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IMPLEMENTATION GUIDE
for use with
DOE ORDER 440.1

OCCUPATIONAL EXPOSURE ASSESSMENT

OFFICE OF WORKER HEALTH AND SAFETY

FOREWORD

1. This Department of Energy (DOE) Guide is approved by the Office of Environment, Safety and Health and is available for use by all DOE elements and their contractors.

2. Beneficial comments (recommendations, additions, and deletions) and any pertinent data that may improve this document should be sent to the Office of Worker Protection and Hazards Management (EH-52), U.S. Department of Energy, Washington, D.C. 20585, by letter or by sending the self-addressed Standardization Document Improvement Proposal (DOE F 1300.3).

3. This Guide is intended to identify applicable methods for implementing the provisions of DOE O 440.1, WORKER PROTECTION MANAGEMENT FOR DOE FEDERAL AND CONTRACTOR EMPLOYEES.

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Figures and Tables

1. INTRODUCTION

DOE O 440.1, WORKER PROTECTION MANAGEMENT FOR DOE FEDERAL AND CONTRACTOR EMPLOYEES, establishes the framework for an effective worker protection program that will reduce or prevent accidental injuries and illnesses. One element of the worker protection program in DOE O 440.1 is Exposure Assessment (EA). This Guide provides acceptable methodologies for conducting EA for workers.

Exposure assessment should be included in the DOE and contractor written worker protection program, as required by DOE O 440.1. EA documentation should describe the methods and rationale a site uses to characterize and monitor workers' potential and actual exposures to hazardous agents.

2. APPLICATION

DOE O 440.1 applies to all activities (including design, construction, operation, maintenance, decontamination and decommissioning, research and development, and environmental restoration activities) performed by DOE and its contractors (and their subcontractors). The Order (including the functional area requirements in Attachment 1 to the Order) is applicable to all DOE elements except the Naval Nuclear Propulsion Program and activities conducted under the Nuclear Explosives and Weapons Safety Program relating to the prevention of accidental or unauthorized nuclear detonations to the extent a requirement under this part cannot be implemented for a particular facility in a manner that does not compromise the effectiveness of such activities. The Contractor Requirements Document (CRD) (Attachment 2 to the Order) delineates requirements that are to be applied to contractors that have been awarded contracts for performing work for DOE on DOE-owned or -leased facilities. Contractor compliance with the CRD will be required to the extent set forth in a contract.

This Guide provides guidance for implementing the EA requirements of DOE O 440.1, WORKER PROTECTION MANAGEMENT FOR DOE FEDERAL AND CONTRACTOR EMPLOYEES. In addition to DOE O 440.1, other directives containing requirements for EA are applicable to DOE or its contractors [e.g., Title 29 Code of Federal Regulations (CFR) Part 1960, *Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters,* and 42 USC Sect. 7274i, *Program to Monitor Department of Energy Workers*

Exposed to Hazardous and Radioactive Substances; for radiological hazards, consider 10 CFR 835, *Occupational Radiation Protection,* and the guidance contained in the series of implementation guides (b through l) that accompany 10 CFR 835]. These guidelines are discretionary and describe an acceptable mechanism for meeting the requirements of the Order, but they are not the only acceptable mechanism.

Other related worker protection implementation guides for DOE O 440.1 include:

- G 440.1-1, WORKER PROTECTION MANAGEMENT FOR DOE FEDERAL AND CONTRACTOR EMPLOYEES
- G 440.1-2, CONSTRUCTION SAFETY MANAGEMENT
- G 440.1-4, CONTRACTOR OCCUPATIONAL MEDICAL PROGRAM
- G 440.1-5, FIRE SAFETY PROGRAM
- G 440.1-6, IMPLEMENTATION GUIDE FOR USE WITH SUSPECT/COUNTERFEIT ITEMS REQUIREMENTS OF DOE O 440.1, WORKER PROTECTION MANAGEMENT; 10 CFR 830.120; and DOE 5700.6C, QUALITY ASSURANCE

3. GENERAL INFORMATION

3.1 Background

DOE O 440.1 requires that actions to assess and mitigate exposures be taken by DOE and its contractors. This should be done in conjunction with establishing appropriate goals for exposure reduction.

Specific applicable requirements for EA contained in DOE O 440.1 include:

- Identify existing and potential workplace hazards and evaluate the potential risk of associated worker injury or illness. Assess worker exposure to chemical, physical, biological, or ergonomic hazards through appropriate workplace monitoring (including personal, area, wipe, and bulk sampling), biological monitoring, and observation. Monitoring results need to be recorded. Documentation shall describe the tasks and locations where monitoring occurred, identify workers monitored or represented by the monitoring, and identify the sampling methods and durations, control measures in place

during monitoring [including the use of personal protective equipment (PPE)], and any other factors that may have affected sampling results. [Sect. 4.i and Attachment 2, Sect. 9]

- Implement a comprehensive and effective industrial hygiene program to reduce the risk of work-related disease or illness at affected facilities. Industrial hygiene programs shall include the following elements:
  - -- Initial or baseline surveys of all work areas or operations to identify and evaluate potential worker health risks. [Attachment 1, Sect. 5.a; and Attachment 2, Sect. 17.a]
  - -- Periodic resurveys and/or exposure monitoring as appropriate. [Attachment 1, Sect. 5.c; and Attachment 2, Sect. 17.c)]
  - -- Documented exposure assessment for chemical, physical, and biological agents and ergonomic stressors using recognized exposure assessment methodologies and use of accredited industrial hygiene laboratories. [Attachment 1, Sect. 5.d; and Attachment 2, Sect. 17.d]

- Evaluate workplace and activities (1) routinely by workers, supervisors, and managers and (2) periodically by qualified worker protection professionals. [Sect. 4.i.(3) and Attachment 2, Sect. 9.c]

- Comply with the following worker protection requirements.
  - -- 29 CFR 1910, *Occupational Safety and Health Standards*.
  - -- 29 CFR 1915, *Shipyard Employment*.
  - -- 29 CFR 1917, *Marine Terminals*.
  - -- 29 CFR 1918, *Safety and Health Regulations for Longshoring*.
  - -- 29 CFR 1926, *Safety and Health Regulations for Construction*.
  - -- 29 CFR 1928, *Occupational Safety and Health Standards for Agriculture*.
  - -- 10 CFR 835, *Occupational Radiation Protection*.
  - -- American Conference of Governmental Industrial Hygienists (ACGIH), *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* (most recent edition), when ACGIH Threshold Limit Values (TLVs) are lower (more protective) than Occupational Safety and Health

Administration (OSHA) Permissible Exposure Limits (PELs). (When ACGIH TLVs are used as exposure limits, DOE operations shall nonetheless comply with the other provisions of any applicable OSHA-expanded health standard.) The TLVs for exposures to laser emissions in the ACGIH Indices are excluded from this requirement.

-- American National Standards Institute Z136.1, *Safe Use of Lasers*. (Only the exposure limits and technical requirements apply. Programmatic components of American National Standards Institute Z136.1 do not apply.) [Sect. 4.l and Attachment 2, Sect. 12]

DOE and its contractors should be able to demonstrate an exposure assessment strategy that includes:

- A basis on national consensus standards, such as that developed by the American Industrial Hygiene Association, *A Strategy for Occupational Exposure Assessment* (hereafter referred to as the "AIHA Strategy" document). The contractor should document the approach chosen in the written worker protection program required in DOE O 440.1. For radiological hazards, DOE and its contractors should consider 10 CFR 835, *Occupational Radiation Protection,* and the accompanying series of implementation guides (b through l).

- Documentation as a part of the written worker protection program the approaches to be used in complying with 42 USC Sect. 7274i, *Program to Monitor Department of Energy Workers Exposed to Hazardous and Radioactive Substances*. In addition to guidance in the "AIHA Strategy" document, DOE and its contractors should consider other practices for exposure assessment and health surveillance that incorporate a preventative public health approach and that link the surveillance of workplace hazards, medical surveillance, reduction and prevention of exposure and disease (see *Preventing Occupational Disease and Injury*, American Public Health Association, and *Public Health Surveillance*, Van Nostrand and Reinhold, for more information on the public health model.)

