipment traffic, overhead lifts, inhalation and skin chemical exposures, heat and cold stress, ionizing radiation, nonionizing radiation, ergonomics.

Section 9. Health and Safety Plan Required Elements

In addition to complying with the Hazardous Waste Operations and Emergency Response (HAZWOPER) Standard program requirements, 29 CFR 1910.120, the following site-specific issues must be addressed:

Air Monitoring
Because the technology is a closed system, the focus of an air monitoring program should be in the initial startup and during maintenance operations of the system. If, through initial air monitoring, the exposures to workers can be consistently demonstrated to be low, additional testing would be required only when the system was in maintenance phase, during emergency spills, or if operating conditions changed. Personnel exposure monitoring would be necessary on 6-month or annual frequency to comply with 29 CFR 1910.1000.

Worker Training
Pump and treatment technology, once out of the construction phase and into operation, does not require much labor. The technology is automated so that it can run without an operator and will do so on weekends. Consequently, the focus of training programs should be the operating procedures, hazards associated with construction, startup procedures, and how to recognize alarms indicating the system is not functioning properly. All procedures necessary for the various phases of the technology will have training sessions that include reading the procedure and walking it down in the presence of the project superintendent. All training will be properly documented. The site-specific hazard communication program and the site-specific health and safety plan will require training. It is very important to hold site-specific training dealing with natural disasters, notification and reporting requirements, fires, emergency decontamination, first aid, frisking, personnel and equipment decontamination, spill containment, and emergency phone numbers.

Section 9. Health and Safety Plan Required Elements (continued)

Emergency Response
Automatic shutdown procedures are built into this technology that are triggered by contaminant breakthrough from the collection media, effluent changes, pipe breaks, drastic change in the inflow parameters, or some other perturbation of operating parameters. The hazards of fire and explosion need to be considered and addressed in the emergency response plan. The Test Area North Site will ensure that emergency response personnel are at the site 24 hours a day, 7 days a week and monitor the project radio. The emergency phone number is 777.

Medical Surveillance
The medical surveillance program should be specific for the potential exposures to the contaminants identified in Section 4. Because low exposures are expected from this closed system, biological monitoring for these contaminants may not be warranted. An occupational medicine physician should be consulted when air monitoring results have been obtained for further decisions on biological monitoring. The occupational medicine physician performing the fitness-for-duty physicals must be made aware of the identified hazards on the project (see Sections 5 and 6) and the employees will need to be able to wear negative pressure respirators.

Informational Program
This standard program element should include distribution and availability of this TSDS as well as conveyance of any change in operating procedures.

Section 10. Emergency Conditions Information

Technology-specific information should be provided here to facilitate appropriate emergency response planning and actions in the event that an upset, failure, or other condition develops which can present hazards to operators, site workers, maintenance staff, the public, and emergency response personnel. Part II provides additional information to aid the developer in preparing this section of the TSDS.

Section 11. Comments and Special Considerations

No employees should be assigned to work on this groundwater pump and treatment technology until they understand all the hazards associated with it and know how to handle themselves in the event of an emergency.

APPENDIX A

WORKSHOP REPORT

Preventing Work-Related Injury and Illness During Development and Implementation of New Environmental Cleanup Technologies

Sponsored by:
National Institute of Environmental Health Sciences
&
United States Department of Energy

George Meany Center for Labor Studies
Silver Spring, Maryland 20903

March 23-24, 1995

Co-chairs

John Moran
Deputy Assistant to the Deputy Assistant Secretary
Office of Worker Health and Safety
Divsion of Environment, Safety and Health
U.S. Department of Energy

Denny Dobbin
Program Administrator
Worker Education and Training Program
Division of Extramural Research and Training
National Institute of Environmental Health Sciences

PREFACE

National Institute of Environmental Health Sciences and US Department of Energy Technical Workshop

On March 23-24, 1995, representatives from labor, management, academia, and governmental agencies with expertise in the development of new environmental cleanup technologies and worker health and safety training met to discuss how to incorporate health and safety considerations into the development, field testing, and application of environmental remediation technologies to prevent work-related injury and illness and to facilitate effective emergency response planning. Held at the George Meany Center for Labor Studies, the workshop was titled “Preventing Work-Related Injury and Illness during Development and Implementation of New Environmental Cleanup Technologies.” This appendix includes a summary of the activities and results from that workshop.

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Report on the Technical Workshop

AGENDA

March 23, Thursday

8:00 am	Registration - Auditorium
8:30 am	Introduction: Co-chairs George Meany Center, Welcome: Robert Pleasure, Director Opening Remarks: William Wisenbaker, Director, Office of Program Integration, U.S. DOE Workshop Purpose: John Moran
8:45 am	Panel: Agency Perspective DOE - Joseph E. Fitzgerald, Jr., Deputy Assistant Secretary, Worker Health and Safety, U.S. DOE
9:05 am	EPA - John Martin, Superfund Innovative Technology Evaluation (SITE) Program
9:25 am	DoD - Don Pittenger, Safety Engineer, U.S. Army Corps of Engineers
9:45 am	NIOSH -Joe Cocalis, Engineer-Division of Respiratory and Disease Studies, National Institute of Occupational Safety and Health (NIOSH)
10:05 am	Break
10:30 am	NIEHS Superfund Research Program-Technology Development: Dr. Joseph A. Caruso, Dean of the College of Arts and Sciences, University of Cincinnati
10:50 am	University Technology Development-Safety and Health: Lou DiBerardinis, Industrial Hygiene Officer, Environmental / Medical Services, Massachusetts Institute of Technology (MIT)
11:10 am	Review of OSHA Requirements for Informational and New Technology Programs: Earl Cook, Directorate of Compliance Programs, OSHA

11:40 am	Identification of Safety and Health Hazards Associated with CERCLA Remediation Technologies: A Comprehensive Approach: Bruce Lippy / Matthew Fitzgerald, SCIENTECH, Inc.
12:10 pm	Workshop Charge: Denny Dobbin
12:20 pm	Lunch
1:00 pm	Breakout sessions: Convene workshops (2 leaders; 1 scribe). The first task is a review by the workshops of the "General Principles and Issues" from the perspectives of their main topics.

Issue	**Leaders**	**Location**
Illness prevention	Joe Cocalis / Matthew Fitzgerald / Chip Hughes	Room A
Injury prevention	B. P. Shagula / William Bergfeld / Sharon Beard	Room B
Emergency response	Les Murphy / John Malool / John Moran	Auditorium
Implementation / training information	Carol Rice / Bruce Lippy / Denny Dobbin	Boardroom

4:30 pm	Preliminary reports back from workshop groups re: "General Principles and Issues" from each topical area. Sharon Beard
5:30 pm	Social Hour
6:30 pm	Dinner
7:30 pm	Social Hour

March 24, Friday

8:00 am	Reports back of written summations from workshop groups re: "General Principles and Issues" from each topical area. Sharon Beard
8:10 am	Break into strategy workshops

Issue	Leaders	Location
Illness prevention strategies	Matthew Fitzgerald / Chip Hughes	Room A
Injury prevention strategies	B. P. Shagula / Bill Bergfeld / Sharon Beard	Room B
Emergency response strategies	Les Murphy / John Malool / John Moran	Auditorium
Implementation / training information strategies	Carol Rice / Bruce Lippy / Denny Dobbin	Boardroom

11:00 am	Reports back from workshop groups re: "Prevention Practices and Strategies" from each topical area: Denny Dobbin / John Moran
12:00 noon	Workshop wrap-up / next steps: Discuss general plan for second workshop: Denny Dobbin / John Moran
12:30 pm	Adjourn

TECHNICAL WORKSHOP REPORT

Introduction

On March 23-24, 1995, representatives from labor, management, academia, and government agencies with expertise in new-technology development and worker health and safety training met to discuss how to incorporate health and safety considerations into the development, field testing, and application of innovative environmental remediation technologies to prevent work-related injury and illness.

The workshop was sponsored by the National Institute of Environmental Health Sciences (NIEHS), Worker Education and Training Program, Division of Extramural Research and Training, and by the Department of Energy (DOE), Office of Worker Health and Safety, Division of Environment, Safety and Health, and the Office of Program Integration, Division of Environmental Management.

Purpose

In his opening remarks, Co-chair Denny Dobin introduced the workshop as the first step in what is expected to be a multiphase process of meetings and guidance document development, the purpose of which is to reduce injury, illness, and costs associated with new environmental cleanup technologies. Guidance is to be developed by assessing such technologies from the earliest stages of their development onward, in terms of their potential to cause work-related harm. Information developed from these assessments will be used to —

- Inform technology designers so they may incorporate worker protection into the design and development of new technologies before they become operational; and
- Inform workers about the hazards to which they may be exposed.

As William Wisenbaker, who directs the Department of Energy's Office of Program Integration, EM-43, explained, DOE's interest is to ensure that worker health and safety are not neglected as the Department shifts its emphasis from weapons production to environmental cleanup. Development of innovative environmental remediation technologies is crucial to this mission transition because current technology is not adequate for the task at hand. DOE is also seeking to develop new waste management technologies that will support onsite, as opposed to offsite, disposal of contaminants.

Background

In accordance with the Superfund Amendments and Reauthorization Act of 1986 (SARA), Section 126, the Occupational Safety and Health Administration (OSHA) published worker health and safety regulations for hazardous waste operations and emergency response (HAZWOPER). Codified as 29 CFR 1910.120, these regulations include programmatic requirements that apply to training, new technology, and information management. Meanwhile, new cleanup technologies continue to be developed by DOE, the Environmental Protection Agency (EPA), and other agencies. EPA, the Department of Defense (DoD), the Air Force, and DOE have evaluated roughly 150 different remediation technologies, the results of which are available on databases such as the EPA's Superfund Innovative Technology Evaluation (SITE) Program's database and DOE's "Protech." The new technologies have been evaluated based on a wide array of criteria (e.g., startup cost, cost of operation, commercial availability, minimum contaminant levels achievable, and acceptability to local communities). Some of the databases list over 20 individual criteria for which the subject technologies were evaluated. Yet in none of the evaluations were the safety and health hazards associated with using the subject technologies included as evaluative criteria. This is disquieting in light of reports that as much as 40% of the budget of a remediation operation has been spent on ensuring a safe and healthful work environment during remediation operations.

Workshop co-chair John Moran of the DOE Office of Worker Health and Safety noted that the EPA Superfund-Labor Task Force began addressing issues surrounding the new technologies some two and a half years ago. This led to development of an EPA-OSHA agreement to conduct extensive field inspections, investigations, and analyses of these innovative technologies, culminating in development of an OSHA protocol for performing safety and health inspections of thermal destruction units for application across the cleanup industry.

Concerns about use of new technologies arose at DOE after problems began to surface in the Department's thermal destruction processes and at hazardous waste sites. The enormous cost to taxpayers of the DOE cleanup will continue to spur development of new technologies aimed at reducing costs and accelerating the pace of cleanup, Moran contended. To prevent illness and injury, it is vital, he said, that health and safety be addressed at the front end of technology development, not after use has begun.

Federal Agency Perspective—Presentation Highlights

Occupational Safety and Health Administration

Earl Cook, from OSHA's Regional Office in Salt Lake City, Utah, reviewed the requirements of paragraphs (i) and (o) of the OSHA HAZWOPER Standard (29 CFR 1910.120), which deal with information and new technology programs, respectively.

The informational program requirement states that site safety and health plans at hazardous waste sites are to direct that onsite hazards be communicated to workers in an ongoing manner. If new hazards are identified or introduced, employees must be notified within a reasonable time about what those hazards are and how to protect themselves from them.

The new-technology requirements state that any technology in use at a hazardous waste site must have its hazards characterized and its personnel trained in the safe operation of related equipment. OSHA does not regulate new technology per se, Cook said, but does regulate work practices. Within this context, for instance, OSHA might question why an employer is using an older technology when a newer method would present fewer hazards to the workforce. OSHA's interests in innovative technology have more to do with improving characterizations of employee exposure than they do with new remediation techniques. At OSHA's own laboratories, this is the focus of research underway.

Paragraphs (i) and (o) are rarely cited by OSHA. They are more likely to be used as programmatic stimuli to guide employer development of site safety and health plans. Because these paragraphs are viewed as relatively obscure, compliance officers are more likely to cite an alternate, more familiar standard to accomplish the same purpose.

Department of Energy

According to Joseph Fitzgerald, DOE's Deputy Assistant Secretary for Worker Health and Safety, Office of Environment, Safety and Health, most environmental protection specialists do not receive training in occupational health and safety, nor do they have much experience in the field. As a result, worker health and safety are often neglected. Fitzgerald has elaborated on this problem in a paper entitled “Cleanup Worker Health and Safety: Missing in the Action,” which he delivered at a recent waste management meeting.

The DOE cleanup presents an opportunity to effectively inject safety and health considerations into the remedial process. Safety and health technology development needs to be treated as an adjunct to environmental technology development and as an opportunity to advance development of safety and health protection technology in tandem with environmental control technology. This should help push some of the needed measurement and instrumentation innovations over the threshold into application, Fitzgerald said.

Another significant issue is how to integrate an analysis of the hazards a worker is likely to confront into the work planning process so that the necessary precautions can be taken up front. Fitzgerald cited several cases, such as that paraphrased below, where death or injury occurred because work planning of this type had not occurred.

- The massive Texas Super Collider project, which terminated approximately a year ago, involved building a massive 50-mile tunnel to house an accelerator. This involved digging a shallow culvert and covering it. Considerable attention focused on construction safety issues, but little on what was to be DOE’s first major use of tunnel-boring machines. The site contractor relied on a subcontractor, who had extensive experience with the technology, to actually do the boring. Despite the conventional use of such equipment, its operation and safety have not been well understood, nor was the need for training of operators and support staff sufficiently recognized. From a management standpoint, there was also too much deferral to a subcontractor. A fatality occurred within only a month or two of construction commencement. The fatality occurred when a piece of wall lining was being placed by the equipment as the machine dug forward. The injured worker was standing at a point where the piece of concrete could strike him, which it did.

A technology hazard assessment document would have warned workers against proximity to the equipment under certain operating conditions. Considering that dangers are posed even by equipment that is in widespread use, how much more dangerous will more complex and innovative equipment be? It is crucial that means be developed to convey the unique hazards of new equipment to managers and workers alike, Fitzgerald stated.

EPA SITE Demonstration and Evaluation Branch/EPA Risk Reduction Laboratory

The chief mission of the Superfund Innovative Technology Evaluation (SITE) Program is technology transfer to the user community (i.e., EPA regional offices, state and local control agencies, other Federal agencies, contractors, and the site owner community), according to SITE presenter John Martin.

Established under SARA, Section 311(b), the SITE program provides for coordinated Federal development, research, demonstration, and training in how to use alternative hazardous waste treatment technologies. SITE is also supposed to provide incentives for such technology development.

SITE has three parts: (1) an emerging technology program at the lab or pilot stage, (2) a demonstration program where technologies that are field-ready are reviewed, and (3) a measurement and monitoring program whose purpose is to devise new, more efficient evaluations of the nature and extent of pollutants at Superfund sites. Because SITE is in a position to affect the commercial future of the technologies it studies, considerable effort is expended to ensure the quality of the data collection and assessment activities performed.

As defined by SITE, innovative technologies are those for which there are not yet sufficient cost or performance data to warrant commercialization. Such innovations may include adapting a well-entrenched technology (e.g., adapting a Bureau of Mines technology traditionally used for classifying and removing minerals to washing soil).

The SITE objective is to produce three types of reliable information: engineering data to help understand how the systems operate, performance data to assess how well the given technology serves the cleanup, and cost data on how economically it performs. Because demonstrations generally last a year or less, findings are valid over the short term, but not necessarily over the long term (i.e., over periods of a decade or more).

SITE is not designed to assess whether a technology is protective of human health. In terms of quality assurance, no specific review of health and safety plans takes place, other than through regular program channels. The SITE demonstration plan includes how to evaluate the technology and perform quality assurance and sampling, but the health and safety component usually involves little more than adding vendor hazard information to the existing site safety and health plan. SITE itself does not have expertise in developing such plans.

Although innovative technologies may present exotic new hazards, many hazards that continue to be seen at hazardous waste sites are common to industrial settings (e.g., slip, trip, and fall hazards, heat stress, and, in some cases, cold). High pressures and high temperatures around the equipment are also common hazards. Martin provided the following examples of some new technologies and their potential hazards.

- *In situ* technology involving a two-zone capture of a pollutant plume underground, which is accomplished by injecting or putting in wells. Most of the actual cleanup is done underground, hence it is the surface installations that present the hazards. In many cases all that can be seen on the surface is a well head, a few pipes, and a few pressure gauges.
- *In situ* thermal technology in which soil is melted using the geo-safe process to drive off organics, incinerate the substance, and form a glass-like melt in which other inorganic pollutants can be trapped. Hazards here involve high heat below the surface and possible cave-ins. In one case, the melt came to the surface, causing liquid magma to splatter, which in turn caused all of the superstructures to catch fire.
- Lower temperature thermal processes, such as thermal absorption, of which there are various types. In one instance, thermal absorption was being applied to soils contaminated by a plasticizer. Because of site constraints, including the inability to move equipment around, numerous conveyers, thermal equipment, hot soil, and front-end loaders were congregated in a small area. The inability to see around the equipment presented a hazard.
- Biological treatment processes to treat groundwater through a submerged fixed film biological reactor. In one case the reactor was merely a series of tanks inside a tractor trailer. In another case where the reactor was located at the site of an operating lumber yard, the contaminants were being tracked outside the "hot zone."
- Soil and debris washing during which heavy pieces of equipment contaminated by polychlorinated biphenyls (PCBs) are lifted by crane and placed into the washing unit and afterwards placed back on the ground. This creates overhead hazards.
- Removal of pollutants from groundwater and from oil pumped out of a landfill through a chemical reaction using hydrogen. Hazards may include elevated temperatures and PCB-laden seepage.
- Filtration processes such as those using reverse osmosis at high pressure. Hazards include high pressure in the canisters and lines.