- Demonstration of compliance with applicable requirements and document the acceptability or uncertainty of exposures.

- Use of existing data about facilities, equipment, materials, and tasks for implementing strategies to identify potential hazards and to prevent or mitigate exposures.

- Linking of data about hazards, exposures and medical monitoring to individuals and groups of individuals.

- Focused exposure and medical monitoring through prioritizing and targeting individuals and groups at significant potential risk.

- Documented analysis of the hazards of jobs and tasks.

- Documented medical monitoring and risk-estimating information.

- Trending of exposure measurements as an indicator of worker protection performance.

- Use of exposure information to focus worker protection efforts so that resources are used efficiently.

3.2 Definitions

Absorbed Dose (D) (radiation): Energy absorbed by matter from ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rads (or grays) (1 rad = 0.01 gray).

Administrative Control Level (ACL): The airborne concentration of a chemical contaminant below which additional assessment may not be necessary. The ACL should be initially set at 10% to 25% of an occupational exposure limit (OEL) and should be confirmed or changed as monitoring data and hazard analyses become available. The ACL is intended to be used as a decision point for determining compliance with the OEL and whether additional monitoring is necessary to determine compliance. The ACL is not intended to be used as a modified OEL.

Area Sample: An environmental sample collected at a fixed point in the workplace that reflects chemical contaminant concentrations or levels of physical or biological agents present at that point. Results from area sampling should be interpreted with caution because they do not represent employees' actual exposures to hazardous agents.

Bioassay: The determination of the kinds, quantities, or concentrations and, in some cases, locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of materials excreted or removed from the human body.

Breathing Zone: A hemisphere forward of the shoulders with a radius of approximately 6 to 9 inches (i.e., an area as close as practicable to the nose and mouth of the employee being monitored for a chemical or biological hazard). Breathing zone samples provide the best representation of actual exposure.

Collective Dose (radiation): The sum of the total effective dose equivalent values for all individuals in a specified population. Collective dose is expressed in units of person-rem (or person-sievert).

Committed Dose Equivalent ($H_{T,50}$) (radiation): The dose equivalent calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem (or sievert).

Committed Effective Dose Equivalent ($H_{E,50}$) (radiation): The sum of the committed dose equivalents to various tissues in the body ($H_{T,50}$), each multiplied by the appropriate weighting factor (W_T), i.e., $(H_{E,50}) = \sum W_T H_{T,50}$. Committed effective dose equivalent is expressed in units of rems (or sieverts).

Derived Air Concentration (DAC) (radiation): For the radionuclides listed in Appendix A of 10 CFR 835, the airborne concentration that equals the annual limit of intake (ALI) divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m^3). For radionuclides listed in Appendix C of 10 CFR 835, the air-

immersion DACs were calculated for a continuous, nonshielded exposure via immersion in a semi-infinite atmospheric cloud. The values are based on the derived airborne concentration found in Table 1 of the Environmental Protection Agency's *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (EPA, 1988).

DOE-Prescribed Exposure Limit: Any mandatory limit on employee exposure to a hazardous chemical, physical, or biological agent that is contained in a DOE regulation, Order, or Notice.

Dose (industrial hygiene): The amount of a substance available for interaction with metabolic processes of a worker following exposure and absorption. The amount of a substance crossing the exchange boundaries of skin, lungs, or digestive tract is termed *absorbed dose;* the amount available for interaction with any particular organ or cell is termed the *delivered dose* for that organ or cell.

Dose (radiation): The amount of energy deposited in body tissue due to radiation exposure. Some types of radiation, such as neutron and alpha, deposit their energy more densely in affected tissue than gamma radiation, thereby causing more damage to tissue. The term dose equivalent, measured in rems, takes into account this difference in tissue damage. Therefore, 1 rem from gamma radiation causes damage equivalent to 1 rem from alpha radiation. However, it takes 1/20 as much energy from alpha radiation as from gamma radiation to produce this 1 rem dose equivalent.

Dose Assessment (radiation): The process of determining radiological dose and uncertainty included in the dose estimate through the use of exposure scenarios, bioassay results, monitoring data, source-term information, and pathway analysis.

Dose Equivalent (H) (radiation): The product of the absorbed dose (D) in tissue (in rads or grays), a quality factor (Q), and all other modifying factors (N). Dose equivalent is expressed in rems (or sieverts) (1 rem = 0.01 Sv).

Effective Dose Equivalent (H_E) (radiation): The sum of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factors (W_T)—that is, $H_E = \Sigma W_T H_T$. It includes the dose from radiation sources internal and/or external to the body. The effective dose equivalent is expressed in rems (or sieverts).

Exposure Assessment (EA): The systematic collection and analysis of occupational hazards and exposure determinants such as work tasks; magnitude, frequency, variability, duration, and route of exposure; and the linkage of the resulting exposure profiles of individuals and similarly exposed groups for the purposes of risk management and health surveillance.

Exposure Profile: A representation, commonly as a matrix or other means, of the most relevant exposure and hazard determinants of a similarly exposed group or individual (e.g., population demographics; type or nature of the hazard; work conditions; and exposure time, frequency, or variability). This profile permits the health effects data or medical monitoring data to be evaluated and inferences to be made so that linkages can be drawn between hazards and exposures for purposes of qualitative estimation of risk or quantitative risk analysis and epidemiology, if warranted. Such evaluations should be conducted in collaboration with occupational medicine. Objectives include targeting exposure reduction, control efforts, and medical monitoring of individuals or groups at significant risk of exceeding the Occupational Exposure Limit in order to prevent adverse health effects.

External Dose or Exposure (radiation): That portion of the dose equivalent received from radiation sources outside the body (i.e., external sources).

Hazardous Exposure: Exposure to any toxic substance, harmful physical agent, ergonomic stressor, or harmful biological agent that poses or may pose a recognized hazard to the health of employees.

Health Hazard: Any hazardous agent (physical, chemical, or biological) or ergonomic stressor for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or

highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes. Appendix A of 29 CFR 1910.1200 provides further definitions and explanations of the scope of health hazards, and Appendix B of that standard describes the criteria to be used to determine whether or not a chemical is considered to be hazardous.

Homogeneous Exposure Group (HEG): A group of employees whose exposures to a hazardous agent have been determined to be statistically similar enough that, by monitoring a small number of individuals in the group, the exposures of the remaining workers can be defined. The group is statistically homogeneous in the sense that the probability and distribution of exposures is the same for all members of the group.

Internal Dose or Exposure (radiation): That portion of the dose equivalent received from radioactive material taken into the body (i.e., internal sources).

Medical Profile: A representation, commonly as a matrix or other means, of the most relevant medical monitoring data of a similarly exposed group or individual (e.g., a comparison of baseline and periodic medical examinations and test data, along with exposure assessment data) in a manner that allows inferences to be made about health effects. This may be done to promote analysis of data as a means to target primary intervention strategies to reduce exposures and health effects, to facilitate employee counseling, to target medical monitoring of at-risk groups or individuals, or to support epidemiology. Information is fed back to industrial hygiene and health physics professionals to assist them in making decisions about the need for continuing exposure assessment or for improving monitoring strategies, controls, exposure reduction efforts, and worker training.

Occupational Carcinogen: For purposes of this Guide, a chemical substance utilized in the workplace that has been designated in the following sources as a carcinogen or potential carcinogen: (1) National Toxicology Program, *Annual Report on Carcinogens* (latest edition); (2) International Agency for Research on Cancer, *Monographs* (latest editions); (3) OSHA standard 29 CFR 1910, Subpart Z, *Toxic and Hazardous Substances;* and (4) American Conference of

Governmental Industrial Hygienists, *Threshold Limit Values for Chemical Substances and Physical Agents.*

Occupational Dose (radiation): An individual's dose due to exposure to ionizing radiation (external and internal) as a result of that individual's work assignment. Occupational dose does not include planned special exposures, exposure received as a medical patient, background radiation, or voluntary participation in medical research programs.