National Institute of Occupational Safety and Health (NIOSH)

Joseph Cocalis, Division of Respiratory Disease Studies, NIOSH, warned that costly and serious consequences result from neglecting health and safety aspects of innovative technology. He described how a design flaw in one innovative remediation technology led OSHA to close down an operation:

- An enclosure was built around contaminated soil to protect the public from fugitive emissions. A small fan, which was the only ventilation available to equipment operators working in the enclosure, failed to prevent chemical concentrations from reaching levels that were immediately dangerous to life and health (IDLH). This forced OSHA to close the operation.

Routine operations associated with innovative technologies must also be addressed. To demonstrate his point, Cocalis showed a slide of a 46-year-old driller seen at West Virginia University Hospital in 1992 who died in 1994.

- Although the worker had not operated a drill since 1987, the lower portion of his lung had petrified and filled with sand. Drilling of the type that caused this worker's problem is common among the new technologies currently being demonstrated on Superfund sites. Some of this drilling is taking place in uncharacterized soil, which may exacerbate the hazard.

Unfortunately, the conflict between budgetary constraints and occupational health and safety is recurring in this new arena. Noting the inadequacy of ventilation within a particular enclosure, Cocalis was told that adequate ventilation would cost too much.

The NIOSH Educational Resource Centers, Hazardous Substances Training Program (which targets environmental health professionals), and Hazard Evaluation and Technical Assistance Programs are all resources that can be tapped more fully to disseminate information on the health and safety hazards associated with emerging technologies. NIOSH is participating in the EPA Superfund-Labor Health and Safety Task Force through which the agency hopes to open lines of communication and be of greater assistance where its expertise is needed.

Department of Defense/Army Corps of Engineers

DoD and the Army Corps of Engineers are trying to move from a compliance mode to a systematic or system safety mode of operating, according to Don Pittenger, Principal Safety Engineer for the Corps since 1981. Compliance is only as good as the standards in place, Pittenger said, and with regard to new technology often no validated standards exist. Those standards that do exist often have large gaps in protection.

By definition, a good design should be a safe one, Pittenger said, but increasing complexity in today's world militates against that. Other impediments to optimizing health and safety include overemphasis on "exotic" hazards, problems with identifying crucial variables and controlling them as early on in the process as possible, and failure to anticipate additional risks. A team effort — one that includes end-users and health and safety specialists — is needed to optimize safety. Adequate risk or hazard analyses should (1) identify the information needed to make decisions and (2) assess the tradeoffs they entail. Military Standard 882 involves a precedence sequence directed toward "designing the hazard out." If that can't be done, safety devices and warning devices should be added. Control through the use of procedures, training, and personal protective equipment should be the last lines of defense, Pittenger maintained.

DoD employs "safety working groups" at the early stage in an innovative technology's conceptual development. Usually, an end-user will participate. As part of a typical design process, the safety groups take the following actions.

- Discuss safety concerns up front.
- Conduct a system or subsystem hazard analysis of areas of significant concern.
- Conduct a fault tree and / or operational analysis, if merited.
- Conduct reviews of the system for its health and safety impacts as alterations are made.

A method called "Hazard Tracking Law" involves identifying and documenting hazards, identifying controls, and using the resulting information as "connective tissue" between different phases of a design project.

Incident analysis also becomes important. No matter how much early work is done, some risks and problems are bound to be overlooked. When hazardous and injurious incidents occur, they must be analyzed and corrections made to prevent their recurrence.

Ideally, if people did their jobs right, health and safety would be ensured. Usually, however, there are competing definitions of what constitutes “right.” Too often the definitions do not include health and safety and, where they do, it is often not across the whole life cycle of the project or technology, Pittenger stated.

Design Stage in Innovative Technology Development

NIEHS Superfund Research Program — Technology Development

The NIEHS Superfund Basic Research Program funds 13 programs nationwide, of which the University of Cincinnati research project is one, according to Dr. Joseph A. Caruso, Dean of the Colleges of Arts and Sciences at the University of Cincinnati. The Cincinnati project in turn is composed of seven other research projects, which consist by and large of interdisciplinary research, training, and industrial and outreach programs whose aim is to reduce risk to human health through development of advanced microbial systems to degrade hazardous, environmentally recalcitrant pollutants. Besides investigating which bioorganisms are most effective in degrading contaminants, the project analysts also investigate basic molecular and genetic processes that might be applied to environmental cleanup.

Caruso described the seven research projects that Cincinnati is engaged in and the problems that have surfaced in the course of the research. One issue that has arisen is whether hazardous metals should be regulated in their entirety or whether only the “bio-available” portions of the elements should be. Scientists have also been looking at “element-specific species.” For example, some arsenic is contained in seafood in an entirely innocuous form, whereas other forms of arsenic can be harmful merely if breathed. The various forms also occur in mixtures. This raises questions such as how to separate and examine a mixture’s components and whether the bio-available amounts are sufficient to present a hazard.

University Technology Development — Safety and Health

Lou DiBerardinis, Industrial Hygiene Officer, Environmental/Medical Services at the Massachusetts Institute of Technology (MIT), is associated with an “in-house environmental health and safety organization” engaged in protecting personnel working on the type of research projects Dr. Caruso described. He made the point that if health and safety are addressed at the research stage—with respect to the researchers themselves and other workers—some of that orientation may carry over into the development and application of new technologies.

Founded in 1948 by Harriet Hardy, who trained under Alice Hamilton, a pioneer in the field of occupational medicine, MIT’s environmental health and safety organization is charged with protecting the environmental health and safety of the institute and has four components: (1) occupational medicine, (2) industrial hygiene, (3) radiation, and (4) bio-safety. Occupational safety is dealt with separately.

With roughly 2,500 laboratories to oversee, the department’s responsibility is to conduct “process hazard reviews.” This entails meeting with each principal investigator before research begins, obtaining information about the given project, developing standard operating procedures, and evaluating whether the facilities are adequate for the task (e.g., protection against fire and explosions is sufficient, venting is adequate). All these activities are to take place before project startup. As research begins, the review continues while equipment is built and prepared for operation. Routine inspections and exposure monitoring occur after startup.

Researcher cooperation and compliance have been problematic, DiBerardinis said. Much of the impetus driving improved practice has had to come from regulatory agencies. One of MIT’s goals is to write “standard operating procedures,” one of the regulatory requirements of the laboratory standard OSHA promulgated some 5 years ago. At MIT this has been a highly decentralized process, despite the overlap and redundancy of issues like program monitoring, medical surveillance, and emergency response. Moreover, some sectors, such as offsite research, are being overlooked altogether, DiBerardinis suspects. Another relatively neglected area is the education of researchers in procedures for safe handling of hazardous substances, such as asbestos, which they may be using in their experiments.

A Comprehensive Approach to Hazard Assessment of Innovative Remediation Technology

Bruce Lippy and Matthew Fitzgerald discussed the paper they had prepared on identification of safety and health hazards associated with hazardous waste technologies. It took nearly a decade after the Superfund legislation was passed, Lippy pointed out, before OSHA issued specific standards to protect workers in a hazardous waste environment. He was hopeful that progress would be made more rapidly with respect to innovative technologies as a result of the investigations inaugurated through this workshop. Little has been done thus far, however. Health and safety are notably absent among the various criteria used to evaluate new technologies in the various EPA matrices. The situation is similar with regard to DOE analyses.

Too often safety and health are not addressed until the very end of the work process analysis, at the point when the plan is about to be implemented, Lippy pointed out. This puts the safety and health professional in the position of seeming obstructionist rather than helpful. Hazards need to be considered further upstream and safety and health professionals need to be members of the team throughout the development process.

Matthew Fitzgerald focused on how to package safety and health information in usable forms. Proposed tools include safety hazard matrices, health hazard matrices, transition checklists, and technology safety data sheets (TSDSs). Checklists should be particularly helpful for research scientists and design engineers to use as they go through the various stages of development, Fitzgerald said. Contract clauses between remediation companies and responsible parties are another tool that could be used. Various formats and tools are needed because information needs vary at different stages of development.

Lippy and Fitzgerald said that safety and health hazards need to be broken out; hazards to safety have tended to receive less attention than have hazards to health. By introducing safety as an additional criterion, safety and health matrices make comparison possible between one technology and another in terms of both health and safety. For instance, the various technologies would be listed along the left-hand column of a matrix, and the various safety hazards one might expect to be associated with them (e.g., lockout/tagout, confined space, flammability, explosion, electrical hazard) would be listed across the top. A certified safety professional, certified industrial hygienist, design engineer, or other competent person would rate the hazards associated with the different technologies, based on some commonly accepted scale. The health hazard matrix would be similar, listing hazards such as inhalation, absorption, biohazards, noise, and ingestion. These matrices could serve as the bases for developing an information vehicle similar to the Material Safety Data Sheets (MSDSs) developed under the Hazard Communication Standard.

TSDSs are especially useful for capturing large amounts of information in a concise manner. Like the MSDSs, they could be used to identify a given technology, its applicable regulations and references, its uses and other names, emergency contacts, the contaminants and media that it is designed to treat, and the hazards associated with the contaminant media. The sheet could also be used to provide a process description with diagrams. Like the MSDSs, the TSDSs would be designed to facilitate worker understanding of the hazards associated with the given technology. A hazard ranking system such as the following could be applied:

#1 No excess hazard level (i.e., background);

#2 Elevated risk or hazard known to be present;

#3 Extremely high hazard; and

#4 Potentially IDLH.

The results of phase analysis and a list of the hazards associated with each phase should be included, as should guidance on plans and programs unique to use of the particular technology. Case studies are a powerful training tool and should be included, also.

It is imperative to distinguish among the various phases of operation because, frequently, it is in the transitions from phase to phase that incidents hazardous to health and safety occur. Hazards during transition periods could be identified using a checklist.

During discussion it was observed that TSDSs could be useful in other spheres besides environmental cleanup—and in the design as well as the implementation phase.

At the conclusion of their presentation, Lippy and Fitzgerald presented footage from EPA videotapes, illustrating a variety of hazards evident at Superfund innovative technology evaluation pilot sites. Some of the technologies and associated hazards were quite complex, while others were very basic. The hazards illustrated had to do with walking-working surfaces, elevated structures, inconsistent use of personal protective equipment, ergonomics, and poor machine guarding on equipment.

Breakout Session Summaries

Illness Prevention Issues and Strategies
Rapporteur: Matthew Fitzgerald

It appears that technology designers expect safety and health hazards to be addressed later in the process (i.e., at the demonstration and commercialization stages). On the other hand, research scientists are addressing health and safety in their own laboratories. It might be useful therefore to capture information about the ways they are protecting their own health and safety, both for the value of the information itself, and to inject a safety and health orientation earlier on in the process.

The use of checklists may facilitate the injection of health and safety considerations into the process. For example, a checklist could be formatted into a decision tree that scientists could use to work through hazard abatement procedures. In assessing a hazard such as a solvent, scientists could use a decision tree to determine whether a substitute could be used or if the solvent was regulated by OSHA, NIOSH, or the American Conference of Governmental Industrial Hygienists (ACGIH). The scientists could use the tree as they proceeded through the development process. Marshaling all available scientific knowledge about the hazards would also be invaluable. Because a great deal of toxicological data exists on substances on which no MSDSs are available, scientists need to know about alternative data sources as they move through decision trees.

Decision trees could be computerized (e.g., with prompts such as "What solvents are being used?" "What substitutes could be used?") The deliberative process employed by Food and Drug Administration research scientists might be a useful model in heightening awareness and responsibility among the technology research and engineering community.

Another idea is to look at the development of technologies through time. At the laboratory research stage, health would be the focus, since this is the stage that decisions are made about chemical use. Safety hazards arise later in the pilot, demonstration, and commercialization stages and would become the focal points then.

In implementing the safety and health hazard matrices, users should identify the regulation that applies to each hazard. This has a two-fold purpose: (1) it helps workers educate themselves further by encouraging them to request copies of the applicable standards; and (2) it provides ammunition for industrial hygienists to use with management.

TSDSs need to be written so that workers can understand each subject technology and its associated hazards.

Case studies are still another means of heightening DOE and EPA SITE attentiveness to technology hazards.

Injury Prevention Issues and Strategies
Rapporteurs: Bill Bergfeld and B. P. Shagula

Bergfeld and Shagula emphasized the importance of identifying target audiences that need to hear about the health and safety aspects of technology innovation. Scientists engaged in basic research and those who will apply that research in the design of innovative technology are one such audience. Engineers, manufacturing companies, and national laboratories are examples of others. Within these audiences are various subgroups, such as field-testing personnel who may or may not be designers, training personnel, consumers, Federal agencies, and contractors. Decisionmakers are yet another audience that needs to be informed about these issues.

The information products needed may differ from group to group. Researchers, for instance, could use chemical factsheets, sets or lists of safety and health issues, lists of databases of safety and health information, and training in professional settings such as symposia. Development of database-decision tree software could be helpful. The decision trees might differ for different research audiences. Because mechanical engineers, for instance, may not know what types of technical support they need, a decision tree could identify a range of sources, such as safety engineers, toxicologists, and epidemiologists. This might also be the first time a TSDS would come into play. Job hazard analyses might be useful to some audiences.

Information products for the consumer or user would be the completed TSDS and standard operating procedures. Other important information products include contract specifications, guidance on selecting and evaluating new technologies, quality assurance procedures, and guidance on how to employ a team approach for health and safety analysis across all phases of the project.

The TSDSs need to be comprehensive in nature, addressing both health and safety, and including room for application issues.

Bergfeld and Shagula applauded the fact that DOE is developing a limited standard on health and safety related to innovative cleanup technology.

They said that organized labor should take the lead in urging EPA as well as DOE to move this process along more rapidly and they noted that the insurance industry may be a potential ally.

Emergency Response
Rapporteur: John Moran

The emergency response group identified the following issues.

1. Minimum levels of training, equipment, and specialized gear necessary on a site-specific basis need to be identified. At most sites, the offsite emergency responders are not trained to the Title I or Title III requirements, much less appropriately equipped.
2. The guidance document developed from these workshops should devote a chapter to community emergency response needs. Communities need to know, for instance, that if they use an incinerator, large quantities of foam need to be stored onsite in the event of fire.
3. The entire emergency response community needs to be involved in the emergency response process, not just hazardous material (HAZMAT) teams. This includes other firefighters, emergency medical service personnel, and emergency medical facilities. Although HAZMAT is usually the focus, in reality some 70 to 80 percent of emergency medical calls are because of injury [not illness].
4. The guidance document should include as many case studies as possible to establish the seriousness of a given problem and the range of hazards it presents. The emergency response breakout group will be collecting such case studies for use in the initial draft of the guidance document.
5. The unique emergency response threats created by innovative technology, the unique hazards in the training, and the special training and equipment required all need to be identified. It cannot be assumed that any Title III or Level 3 emergency response group may be able to respond to all emergencies.
6. Virtually all the equipment used onsite, which emergency response personnel are introduced to during pre-incident planning, is new to them. Hence, the group recommends that TSDSs with emergency response requirements be developed for all existing remediation technology. These sheets should be a required component of all site safety and health plans.
7. Minimum standards applicable to the emergency response community need to be defined. These may include National Fire Protection

Association (NFPA) standards, Federal regulations, and others. At present, there are no minimum standards, and the capabilities of local emergency response crews vary enormously.

8. It would be useful to have an audience-keyed resource guideline list as an appendix to the guidance document or the document chapters.

9. Good, effective, early communication needs to be established with the emergency response community at the outset of site cleanup, even when current technology is being applied. Currently, 6 to 8 years are spent assessing a given site, developing and gaining approval for a record of decision, issuing a contract, hiring a cleanup contractor, and developing a health and safety plan. It is only then, generally, that the associated fire chief is apprised of what will be done.

10. Hazard analyses should focus on the Process Safety Management (PSM) standard because most innovative technology involves applying macrochemical industrial techniques on a microscale at hazardous waste sites. Extensive PSM compliance programs may apply to decision tree and other hazard analysis approaches.

11. The EPA SITE, DOE, and DoD innovative technology programs need to stipulate that a health and safety guidance document be a required element of their development and demonstration programs.

12. Different informational and technological needs among audiences must be recognized in the course of developing a guidance document.

13. Every guidance document should facilitate assessment of technology onsite today, as well as of technology developed in the future.

Implementation/Training/Information Issues and Strategies
Rapporteur: Carol Rice

This group focused on two target populations. The first was workers. In the pilot, demonstration, and all subsequent phases of technology innovation, contractual and other types of language are needed to mandate establishment of health and safety committees with membership consisting of both workers and management. Operators, maintenance people, and emergency responders also need to be represented on these committees. Participants need to be trained in working with quality circles or other structured processes to ensure incorporation of their expertise into the process.

Prior to the demonstration phase when an established workforce may not be available, lists of various resource people should be developed to enable designers to access the necessary expertise. NIEHS trainees who have completed 40-hour programs or technician-level training are appropriate candidates, as are labor health and safety representatives.

Once implemented, this consultative process needs to be ongoing so that, as new technology is introduced, the health and safety committee can review hazard assessments, as well as the appropriateness of standard operating procedures and compliance with them.

Some of the case studies of accident costs that Ruth Ruttenberg & Associates, Inc., has been developing might be beneficial to the committees, as would other case studies. In research grant applications and in contracts, language should be included requiring that health and safety expertise be used and that health and safety considerations be incorporated into the design process of new technologies.

A more fundamental approach would be to work with professional organizations, such as the American Chemical Society, as well as the training institutions. The goal would be to ensure that new designers entering the workforce consider health and safety in the initial stages of their designs. This could be fostered through interactions with the accrediting bodies of engineering schools. Attempts to add health and safety questions to Professional Engineer exams are already being made. More interaction is needed to encourage the consideration of health and safety issues at universities, where scientists and engineers are “retrofitted” for new responsibilities. The insurance industry and indemnifiers could help advance this work.

Concluding Summary
Rapporteur: John Moran, Workshop Co-Chair

Delineating target audiences and creating user-friendly means for them to access and exchange information are core approaches to stimulating consideration of health and safety in the development of innovative cleanup technologies. Most of the focus should be on innovative technology development programs, particularly those subsidized with substantial Federal resources. Producing a guidance document that will institutionalize an approach to ensuring that health and safety are integral to innovative technologies should be a prime objective. This could prevent a great deal of injury and illness and save many lives.

A draft guidance document will be developed as the product of this workshop and will be sent to all participants. Sufficient review time must be built into the process to permit Federal agency participants to obtain comments from their constituents and colleagues both inside and outside their respective agencies.

After the initial draft has been completed and, circulated, and comments have been received, an interim document will be developed to serve as the basis for the next workshop on this issue.

This workshop has been a valuable event because it is the first time that any group has come together to focus on this issue. Getting the Federal agencies such as EPA and DOE to actually apply and enforce the approaches conceived of to advance health and safety in this area will be extremely difficult and may require legislation or regulatory action. Such actions cannot be pursued, however, until a consensus is reached on the proposed guidance. The first step has now been taken toward that goal.

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APPENDIX A

Report of March 23-24, 1995

NIEHS/DOE Workshop

APPENDIXES

APPENDIX B

WORKSHOP REPORT

Innovative Technologies II:
Design and Implementation to Protect Workers

Sponsored by:
National Institute of Environmental Health Sciences
&
United States Department of Energy

George Meany Center for Labor Studies
Silver Spring, Maryland 20903

November 30 - December 1, 1995

Co-chairs

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AGENDA

November 30, 1995

I. Plenary 8:30 - 12:00 pm

8:30 am Introductions: Ruth Ruttenberg, National Clearinghouse
Welcome: Jeff MacDonald, George Meany Center for Labor Studies
Opening: John Moran, Department of Energy

Agency/Organizational Perspectives:

8:45 am DOE - The DOE Safety and Health Perspective: Joe Fitzgerald, Deputy Assistant Secretary, Worker Health and Safety

9:00 am The DOE Technology Development Perspective: Clyde Frank, Assistant Secretary, Science and Technology/Environmental Management

9:15 am Labor - Construction: International Union of Operating Engineers, Don Carson

9:30 am Preparedness and Emergency Response: Les Murphy, International Association of Fire Fighters

9:45 am Management - Design Group: Ivan Stepan, MSE, Inc.

10:00 am User Group - Dennis Stevenson, Bechtel

10:15 am OSHA - HAZWOPER and New Technology: Ruth McCully, Health Compliance Assistance

10:30 am EPA - Technology and Innovation Office, John Kingscott

10:45 - 11:00 Discussion

11:00 - 11:15 BREAK

II. Introduction to and review of the draft document 11:15 - 12:00 pm

11:15 am Overview: John Moran, DOE

11:25 am Standard Operating Procedures: Anne Manfre, Scientech

11:35 am Preparedness and Emergency Response: Matt Fitzgerald, Scientech

11:45 am Discussion: John Moran, DOE

11:55 am Charge to the Breakout groups: Denny Dobbin, NIEHS

12:00 - 1:00 pm Lunch

III. Breakout Sessions 1:00 - 5:00 pm

1. Design Considerations and Standard Operating Procedures for Operation and Maintenance (Appendix B): B.P. Shagula, IUOE; Ann Manfre, Scientech, Inc.

2. Preparedness and Emergency Response (Appendix A): Tim Henry, HazMat Captain, Fresno City, CA; Dave Smith, DOE; Matt Fitzgerald, Scientech, Inc.

3. Implementation: Myrna Steele, DOE; Dennis Stevenson, Bechtel

4. Training: Glenn Florczak, DOE; Michael Glassic, Laborers-AGC

December 1, 1995

I. Reports of the four Breakout Sessions
(20 minutes each with 10 minutes of discussion)

8:00 am	1. Design Considerations and Standard Operating Procedures for Operations and Maintenance
8:30 am	2. Preparedness and Emergency Response
9:00 am	BREAK
9:15 am	3. Implementation
9:45 am	4. Training
10:15 am	BREAK

II. Summary of reports: pull together major recommendations, changes, etc. 10:30 - 11:30 am

III. Next steps/closure: John Moran 11:30 - 12:00 pm

12:00 pm Adjourn

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Innovative Technology II Workshop • November 30-December 1, 1995
Training Breakout Session

Attendance

Name	Organization
Glenn Florczak	DOE, EH-51
Mike Glassic	Laborers - AGC
Marian Meiselman	Carpenters' H&S Fund
Sonny Bolls	Jackson State University
Dennis Graham	DePaul University
Mike Senew	HMTRI Community College Consortia
Bruce Lippy	UMAB
Jack Mallino	NEETC
Mitchel Rosen	NJ/NY Consortium
H. Wayne Patrick	ICWU
Alphonse Gonzales	DePaul University
Lina Santamaria	Natl. Clearinghouse for Worker Safety and Health Training
Kenny Oldfield	University of Alabama at Birmingham
Karen Miles	ICWU
Dan Marsick	DOE, EH-51
Harold Bowers	PNL
Lisa Sutton	Environmental Justice Resource Center

Discussion Points

1. We should look at the EPA AHERA model and set up training requirements or model curriculum for inspectors, workers, etc.

2. Every project personnel should have at least one day of safety and health training. And one must be careful about assuming that this person is then qualified.

3. Glenn Florczak suggested that Chapter 4 from the DOE HAZWOPER document be added to the innovative technology guidance document.

4. The group urged that there be emphasis in the document about the need to work as a team. While this is not S&H training, it is important.

5. We should try to get ISO to incorporate these ideas in these standards.

6. Design engineers who go onto the site to view their work may be exposed and must also receive training.

7. There is a need to keep the workers involved in every step of the process, including developing the training programs. Workers have more common sense and will be using the equipment.

8. Should also consider the populations clearly and what they need.

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Training Breakout Session (cont'd.)

9. Equity issues must be considered. Often minority workers do not receive as much training.

10. This group should include information as well as training and not be limited to skills. Awareness training should be considered as well, and making designers aware.

11. At the point of a concept there is need for a joint discussion that includes workers.

12. There are many different engineering disciplines involved, and they should be addressed in training.

13. Mil Standard 1472 lays out ergonomic design standards.

14. Design team at the beginning should discuss safety and health concerns. There was consensus on this issue by the group -- and groups should work together not sequentially.

15. The group, which includes the design team, should list the types of training that are needed -- first broadly -- and then for specific health and safety training.

16. According to Chubb Bowers, we should encourage an interdisciplinary, multi-level team as early in the process as possible. There was consensus about this among breakout group members.

17. Where does the training start? There was disagreement over whether it should start at the beginning or at the demo stage. Glenn Florczak suggested that a "graded" approach made sense here, with each person getting as much training as they need when they need it.

18. We need to specifically decide how much can be automated so that human exposure will be taken out. This is part of the design.

19. Types of training:

    <u>Worker, health and safety professionals (user)</u>
    basic skills
    English as a second language?
    Health and safety
    Emergency response

Chubb Bowers suggested that this could be broken into the format of: management and supervisory, technical support disciplines, scientists and engineers, workers as operators, and workers as responders.

Another approach from Chubb was: Concept person, designer, user, emergency responder.

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Training Breakout Session (cont'd.)**

20. Where should training be included in the guidance document? The consensus was that the information should be integrated into the body and have a separate chapter. There was a discussion about incorporating this into an appendix.

21. We should consider the training juncture: refresher, onsite etc. for all of the information.

22. Marian Meiselman raised the concern that MSDS training onsite often involves workers receiving a copy of the MSDS and then having to sign that they received training. We don't want to substitute TSDSs for this without real training.

23. What training mechanisms do we expect to use:
    TSDS
    Technology Profiles
    JHAs, JSAs
    Lessons Learned
    Case Studies
    Bottom line information including economic information that should include indirect costs of OSHA training programs
    Databases - add info to OCIS or OSCAR or EPA databases

24. Need to train professionals about providing information to workers that they can really use. We want to avoid the problems with readability that are associated with MSDS. Marian Meiselman suggested that rather than try to train engineers we should see that worker materials are prepared by experts in worker safety and health.

25. We need to consider performance-based training for the actual operation of the equipment. This can only be done onsite.

26. All designers, engineers, and scientists should receive basic S&H training which will enable them to recognize most S&H hazards and the applicable hazard control methodologies. Work should be done on communicating hazards of new technology downstream and putting information into understandable format. It is also important to utilize other resources such as getting input from health and safety and other.

A goal: that every designer will know one worker.

<u>Users</u>

27. What are the unique issues for new technology that wouldn't be covered in 1910.120 training?

28. Understand the purpose of the new technology. What are the capabilities and limitations? What are the hazards involved? What are the operational safety parameters? What are one's functions and procedures in the job? What needs to be done when there is an emergency?

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Training Breakout Session (cont'd.)

29. Chubb Bowers pointed out that they had two fires with the in situ vitrification process. It was important to know that you couldn't put flammable cover over the operation.

30. Should consider hold points involved with phases of the operation.

31. This differs from historical hazcom in that we are looking at distinct hazards with each phase; i.e., decon and construction.

32. Phase-specific training is the key.

Usefulness of TSDS

1. Must get more detailed on the procedural issues. Chubb Bowers saw TSDSs as very valuable.

2. Need to be concerned about the quality of the data. There have been real problems with the quality of the information on MSDSs.

3. Chubb Bowers indicated that PNL wants to be the provider of choice for environmental technologies. PNL should then be responsible for providing the TSDS. The problem is that there is a real rush to get the information on the street.

4. This group has got to convince managers that it is in their best interests to get workers involved.

Training Chapter

1. Should include that the training must be interactive.

2. Training should include one-third hands-on work.

3. Need to consider including the chapter 4 from the DOE document as an appendix here.

4. Need to be concerned about applying the PSM standard to this process considering that the quantities are so small. It may be better to consider MilStd 882 or other industry standards rather than seeing this force designers to abide by PSM.

There was consensus that there should be NO certification process associated with this training.

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Breakout Session on Standard Operating Procedures

Attendance

Earl Cook
Tom Evans
Chip Hughes
Betsy Lewis
George Macalusa
Ann Manfre
Tammy Marshall
Bruce Reinert
Ken Rock
B.P. Shagula
Craig Slatin
Ivan Stepan

Important Issues

Creating a new culture
Justify the remaining risk
"Chain of custody"

Weaknesses

Not enough detail is given to the design phase.
Drop the hazard disclosure form.
Need an early page for "guidelines."

Suggestions

Have B-18 follow B-7

Simplified B-18:
- confined space
- lockout/tagout
- emergency response
- construction phase
- decommissioning
- maintenance

For testing/design/evaluation:
- user/worker
- CIH
- engineer (industrial, civil, process, mechanical)
- ergonomist
- CSP
- manufacturer's representative
- maintenance people
- transportation people
- stakeholders: community, state/local permitters, regulators, utilities

APPENDIX B

Report of November 30 - December 1, 1995

NIEHS/DOE Workshop

APPENDIX C-1

Development: Identifying and Mitigating Hazards From the Outset

Stages of Technology Development

Most remediation technologies evolve along similar lines, with key stages as follows: proof of concept, bench scale, pilot scale, demonstration, commercialization, construction, operation, and dismantlement and disposition. The protection of workers can and should be considered at each of these stages and in transitional phases between. As a technology develops, more specific safety interventions are possible, but decisions made early in the process can have profound implications for workers.

Research scientists and design engineers are among those in the best position to protect the people who some day may operate the technologies they conceive and devise. Yet few of them are trained to consider the safety and health hazards associated with technologies. This appendix provides guidance on the types of hazards to be considered and how they might be addressed in the design and development stages; case studies are used to illustrate the possibilities.

Case Study

A technology designed for reducing and stabilizing the amount of highly radioactive waste in a process at the Department of Energy (DOE) Savannah River Site makes use of sodium tetraphenylborate (STPB) as the main precipitating agent. STPB accomplishes the desired precipitation but also decomposes to aromatic organics, including benzene. This requires a separate benzene stripping step after the desired precipitation. Even after the stripping, continued decomposition releases up to 5 parts per million (ppm) of benzene in the exhaust from the tank. The National Institute for Occupational Safety and Health (NIOSH) recommends that worker exposures be kept below 0.1 ppm because benzene is a potent carcinogen, causing aplastic anemia. Consequently, the workers entering this process unit are required to wear respiratory protection, the last line of defense. In addition, benzene is flammable.

This example illustrates the need for research scientists and design engineers to take specific steps to reduce the risks to workers in the above situation, even at the earliest stages of development. The opportunity to reduce or eliminate potential hazards is greater for health than for safety because interventions on behalf of safety require a more complete understanding of the process equipment than is possible at this early stage. In contrast, health hazards can be reduced by identifying the least toxic or flammable chemicals available that will provide the desired results. Even if the reagents are relatively innocuous, an effort to minimize the hazards can be important because the by-products from chemical reactions may be dangerous to human health, as in the case above. If significant amounts of heat or pressure are required for a particular process, the safety and health ramifications can be serious.

Laboratory Safety

Once a concept for a new technology is strong enough to test, it undergoes experimental analysis in a laboratory, where researchers are exposed to the risks to health or safety involved in conducting the experimental tests.

Research laboratories often are hazardous places to work. For example, a study of 23 university laboratories found a common lack of eyewash facilities, failure to use personal protective equipment (PPE), ingestion of food and drink in the labs, and use of ventilation hoods not certified for adequate performance.[1]

Applying proper safety techniques in a lab is an example of how protecting one population can lead to the protection of another. For instance, avoiding highly oxidizing or pyrophoric compounds during research not only lowers the risk to laboratory personnel, but also to the workers who will eventually be using the resulting technology in the field.

Researchers should incorporate worker safety and health implications of their research into the formal documentation that will accompany a technology development project as it moves along the development continuum. Such incorporation is important because the two disciplines of research science and design engineering often interface very little. Designers who perform bench scaling review the documentation they receive and rely on those portions that provide answers to problems they are trying to solve. If the documentation identifies safety and health issues associated with the technology, then designers can address the issues from the outset.

[1] Guarino, J. "Health and Safety Surveys at University Chemistry Laboratories," *Applied Occupational Environmental Hygiene*, p.291, May 1990.

Substitution of Less Hazardous Reagents

In selecting chemicals to be used in a technology, researchers and designers should always consider their impact on the workers who will handle related equipment or who will work in the vicinity of remediation operations. Often the effect desired can be achieved with use of a member of a chemical group that is similar in structure but less toxic than the one originally proposed. For example, aromatic hydrocarbons, in some cases, can be substituted for benzene. Researchers can make a major difference by avoiding particularly hazardous chemicals from the outset. By doing so, they benefit as well by avoiding the sometimes onerous regulatory requirements associated with the use of the more toxic chemicals.

Admittedly, a substitution that eliminates health and safety risks is not always easy to achieve. For example, many years ago, petroleum naphtha was the principal cold cleaning solvent, and a source of great concern because it posed a significant fire hazard. Eventually, carbon tetrachloride, prized as it was for its low flammability, good solvent power, and low price, replaced petroleum naphtha — until it was found to be a liver carcinogen.[2] A serious fire hazard had been traded for a serious health hazard.

Similarly, in a recent study of the effects of substitution,[3] the authors recounted the substitution of the citrus oil, D-limonene, to replace alkaline degreasing agents at a time when the toxicity of citrus oil was not well known or understood. Although believed to be non-allergenic, it was subsequently discovered that when D-limonene is used in degreasing baths, it becomes oxidized and allergenic. The study concluded that:

- New problems arise through the use of new chemicals for which sufficient health hazard information may not be available; and
- Substitution may affect the production system in many different ways, giving rise to other improvements or other problems.

Clearly, although substitution is always worth considering because of its capacity to make a real difference in health and safety, only chemicals whose toxicological properties are well established should be considered and these should receive careful analysis before they are tried.

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[2] Amdur, M.O., et al., *The Industrial Environment—Its Evaluation & Control,* National Institute for Occupational Safety and Health, pp.511-513, 1973.

[3] Antonsson, Ann-Beth. "Substitution of Dangerous Chemicals—The Solution to Problems with Chemical Health Hazards in the Work Environment?" *Journal of the American Industrial Hygiene Association,* Vol.56, p.256, April 1995.

The research scientist or engineer can investigate the hazardous nature of chemicals through many sources available electronically and on paper. Many chemicals have been evaluated through standard toxicological tests on animals. The designation "LD50" can be found in many references, and are included on Material Safety Data Sheets (MSDSs) discussed below.

LD50 is the lethal dose that will kill 50 percent of the test-animal population exposed over a specific period and usually is expressed in milligrams of the substance per kilogram of animal weight. Generally, if the oral LD50 for a substance is less than 50 mg/kg, the substance may be characterized as highly toxic. On the other hand, an oral LD50 greater than 500 mg/kg is characterized as practically nontoxic. A poison is legally defined as a substance that has an LD50 less than or equal to 50 mg/kg.[4] The LD50 value allows for a crude comparison of toxicity and is reported widely. If available, the LD50 will appear on the MSDS for a given chemical (see Figure C-1).

Identifying Hazardous Chemicals

Use of Material Safety Data Sheets

In 1982, the Occupational Safety and Health Administration promulgated a Hazard Communication Standard (29 CFR 1910.1200), which requires employers to train workers in the hazards of the substances with which they work. To facilitate compliance with this Standard, OSHA requires importers or manufacturers to create MSDSs that contain pertinent information about the hazardous chemicals they import or manufacture, and to distribute the sheets to customers when they purchase the hazardous chemicals. OSHA requires that these documents be maintained in locations where individuals potentially exposed to the chemicals have easy access to them. Because MSDSs contain chemical-specific information, they can provide valuable information to research scientists and design engineers as well (see Figure C-1).

The Importance of Occupational Exposure Values

For more than 40 years, professional organizations have been publishing guidelines on occupational exposure limits to hazardous substances. These exposure limits,

[4] Kavianian, H.R., and C.A. Wentz. *Occupational and Environmental Safety Engineering and Management*, Van Nostrand Reinhold, p.93, New York, 1990.

Figure C-1. A Material Safety Data Sheet for carbon tetrachloride.