Occupational Exposure Limit (OEL): A generic term used to represent: (1) the concentration or intensity of the agent that is allowable, (2) the time period over which workplace concentrations are averaged to compare with the allowable intensity, and (3) the allowable level of a determinant in a biological sample. Some substances may have several OELs (e.g., one for 8 hours, one for 15 minutes, and a not-to-exceed ceiling). OELs include regulated limits [e.g., OSHA's Permissible Exposure Limits (PELs)] and recommended limits [e.g., the Threshold Limit Values (TLVs) published by the American Conference of Governmental Industrial Hygienists (ACGIH)].

Permissible Exposure Limit (PEL): The maximum level to which an employee may be exposed to a hazardous agent in a specified period, as defined by OSHA in 29 CFR 1910 or 29 CFR 1926. (The airborne PEL is based on concentrations in the ambient air and does not consider personal protective equipment.)

Personal Dosimetry (radiation): Devices such as film badges, thermoluminescent dosimeters, and pocket ionization chambers designed to be worn by an individual for the assessment of dose equivalent.

Personnel Monitoring (radiation): Systematic and periodic estimate of radiation dose received by personnel during working hours. Also, the monitoring of personnel, their excretions, skin, or any part of their clothing to determine the amount of radioactivity present.

Personal Monitoring: The process of measuring the concentration of a hazardous chemical in the breathing zone of an individual, using a method such as a personal air pump to gather a sample for analysis, a direct-reading instrument, or a monitor worn by the worker in the breathing zone. For physical or biological agents, it is the process of measuring the quantity that potentially contacts or affects any part of an exposed individual. Area monitoring is not considered personal monitoring.

Professional Judgment: That capability of an experienced professional to draw correct inferences from incomplete data. Such judgment is based on observation, analogy, past experience, and peer review.

Qualitative Assessment: The estimation of the magnitude, frequency, duration, and route of exposure based on integration of available information and professional judgment.

Quantitative Assessment: The determination of the magnitude, frequency, duration, and route of exposure based on collection and quantitative analysis of data sufficient to adequately characterize exposures.

Risk Profile: A representation, commonly as a matrix or other means, of the analysis of exposure assessment data and medical profile data, resulting in a qualitative or quantitative estimation of the risk of health effects. This estimation is used to guide risk management decisions and decisions about the need for additional health effects, epidemiological, or toxicological studies. The profile should, at a minimum, relate the potential for exceeding the Occupational Exposure Limit to observed or measured medical monitoring data or trends.

Senior Industrial Hygienist: A person who is certified in the practice of industrial hygiene or who meets the American Board of Industrial Hygiene's (ABIH's) requirements for eligibility to take the examinations for certification. At a minimum, such individuals must have a college or university degree in industrial hygiene; chemistry; physics; chemical, mechanical, or sanitary engineering; medicine; or biology; special studies and training; and 5 years of full-time employment in the professional practice of industrial hygiene. (See the ABIH *Bulletin* for detailed requirements for certification or eligibility for certification.)

Similar Exposure Group (SEG): A group of employees whose exposures to chemical substances have been determined to be similar enough that monitoring the exposures of randomly selected workers in the group provides data useful for predicting the exposures or exposure profiles of the remaining workers. An SEG is also defined as a group of individuals who perform the same jobs or tasks and who have similar potentials for exposure to a single hazardous agent. Exposure groups may be reclassified into Homogeneous Exposure Groups (HEGs), providing that the Exposure Group meets the statistical requirements of an HEG, as defined in the "AIHA Strategy" document.

Surveillance Linkage: The process of relating exposure assessment, medical monitoring, and risk data to individuals or similarly exposed groups.

4. GUIDELINES

This section provides guidelines for implementing and documenting EA activities as well as integrating EA with existing programs and operations. The overall approach is shown in Fig. 1.

This Guide is intended to address specific implementation issues relating to EA at DOE sites. Specifically, this Guide goes beyond encouraging DOE and its contractors to use appropriate consensus standards and provides guidance on the integration of those standards with existing DOE operations and requirements.

The written worker protection program required by DOE O 440.1 should include the mechanism for program integration with other disciplines, integration of hazards analysis from upper level facility analysis to activity based analysis, documentation of exposure assessment, performance measurement, exposure reduction and minimization goals, trends analysis, occurrence reporting, work planning and project management, and a description of how EA is linked to integrated safety management objectives.

4.1 Use of Technical Guidance

DOE and its contractors should consider using the most recent version of the following technical guidance documents as appropriate to establish site-specific EA strategy and data analysis methods:

- American Industrial Hygiene Association (AIHA), *A Strategy for Occupational Exposure Assessment* (the "AIHA Strategy" document);
- National Institute for Occupational Safety and Health (NIOSH), *Manual of Analytical Methods;*
- N. A. Leidel, K. A. Busch, and J. R. Lynch, *Occupational Exposure Sampling Strategy Manual,* NIOSH, January 1977;
- OSHA *Technical Manual;*
- U.S. Environmental Protection Agency, *Guidelines for Exposure Assessment;*
- 10 CFR 835, *Occupational Radiation Protection,* and its implementation guides (b through l); and
- The *DOE Radiological Control Manual* (DOE, 1994a) (commonly referred to as the *RadCon Manual*).

The DOE element or contractor should consider the data analysis methods for non-radiological hazards as described in the relevant preceding documents and analyze employee exposure data to determine:

- compliance with DOE-prescribed exposure limits;
- distributions of the exposure data, to include geometric mean, geometric standard deviation, variance, and cumulative dose for each worker for each hazardous agent;
- the distribution of exposures within similarly exposed groups, using accepted statistical methods; and
- trends in exposure or biological monitoring data for individuals and groups of individuals (i.e., exposure groups).

Figure 1 has been modified slightly from the "AIHA Strategy" document to incorporate aspects of integration with other DOE requirements for hazards analysis, documentation, and occupational medicine/health surveillance. Note that the general EA process is applicable to both radiological and nonradiological hazards.