1 – PRODUCT IDENTIFICATION

PRODUCT NAME:	Carbon Tetrachloride
FORMULA:	CCL4
FORMULA WT:	153.82
CAS NO.:	56–23–5
NIOSH/RTECS NO.:	FG4900000
COMMON SYNONYMS:	Carbon Tet; Tetrachloromethane; Methanetetrachloride; Perchloromethane
PRODUCT CODES:	1513, 1512, 1511, 1514, 1516, 1510
EFFECTIVE:	08/18/86 – Revision #102

PRECAUTIONARY LABELING
BAKER SAF-T-DATA™ SYSTEM

HEALTH	3 – SEVERE (CANCER CAUSING)
FLAMMABILITY	0 – NONE
REACTIVITY	1 – SLIGHT
CONTACT	3 – SEVERE (LIFE)

HAZARD RATINGS ARE 0 TO 4 (0 = NO HAZARD; 4 = EXTREME HAZARD)

LABORATORY PROTECTIVE EQUIPMENT

GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES

PRECAUTIONARYT LABEL STATEMENTS

POISON DANGER
NOT FOR HOUSEHOLD USE
MAY BE FATAL IF SWALLOWED OR INHALED
EXCEPTIONAL HEALTH AND CONTACT HAZARDS
READ MATERIAL SAFETY DATA SHEET

NOTE: REPORTED AS CAUSING CANCER IN LABORATORY ANIMALS. EXERCISE DUE CARE.

DO NOT GET IN EYES, ON SKIN, ON CLOTHING. DO NOT BREATHE VAPOR. KEEP IN TIGHTLY CLOSED CONTAINER. USE WITH ADEQUATE VENTILATION. WASH THOROUGHLY AFTER HANDLING.

SAF-T-DATA™ STORAGE COLOR CODE: BLUE (HEALTH)

2 – HAZARDOUS COMPONENTS

COMPONENT	%	CAS NO.
CARBON TETRACHLORIDE	90–100	56–23–5
CARBON TETRACHLORIDE	90–100	56–23–5

Figure C-1. A Material Safety Data Sheet for carbon tetrachloride (continued).

3 – PHYSICAL DATA

BOILING POINT: 77 C (171 F), VAPOR PRESSURE (MM HG): 91

MELTING POINT: -23 C (-9 F), VAPOR DENSITY (AIR = 1): 5.3

SPECIFIC GRAVITY: (H_2O = 1) 1.59 EVAPORATION RATE: (BUTYLACETATE = 1) N/A

SOLUBILITY (H_2O): NEGLIGIBLE (LESS THAN 0.1%)

% VOLATILES BY VOLUME: 100

APPEARANCE AND ODOR: CLEAR, COLORLESS, HEAVY LIQUID WITH CHARACTERISTIC ODOR

4 – FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (CLOSED CUP): N/A NFPA 704M RATING: 3–0–0

FLAMMABLE LIMITS: UPPER – N/A % LOWER – N/A %

FIRE EXTINGUISHING MEDIA
USE EXTINGUISHING MEDIA APPROPRIATE FOR SURROUNDING FIRE

SPECIAL FIRE-FIGHTING PROCEDURES
FIREFIGHTERS SHOULD WEAR PROPER PROTECTIVE EQUIPMENT AND SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN POSITIVE PRESSURE MODE

TOXIC GASES PRODUCED
HYDROGEN CHLORIDE, PHOSGENE, CHLORINE

5 – HEALTH HAZARD DATA

TLV LISTED DENOTES (TLV-SKIN)

THRESHOLD LIMIT VALUE (TLV/TWA): 30 MG/M3 (5 PPM)

PERMISSIBLE EXPOSURE LIMIT (PEL); MG/M3 (10 PPM)

TOXICITY:	LD50 (ORAL-RAT) (MG/KG)	– 2800
	LD50 (ORAL-MOUSE) (G/DG)	– 12.8
	LD50 (IPR-RAT) (MG/KG)	– 1500
	LD50 (SKN-RAT) (MG/KG)	– 5070

CARCINOGENICITY: NTP: YES; IARC: YES; Z LIST: NO; OSHA REG: NO

Figure C-1. A Material Safety Data Sheet for carbon tetrachloride (continued).

EFFECTS OF OVEREXPOSURE

- INHALATION AND INGESTION ARE HARMFUL AND MAY BE FATAL
- INHALATION OF VAPORS MAY CAUSE HEADACHE, NAUSEA, VOMITING, DIZZINESS, DROWSINESS, IRRITATION OF RESPIRATORY TRACT, AND LOSS OF CONSCIOUSNESS
- LIQUID MAY BE IRRITATING TO SKIN AND EYES
- PROLONGED SKIN CONTACT MAY RESULT IN DERMATITIS
- EYE CONTACT MAY RESULT IN TEMPORARY CORNEAL DAMAGE
- LIQUID IS READILY ABSORBED THROUGH THE SKIN
- INGESTION MAY CAUSE NAUSEA, VOMITING, HEADACHES, DIZZINESS, GASTRO-INTESTINAL IRRITATION, BLURRED VISION, LOWERING OF BLOOD PRESSURE
- CHRONIC EFFECTS OF OVEREXPOSURE MAY INCLUDE KIDNEY AND/OR LIVER DAMAGE

TARGET ORGANS
- CENTRAL NERVOUS SYSTEM, EYES, SKIN, LUNGS, LIVER, KIDNEYS

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE
- LIVER DISORDERS, KIDNEY DISORDERS, ALCOHOLISM, CENTRAL NERVOUS SYSTEM DISORDERS

ROUTES OF ENTRY
- INHALATION, INGESTION, ABSORPTION, EYE CONTACT, SKIN CONTACT

EMERGENCY AND FIRST AID PROCEDURES

CALL A PHYSICIAN. IF SWALLOWED, DO NOT INDUCE VOMITING. NOTE TO PHYSICIAN: ADRENALINE SHOULD NEVER BE GIVEN TO PERSONS OVEREX-POSED TO CARBON TETRACHLORIDE. IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING, GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN. IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES OR SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING AND SHOES. WASH CLOTHING BEFORE RE-USE.

THIS SUBSTANCE IS LISTED AS ACGIH SUSPECT HUMAN CARCINOGEN, NTP. ANTICIPATED HUMAN CARCINOGEN AND IARC PROBABLE HUMAN CARCINOGEN (GROUPS 2A AND 2B); ACCEPTABLE MAXIMUM PEAK ABOVE THE ACCEPTANCE CEILING CONCENTRATION FOR AN IEGHT-HOUR SHIFT = 200 PPM FOR 5 MINUTES IN ANY 4 HOURS; (PEL) CEILING = 25 PPM.

6 – REACTIVITY DATA

STABILITY:	STABLE, HAZARDOUS POLYMERIZATION WILL NOT OCCUR
CONDITIONS TO AVOID:	HEAT, FLAME, OTHER SOURCES OF IGNITION
INCOMPATIBLES:	ALKALI METALS, SODIUM METAL, POTASSIUM METAL, CHEMICALLY ACTIVE METALS, STRONG OXIDIZING AGENTS, ALLYLALCOHOL, DIMETHYL FORMAMIDE, FLUORINE, STRONG BASES DECOMPOSITION PRODUCTS: HYDROGEN CHLORIDE, CHLORINE, PHOSGENE

Figure C-1. A Material Safety Data Sheet for carbon tetrachloride (continued).

7 – SPILL AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN THE EVENT OF A SPILL OR DISCHARGE — WEAR SELF-CONTAINED BREATHING APPARATUS AND FULL PROTECTIVE CLOTHING.

STOP LEAK IF YOU CAN. DO SO WITHOUT RISK. USE WATER SPRAY TO REDUCE VAPORS. TAKE UP WITH SAND OR OTHER NON-COMBUSTIBLE ABSORBENT MATERIAL AND PLACE INTO CONTAINER FOR LATER DISPOSAL. FLUSH SPILL AREA WITH WATER. J. T. BAKER SOLUSORB® SOLVENT ADSORBENT IS RECOMMENDED FOR SPILLS OF THIS PRODUCT.

DISPOSAL PROCEDURE:

DISPOSE OF IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL ENVIRONMENTAL REGULATIONS.

EPA HAZARDOUS WASTE NUMBER: U211 (TOXIC WASTE)

8 – PROTECTIVE EQUIPMENT

VENTILATION:	USE GENERAL OR LOCAL EXHAUST VENTILATION TO MEET TLV REQUIREMENTS.
RESPIRATORY PROTECTION:	RESPIRATORY PROTECTION REQUIRED IF AIRBORNE CONCENTRATION EXCEEDS TLV. AT CONCENTRATIONS ABOVE 5 PPM, A SELF-CONTAINED BREATHING APPARATUS IS ADVISED.
EYE/SKIN PROTECTION:	SAFETY GOGGLES AND FACE SHIELD, UNIFORM, PROTECTIVE SUIT, POLYVINYL ALCOHOL GLOVES ARE RECOMMENDED

9 – STORAGE AND HANDLING PRECAUTIONS

SAF-T-DATA™ STORAGE COLOR CODE: BLUE (HEALTH)

SPECIAL PRECAUTIONS:	KEEP CONTAINER TIGHTLY CLOSED. STORE IN SECURE POISON AREA

10 – TRANSPORTATION DATA AND ADDITIONAL INFORMATION

DOMESTIC (D.O.T.)

PROPER SHIPPING NAME:	CARBON TETRACHLORIDE (AIR AND WATER ONLY)
HAZARD CLASS:	ORM-A
UN/NA	UN1846
LABELS	NONE
REPORTABLE QUANTITY	5000 LBS.

INTERNATIONAL (I.M.O.)

PROPER SHIPPING NAME:	CARBON TETRACHLORIDE
HAZARD CLASS:	6.1
UN/NA	UN1846
LABELS	POISON

which have various names and are issued by various professional trade associations and government agencies, share the same purpose — protecting the worker from deleterious exposures. The common exposure limit is an air concentration, which may be expressed in the volume or mass of a contaminant, such as part per million (milliliter of contaminant per cubic meter of air, or milligram of contaminant per cubic meter of air) as a time-weighted average over some defined period, usually a full working shift of 8 hours. Other sampling intervals, such as 15-minute values, short-term exposure limits (STELs), and ceiling values must not be exceeded regardless of the timeframe.

In 1971, shortly after the passage of the Occupational Safety and Health Act of 1970, OSHA was created and charged with developing occupational safety and health exposure limits. The result of that mandate was OSHA's establishment of approximately 450 substance-specific "Permissible Exposure Limits" or PELs, which are 8-hour, time-weighted average exposures that must not be exceeded by law.

Referred to routinely by industrial hygienists, the PELs are useful to research scientists and design engineers as well, helping them to identify not only hazardous chemicals, but also potential replacements. MSDSs list occupational exposure limits, several of which are described below.

Threshold Limit Values

The American Conference of Governmental Industrial Hygienists (ACGIH), a professional society dedicated to the administrative and technical aspects of occupational and environmental health, has established exposure guidelines that are expressed in terms of Threshold Limit Values (TLVs). The organization indicates that TLVs refer to:

> . . . airborne concentrations of substances [that] represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit; a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.[5]

TLVs generally are expressed as 8-hour, time-weighted averages. Excursions above the values are permitted, as long as the average exposure for any given day is below the established TLV. Recognizing that this approach is unacceptable for fast-acting, acute substances, the ACGIH created ceiling concentrations for such agents.

Cautions About Using TLVs

The TLVs that the ACGIH established in 1968 set limits primarily on exposure to the acute — not the chronic — effects of toxicity.[6] Most of these TLVs do not take into account the long-term health effects of exposure, such as cancer, reproductive damage, or hard-to-pinpoint illnesses like fatigue, headaches, or slowed nerve-conduction response times. Moreover, at present, there is no way to predict the effect of a worker's exposure to multiple substances. Almost no research has been conducted on the effects of exposure to complex mixtures.[7]

OSHA's Permissible Exposure Limits

NIOSH is federally mandated to comprehensively review the research conducted on a specific workplace toxin and then recommend a level that should be set by OSHA as a regulatory standard for airborne concentrations (i.e., as a PEL).

The ACGIH TLVs have had a much more significant influence on the PELs than the recommendations of NIOSH, which Congress created at the same time it created OSHA. Because OSHA could not delay execution of its enforcement mandate to wait for NIOSH to complete the lengthy scientific reviews needed to establish PELs, OSHA adopted the ACGIH TLVs, which were intended as guidelines, and gave them the force of regulatory PELs.[8] The NIOSH Recommended Exposure Limits (RELs) generally are lower than the corresponding OSHA PELs.

Workplace Environmental Exposure Level Guides

The American Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Level Guides (WEELs) apply to agents for which no other exposure guidelines exist. WEELs represent the workplace exposure level to which it is believed nearly all employees could be exposed repeatedly without adverse effect. All WEELs are expressed as time-weighted average concentrations or ceiling values.

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[5] 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists, p.2, Cincinnati, OH.

[6] Ibid.

[7] Lippy, B.E., and R. Turner. "Complex Mixtures in Industrial Workspaces: Lessons for Indoor Air Quality Evaluations," *Environmental Health Perspectives*, Vol.95, pp.81-83, 1991.

Engineering Controls

If hazardous substances cannot be eliminated or replaced by substitutes, engineering controls to minimize exposure need to be considered. Local exhaust ventilation is an example of such a control, one of the key concepts of which is to control the contaminant at its source. Using *in situ* cleanup technologies at hazardous waste sites rather than bringing contaminants to the surface is another way to control exposure.

However, for the research scientist or design engineer who is trying, for example, to identify a particular process to remove chemical contamination from metal debris, there is little to be gained from engineering controls. Substitution has to be relied on to minimize exposure not only to chemical hazards, but to physical and biological hazards as well.

Health Hazards

Researchers should be aware of the major health hazards that exist in the industries for which they are developing new technologies and should consider the occupational health risks that their new products and processes may pose. Occupational health hazards may be physical, chemical, or biological; remediation technologies pose hazards in all three of these categories.

Sources of Ionizing Radiation

Ionizing radiation includes alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles. The OSHA Standard applicable to ionizing radiation requires employers to ensure that employee exposures are kept below certain levels; exposures of employees under 18 years of age must be kept below one-tenth of these same levels. The Standard further requires employers to be responsible for providing radiation monitoring devices, such as film badges, and for ensuring that employees use them, and for issuing appropriate warnings to workers about radiation exposure.

Radioactive wastes must be handled during many remediation projects. For example, DOE has identified more than 1 million 55-gallon drums of waste in storage and 77 million gallons of highly radioactive liquids and sludge stored in underground tanks, which workers may have to handle during remediation or new disposal efforts.[9]

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[8] Part VII: Governmental Regulations and Their Impact, *Fundamentals of Industrial Hygiene*, Third Edition. Barbara A. Plog, ed. Chicago: National Safety Council, pp.694-695, 1988.

Sources of Non-Ionizing Radiation

Lasers, microwaves, and radio waves, which are considered non-ionizing sources of radiation, are all employed in remediation technologies. Light ablation is a decontamination technique that involves the absorption of light energy and its conversion into heat in order to remove contaminants. With light intensity high enough, a surface can be heated to 2,000 ºC in microseconds, changing the surface contaminant from a solid into a plasma that erupts with a brilliant flash and a loud blast (up to 90 decibels [dB]). Fortunately, the technique can be performed at a distance by transporting the light through periscopes or fiber optics up to 450 feet long. In this case, distance alone can reduce worker exposure to hazard.

Microwave scabbing, a technique developed at the Oak Ridge Y-12 Plant, directs microwave energy at contaminated concrete surfaces and heats the moisture present in the concrete matrix. Continued heating breaks surface layers of concrete into chips small enough to be collected by a vacuum connected at the tailing end of a mobile unit. Worker protection was integrated into the development of this technology because the developers wanted to avoid worker inhalation of any chips small enough to become airborne. Microwave radiation, however, may still pose a hazard to workers within its range.

In situ heating currently being evaluated by DOE includes radio-frequency heating, which involves placing a dipole wand down a borehole to heat a 25-foot-long zone within the screened area of a well.[10] Theoretically, *in situ* techniques reduce risk of exposure to contaminants in the soil but the methods themselves (e.g., radio-frequency heating) may increase risks to workers.

Noise

In the United States an estimated 14 million workers suffer on-the-job exposure to noise at hazardous levels.[11] Designers of remediation technologies should not add to this number. Exposure to noise can be controlled by —

- Using quieter work processes;
- Altering or enclosing equipment to reduce noise at the source; and
- Using sound-absorbing materials to prevent the spread of noise by isolating the source.

[9] FY 1993 Program Summary, Office of Demonstration, Testing, and Evaluation, U.S. Department of Energy, Office of Environmental Restoration and Waste Management, p.10, October 1993.

[10] Decommissioning Handbook, DOE/EM-0142P, U.S. Department of Energy, Office of Environmental restoration, pp.9-68, March 1994.

The damage that noise can do to human health depends on how loud it is and how long the exposure lasts. The frequency or pitch can also have some effect, since high-pitched sounds are more damaging than low-pitched ones. If exposed to continual noise, the human ear will lose its ability to recover from temporary hearing loss, and damage will become permanent. Noise also contributes to stress, quickens the pulse rate, increases blood pressure, and causes muscle tensing. Workers exposed to noise sometimes complain of nervousness, sleeplessness, and fatigue.[12] OSHA requires every employer to limit worker exposure to 90 dB averaged over an 8-hour period. Noise levels at higher decibels have limits that are averaged over a shorter period.

If exposure to noise rises above these levels, the employer must try to eliminate the problem. Many remediation technologies involve high noise levels, particularly technologies for dismantlement and demolition.

Because noise is a significant, widespread hazard to workers, those engaged in the development of emerging remediation technologies should look for ways to engineer this hazard out. Often, concerns are raised about the noise levels that a surrounding population will be subjected to when a new technology is implemented. Designers should remember that if workers are protected, nearby residents will be protected as well.

Chronic Exposure Hazards

In addition to immediate hazards, it is essential to evaluate the potential for harm from long-term, chronic exposures to dangerous substances and conditions associated with the development and use of new remediation technologies. NIOSH, for example, has seen reported instances of silicosis in workers operating drill rigs at hazardous waste sites. In addition to posing inhalation risks, contaminants, particularly organic solvents, can pose serious risks as a result of absorption through the skin. Accidental ingestion has been the source of lead poisoning of workers when they eat and drink at contaminated worksites.

Safety Hazards

[11] *Industrial Noise and Hearing Conservation.* Edited by Julian B. Olishifski and Earl R. Harford, pp. 13-14. Chicago: National Safety Council, 1975.

[12] Ibid.

Occupational safety hazards claim the lives of approximately 6,000 workers every year in the United States. These deaths can and must be avoided. As a technology is being developed, the research scientist and design engineer should take into consideration typical occupational safety hazards and attempt to eliminate as many of them as possible.