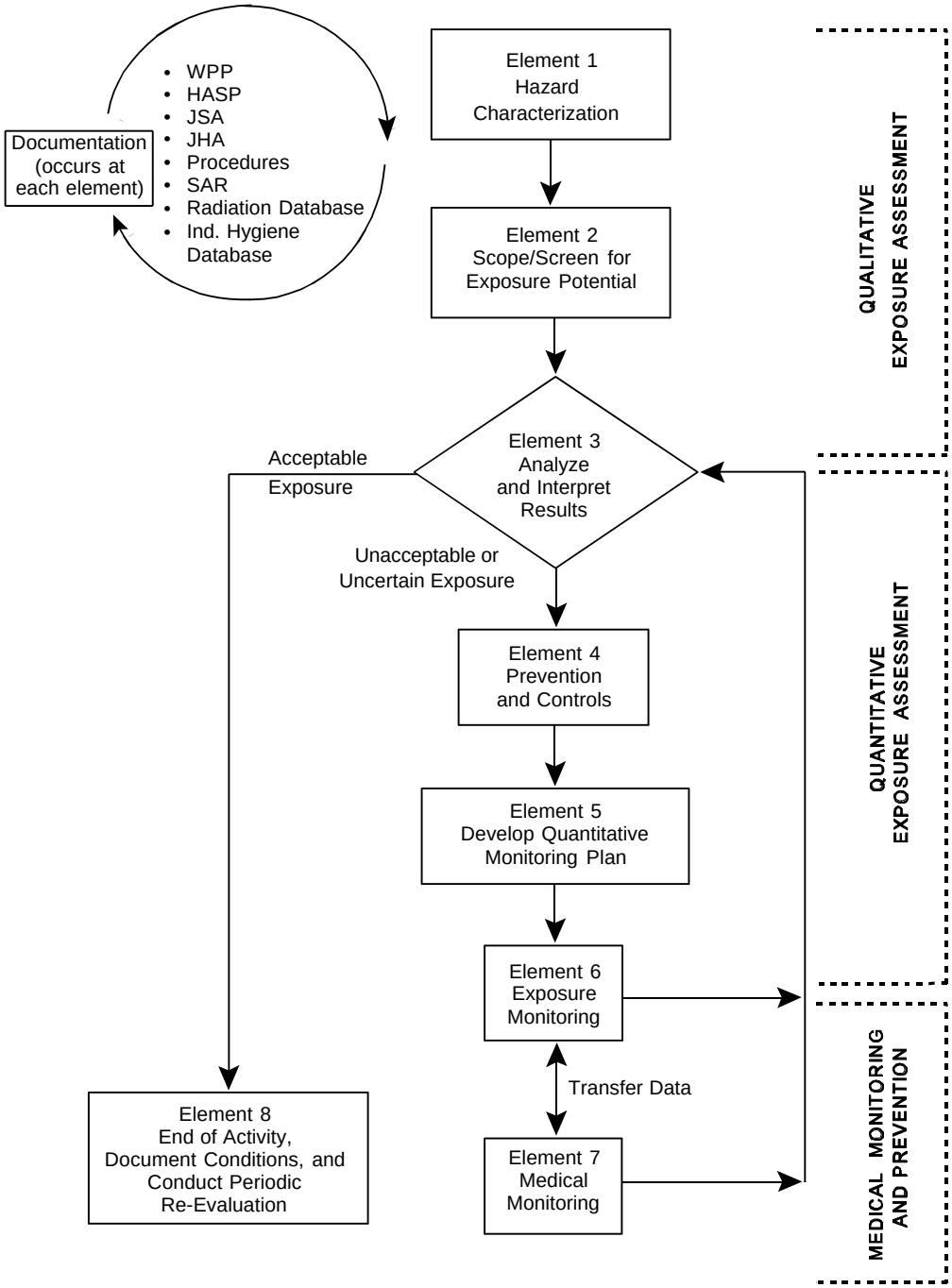

Figure 1. Overview of the Exposure Assessment Strategy

4.2 Exposure Assessment Approaches

DOE O 440.1 requires DOE and its contractors to include at least the following items in their assessments:

- Analysis of proposed new designs, operations, processes, materials, or equipment before use to determine potentially hazardous exposures. These analyses should be performed in conjunction with the contractor's purchasing, engineering, and contracting organizations, as appropriate [paragraph 4.i and Attachment 2, Sect. 9].

- Analysis of any changes (both proposed and completed) in operations, processes, materials, control equipment, work practices, or personnel that have the potential to cause new or additional hazardous exposures [paragraph 4.i and Attachment 2, Sect. 9].

- A comprehensive baseline or periodic survey of all areas and operations identified by the senior industrial hygienist or senior health physicist as having potential occupational exposure hazards. The survey should include input from line management, occupational medicine, occupational safety, fire protection, radiation protection, environmental protection, maintenance, and engineering, as appropriate [Attachment 1, Sect. 5.a, and Attachment 2, Sect. 17.a].

Beyond the guidance for exposure assessment contained in the “AIHA Strategy” document, DOE and its contractors should develop exposure assessment plans that recognize that exposure assessment is an iterative process that begins with basic hazard identification (see Fig. 1) and is linked to various other worker protection activities and requirements. This planning process is the critical step, and, depending on the nature of the hazard and the exposure potential, the planning may lead to a decision that either no monitoring or various degrees and types of monitoring (qualitative or quantitative) may be needed. It is important to involve the workers and appropriate staff (e.g., occupational medical staff and those responsible for hazard control) and to document all rationale, results, and decisions. This aspect should also be integrated into the DOE or contractor integrated work planning and project management system.

4.3 Integration of Non-Radiological and Radiological Issues

- *Radiological hazard*s refer to those associated with ionizing radiation and radioactive materials. The health physicist is the professional concerned with protection of individuals from these hazards. Health physics, a discipline concerned with protection from ionizing radiation, has its own dose terms such as *absorbed dose*, *dose equivalent*, and *effective dose equivalent*, which have definite prescribed meanings. In health physics, the term *dose* refers to the energy absorbed by the tissue.

- *Industrial hygiene hazards* include chemical agents; physical agents such as noise, nonionizing radiation, temperature extremes, and vibration; ergonomic hazards; and biological agents. The industrial hygienist is the professional concerned with protection of individuals from these hazards.

An important distinction between the disciplines is the focus of the industrial hygienist on using exposure to estimate the risk to the individual, whereas the health physicist uses dose to estimate the risk. In industrial hygiene, worksite exposures are measured both to control risk and to estimate individual risk. In health physics, worksite exposures are measured to control risk, whereas doses are measured or assessed to estimate individual risk.

This Guide primarily deals with exposure assessment for non-radiological hazards. However, the intent is to promote the integration of common aspects of work-activity-based hazards assessments and exposure monitoring activities. For the purposes of this Guide, radiological hazards are considered a subset of physical hazards. The industrial hygienist and the health physicist should cooperate and exchange information in order to combine the strengths of both, maximize controls, eliminate conflicts in approaches, expedite and streamline the process and documentation effort, and communicate a coherent approach to workers and supervision.

There are some distinctions between actions that should be taken for *non-radiological* (industrial hygiene) hazards and those that should be taken for *radiological* (health physics) hazards. In many respects, however, the distinction between the two disciplines is artificial. Certain substances (e.g., uranium) are both radiological and chemical hazards, and often exposures are both chemical and radiological in nature.

This Guide does not attempt to restate guidance for radiological hazards that may be found elsewhere (e.g., 10 CFR 835, *Occupational Radiation Protection,* and its implementation guides. In developing exposure assessments, DOE and its contractors should endeavor to integrate the process of assessment of all hazards including radiological and non-radiological health hazards. The general approach, as noted in Fig. 1, applies to both radiological and non-radiological health hazards. Accordingly, the industrial hygienist and the health physicist should work as a team and collaborate on developing their exposure assessments and integrate their documentation wherever possible (e.g., in the development of Job Safety and Hazard Analysis, Job Work Planning documentation, and integrated procedures for all potential hazards).

Limits for radiation exposures are defined in 10 CFR 835, *Occupational Radiation Protection*. Guidance for implementing the requirements of 10 CFR 835 has been prepared as a series of implementation guides (DOE, 1993 b-l). DOE regulations for radiological hazards partition the dose into that received by the whole body, the skin, the eye, and the extremities. Also, these regulations provide specific guidance concerning dose to the embryos/fetuses of declared pregnant females (10 CFR 835.206) and the exposures of minors (10 CFR 835.207) and members of the public (10 CFR 835.208) to radiation during on-site access to DOE sites or facilities. The *RadCon Manual* provides additional guidance on (1) good practices for conducting a radiation protection program and (2) methods for limiting exposures of workers to radiation and radioactive material.

4.4 Qualitative Exposure Assessment

4.4.1 Initial Hazard Identification

DOE and its contractors should consider the approaches contained in the "AIHA Strategy" document in implementing the initial hazards baseline or characterization. To meet the intent of the requirements of DOE O 440.1, a review and appropriate inventory of available information should be conducted. This should also include an inventory of hazards, potential exposures, and work activities/tasks; a list of potentially exposed workers; prior exposure monitoring data or an estimate of potential exposures for similarly exposed groups of workers; and judgment of the acceptability and uncertainty of the exposures.

Qualitative exposure assessment should be incorporated into the design of a site's processes or operations, the development of procedures, and the planning and control of work.

DOE and its contractors should consider reviewing existing documentation and other available sources of information on the hazardous agents used and the hazards that result from the way a job or task is performed. Such sources may include:

- chemical inventories and the Material Safety Data Sheets (MSDSs) for those chemicals;
- standard operating procedures;
- site maps;
- experimental procedures;
- rosters of workers in facilities with known or potential hazards;
- process flow diagrams;
- environmental documents (e.g., EPA reporting documents);
- procurement documents;
- Occurrence Reporting and Processing System (ORPS) reports and Computerized Accident/Incident Reporting System (CAIRS) reports;
- carcinogen control program data;
- OSHA 200 logs;
- facility operating manuals;
- Safety Analysis Reports (SARs);
- onsite walk-through observations; and
- input from trade workers, engineers, managers, worker protection professionals, and other professionals.