Work-Related Injury Potential

As a technology moves from one stage in its development to another, the following list of occupational safety hazards should be reviewed. If the technology can be modified to reduce or eliminate any of the hazards associated with it, the modifications should be made.

Potential Safety Hazards

Falls from heights	Electrical hazards
Machine guarding	Explosives
Confined space	Flammability and fires
Oxygen deficiency	Mechanical hazards
Acceleration	Pressure hazards
Deceleration	Working and walking surfaces
Chemical reaction	

Decision Tree for Hazard Identification and Mitigation:
Safety Hazards to be Considered During Design and Development

To facilitate consideration of potential safety and health hazards over the course of development of remediation technology, design engineers may choose to employ a hazard identification decision tree such as the one presented in Figure C-2. When a hazard is identified that cannot be designed out of a technology, pertinent information about it must be communicated to the end users to ensure that it is addressed onsite.

Emergency Response Operations

The potential for hazardous substances to be released into the environment under accidental and uncontrolled circumstances needs to be considered in the design phase of technology development, so that plans can be devised and put into place to respond to such emergencies.

Typically, hazardous wastes that are treated by remediation technologies are dispersed in environmental media (soil, groundwater) and therefore are relatively dilute. Although many industries use pure substances in manufacturing processes and often store large quantities of hazardous substances in a pure state, this is not usually the case in remediation operations. Indeed the relatively dilute state of the hazardous substances involved in most remediation operations limits the potential for the release of hazardous substances.

Characterization of a Waste Stream

Adequate characterization of a waste stream as it enters a technology can help ensure safe operation. Instantaneous-readout equipment can be integrated into a treatment technology and used to ensure that a homogeneous waste stream is treated. A technology may incorporate alarms and automatic shutdown criteria to shut the process flow off if there is a significant change in the waste stream's characteristics.

Perturbations in the process flow have been associated with drastic changes in the characteristics of waste streams. These perturbations can be avoided in two ways — through vigilant characterization of the given waste stream and through constant mixing to ensure a homogeneous concentration of hazardous substances in the stream as it is being treated.

Waste Stream Mixing

Treatment technologies often include pretreatment processes, such as the mixing and homogenizing procedures described above. These procedures can eliminate some potential for spikes in a waste stream's concentration of hazardous constituents before further treatment occurs. However, there are hazards associated with the mixing process, such as drawing workers into the equipment. Appropriate shielding of such equipment is essential for safe operation.

Hazardous Substances Introduced by the Process

The solvents and hazardous substances used in a treatment technology may themselves present the greatest hazards in terms of release at levels requiring an emergency response. Safe storage of these substances and establishment of proper controls at potential release points need to be considered during the design phase.

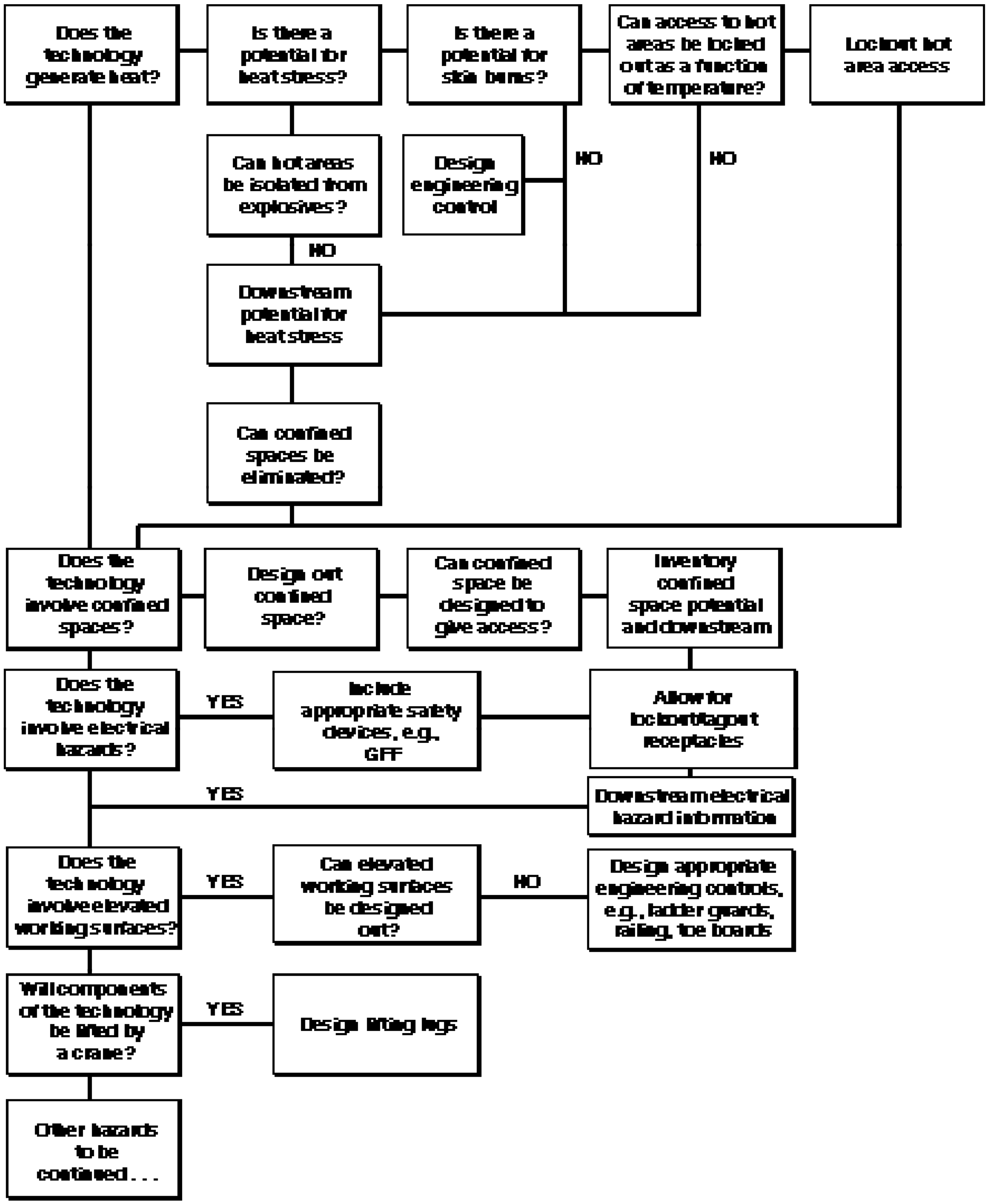

Figure C-2. Hazard analysis decision tree.

Down-Streaming Hazard Information

Potential hazards that cannot be designed out of a technology must be addressed in the Emergency Response Plan (ERP) for each implementation site. All information about potential hazards learned during the design stage needs to be relayed to users of a technology for use in developing a site ERP and procedures.

Research scientists and design engineers who become aware of a hazard or hazardous exposure associated with the technology under development should ensure that the pertinent information about the hazard potential is entered onto an MSDS and onto a Technology Safety Data Sheet (TSDS), which parallels the MSDS and is the central repository for hazard information.

APPENDIX C

C-1 Development: Identifying and Mitigating Hazards From the Outset

C-2 Deployment: Dealing With Residual Safety and Health Hazards

C-3 Implementation: Putting the Technologies to Work

APPENDIX C-2

Deployment: Dealing With Residual Safety and Health Hazards

Once an emerging remediation technology is tested and demonstrated to be successful, it is ready for the next step in the development process, commercialization. As part of this process, the technology undergoes a comprehensive review to identify safety and health hazards associated with its implementation, including residual hazards that could not be designed out. A system safety analysis of the technology should be performed and the results disseminated in documents aimed at different audiences, depending on how the technology will affect them. Procedures for performing a system safety analysis and communicating the results are presented in this appendix.

Description of the System

It is important to have a detailed functional diagram of a given technology to facilitate hazard identification throughout the development process. Such a diagram should be detailed enough to include —

- Piping,
- Instrumentation layouts,
- Flow diagrams, and
- Major component parts and their specifications.

The system description and diagram (see Figure C-3) must be sent with the technology as it passes along the development continuum and received by those with responsibility for development of the Technology Safety Data Sheet (TSDS), training, informational programs, and other functions.

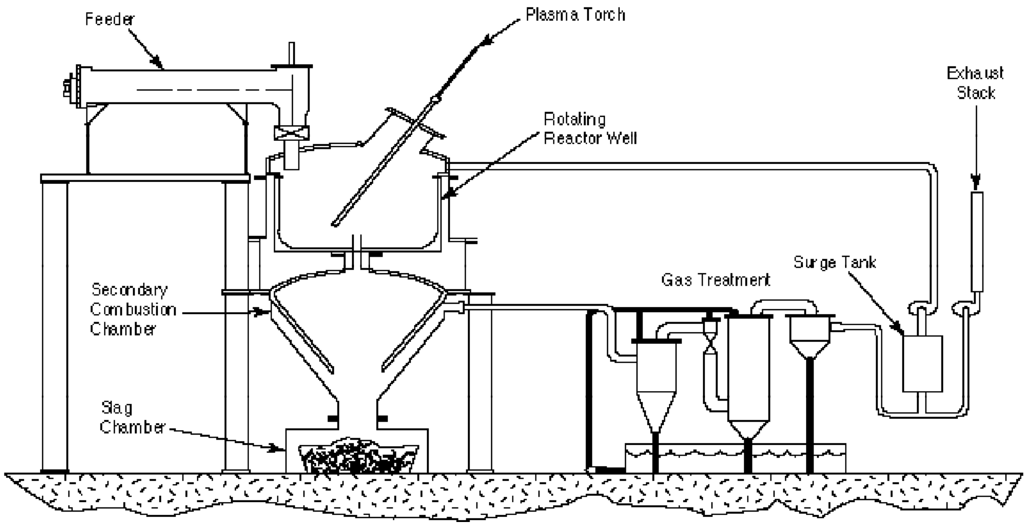

Figure C-3. System diagram, plasma centrifugal furnace.

Description of Support Technologies

To arrive at a relatively accurate estimate of the hazards posed by a particular technology, hazards associated with support technologies must be taken into consideration. Support technologies can be extremely hazardous in themselves and, if not considered in the overall analysis, the relative hazard ranking of one technology may prove to be miscalculated as compared with another.

For example, preliminary analysis of treating contaminated soil in place may show it as being preferable to the use of soil-washing technologies because of the hazards associated with the excavation that must be done to wash soil. However, *in situ* technologies often require an extensive wellfield to be drilled for the injection of nutrients and oxidants. Once the hazards of the drilling operations are considered, the soil-washing procedures may prove to be the preferred technology.

The Modifying Effects of the Medium to be Treated

The assessment of a remediation technology must address the hazards associated with the contaminant and the modifying effects of the medium to be treated. This process is equivalent to analyzing the input hazardous chemicals in a chemical manufacturing process. The major difference, however, is the modifying effect the environmental medium plays in limiting the potential exposure to the hazardous substances in question.

A contaminant in groundwater, even at significant levels, is significantly less hazardous than in its undiluted, pure form. Similarly, contaminants in soils also present less of a hazard because of the tendency of many hazardous substances to bind tightly to the soils and not be released easily.

In many cases, the potential for exposure to a hazardous substance in an environmental medium can be predicted based on the physical characteristics of the substance. If information about such characteristics is available, it can be used to predict off-gassing and atmospheric concentrations of hazardous substances. Physical parameters (e.g., temperature, pressure) at different points in a technological process can be used to predict airborne concentrations and the potential for exposure.

The toxicology of a hazardous waste can be analyzed early in the technology development process and the results relayed as the technology moves along the development continuum. If a technology is designed to treat a range of hazardous substances and environmental media, information specific to each group or category should be captured and relayed.

Safety Hazards

System Safety Analysis and Hazard Identification

The Occupational Safety and Health Administration (OSHA) has concluded that effective management of worker safety and health protection is a decisive factor in reducing the extent and severity of work-related injuries and illnesses. Management that is effective addresses all work-related hazards, including those that could result from a change in worksite conditions or practices.

Predictive Hazard Identification

Predictive hazard identification techniques are used to systematically analyze processes, jobs, and operations and to anticipate hazards that might arise under planned operating conditions. Efforts can then be made to control such hazards before employees are exposed to them. However, even the most disciplined approaches to predictive hazard analysis do not always succeed in identifying all hazards. Predictive hazard analysis requires the skills of individuals with significant experience in recognizing occupational hazards. Moreover, such an analysis is most useful with respect to new or startup operations or to those undergoing significant changes. Predictive hazard identification processes include —

- Process hazard analysis,
- Checklist analysis,
- What-if analysis,
- Change analysis,
- Fault tree analysis,
- What-if checklist analysis,
- Failure mode and effects analysis,
- Hazard and operability studies,
- Human reliability analysis,
- Phase hazard analysis, and
- Nuclear safety analysis.

Hazard Identification Team

To protect employees from workplace hazards, those hazards must be recognized, evaluated, and understood. A team of safety and health professionals experienced in hazard identification and system safety analysis techniques should be formed to predict or observe the hazards of a remediation technology.

Types of Analyses

The following sections briefly describe systematic approaches to identifying occupational safety and health hazards. The overlap of the methods used in these various approaches ensures total coverage and a comprehensive hazard inventory.

Observational Hazard Analysis

In observational hazard analysis, hazard identification is performed under actual operating conditions and is based on examination of work conditions and equipment, work practices, accidents and near-accidents, and injury and illness trends. Unfortunately, such identifications frequently occur after employees have been exposed to a hazard or after the hazard has resulted in an accident, injury, or illness. Nevertheless, observational hazard identification is valuable because it accounts for both work site conditions and employee behavior and can reduce the likelihood of injury to exposed workers as well as prevent exposure in the future. The efforts of experienced safety and health professionals can be supplemented by the observations of supervisors and workers during routine safety inspections and accident/ incident investigations.

Process Hazard Analysis

A process hazard analysis (PrHA) is performed to identify every possible worksite hazard to employees. It is directed toward analyzing potential causes and consequences of fires and explosions, releases of toxic or flammable chemicals, and major spills of hazardous chemicals. The analysis also focuses on equipment, instrumentation, utilities, and external factors that might have an impact on the process being examined. A “process” can be any series of actions or operations that terminates in a finished product ready for consumption or in a product that is the raw material for subsequent processes.

A PrHA includes documentation of the results for use in followup and in training personnel to prevent future injuries and incidents. Such an analysis builds on the identification of hazards with the objective of a complete understanding of those at hand. Moreover, control of the hazards identified is attempted through recommendations that arise from the process hazard review. OSHA suggests that any organization contemplating a comprehensive safety and health program will benefit from conducting a PrHA.

Once it is identified, an element of a process (e.g., a series of actions or operations that terminates in a finished product or in a product used in a subsequent process) is analyzed to determine if it presents no hazard, an uncontrolled hazard, or one that can be controlled in every foreseeable circumstance. The earlier such an analysis is performed in the development of a remediation technology, the better the opportunity for identifying hazards and engineering them out. Conducting a PrHA when a process is being designed enables the selection of process equipment that is effective, efficient, and safe. Information from a PrHA can also can be used to develop an appropriate inspection and maintenance schedule.

In "Managing Worker Safety and Health," OSHA recommends a team approach to performing a PrHA, because one person usually will not possess all the necessary knowledge and experience.[1] Moreover, a team approach usually will ensure that a range of disciplines, opinions, and perspectives is drawn on, and that the knowledge and expertise of several individuals contribute to the analysis.

Checklist Analysis

Performance of a checklist analysis is an easy way to verify the status of a system[2] and to evaluate materials, equipment, and procedures. Such an analysis is performed primarily to indicate compliance with standards and work practices, and secondarily to identify hazards, design deficiencies, and potential accidents associated with common process equipment and procedures. Resources used to develop checklists include codes, standards, and regulations. Among the checklists available is the Well's Checklist, the main headings of which listed below. An exhaustive checklist appears in the "Guidelines for Hazard Evaluation Procedures" developed by the Center for Chemical Process Safety in 1992.

Well's Checklist Main Headings

A. Basic process considerations

B. Some overall considerations

C. Operating limits

D. Modes of plant startup, shutdown, construction, inspection and maintenance, trigger events, and deviations of the system

E. Hazardous conditions

F. Ways of changing hazardous events or the frequency of their occurrence

G. Corrective and contingency actions

H. Controls safeguards and analysis

I. Fire, layout, and further precautions

J. Documentation and responsibilities.

[1] U. S. Department of Labor: "Managing Worker Safety and Health," Office of Cooperative Programs, OSHA. 1993.

[2] U. S. Department of Energy. DOE Guideline: Guide for Chemical Process Hazard Analysis, Draft, DOE/EH, Washington, D. C., 1993. pp. 36-43.

To provide maximum usefulness, a checklist should be designed for a specific facility, operation, or process and should beaudited and updated regularly. Checklist analyses, whether simple or in-depth, are cost-effective tools for identifying customarily recognized hazards, and they constitute a common basis for management review of an analyst's assessment of processes and operations.

It is good practice to have all checklists approved by appropriate staff and managers before a process or operation moves from one stage to another. The output of a checklist analysis can serve as a source of information for managers to consider when making safety improvements and taking other actions.

Samples of Brief Checklist Analyses

Material

- Do all the raw materials continue to conform to the original specifications?
- Is each receipt of the material checked?
- Does the operating staff have access to material safety data sheets (MSDSs)?

Equipment

- Has all equipment been inspected as scheduled?
- Have pressure relief valves been inspected as scheduled?

Procedures

- Are the operating procedures current?
- Are the operators following the operating procedures?
- Are all the new operating staff trained properly?

A checklist, useful as it is, has its limitations: it is somewhat narrow in scope and, especially if the checklist is preformulated, it is difficult to ensure that all hazards are covered. Checklists may indicate what hazards exist, but they do not provide information about the accident scenarios associated with them. Other types of analyses can and should be used to supplement checklist analyses.

What-If Analysis

A what-if analysis identifies hazards, hazardous situations, or specific accident events that could produce an undesirable consequence.[3] As its name implies, what-if analysis involves the examination of possible deviations from the design, construction, modification, or operating intent of a process. A process can be assessed from beginning to end, or at any stage, using whatever information and knowledge are available at the time. Similar to "brainstorming," a what-if analysis is performed by individuals who ask questions and voice concerns about any undesirable event they can conceive of in a given process. Potential accidents are not ranked nor are they measured quantitatively. What results instead from such an analysis is a list of questions about the given process. The following are examples of such questions:

"I wonder what would happen if the wrong material were delivered?"