Initial evaluations of priority employees and tasks for exposure monitoring and exposure groupings should begin with:

- all agents having an OSHA or DOE-prescribed substance-specific standard,
- agents with short-term acute effects,
- occupational carcinogens (see definition in Sect. 3.), and
- any substance without an OEL or NIOSH Recommended Exposure Limit.

Checklists have proven useful for initial hazard identification. An example checklist for an individual worker may be found in Appendix B, and an example for a hazardous waste activity may be found in the DOE-EH/EM document, *Handbook for Occupational Health and Safety During Hazardous Waste Activities*, June 1996.

4.4.2 Integrating Qualitative Exposure Assessment into Work Planning

DOE O 440.1 requires that DOE and its contractors

- "analyze and review designs for new facilities and for modifications to existing facilities and equipment; operations and procedures; and equipment, product, and service needs" [paragraph 4.i.(1) and Attachment 2, paragraph 9.a] and
- "implement a hazard prevention/abatement process to ensure that all identified hazards are managed through final abatement or control." [paragraph 4.j and Attachment 2, paragraph 10].

Department of Energy Acquisition Regulations (the DEAR clauses) require the contractor to "ensure that management of environment, safety and health (ES&H) functions and activities becomes an integral but visible part of the contractor's work planning and execution process" (see 48 CFR 970.5204-2, *Integrating Environment, Safety and Health into Work Planning and Execution*,paragraph b).

Early integration of exposure assessment with work planning activities will help to ensure that potential exposures associated with the work are addressed in the work plan. The use of a multidisciplinary team in planning work will help facilitate this integration. This team, convened at the earliest stage of a job or project, can effectively plan the work to be done and include the hazard characterization and exposure assessment to be performed as part of the job. Team members should include planners, engineers, managers, health and safety professionals, occupational medicine staff, professionals from other technical disciplines, technicians, and representative workers. The DOE Enhanced Work Planning (EWP) initiative is an example of how this aspect may be implemented and how this may fulfill the guiding principles of Integrated Safety Management. For more information on EWP, visit the EWP worldwide web site on the Office of Environment, Safety and Health home page (http://tis-nt.eh.doe.gov/whs/) or call the

DOE Occupational Safety and Health Standards Interpretations Response Line at 1(800)-292-8061.

Several of the activities associated with work planning are also beneficial in identifying the need for exposure assessment; these include:

- Gathering and interpreting prior risk information.

- Performing a task- or project-based hazard analysis commensurate with the risk and complexity of the work.

- Reviewing engineering drawings, process flow diagrams, and operational procedures to understand potentials for worker exposure to hazards.

- Incorporating worker knowledge of past jobs and their hazards into the hazard analysis.

- Developing worksite access requirements, including permits, worker training, medical qualifications, and other job-specific qualifications and hazard controls for all phases of the project.

4.4.2.1 Role of Mentoring in Successful Exposure Assessment

Mentoring is an important component in implementing exposure assessments. This should include the mentoring of junior-level industrial hygienists by more senior industrial hygienists on the technical aspects of EA, monitoring techniques, statistics, etc. Training courses on EA are also offered by the AIHA.

More important to the success of implementation is selection of a champion from line management (not the industrial hygienist), who will act as a mentor and advocate within the organization's management structure, and an employee representative, who will promote worker participation. These individuals should take the lead in promoting EAs and hazards management from an integrated team approach. This is where the cost avoidance and risk management benefits of performing EAs as a part of integrated work planning are derived.

During the Enhanced Work Planning initiative (which included piloting aspects of EA, job hazards analysis, and medical surveillance), DOE found that the sites that were most successful in implementation were those with a strong line management advocate and those that employed the mentoring concept. This mentoring included not only technical professionals but also worker-to-worker and manager-to-manager mentoring, with frequent and ongoing team communications. Accordingly, prime contractors should endeavor to promote mentoring and communicate the importance of EA and team-building, not only internally (among line managers, safety and health professionals, and workers) but also within its subcontractor organizations. DOE's Office of Worker Safety (EH-5) is available to provide technical assistance by making available specialized technical professionals to provide mentoring in the areas epidemiology, occupational medicine, toxicology, statistics, and industrial hygiene.

In implementing EAs, DOE and its contractors are encouraged to review the lessons learned from the Enhanced Work Planning pilot projects and use other relevant experiences in developing an EA process that is tailored to how the organization accomplishes its mission and identifies and manages its significant risks. For more information on mentoring, the team approach, and Enhanced Work Planning as a vehicle for implementing EA, see the Enhanced Work Planning web site at http://tis-nt.eh.doe.gov/WPPHM/ewp/ewp2.htm.

4.4.3 Relationship of Integrated Safety Management to Exposure Assessment

Exposure assessment is an integral part of the Integrated Safety Management System (ISMS) described in DOE Policy 450.4 and included in the DEAR clauses. There should be a clear and documented link of EA at all levels of hazard analysis (i.e., site, facility, and work/task level) as part of the overal ISMS structure under Component 2, "Guiding Principles," and Component 4, "Core Functions." To accomplish this, analysis report data developed for the purpose of performing the exposure-related hazards analysis at the site and facility level should be used as a basis for work/task hazard analysis. Similarly, the outcome of the hazards analysis conducted to document and determine work activity hazards and exposures should be considered in reinforcing other required analysis. This also promotes the tie-in to the ISMS concept.

4.4.4 Integrating Exposure Assessment as Part of Job Safety and Hazard Analysis

One approach that DOE and its contractors should consider is the integration of site and facility EA data with the development of Job Safety Analyses (JSAs) and Job Hazard Analyses (JHAs). The JSA and JHA are key processes in evaluating and controlling hazards associated with planned activities and specific tasks. They are fundamental to safe, effective work control systems, applied as part of Integrated Safety Management and Conduct of Operations. These tools help integrate health and safety issues into the work planning process. JSAs break down tasks and serve to identify and evaluate potential safety and health hazards. Relative to those hazards, the JSA specifies minimum hazard control requirements. Appendix B contains an example of a JSA for an individual worker.

The methods for controlling the identified hazards are also specified or referenced in the JSA. This information is gathered from the workplace characterization, hazard analyses (baseline and periodic), and exposure assessments conducted as a fundamental part of the operation. JSA information, along with hazard characterization and analysis information, is incorporated into the site-specific safety and health plan for hazardous waste activities, requiring task-based hazard analyses.

A JHA is generally conducted as part of the work control process as a specific task is planned. It applies the hazard analysis and exposure assessment information to delineate potential hazards and specify control requirements. The JHA is, in essence, a more detailed and task-specific JSA. Hazard control and safe work practice requirements fall out of the JHA and are included in the task plan as well as in any associated safety or radiation work permits. The JHA process may also be used to specify exposure monitoring and assessment for the specific activity.

4.4.5 Integrating Exposure Assessment as Part of Environmental Restoration and Facility Decommissioning

All safety and health professionals should be active participants in the development of the site environmental remediation plans. It is important that worker health and safety and exposure assessment considerations (both non-radiological and radiological) be incorporated into the decision-making and review process during preparation of a site's environmental remediation or facility decommissioning plans as well as the more task-specific Health and Safety Plan (HASP).

If this is not done, the amount of exposure data collected will be insufficient to characterize worker exposure levels. The development of an exposure assessment strategy in tandem with the development of the environmental remediation plan affords the most efficient use of available monitoring resources. Similarly, the multidisiplinary team concept explained in the work planning section of this Guide may also be useful in developing environmental project plans. Data from environmental monitoring equipment and site characterization methods (i.e., EPA approved methods) may be useful in determining the premonitoring requirements, in identifying needed hazard assessments, and in the continual reevaluation of the hazards and EA.