"What if the Pump Y seals began to leak?"

"What if Valve X failed to open?"

Once questions have been formulated, they may be grouped into specific topical areas (e.g., industrial hygiene, electrical safety, fire protection, or construction safety) to be addressed by experts in each area. The results of the analysis are documented on worksheets in narrative form, including the questions and answers that constitute potential accident scenarios, their consequences, and possible risk-reduction or protection methods.

Because of its unstructured nature, a what-if analysis requires an experienced staff and careful organization to produce results that are useful and complete.

Change Analysis

When something new is introduced into a workplace, it can bring one or more hazards along. Identifying and evaluating such potential hazard(s) is called a change analysis.[4] Personnel need to be notified of changes in the workplace and in some cases to receive related training. Changes that should trigger an analysis include —

- New materials introduced to a process,

[3] DOE Guideline: Guide for Chemical Process Hazard Analysis, pp. 44-52.

[4] U. S. Department of Labor: Managing Worker Safety and Health.

- New processes,
- Changes to the workforce, and
- New equipment.

Obviously, the human element should always be part of a change analysis. Changes involving personnel, including the results of medical or other problems, should be analyzed. Effective managers are sensitive to such changes and their potential effects on the safety and health of individuals, as well as on the facility.

Fault Tree Analysis

Fault tree analysis (FTA) is a deductive failure analysis technique focusing on an accident or undesired outcome to study the events that caused it.[5, 6] As shown in Figure C-4, the causes of a top event or accident are separated into basic equipment failures and human errors, and the resulting diagram looks like a tree with many branches, each branch listing the sequential events (failures) in the independent paths to the top event. Probabilities (using failure rate data) are then assigned to each event and are used to calculate the probability of occurrence of the undesired event. The FTA model is used by both technical and nontechnical decisionmakers.

FTA is not a practical method for identifying the hazards in a system or process; instead, it is useful in evaluating the effects of alternative actions, in order to reduce the probability of an undesired event and also to perform an in-depth analysis of significant hazardous events identified using other hazard evaluation techniques. FTA is most effective for analyzing complex systems and new facilities or processes, because it enables undesirable outcomes to be traced to their origins. Once the sequence of undesirable events has been traced, design prevention and control can be used to help protect against them.

[5] DOE Guideline: Guide for Chemical Process Hazard Analysis. pp. 78-88.

[6] Garrett, Jack T., Lewis J. Cralley, Lester V. Cralley: *Industrial Hygiene Management*. New York; John Wiley and Sons, 1988. p. 148.

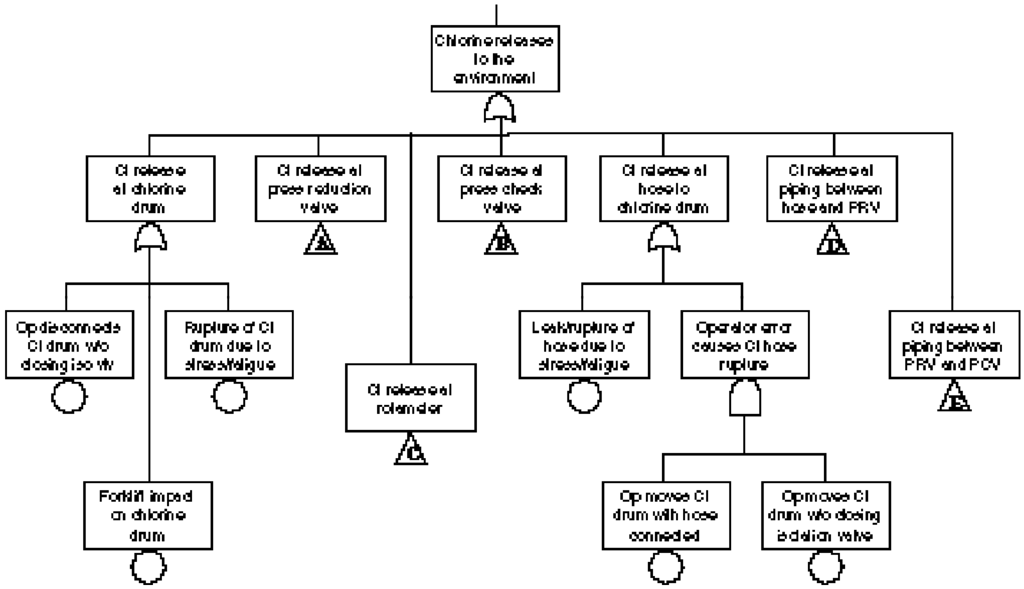

Figure C-4. Example of FTA for chlorine release to environment[7].

FTA consists of four steps:

1. Defining the system or process,
2. Constructing the fault tree,
3. Analyzing the fault tree qualitatively or quantitatively or both, and
4. Documenting the results.

The analysis consists of reviewing the system requirements, function, design, environment, and other factors to determine the conditions, events, and failures that could contribute to an occurrence of the undesired top event. This top event is defined in terms of subtop events (i.e., events that describe the "whens" and "wheres" of the hazard in the top event.) These are not basic causes but are intermediate faults that require further development. The analyst follows this process until all intermediate faults are identified with their causes. Typical fault causes include equipment failures, human response errors, and initiating events.

[7] DOE Guideline: Guide for Chemical Process Hazard Analysis. p. 87.

An FTA is usually performed by a team. Resources required to perform an FTA include a detailed understanding of how a process or system functions, detailed process drawings and procedures, and knowledge of component failures and effects — a breadth of knowledge more easily supplied by a team than by an individual. The amount of time required for a team to model a single top event involving a simple process could be 1 day or less.

What-If Checklist Analysis

A what-if checklist analysis is a hybrid of two other PrHA techniques, discussed above (i.e., what-if and checklist analyses).[8,9] Combining creative thinking with a methodical focus, the what-if checklist analysis is used to —

- Identify hazards,
- Consider types of accidents that can occur in a process or activity,
- Evaluate the consequences of potential accident scenarios, and
- Determine whether the safeguards against them are adequate.

A what-if checklist analysis team made up of staff from a wide range of disciplines reads background information about a facility and then conducts a walkthrough evaluation, asking “what-if” questions about the hazards and safety of the operation or facility.

Based on the checklist, the team suggests ways of reducing the risk or protecting the operating process. This information is documented in a narrative-style, question-and-answer format on the what-if checklist analysis worksheet. The worksheet serves as a repository of field information and results, but can also serve as a training tool for operating personnel on the hazards of a particular operation.

The limitations of a what-if checklist analysis depend on the individuals who make up the analysis team. Without an experienced team, the checklist and the analysis may not be complete and not all hazardous situations may be addressed. The number of individuals needed for such a study depends on the complexity of the process and the stage at which a given process is evaluated.

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[8] DOE Guideline: Guide for Chemical Process Hazard Analysis. pp. 53-58.

[9] Garrett, Jack T., et al.: *Industrial Hygiene Management*. p. 147.

Failure Mode and Effects Analysis

Failure mode and effects analysis (FMEA) is a methodical study of symptom or condition failures of equipment (hardware) that should be performed prior to operation of new facilities.[10,11] A failure mode is defined as —

- Loss of function,
- Premature function (function without demand),
- Out-of-tolerance condition, or
- Physical characteristic noted during an observation.

Before an FMEA can be performed, the problem that is the subject of the analysis must be defined in detail. If a known system or process hazard is being evaluated, the FMEA should concentrate on the failure modes of equipment and their components. If, however, the hazards of the system or process are not known, the FMEA should focus on the failure modes and effects of individual equipment. This analysis begins with a review of a process diagram that includes all components the failures of which could conceivably affect the safety of the operation (e.g., instrument transmitters, controllers, valves, and pumps). Each component is analyzed for its potential mode of failure, the effects of failure, detection methods, and other factors. Concurrent failures are also included in the analysis.

Key to performing an accurate FMEA is ensuring that the effects of potential equipment failures are analyzed using common tools. Typically, an analyst evaluates the effects on a worst-case basis, assuming that existing safeguards do not work. The data produced by the analysis are recorded onto tabular worksheets to avoid the possibilities of omissions. The worksheet is completed by beginning at the system boundary of a reference drawing and systematically evaluating the components in the order in which they appear in the process flow path. The data are then analyzed, and recommendations for risk management are developed.

In 29 CFR 1910.119, “Process Safety Management,” OSHA states that an FMEA is usually aimed at the major component level because it provides the best tradeoff between the time necessary to complete it and the usefulness of the information it provides.

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[10] DOE Guideline: Guide for Chemical Process Hazard Analysis. pp. 69-77.

[11] Garrett, Jack T., et al.: *Industrial Hygiene Management*. pp. 147-148.

Conducting an FMEA is appropriate for analyzing batch systems in which the state of a component or the consequences of a failure may vary at different times. Performing an FMEA is also a good way to analyze a continuous process system during its various modes of operation, including startup, operation, and shutdown. During the feed operation, for example, a feed valve to a batch reactor should be open. If the valve does not open, one set of consequences occurs. During a later processing step, this valve should be closed. If the valve does not close, another set of consequences occurs.

An FMEA generates a qualitative, systematic reference list of the analyzed equipment, failure modes, and effects. An FMEA should not be performed by one person, but by teams of qualified and experienced individuals. Best suited to the study of single-event failures, FMEAs are not often used to investigate damage, injury, or operator errors that may occur if a system or process successfully operates without failures, nor are they recommended for the study of many combinations of equipment failures that result in accidents.

Hazard and Operability Study

A hazard and operability (HAZOP) study identifies the safety hazards in process plants and the operability problems that could adversely affect productivity.[12] The underlying assumptions of a HAZOP study are that, when operating, processes and systems work as they were designed to do and that when deviations occur, so do HAZOP problems. Like what-if analysis, a HAZOP study involves brainstorming to generate accident scenarios. The difference between the two PrHA techniques is that the HAZOP study uses guide words to focus the discussions. The guide words also serve to ensure that all relevant process deviations are evaluated.

A HAZOP study focuses on the specific points of a process, variously called study nodes, process sections, or operating steps. A HAZOP team evaluates each study node for potential hazardous deviations in the process. Process deviations are developed by combining guide words with process components. Care should be taken to avoid including too much of a process into a study node, because the deviations that should be investigated may then be missed. Conversely, if too little of a process is included in a study node, the root causes of deviations and the resulting consequences tend to become separated from one another.

[12] DOE Guideline: Guide for Chemical Process Hazard Analysis. pp. 59-68.

An example of a HAZOP study begins with the review of a piping and instrumentation diagram by a team of specialists who critically analyze the effects of problems arising in each pipeline and vessel involved in an operation. The team selects pertinent parameters (e.g., flow, temperature, pressure) and evaluates them for potential hazardous situations. In the case of deviations from design, the consequences of failure are examined. Existing safeguards and controls are identified. The HAZOP assessment is made based on weighing the consequence, causes, and protection requirements involved; results are recorded on a HAZOP worksheet. A typical HAZOP study report should contain a brief system description, a list of drawings or equipment analyzed, the design intent, the HAZOP worksheets, and a list of action items.

A HAZOP study should be performed deliberately and systematically to reduce the possibility of omissions. The team assembled to perform such a study must have considerable knowledge of the process, its instrumentation, and its operation.

One limitation of a HAZOP study is the time and effort it takes, because it is designed to provide a complete analysis of a process or system. Another big limitation is that it does not analyze occupational hazards. An excerpt from an actual HAZOP is shown in Figure C-5.

Figure C-5. Excerpt from actual HAZOP worksheet.

Company: XYZ, Inc. Node:

Facility: Tract 6 - Pumps Page: 1

Session: 1 04-11-94, Revision: 0 04-08-94 Dwg#: 1

Node: 1 From pumps PU-3194, 8924, etc...thru fume header to knock-out pot

Parameter: Flow

Intention: To flow process fumes at a rate of 300 scfh from the pump through the knock-out pot where condensate is removed.

G W	Deviation	Causes	Consequences	Safeguards	S	L	R	Recommendations	Remarks	B
More	More Flow	1. High fume header vacuum.	1.1 Low temperature in processor due to overcapacity processing. 1.2 Poor VOC destruction.	1. TIC-101 range of 1400-2000° F causes low temperature alarm TAL-101 locally. 2. Routine operator surveillance. 3. Operating procedures and operator training.	5	3	6			
		2. Higher inlet pressure into the eductor.	2.1 Low temperature in processor due to overcapacity processing. 2.2 Poor VOC destruction.	1. TIC-101 range of 1400-2000° F causes low temperature alarm TAL-101 locally. 2. Routine operator surveillance. 3. Operating procedures and operator training.	5	3	6		Make sure pressure indicator and regulator on plant air line appear on P&ID.	
		3. Incorrect setting of rotameter.	3.1 Low temperature in processor due to overcapacity processing. 3.2 Poor VOC destruction.	1. TIC-101 range of 1400-2000° F causes low temperature alarm TAL-101 locally. 2. Routine operator surveillance. 3. Operating procedures and operator training. 4. Pressure indicator and regulator on Plant Air line.	5	2	6	1. Operating procedures should include maintains on rotameter only.		
		4. More pump seal failure than system is designed for (roughly 8,000 ppm avergage at inlet to the oxidizer).	4.1 Overtemp the oxidizer. 4.2 Possible VOC release to atmosphere. Environmental concern. 4.3 High level in the knock-out pot. 4.4 Unit shutdown.	1. TSH-101 A/B set at 2000° F and 350° F, respectively, is an automatic shutdown on high temperature. 2. Shutdown alarm in control room. 3. TIC-101 range of 1400°-2000° F. 4. LSH-100 would cause unit shutdown. 5. Routine operator surveillance. 6. Operating procedures and training.	4	1	5			

Figure C-5. Excerpt from actual HAZOP worksheet (continued).

G W	Devi-ation	Causes	Consequences	Safeguards	S	L	R	Recom-mendations	Remarks	B
Less		1. Block valve pinched; line partially blocked/ plugged; check valve partially restricted.	1.1 Possible VOC release to atmosphere from pump seal. Operational concern.	1. Flow indicator on line. 2. Routine operator surveillance. 3. Operator training.	5	3	6			
		2. Reduced fume header vacuum.	2.1 Possible VOC release to atmosphere from pump seal. Operational concern.	1. Flow indicator on line. 2. Routine operator surveillance. 3. Operator training.	5	2	6			
	Less Flow	3. Low setting on rotameter.	3.1 Possible VOC release to atmosphere from pump seal. Operational concern.	1. Flow indicator on line. 2. Routine operator surveillance. 3. Operator training.	5	3	6			
		4. Line rupture	4.1 Possible VOC release to atmosphere from pump seal. Operational concern. 4.2 Possible liquid (gasoline) loss to ground.	1. Routine operator surveillance. 2. Maintenance procedures and training. 3. Pressure indicator on fume header. 4. Operating procedures and operator training.					One PI is on header add as sg.	

Risk Assessment Code

For each safety and health hazard identified, a risk assessment code (RAC) should be assigned. The RAC represents the degree of risk associated with the hazard considering its severity and mishap probability (likelihood or chance of occurring). A RAC code helps employees make informed judgments about the hazards they may work with so that they can take necessary precautions.

The following RAC description is the one the Navy uses to assess hazards (OPNAVINST 5100.23C, 2 November 1992). Other RAC methodologies also exist.

Hazard Severity

The hazard severity is an assessment of the potential consequences of the hazard, as defined by the degree of injury, occupational illness, or property damage that is likely to occur as a result of the hazard. A hazard is assigned to a severity category using Roman numerals according to the following criteria:

Category I -	Catastrophic: May cause death, or loss of a facility.
Category II -	Critical: May cause severe injury, severe occupational illnesses, or major property damage.
Category III -	Marginal: May cause injury, occupational illnesses, or property damage.
Category IV -	Negligible: Probably would not affect personnel safety or health, but is nevertheless an OSHA violation.

Mishap Probability

The mishap probability is the probability that a hazard will result in a mishap, based on an assessment of such factors as location, exposure in terms of cycles or hours of operation, and affected population. Mishap probability is assigned an Arabic letter according to the following criteria:

Subcategory A	Likely to occur immediately or within a short period of time.
Subcategory B	Probably will occur in time.
Subcategory C	May occur in time.
Subcategory D	Unlikely to occur.

Risk Assessment Code

The RAC, then, is an expression of risk that combines the elements of hazard severity and mishap probability. Using the matrix below, the RAC is expressed as a single Arabic number that is used to rate the hazard.

Hazard Severity	Mishap Probability			
	A	**B**	**C**	**D**
I	1	1	2	3
II	1	2	3	4
III	2	3	4	5
IV	3	4	5	5

RAC	
1	Critical
2	Serious
3	Moderate
4	Minor
5	Negligible

Phase Hazard Analysis

Phase hazard analysis is a helpful tool in the construction industry and other industries that involve a rapidly changing work environment, different contractors, and widely differing operations. Phase hazard analysis is performed when a new phase of an operation is to be started that involves hazards not experienced in previous phases or when a new subcontractor or work crew is to work on an existing operation.[13]

Before beginning a major new work phase, a contractor or site manager should assess the hazards anticipated, coordinate supplies and support, and establish a plan to eliminate or control the hazards, using PrHA techniques such as job safety analysis (JSA) or change analysis. The major additional task is to identify hazards that develop when combinations of activities occur close to one another.

[13] U. S. Department of Labor: Managing Worker Safety and Health, Office of Cooperative Programs. OSHA. 1993. pp. 7-16.

Hazardous waste site remediation operations and their associated technologies are as unique as chemical package plant operations because they are used in a fashion similar to a construction operation, as compared with the operations of a process plant. That is, hazardous waste site remediation operations have a beginning, an operating phase, a shutdown phase, and an end or closure. The dynamic nature of site operations requires the safety and health professional to examine the phases of technology implementation, construction, operation, maintenance, and dismantlement and decommissioning. Each phase poses hazards that are technology-specific, and that can be identified, designed out, or incorporated into training and informational programs.

Because hazardous waste treatment technologies move rapidly through construction, startup, operation, shutdown, maintenance and decommissioning, all phases of a technology should be analyzed in the safety systems analysis. The hazard identification team should include process engineers or other professionals familiar with each phase of the technology. Implementation of hazardous waste remediation technologies has been found to include all the hazards of a typical hazardous waste site.

Hazards associated with equipment transportation need to be considered when a hazard analysis of remediation technologies is performed, since many remediation technologies are packaged onto flatbed trailer trucks for transportation. For example, the hazardous waste incinerator site at the Bridgeport, New Jersey, Superfund site required 30 flatbed tractor trailer trucks. Transportation accidents, including those involving trucks, are the number one cause of occupational fatalities nationwide. Being struck by a motor vehicle is also another major cause.

Cranes and slings and harnesses may play a critical role in the construction phase of remediation technologies. The hazards associated with lifting heavy components of a technology must be considered during the design phase. General construction safety must also be included in the hazard analysis of a technology.

Operation may be one of the safest phases of a technology's use. However, particular attention should be paid to the effect of perturbations in the concentration of the hazardous substance in the waste stream. Concentration spikes can derail a treatment process, initiate uncontrolled chemical reactions, and result in catastrophic explosion.

Special attention should be given to maintenance operations; experience with hazardous waste treatment technologies indicates that these operations are particularly dangerous. Lockout/tagout of energy sources, safety systems for ensuring that components have sufficiently cooled down, and other engineering controls should be considered and incorporated into system design.

Periods of transition from one phase to another (e.g., from construction to operation, operation to maintenance) may be particularly hazardous. The information obtained from a phase hazard analysis should be incorporated into checklists that are designed to remind operators of all the procedures that must be followed before a technology may progress into the next phase. For example, it is critically important that thermal destruction units be allowed to cool before maintenance operations are performed. Nevertheless, because of production requirements, workers have often been expected to perform operations on hot equipment. This practice has led to several incidents where workers tasked with removing slag from combustion chambers have received severe burns when hot slag has fallen on them.

Equipment Hazard Reviews

Equipment Hazard Reviews (EHRs) can be conducted at any time. A team that includes operators of the equipment and others is recommended. EHRs use a variety of types of analysis. An EHR Worksheet follows:

Hazard Review Open-Ended "Equipment Hazard Review" Worksheet

The equipment must be reviewed to identify potential hazards to employees. Possible groups of concerns are the following:

1. Hazardous Materials
2. Physical Hazards
3. Psychological Concerns

A review of the materials that are used in the new technology and a determination of the products of the process are necessary. Each material should be reviewed to determine if it is classified as a hazardous material according to the hazard definitions of the Department of Transportation (DOT) and the EPA (e.g., ignitability and corrosivity). It is important to review each material to determine its classification. If the materials are mixed, the classifications are added. For instance, if a mixture was created by mixing a flammable liquid, a corrosive material, and a poison, the mixture should be handled as a flammable, corrosive substance that also contains a poison.

1. Hazardous Materials

DOT Classification

1. Explosives, six subgroups
2. Oxygen (allowed label)
2.1 Flammable gas
2.2 Nonflammable gas, non-poisionous
2.3 Gas, poisonous by inhalation
3. Flammable liquids or combustible liquids
4.1 Flammable solid
4.2 Spontaneously combustible
4.3 Dangerous when wet
5.1 Oxidizer
5.2 Organic peroxides
6.1 Poisonous materials
6.2 Infectious substances
7. Radioactive
8. Corrosive
9. Miscellaneous

EPA's definitions

10. Ignitability
11. Reactivity
12. Corrosivity
13. Toxicity

2. Physical Hazards - Conduct Equipment Hazard Review

Assemble a multidisciplinary team that includes the operators of the equipment and workers.

1. Identify safeguards that are in place.
2. Do the safeguards work?

Learn how the equipment is expected to be used.

3. Can the equipment be misused?

   Look for the following concerns:

   1. Machine guarding
   2. Ergonomics
   3. Electricity
   4. Noise
   5. Confined space
   6. Walking, working surfaces
   7. Personal protective equipment
   8. Utilities
   9. Process safety
   10. Temperatures, hot, cold, other
   11. Add others when recognized
   12. Stored energy in the equipment (air cylinders, high temperatures, etc.)
   13. Shearing, cutting, crushing
   14. Pressure, high, low, none (pressure could be steam, water, air, hydraulic, other)
   15. Temperature, too high, too low
   16. Flow, excessive, low, no flow
   17. Material handling
   18. Add others when recognized

3. Psychological Concerns

1. Scared of workstation
2. Monotonous jobs
3. Claustrophobia
4. Disorientation while using personal protective equipment
5. Add others when recognized

Safety standards are published for nearly everything that is built. Equipment must meet all the requirements of the published standards. Some standard sources are OSHA, the American National Standards Institute, and the American Society for Testing and Materials.

All concerns must be addressed by creating a plan to manage them. This is an open-ended document.

For pathogens (harmful agents or micro-organisms), DOT uses the term “infectious agents” and OSHA uses the term “biological hazards”. Both address the same concern, safe management. Following is a list of pathogenic agents.

DOT Infectious Agents (EPA Biological Hazards)

1. Bacteria, pathogens
2. Fungal, viral-hepatitis-B
3. Molds, nuisance
4. Parasites, ticks, chiggers, mites
5. Plants, poison ivy
6. Animals, snakes

Job Safety Analysis

One of the quickest, surest ways to reduce accidents is to improve employee skills. Job skills improve with experience and are enhanced with training.[14] To determine training needs, a job function or task must be analyzed systematically.[15]

JSA is the most basic and widely used tool to identify job and task hazards and to prevent accidents. JSAs can be used to perform a large portion of the hazard identification tasks at a facility, and are appropriate to analyze activities such as construction that involve dynamic tasks. JSAs also are appropriate in static work environments (i.e., operations and maintenance activities). Quick completion time with limited resource allocation makes

[14] U. S. Department of Energy. Job Safety Analysis by Division of Operational and Environmental Safety (DOE 76-45/19 SSDC-19). Idaho Falls, Idaho. 1979. p. 2.

[15] U. S. Department of Labor Mine Safety and Health Administration: Job Safety Analysis Development by National Mine Health and Safety Academy (MSHA Instruction Guide 32 C). Beckley, West Virginia, 1982. p. 1.

the JSA a very adaptable and widely used hazard identification technique. Hazard identification needs may be satisfied without using other costly or time-consuming techniques. For that reason, a JSA should be completed before other predictive hazard identification techniques are used. Like other PrHA techniques, the JSA requires a commitment from management to be successful and fully implemented.

JSAs are performed to satisfy the requirements of OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) Standard, 29 CFR 1910.120, which includes the requirements to perform preliminary site evaluations and hazard identification before employees may be permitted onsite (29 CFR 1910.120 (c)). Health and safety plans (HASPs) address the hazards of each phase of site operation and include requirements and procedures for employee protection. They are a mandatory requirement set forth by OSHA (29 CFR 1910.120 (b)(4)). JSAs are used to supplement HASPs where generic procedures may not address the specific and changing situations of hazardous waste site work.

A JSA is performed by breaking down a job into its component steps and then examining each step to determine the sources of hazards and causes of accidents that may potentially occur.[16] Reviewing the job steps and hazards with the employees performing the job helps ensure that a comprehensive and accurate list of hazards is identified and documented. Consideration must be given to job mobility, area of performance, ongoing operations performed by others in surrounding areas, specific hazards in an area, relative age and job experience of the workforce, applicable safety and health rules, and the recognition of abnormal or unforeseen problems. JSAs benefit new employees by providing a basis for them to perform their jobs. Experienced employees also benefit from JSAs by being reminded of the safety-related aspects of their jobs.

When a JSA is completed, it should be reviewed by a qualified person who was not part of the process. This independent check will lend more credibility to the JSA and could identify areas that were missed or are not clear. It is very important for the language in the JSA to be appropriate to the target audience. The results of the JSA must be communicated to employees. "Tool box" meetings are a good place to make workers aware that a JSA was completed. JSAs should be incorporated into safe work permits and construction safe work permits. Those workers directly involved in the performance of a JSA should receive appropriate training.

[16] U. S. Department of Labor Mine Safety and Health Administration: Job Safety Analysis Development by National Mine Health and Safety Academy. p. 3.

JSA training should be documented and workers should be asked to sign off on understanding and adhering to related requirements.

Because a job or process is subject to change over time, it is imperative to review the associated JSA regularly. Part of an effective JSA process includes periodic review of its functionality, which can lead to improvements. Such reviews also show if workers are following job procedures. To help determine if a particular process or job itself is creating unsafe conditions, accident injury and illness data can be reviewed. This information is the "report card" of the procedure developed from the JSA. Accident injury and illness reports should be evaluated for abnormal data and trends.

Whether a job is performed differently or other measures are put in place to eliminate or reduce a hazard, new safe-work procedures should be reviewed with all employees performing the related job. For the JSA to be successful, it is important to solicit worker feedback about the hazards and proposed changes. Employee participation will ensure that the proposed changes are sensible and accepted by the workers who are protected by the process. Improvements in job methods can lead to reduced costs incurred by employee absenteeism and worker's compensation and often to increased productivity.

Experience has shown that when a JSA program is first established it is greeted by a great deal of enthusiasm from all those involved. As time goes on, however, enthusiasm wanes, and workers become less and less safety-conscious. For a JSA program to be successful, the same amount of effort used to establish it must be devoted to maintaining it.[17]

Safety Inspections

Safety inspections are one of the most frequently used tools in identifying work hazards. Sometimes, safety inspections are performed informally by walking through work areas and noting hazardous conditions or activities. A more methodical approach such as the use of checklists usually results in a more thorough assessment and a more efficient use of time. Including employees in safety inspections or interviewing employees has many benefits. Often, employees are the only ones who can provide valuable insights into how things really work because of their long-term involvement with equipment, materials, and processes.

[17] U. S. Department of Energy. Job Safety Analysis by Division of Operational and Environmental Safety (DOE 76-45/19 SSDC-19). Idaho Falls, Idaho. 1979. p. 17.

In addition, employees can provide practical knowledge about their workplaces that is not always obvious to surveyors or inspectors. Employee participation on inspection teams helps employees become more knowledgeable about workplace hazards, prevention, and controls and therefore makes them better able to protect themselves and others. This knowledge is especially important at sites where several contractors' employees of differing expertise may work close to each other. These employees need to know how to protect themselves from hazards associated with the work of nearby colleagues as well as from hazards connected to their own work.

Occupational safety and health professionals should prevent inspections from becoming routine and predictable by performing them periodically and not adhering to a schedule that sites can anticipate. Inspection frequency depends on the size and complexity of the site and its operations. OSHA recommends that medium and large fixed worksites be inspected at least every quarter, with some portions of such inspections being made each month. Non-fixed sites (i.e., construction sites) should be inspected weekly because of their rapidly changing nature and unique hazards. OSHA recommends that even the smallest work sites should be inspected at least quarterly.

Employee Suggestions, Complaints, and Involvement

Because employees have unique and frequently untapped knowledge about work hazards and practical controls, their involvement is critical to a successful hazard analysis. Employees are intimately familiar with work processes, are essential members of the hazard identification team, and can be helpful in conducting inspections, analyzing activities, and designing controls. Their suggestions and complaints provide another route to identifying hazards.

For their involvement in system safety analysis activities to be successful, employees must —

- Be trained in hazard recognition;
- Be provided with appropriate checklists;
- Have ready access to safety and health professionals;
- Have access to reference sources;
- Be able to suggest abatement methods; and
- Be able to track corrective actions.

Employee involvement is also important in performing routine hazard analyses and in designing controls. Where more complex processes require the systematic evaluation of each step of a job or task, employee input is essential because hands-on procedures do not always correlate with written procedures. Employees should also be drawn into the task of developing or reviewing TSDSs.

Trend Analysis

The repetitive occurrence of injuries or illnesses indicates a hazard or type of hazard that is not controlled adequately. Analyses of injury and illness trends lead to the identification of common causes and aid in developing better hazard prevention controls. Trend analysis involves investigating where the injuries or illnesses occurred, what type of work was being done, the time of day, type of equipment in use, and so forth.

Review of illness and injury logs is the most common form of trend analysis. However, any records of hazards can be analyzed for patterns. For example, inspection records and employee hazard reporting records may indicate patterns if they contain enough entries to allow patterns to emerge. A site that has few employees or where very little hazardous work is performed may require a review of records dating back 3 to 5 years. A 5-year review of a site that experiences only one or two injuries each year nevertheless may reveal uncontrolled cumulative trauma hazards or lack of attention to tripping hazards. Larger sites may obtain useful information from yearly, quarterly, or monthly reviews. In any case, each worksite should record and track all occurrences of work-related injuries and illnesses.

Hazard identification should occur more frequently than incidents. Therefore, patterns should emerge over a shorter period of time when reviewing hazard identification records. Whenever the perception is that too many similar incidents of illness or injury have occurred among a group of workers, immediate action must be taken to determine the cause.

Communicating Hazard Information

Hazard Matrices

One of the first and most important uses of technology hazard matrices occurs after a remedial investigation and feasibility analysis is completed and the remedial design and engineering phase of a cleanup project begins. Before selecting a preferred technology for accomplishing the cleanup objectives of a site, an engineer must compare the advantages and disadvantages of several different alternatives. Cost and performance data, along with the likelihood of gaining regulatory agency approval, usually are the most important factors (indeed, often the only factors) used in making such a selection.

The technology hazard matrices shown in Tables C-1 and C-2 summarize and compare the health and safety considerations associated with cleanup technology options. If this information is available to engineers at an early stage of the remedial design decision-making process, significant potential exists to select technology options that will reduce overall health and safety hazards to workers.

Each of the technology hazard matrices shows a variety of health hazards across the top of the chart and potential cleanup options (i.e., technology alternatives) in the left column. This format allows an engineer to quickly compare the health and safety pros and cons of various alternatives and to make a selection with some understanding of the safety and health implications. For example, in a situation where two or more cleanup alternatives pose roughly the same level of health and safety risks to workers, the engineer is likely to select the lowest cost alternative. However, in cases where health and safety implications vary significantly among potentially viable environmental remediation technologies, the engineer may analyze the technology hazard matrix and determine that a safer though more costly alternative may be warranted.

Technology hazard matrices are valuable tools when initiating discussion of cleanup options with State and Federal regulatory agency personnel and concurrence in obtaining the option selected from regulators at a relatively early stage of the life cycle process. These tools can provide a basis for rational and defensible technology selections that can withstand scrutiny.

Recent contract awards by the Department of Defense (DoD) and DOE have emphasized the overall importance of worker safety and health, including, in some cases, linking incentive awards and fees to performance. The technology hazard matrix also can be useful in demonstrating to site managers how achieving worker safety and health goals may be advanced by a technology selection process that considers the health and safety implications of several cleanup alternatives. Consideration of such matrices can easily be added to the discussion of cost and performance data and the regulatory approval process in making more informed decisions regarding technology selections.

Technology/Process	Contaminants	Health Hazards										Comments
		Inhalation	Hand/Arm Vibration	BioHazards	Skin Adsorption	Heat Stress	Ingestion	Noise	Radiation	Nonionizing Radiation	Other Ergonomic	
PACT Wastewater Treatment System	Biodegradable VOCs and SVOCs											
ZenoGem Process	Non-Specific Biodegradable Organics											
Ultraviolet Radiation and Oxidation	Halogenated Hydrocarbons, VOCs, Pesticides, PCBs											
In Situ Steam Enhanced Extraction	VOCs, SVOCs, Hydrocarbons, Solvents											
Membrane Separation, Bioremediation	PAHs, PCBs, TCEs, Organic Compounds											
Hydraulic Fracturing	Cyanides, Sulfites, Non-Specific Organics											
Chemical Oxidation Technology	Fuel Hydrocarbons, VOCs, SVOCs, Chlorinated Solvents											
Vapor Treatment Process	Fuel Hydrocarbons, VOCs, SVOCs, Chlorinated Solvents											
CA-VOX Process	Non-Specific Organic Compounds											
In Situ Remediation of Chromium in Groundwater	Hexavalent Chromium, Uranium, Selenium, Arsenic											
Heavy Metals and Radionuclide Sorption Method	Heavy Metals, Radionuclides											
Soil Washing and Catalytic Ozone Oxidation	Cyanide, SVOCs, Pesticides, PCBs, PCP, Dioxins											
Membrane Microfiltration	Heavy Metals, Cyanide, Uranium											
PO*WW*ER Technology	Metals, VOCs, Non-Volatiles, Salts											
Biological Aqueous Treatment Systems	Nitrates, Chlorinated and Nonchlorinated Hydrocarbons, Pesticides											
In Situ Subsurface Bioremediation	Hydrocarbons, Halogenated Hydrocarbons, and Chlorinated Hydrocarbons											
Subsurface Volatilization and Venting System	BTEX Compounds											
Integrated Vapor Extraction and Steam Vapor Stripping	Non-specific Organics, Low-Level Radionuclides											
Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization	Heavy Metals											
ICB Biotreatment Method	Readily Biodegradable Organic Compounds											

Table C-1. Health hazard matrix for aqueous phase treatment technology.

Technology/Process	Contaminants	Safety Hazards														Comments
		Lockout/Tagout	Confined Space	Flammable	Explosion	Electrical	Fire	Mechanical Hazards	Pressure Hazards	Traffic	Tripping and Falling	Ladders/Platforms	Unauthorized Entry	Overhead Hazards	Illumination	
PACT Wastewater Treatment System	Biodegradable VOCs and SVOCs															
ZenoGem Process	Organics															
Ultraviolet Radiation and Oxidation	VOCs , Pesticides, PCBs															
In Situ Steam Enhanced Extraction	Hydrocarbons, Solvents															
Membrane Separation, Bioremediation	TCEs, Organic Compounds															
Hydraulic Fracturing	Organics															
Chemical Oxidation Technology	VOCs, SVOCs, Chlorinated Solvents															
Vapor Treatment Process	Chlorinated Solvents															
CA-VOX Process	Compounds															
In Situ Remediation of Chromium in Groundwater	Uranium, Selenium, Arsenic															
Heavy Metals and Radionuclide Sorption Method	Heavy Metals, Radionuclides															
Soil Washing and Catalytic Ozone Oxidation	Pesticides, PCBs, PCP, Dioxins															
Membrane Microfiltration	Cyanide, Uranium															
PO*WW*ER Technology	Volatiles, Salts															
Biological Aqueous Treatment Systems	Hydrocarbons, Pesticides															
In Situ Subsurface Bioremediation	Chlorinated Hydrocarbons															
Subsurface Volatilization and Venting System	BTEX Compounds															
Integrated Vapor Extraction and Steam Vapor Stripping	Organics, Low-level Radionuclides															
Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization	Readily Heavy Metals															
ICB Biotreatment Method	Organic Compounds															

Table C-2. Safety hazard matrix for aqueous phase treatment technology.