The primary difference between hazardous waste operations and conventional industrial operations is, for EA purposes, the non-routine nature of the work. Decontamination and decommissioning work can also differ considerably from industrial operations in terms of technologies applied, associated health risks, and the degree of variability of worker exposures. Because of these differences, the potential health risks of these unique technologies need to be evaluated and emphasized in the EA plan. In evaluating the technologies to be utilized, the safety and health professional should become familiar with the operations and tasks associated with each technology for the purpose of evaluating the potential for exposure and health effects risks and developing the exposure monitoring plan. The environmental remediation plan should be thoroughly examined, and key activities and applied technologies of the remediation should be identified. Each activity or operation should be identified, along with its location within the worksite and its expected duration. Site grid maps should be developed, denoting boundaries and exposure zones and listing the respective hazards. Finally, each worker should be classified into similar exposure groups/exposure zones so that they may be linked to hazards and work tasks/activities. Breaking out this information helps to make worker exposure assessment more manageable and is important for proper medical surveillance and evaluation of health risks. An advantage of using "exposure zones" is that it facilitates segregation of exposure data based on locations and/or tasks. [See M. Corn and N. A. Esmen, "Workplace Exposure Zones for Classification of Employee Exposures to Physical and Chemical Agents," *J. Am. Ind. Hygiene Assoc.*, 40:47 (1979).]

DOE Standard 1120-98, INTEGRATION OF SAFETY AND HEALTH INTO FACILITY DISPOSITION ACTIVITIES, provides useful guidance for integrating and enhancing worker and

public safety during facility disposition activities. This standard provides supplemental information for integrating safety and health considerations with project management requirements in DOE O 430.1, LIFE-CYCLE ASSET MANAGEMENT (LCAM), and associated guidance in DOE G 430.1-3, DEACTIVATION IMPLEMENTATION GUIDE, and DOE G 430.1-4, DECOMMISSIONING IMPLEMENTATION GUIDE. In addition, DOE S 1120-98 is designed to support an ISMS, consistent with the guiding principles contained in DOE P 450.4, INTEGRATED SAFETY MANAGEMENT SYSTEM, and discussed in DOE G 450.4-1, INTEGRATED SAFETY MANAGEMENT SYSTEM GUIDE.

4.4.6 Qualitative Exposure Monitoring

DOE and its contractors should consider the approaches contained in the AIHA Strategy in developing an approach for qualitative monitoring. Additionally, in order to comply with DOE O 440.1, DOE and its contractors should prepare and document a plan for conducting monitoring the hazards identified as warranting further evaluation. This determination may include qualitative monitoring using survey instruments and should give priority to the highest-risk work as determined by a qualitative assessment. Qualitative assessments should be conducted by or under the supervision of a senior industrial hygienist, who should determine if there is a need for more focused qualitative or quantitative EA.

The qualitative assessment should be incorporated into any job safety analyses or work planning processes under consideration. (See DOE G 440.1-1 for additional information about hazard analysis techniques.) The analysis should focus on only those tasks that are directly linked to hazards and exposure potentials. Table 1 illustrates an example of one ranking method to assign risks to qualitative exposure potentials.

Table 1. A Suggested Method for Assigning Qualitative Risks to Exposure Potentials

Exposure Potential	Relative Risk
If **ALL** Data Are < ACL	Low Risk
If **ANY** of the Data Are > ACL	May Be at Significant Risk Needs Further Evaluation as compliance with the OEL may be uncertain
If the Data Indicate a Potential for Frequent Exposures > OEL	Significant Risk

These analyses should be performed in collaboration with front-line workers, line management, maintenance, the occupational medical organization and, if necessary, toxicologists and epidemiologists. Sources of this information may include MSDSs as well as publications of governmental and private organizations (e.g., OSHA, NIOSH, AIHA, ACGIH, and *Patty's Industrial Hygiene and Toxicology*, edited by George D. Clayton and Florence E. Clayton, John Wiley & Sons, Inc., New York).

The predominant exposure determinants and events [such as frequency, magnitude, and variability of exposure and tasks; route of exposure; potentials for short-duration tasks and exposures (acute) and long-term or frequently repeated tasks and exposures (chronic); and the adequacy and potential for failure of engineering and work practice controls] should be considered and documented as a part of this qualitative EA.

When conducting exposure assessments, it may sometimes be appropriate for DOE or the contractor to set a site-specific administrative control limit (ACL) to serve as a "trigger point" for additional samples, more frequent monitoring, and a more detailed assessment. Typically the ACL is initially set at one-tenth to possibly one-fourth the OEL. Exceeding the ACL indicates that exposures may be above the OEL, which would necessitate more detailed hazard characterization and increased monitoring. These ACLs are discussed in more detail in Section 4.4.6.2. If exposures are measured or suspected to be above the ACL, it is appropriate to proceed with more detailed EAs. If the exposure potentials are below the ACL, then routine EAs may be discontinued. Periodic re-evaluation may be needed after routine EAs are discontinued to determine if changes have occurred that can adversely affect exposures. If DOE or its contractor chooses not to use an ACL approach, then they should document the process and data analysis by which exposures are determined to be acceptable with respect to compliance with the OEL.

The qualitative EA should include an evaluation of potential exposures via inhalation, ingestion, dermal contact, physiological interactions, and ergonomic factors. The plan for qualitative EA should also describe the processes and work areas to be evaluated for the assessment, specific observations to be made, and preliminary measurements to be taken (such as air flows, noise levels, non-ionizing radiation levels, heat stress risk factors, ergonomic risk factors, and airborne chemical levels).

As part of the qualitative EA, DOE and its contractors should review relevant information and determine whether employees are potentially exposed to airborne concentrations in excess of the OEL or site-specific ACL and to physical, biological, or ergonomic hazards. When the initial qualitative assessment suggests exposure potentials that exceed allowable standards, all employees in those work areas should be identified as potentially at risk and should be more fully evaluated for exposure and potential health effects.

Where previous measurements have indicated that exposures for individuals or SEGs are below the ACL, these data may be used to document acceptably low exposures without the need for additional exposure monitoring.

4.4.6.1 Development of Exposure Profiles and Identification of Exposure Groups

The development of exposure profiles and identification of exposure groups helps to establish priorities for further assessments based on the exposures of individuals or groups. An exposure profile is usually a graphic representation of the most relevant exposure and hazard determinants of a similarly exposed group or individual (e.g., population demographics; type or nature of the hazard; work conditions; and exposure time, frequency, or variability).

DOE and its contractors are mandated by Federal law to identify workers at significant risk of exposure due to DOE work activities under 42 USC Sect. 7274i, *Program to Monitor Department of Energy Workers Exposed to Hazardous and Radioactive Substances*. As such, the exposure profile with matrix documentation is one approach that may be used to link workers, hazards, and exposures to enable the targeting of medical monitoring as required by 42 USC Sect. 7274i. As illustrated in Fig. 1, this activity should be a part of both qualitative and quantitative exposure assessment.

Once the available data have been collected and analyzed, a matrix may be formed to show the exposure potentials and risk for each task. An example matrix is provided in Table 2. Such a matrix, which compares the jobs or tasks with the risks and any monitoring data that have been collected, can aid in identifying the high-risk exposure potentials and to prioritize for additional exposure monitoring. Collectively, these matrices can be used to develop a site's baseline hazard, risk, and exposure profile. This site profile can be used to determine priorities, the resources

needed to manage those priorities, and the vulnerabilities that will remain by not addressing the lower priorities.

Table 2. Example Exposure Matrix

	Benzene	**Carbon Tet**	**HFl**	**Ammonia**	
Remote Drum Sampling	Low Risk	Low Risk	Concentration below the level of detection Low Risk	Low Risk	
Drum Opening	Suspect 5-35 mg/m^3 Significant Risk	Suspect 35 mg/m^3 Significant Risk	Suspect 1 mg/m^3 May be at Significant Risk	Measured 1 mg/m^3 Low Risk	
Manual Fluid Transfer	Suspect 5-35 mg/m^3 Significant Risk	Concentration measured at 0.5 mg/m^3 - Low Risk	Suspect 1 mg/m^3 May be at Significant Risk		

Linking exposures to specific workers also allows the exposure matrix to be used to create an exposure profile of individual workers, groups, and facilities, which, in turn, makes it possible to divide workers into Similarly Exposed Groups (SEGs). Quantitative assessments should identify individuals and SEGs with significant exposure potentials and attendant risks of chronic health effects.

A sufficient number of individuals should be monitored to establish an exposure profile within the SEG, and the representativeness of the determining data should be described by statistical values and a determination of the homogeneity of the exposure potentials of the group. As matrices are completed for multiple work activities, the exposure profile becomes more accurate and complete. DOE and its contractors should consider linking exposure profiles to medical profiles and risk profile data to support integrated health surveillance and risk management activities (see definitions of medical profile and risk profile in Sect. 3.2).

Information from the exposure matrix should be considered in refining the EA strategy. As data are gathered from qualitative screening and quantitative exposure monitoring, they are used to make a number of decisions about the need for continuing or ending EAs; the adequacy of control measures; the sufficiency of monitoring strategies; the need to establish a biomonitoring program

or to discontinue biomonitoring; etc. The conclusions, rationale, and actions at each EA decision stage should be documented and kept current.

If the site history and planned activities indicate that there is either low or no potential for worker exposure to chemicals, radiation, or other physical agents, additional EA activities or controls are not necessary. In such cases, these conclusions and the supporting rationale should be documented.

Appendix B is an example of a simple method to capture hazard characterization information for an individual worker.

4.4.6.2 Administrative Control Limits

The ACL is a useful statistical screening tool to distinguish exposures that require continued or increased monitoring efforts from those that require no action. The function of the ACL (according to Leidel et al., 1977) is to designate an exposure level at which monitoring procedures become appropriate.

Usually, an ACL is set to one-tenth or possibly one-fourth the OEL when monitoring is initiated or when there are not yet sufficient data to generate a statistically valid exposure profile. If, in initial monitoring, the ACL is not exceeded, this is an indication that the actual exposures are acceptable with respect to the OEL and additional exposure monitoring may not be needed. This is not to say that DOE and its contractors should establish or use ACLs as a surrogate for the OEL, thus driving exposures to progressively lower levels. Based on statistics, the probability of exceeding the OEL is less than 5% if initial, random "measured" exposures are less than one-tenth the OEL and if exposures are not highly variable. It should be noted that, as the ACL is increased (e.g., initial measured exposures are less than one-fourth the OEL), the probability of exceeding the OEL increases [see R. M. Tuggle, "The NIOSH Decision Scheme," *J. Am. Ind. Hygiene Assoc.*, 43:493 (1981); J. Cohen, "Establishing 'Action Levels' in Exposure Assessment Programs," in *Exposure Assessment Reviews*, U.S. Department of Energy, UCRL-AR-118076 (1993); and *Patty's Industrial Hygiene and Toxicology*, L. J. Cralley and L. V. Cralley, eds., Volume 3A (most recent edition)].

The ACL can be set at a level other than one-tenth or one-fourth the OEL for specific chemical hazards, depending on the circumstances. This may permit a reduction in sampling while maintaining confidence that the OEL is not exceeded. An ACL differs from an action level in that an ACL is not a prescribed level; it is site specific, and it is simply a "trigger point" for increasing or decreasing the amount of assessment/monitoring recommended to maintain confidence that exposures are below the OEL. An action level is a limit prescribed by DOE or OSHA that may trigger mandatory measures (exposure monitoring, medical monitoring, controls, PPE, etc.). The determination that exposures are below the ACL does not involve statistical analysis; rather, such determination is simply based on exposure measurements being below the ACL.

4.4.6.3 Use of the ACL for Non-Radiological Versus Radiological Hazards

The purpose of ACLs is not the same for nonradiological hazards as it is for radiological hazards. An ACL for nonradiological hazards is not intended to be used as a surrogate OEL or to continuously drive exposures progressively lower. The ACL for nonradiological hazards is intended to initially demonstrate confidence that exposures are below the OEL until sufficient samples are obtained to perform appropriate statistical analysis to document that exposures are acceptable with respect to the OEL. Therefore, the ACL for nonradiological (industrial hygiene) hazards is based upon demonstrating confidence that most of the exposures (e.g., 95%) are below the OEL.

For radiological hazards, the ACL is based on the total effective dose equivalent for exposures to radiation and radioactive material. The DOE annual ACL for radiological hazards is 2 rem, and the lifetime control level is the number of rems equal to the worker's age in years. The total effective dose equivalent (TEDE) includes both exposure from external sources of radiation and committed effective dose equivalent from internal depositions of radioactive materials. The *RadCon Manual* also requires that each contractor establish ACLs and suggests an annual target level of 500 mrem. Specific approvals are required to exceed established control levels, as noted in the *RadCon Manual*. In addition to establishing limits for radiation exposures, 10 CFR 835 also establishes criteria for monitoring the exposure of workers to radiation and radioactive materials. In particular, monitoring an individual for external exposure to radiation is required when that individual is likely to receive an effective dose equivalent in excess of 100 mrem/year, as stated in 10 CFR 835.402 and DOE O 440.1.

4.5 Quantitative Exposure Assessment

DOE and its contractors should consider the approaches contained in the AIHA Strategy in developing their quanititative EA. Quantitative exposure assessment is warranted for workers who have significant potential for exposure to health hazards and who may be exposed above the OEL, as indicated by the results of the qualitative EA. Similarly, the ACL may be used to trigger the need for more quantitative personal monitoring to characterize workers' exposures.

Monitoring efforts should be reevaluated as the job or task progresses. Monitoring should be eliminated when DOE or the contractor is confident that enough samples have been obtained to adequately characterize workers' exposures with respect to compliance with the OEL. Where the tasks are highly variable or where there is a potential for high exposures, more frequent monitoring should be considered as should increasing the number of workers to be monitored.

4.5.1 Analysis of Qualitative Exposure Assessment Results

Qualitative assessment results should be analyzed to determine the need for and provide the basis for a quantitative exposure monitoring plan.

When available or initial qualitative data are insufficient to support decisions about the need for quantitative monitoring and to determine compliance with the OEL, the decision process should proceed based on best information and judgment of the worker protection professional. In doing so, there is a need to document the judgments, strength of the evidence, likelihood of exceeding the OEL and potential adverse health effects, limits of effective or feasible risk management actions, and need for further data or better understanding of health effects/outcomes.

Examples of typical task-based monitoring that may identified by the Job or Hazard Analysis include:

- 8 hr time-weighted average (TWA),
- Maximum 15-minute short-term exposure limit (STEL),
- Average 15-minute STEL,
- Amount of time > 10% of the OEL,
- Amount of time between 10 % and 50 % of the OEL,
- Amount of time > TLV-Ceiling,

- Amount of time > 50% of the OEL, and
- Amount of time ≥ the OEL.

For additional guidance about such situations, see the "AIHA Strategy" document.

4.5.2 Quantitative Exposure Monitoring

If worker exposures exceed (or are likely to exceed) the OEL, as indicated by qualitative exposure monitoring, a quantitative exposure assessment, which includes the following, should be conducted:

- A written EA plan for each process or work area.

- Coordination with the occupational medical organization to determine the need for medical/biological monitoring and evaluation of the potential for ingestion or skin absorption, which could contribute to the employee's exposure.

- Development and supervision of the conduct of the EA by a Senior Industrial Hygienist utilizing methods such as those described in the NIOSH *Occupational Exposure Sampling Strategy Manual* and the "AIHA Strategy" document.

Exposure data should be maintained such that (1) the resulting exposure measurements and tasks can be linked to the employee or the exposure group and (2) the EA records and medical monitoring data can be made available to employees, their authorized representatives, and other personnel authorized to retrieve their records. Documentation should, as a minimum, describe the tasks and locations where monitoring occurred, identify workers monitored or represented by the monitoring, and identify the sampling methods and durations, control measures in place during monitoring (including the use of PPE), and any other factors that may have affected sampling results. More detailed instructions may be found in a guide developed jointly by the ACGIH and the AIHA, *Key Data Elements for an Occupational Exposure Database, Guidelines and Recommendations*. In developing information systems for industrial hygiene data, DOE and its contractors should consider the information contained in a document developed by the DOE Working Group on Exposure Assessment, *A Systems Requirements Document for the U.S. Department of Energy Industrial Hygiene Database*.