Preparing a Technology Safety Data Sheet

System Analysis and Functional Evaluations for Safe Transitions

If performed correctly, the phase hazard analysis should yield a wealth of information about the hazards of moving from one stage of a technology's implementation to another (e.g., from construction through startup to operation, from operation through shutdown to maintenance, from maintenance through startup to operation and from operation through shutdown to decommissioning). Each transition phase involves performing specific standard operating procedures (SOPs). These SOPs can be developed into checklists that can be used to ensure that all procedures are performed before a technology moves into the next stage of implementation.

APPENDIX C-3

Implementation: Putting the Technologies to Work

Whenever a new technology is being considered for use at a site, site operations and safety and health personnel should form a team to evaluate associated information in terms of identifying and resolving any issues that could affect the technology's suitability for implementation before the technology or process is selected or delivered. The onsite staff should have the option of rejecting a new technology or product if it poses risks or issues that are impractical to manage.

Prior to Delivery

The general operations management structure for implementation of the technology (including roles, responsibilities, objectives, and expectations) must be defined prior to delivery in clear, unambiguous terms. The operations team and its members should have documented roles and interfaces as well. Team members must understand and trust one another's judgment and actions; if necessary, team-building activities and adjustments should be performed. The objective is to have a functioning operations *team* to implement and use the technology or product.

The organization developing or manufacturing the technology or product should be required to provide all documentation available, and, depending on the complexity of the operations to be undertaken, operations personnel should work with the developer or manufacturer to identify and mitigate any hazards or issues that the developer or manufacturer may not have anticipated. Operations personnel will likely have site experience and may be able to share relevant site-specific information. If the product/process is tailored to a specific site, this interaction with the developer/manufacturer is particularly important.

Checklists for Safe Transitions

The operations team should develop a checklist to support the transition into the implementation phase. The transition from one phase of technology implementation to another can be extremely hazardous, as, for example, when a technology moves from construction through startup to operation, or from operation through shutdown to maintenance or decommissioning operations. (See Figure C-6 for details on what should be included on a technology checklist.)

A transition also may occur as the result of an emergency, in which case a technology moves from operation to shutdown in an emergency shutdown mode. To mitigate the hazardous nature of such transitions, standard operating procedures (SOPs) should be developed to assist operators in moving a technology safely from one phase of implementation to another.

This checklist should include, at a minimum, a hazards analysis, a nuclear safety analysis, process descriptions, piping and instrumentation diagrams, electrical schematics and equipment classifications, design (or authorization) basis as they apply, design codes and standards that apply, safety systems (including emergency), operability parameters, information on supporting systems (including emergency), operability parameters, information on supporting systems (e.g., gantries or hoisting and rigging systems needed for construction, including subcontractors for specific instrumentation modules) and potential interactions with other activities near where the work is to take place (including whether they are trained to handle radioactively contaminated workers).

In addition, the operations team should assemble specific process/product information, such as process flow diagrams; contact points for notification for operating limits (upper and lower) for equipment and processes; risk evaluations associated with changes in process, system, or subsystem; heating, ventilation, and air conditioning requirements for both processes and equipment; and operating environment for personnel.

Figure C-6. Technology checklist.

Integration With Existing Programs

During the implementation phase, the Technology Safety Data Sheet (TSDS) should be used as a tool to supplement and support the existing safety and health management system rather than as a stand-alone document. Every environmental remediation site is required to have some form of a Health and Safety Plan (HASP). Because of the commonality of elements, information in the TSDS could be used, for example, to address specific elements and requirements within the HASP.

Similarly, safety analyses performed for the TSDS might be useful in addressing other requirements such as those for Operational Readiness Reviews, permit applications, or the Superfund Amendments and Reauthorization Act (SARA) Title III.

Technology Safety Data Sheets

A TSDS is the central repository for hazard information pertaining to a specific technology. Ideally, each TSDS contains information accumulated throughout the entire process of a technology's development, commercialization, and implementation. Modeled after the material safety data sheet (MSDS) required by the hazard communication standard, the TSDS should be incorporated into a site's hazard communication or Hazardous Waste Operations and Emergency Response (HAZWOPER) informational program. The TSDS should be readily accessible to all workers in proximity to the technology. In addition, the TSDS can be used to inform safety and health professionals of potential hazards and to enhance the site-specific elements of the requisite HAZWOPER training (both initial and refresher courses).

Each TSDS has several component pieces or sections. These sections and their potential usefulness to safety and health professionals are described below. (An example of a TSDS is included in Part I of this document.)

TSDS Section 1: Technology Identity

The first section of a TSDS identifies the technology that is the subject of the sheet, and lists any alternate names that the technology is known by, the manufacturer's name and address, information and emergency contacts, and the TSDS originator's name and address. This last is important because, as information about hazards a technology may pose becomes available, it needs to be relayed to the originator for inclusion on the TSDS. The emergency contacts that are listed on the TSDS should also be included in the site-specific Emergency Response Plan (ERP).

TSDS Section 2: References and Applicable Regulations

Section 2 lists the TSDS's sources of information. References may include operating manuals, SOPs, maintenance procedures and schedules, and transition checklists and applicable regulations. The applicable regulations may include environmental as well as health and safety requirements (e.g., HAZWOPER). Should the onsite safety professional locate and cite additional sources of pertinent information, they should be conveyed to the originator of the TSDS.

TSDS Section 3: Process Description

The third section is a process description, which serves as an introduction to the technology described in the TSDS. Although the process description does not include hazard information, it does familiarize the practicing safety professional with the technology under discussion.

TSDS Section 4: Process Diagram

The process diagram affords the onsite safety professional an overview of the entire system of the technology under discussion. Images that realistically depict the technology are as valuable as diagrams. (See Figure C-7.)

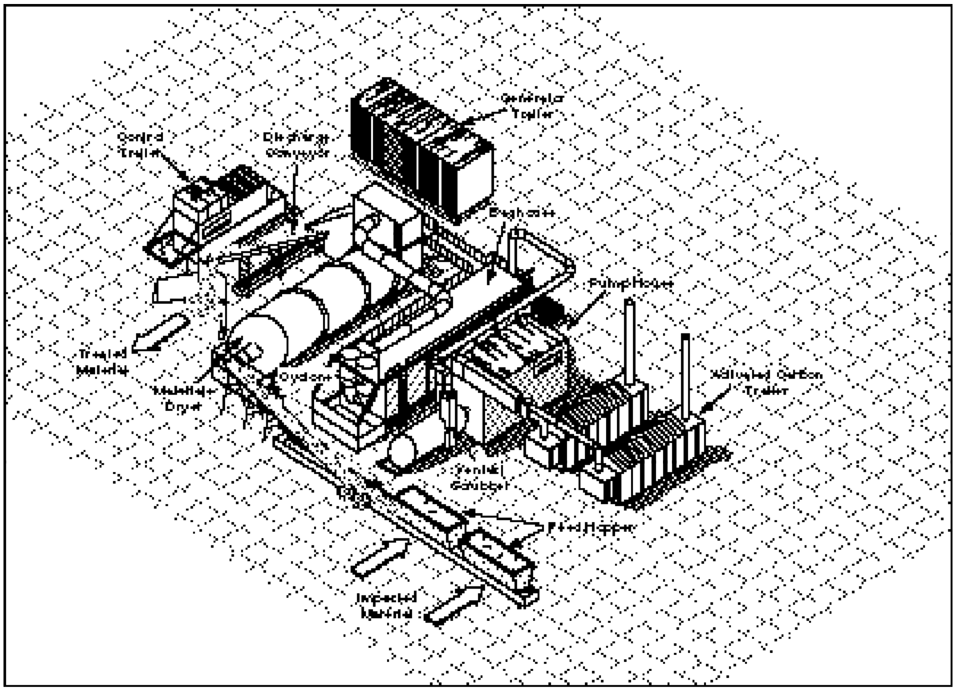

Figure C-7. Low-temperature thermal aerator.

TSDS Section 5: Contaminants and the Medium

A remediation operation may be prompted by the presence of contaminants in a waste stream at quantitative or qualitative levels sufficient to threaten public health. Ironically, however, the health threat posed to the workers who carry out the remediation operation may be higher than it would be to the surrounding population if no action were taken. In such a case, the potential occupational health risks associated with the waste stream must be understood and communicated to the remediation workers, that is, the hazard of the substance involved must be conveyed to the worker. The risk is not always simple to gauge, since the hazards of a pure substance are far different from the hazards of that same substance dispersed throughout a medium like groundwater or soil.

TSDS Section 6: Associated Safety Hazards

The sixth section of the TSDS is a reiteration of the safety hazard matrix. (For more information on this matrix, see Appendix C-2.) The hazards associated with the technologies that have been identified are listed and ranked in terms of severity. A rating of one indicates that a hazard may be present but is not expected to be above background level. For example, electrical hazards may be present but pose no hazard specifically linked to the technology. A rating of two indicates that some level of hazard above background is known to be present. For example, the technology may require 220-volt service as opposed to 110-volt service. A hazard rating of three indicates a high hazard potential, and a rating of four indicates the potential for being immediately dangerous to life and health (IDLH).

TSDS Section 7: Associated Health Hazards

The seventh section of the TSDS is a reiteration of the health hazard matrix (see Appendix C-2). The health hazard rating is identical to that discussed above for safety hazards.

TSDS Section 8: System Safety Analysis

If an in-depth system safety analysis of the technology has been performed, the results are to be presented in this section and must be included in the site-specific HASP. Such a safety analysis should provide the site safety professional with excellent hazard identification information.

TSDS Section 9: Phase Analysis

A hazardous waste site is similar to a construction site in that it is constantly changing, moving from initial characterization, through remediation, and ultimately to closure. A remediation technology is similarly dynamic in nature, and involves four overall phases of implementation: construction, operation, maintenance, and decommissioning. Each phase imposes its own hazards, whose changing nature at a given site must be recognized by the site safety professional and communicated to workers through the site information program as they occur. Similarly, a HASP needs to reflect the dynamic nature of a site. The hazards of each phase of a remediation technology's implementation are identified in this phase.

TSDS Section 10: Technology-Specific Programmatic Elements

This section of the TSDS is written specifically for the onsite safety professional. If the technology to be implemented at a site requires special program elements, guidance is included here on how to develop effective elements for inclusion into the safety and health program and site-specific HASP. For example, if the technology to be implemented requires a lockout/ tagout program, this section of the TSDS identifies that need, offers guidance on how to develop an effective program, and highlights any peculiarities that must be addressed.

TSDS Section 11: Comments and Special Considerations

This section is reserved for the originator and other contributors to insert information not easily categorized and not elicited in other sections of the TSDS. Clearly, this information should be reviewed by the onsite safety professional and any appropriate actions taken.

TSDS Section 12: Case Studies

This section is used to document in narrative form the experience of implementing a given technology, resulting in the creation of a "case" for study. Onsite safety professionals should review TSDS case studies to learn from the experiences of other professionals who have implemented the technologies previously.

Onsite safety professionals should send to the preparer of a TSDS any information they have that could be used to create a case study.

Regulatory Requirements

Anticipating the complexity, ever-changing nature and hazard potential of technologies associated with hazardous waste site remediation, OSHA's HAZWOPER Standard, 29 CFR 1910.120, specifically requires companies to establish programs to ensure the safe introduction of new technologies onsite. HAZWOPER paragraph (o), which discusses new-technology programs, applies to new technologies used in personal protective equipment (PPE) as well as to those used in remediation. Before implementation of a new technology can occur on a large scale, employers or their representatives must assess the effectiveness of the associated methods, materials, or equipment in enhancing employee protection.

The OSHA HAZWOPER Standard requires employers at uncontrolled hazardous waste sites to develop and implement informational programs to inform employees, contractors, and subcontractors of the nature, level, and degree of exposure likely as a result of engagement in hazardous waste operations.[1]

Hazardous waste is exempt from the Hazard Communication Standard because of the labeling requirements to which it is subject under the Resource Conservation and Recovery Act (RCRA). Nevertheless, an information program on hazardous waste might include postings on a safety bulletin board or company newsletter. Any hazardous materials used on a site, other than in the waste stream, should be addressed in a site hazard communication program, and should be described on MSDSs that are readily available to employees.

HAZWOPER requirements for responding to emergencies caused by the uncontrolled release of hazardous substances are presented in the HAZWOPER Standard. This Standard identifies requirements for emergency responses to the uncontrolled release of hazardous substances in three separate paragraphs:

- At hazardous waste sites and the sites of cleanup operations; see paragraph (l);
- At hazardous waste treatment, storage, and disposal facilities; see paragraph (p)(8); and
- At the site of any other type of operation where hazardous substances are released; see paragraph (q).

Although the requirements vary slightly depending on the applicable paragraph, those with the broadest application and most detailed specifications are found in paragraph (q), which applies to all industries subject to the potential for emergencies caused by uncontrolled releases of hazardous substances.

The key to compliance with the emergency response provisions in the HAZWOPER Standard is development of a comprehensive emergency response plan (ERP) as required in 29 CFR 1910.120, paragraph (q)(1) and as further defined in (q)(2), which lays out specific elements the plan must contain. Designers and manufacturers of technologies should be familiar with these specific elements to understand the

[1] Health and Safety Plan Guidelines, DOE Limited Standard, DOE-EM-STD-5503-94, U.S. Department of Energy, Washington, DC, December 1994.

complexity of response operations and the value of information derived from the technology development and system safety analysis process.

In addition to responsibilities under OSHA's HAZWOPER Standard, employers have obligations under SARA Title III to coordinate with local emergency planning committees (LEPCs) in order to establish adequate emergency responses for their facilities. This may require an employer to forward an entire set of MSDS from a facility, if the LEPC requests it. The logical sequel to having to meet these requirements is that industries will advise their LEPCs of the presence and associated hazards of the technologies they use. This may be done by forwarding TSDSs, emergency procedures, SOPs, and other information to the LEPCs.

Emergency Response Considerations

No matter how well designed, technologies have the potential to fail. When a technology is designed to treat media contaminated with hazardous materials, its failure may result in the uncontrolled release of a hazardous substance, energy, or debris that endangers the health or safety of those working in the vicinity. Promptly taken corrective actions may stabilize the situation and allow control to be reestablished safely.

Technology developers and manufacturers must address the potential for their technologies to fail and they must inform users of the procedures to follow, if failures occur. Such information and procedures can be very simple. For example, it has been reported that when an overpressurized vessel at the Union Carbide plant in Bhopal, India, released deadly gas in 1982, it is possible that many lives could have been saved with little additional effort. In this case, if people in the vicinity had breathed through water-soaked towels, they might have been able to counteract the effects of the methyl isocyanate gas that was released into the air and reduce or eliminate its harmful effects.

Emergency response information from technology developers and manufacturers should cover a broad variety of emergencies that could result from the failure of one or more technology processes or components. Moreover, this information is needed in a format that is easy to understand and capable of being used by site personnel and workers.

One important use of this information is for site managers to prepare a site-specific ERP. This plan must reflect not only the unique hazards and risks associated with use of the technology, but also the specific needs of local fire and police departments and hazardous materials (HAZMAT) and emergency response personnel. Although preparing this plan is the responsibility of the site manager and not the technology developers, the information used to develop the plan must be accurate and understandable if it is to be used in pre-incident emergency response planning. One possible tool for technology developers to use is an Emergency Procedures Safety Data Sheet (EPSDS). This tool would serve as a means for technology developers to provide a profile of emergency preparedness and response planning issues that need to be incorporated into a site's ERP.[2]

The intent of the EPSDS is to facilitate the transfer of appropriate emergency preparedness and emergency response information from technology developers to site managers for use in preparing a site-specific ERP. If the potential for failure is considered at the design stage and appropriate information is directed to the right people, the consequences of emergencies at sites using innovative cleanup technologies are less likely to jeopardize the safety and health of workers.

Emergency Response Plan Elements

A discussion of specific elements and procedures for developing the individual components of an ERP is provided in Part II of this document, with particular emphasis on considerations for designers and developers of hazardous waste treatment technologies. The listing of these elements is taken directly from the HAZWOPER Standard requirements for emergency response, as described in 29 CFR 1910.120, paragraphs (q)(1) and (q)(2).

[2] A preliminary review copy of a representative Emergency Procedures Safety Data Sheet is still being developed, but it should be available for review and discussion at the DOE and NIEHS technical workshop on November 30 and December 1, 1995.

ACRONYMS

BMPs .... Best Management Practices
CFR .... Code of Federal Regulations
CPR .... Cardiopulmonary Resuscitation
DOE .... Department of Energy
EMT .... Emergency Medical Technician
EPA .... Environmental Protection Agency
EPSDS .... Emergency Procedures Safety Data Sheet
ERP .... Emergency Response Plan
ERPG .... Emergency Response Planning Guideline
HASP .... Health and Safety Plan
HAZWOPER .... Hazardous Waste Operations and Emergency Response
HSO .... Health and Safety Officer
JSA .... Job Safety Analysis
LC50 .... Lethal Concentration that kills 50% of test subjects
LD50 .... Lethal Dose that kills 50% of test subjects
MSDS .... Material Safety Data Sheet
OSHA .... Occupational Safety and Health Administration
P&ID .... Piping and Instrumentation Diagram
PEL .... Permissible Exposure Limit
PPE .... Personal Protective Equipment
PSM .... Process Safety Management
RAC .... Risk Assessment Code
RCRA .... Resource Conservation and Recovery Act
RFP .... Request for Proposal
SAR .... Safety Analysis Review
SOP .... Standard Operating Procedure
STD .... Standard
SWP .... Safe Work Permit
TLV .... Threshold Limit Value
TSDS .... Technology Safety Data Sheet

NIEHS/DOE Innovative Technology II Workshop
November 30 - December 1, 1995

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