After the monitoring data have been collected and analyzed, certain judgments can be made about potential risk, based on monitoring results in relation to the ACLs and potential health effects. Table 3 shows an example of the decision process that DOE or its contractor should document. Two courses of action are appropriate, depending on whether the risk is judged to be low or potentially significant. Such analysis is appropriate for both qualitative and quantitative assessments.

Table 3. Example of Data Analysis Outcomes

Case 1 - Low Risk **If . . .**	**Then . . .**
1. Monitoring results are below an established administrative control level (ACL) *or* 2. Monitoring results are above the ACL but the data provide statistical confidence that exposures will not exceed the OEL	Routine exposure monitoring may be stopped, the supporting rationale should be documented, and periodic re-evaluation should be conducted. The ACL should be adjusted based on statistical analysis.
Case 2 - Potential Significant Risk **If . . .**	**Then . . .**
1. Monitoring results exceed the ACL and may exceed the OEL *or* 2. The available information is inadequate to define the extent to which health hazards exist at the worksite	Develop a plan for additional quantitative monitoring, conduct monitoring, analyze data, and continue until the situation improves to become Case 1 or until sufficient samples are obtained to document compliance relative to the OEL.

4.5.2.1 Considerations for Integrating Radiological Monitoring

DOE and its contractors should integrate both non-radiological and radiological monitoring requirements in project plans and operational procedures for all identified hazards. Whenever possible, exposure monitoring plans should be integrated at the work activity level to clearly communicate to workers, supervisors, and project managers the hazards and monitoring requirements to be implemented. Considerations for inclusion of radiological hazards include: quantitative assessment of the radiation dose received by workers is performed using (1) dosimeters for exposure to external radiation and (2) bioassay for exposure to internal radiation. To quantify individual exposure to external radiation, the individual wears a radiation dosimeter.

Depending on the radiological conditions, the individual may be issued a whole body dosimeter and dosimeters for the extremities (wrists, fingers, and ankles). Supplemental dosimeters such as pocket ionization chambers (pencils) also may be used. Guidance on external monitoring can be found in the implementation guide on external dosimetry (DOE, 1993e). In situations involving highly variable radiation fields or highly radioactive discrete particles, multiple or special dosimetry may be required. Guidance is provided in the *RadCon Manual*, Articles 512 and 348.

The Radiation Exposure Monitoring System (REMS) was developed as a central repository and gives DOE personnel remote access to occupational radiation exposure monitoring data. The repository contains occupational radiation exposure records for all DOE employees and contractor personnel that were submitted formerly in accordance with DOE O 5484.1, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION INFORMATION REPORTING REQUIREMENTS, and now under DOE O 231.1, ENVIRONMENT, SAFETY AND HEALTH REPORTING. The complete data dictionary is available in the *DOE REMS System User Reference Manual*. The REMS Oracle database can be queried and viewed by any product that has the ability to connect to the Oracle 7.1 database.

The REMS database provides data for the annual DOE Occupational Radiation Exposure Report. The report summarizes and gives analysis of the occupational radiation exposure received by individuals associated with DOE activities. The report is intended to be a tool for managers in their management of radiological safety programs and commitment of resources. The report and the database are the culmination of a significant effort in cooperation with the field, other DOE Offices responsible for related databases, and outside stakeholders such as universities and international agencies involved in radiation protection.

Requests for copies of the report or access to the data files used to compile the report should be directed to Nirmala Rao, REMS Project Manager, U.S. Department of Energy, Office of Worker Protection Programs and Hazards Management, Germantown, MD 20874. In addition, access to the REMS databases, query capability, and the annual DOE Occupational Radiation Exposure Report are available on the worldwide web (http://rems.eh.doe.gov/).

4.5.2.2 Apply Statistical and Trend Analysis

To fully assess the exposure of workers to hazards and demonstrate compliance with the OEL, it may be necessary to employ an appropriate level of statistical techniques. The use of an ACL at 10% of the OEL is based upon application of statistics in order to initially be reasonably confident that exposure are acceptable with respect to the OEL. Once sufficent samples are obtained, other valuable statistics (including means, confidence limits, tolerance limits, and coefficients of variation) should be considered. These techniques, which can be used to describe exposure levels, are discussed in detail in the AIHA Strategy and in NIOSH's *Occupational Exposure Sampling Strategy Manual.* Analysis of exposure information over time can be used as indicators of performance in reaching established goals (see Sects. 4.6.1.1, "Performance Indicators," and 4.6.1.2, "Exposure Reduction Goals").

4.5.2.3 Determine Need for Further Monitoring Based on Compliance with Exposure Limits

For chemical exposures, compliance with occupational exposure limits (OELs) can be determined by comparing the monitoring results with the ACL or statistically to the OEL, as described in Sect. 4.4.6.2. Table 4 describes industrial hygiene compliance considerations.

4.5.2.4 Determine Adequacy of Controls

Qualitative exposure information and quantitative data may also be used to determine the adequacy of existing work controls. This may be done by comparing the exposure levels under existing controls with the OELs. Once levels under existing controls have been examined, it may be necessary to modify the controls or add new controls. PPE used for controls should provide adequate protection of the worker while avoiding any unnecessary stress that may be associated with wearing PPE.

If, at some stage of the project, exposure levels are found to be consistently below the ACL and PPE is no longer required, DOE or its contractor should determine if the monitoring portion may be terminated. The rationale for making any changes in required work controls and/or for ending the EA should be documented.

Table 4. Example Decision Matrix for Monitoring Needs Based on Compliance Considerations

If . . .	Then . . .
Exposure are below the ACL	No further monitoring is needed. This conclusion needs to be documented. Only periodic monitoring, based on professional judgment, is needed to verify conditions have not changed and controls remain adequate.
Assessments of existing, new or changed operations indicate that exposures are at or above the OSHA action level or DOE-prescribed action level	Develop a monitoring plan to conduct quantitative monitoring. Collect sufficient numbers of samples to be determine that exposures are below the action level.
Exposure values may be greater than the ACL or the potential to exceed the OEL exists	Determine the potential for exceeding the OEL; additional monitoring may be needed to determine compliance status. Qualitative or quantitative monitoring for active operations should be repeated at least quarterly when monitoring results are greater than the ACL but less than the OEL. Conduct quantitative monitoring until sufficient numbers of samples are obtained to characterize worker exposures with respect to the OEL.
Exposure values exceed the OEL	Conduct monitoring at least monthly for active operations (or more frequently for short-term operations) until (1) a sufficient number of representative samples are taken, or (2) the results demonstrate that exposures are at or below the ACL, or (3) it is possible to demonstrate with statistical confidence that exposures are below the OEL. If, after collecting a sufficient number of samples, results indicate that work conditions do not permit exposures to be maintained below the OEL, continue monitoring to document exposure and take necessary protective actions based on professional judgment (e.g., respiratory protection).

4.5.2.5 Use Hazard Information to Prioritize Monitoring

DOE and its contractors should utilize some form of a hazard ranking scheme to aid in prioritizing the site health hazards, which will facilitate development of the quantitative monitoring plan and aid in documenting the decision process. Such hazard ranking should consider the potential for contact with the hazardous agent and the degree of exposure, as well as

the toxicity or severity of health effects, to determine a sampling priority. Examples of these approaches may be found in the ACGIH *Air Sampling Instruments Manual* and the "AIHA Strategy" document. DOE and its contractors should be able to document a preliminary prioritization and determination of the need for quantitative monitoring and, if necessary, a list of individuals at risk or Similarly Exposed Groups (SEGs). Any uncertainties about exposures or health effects/risks should be taken into account and documented, with higher priority given for situations with higher uncertainty.

4.5.3 Frequency of Re-surveys

Work activities may change frequently, and exposure monitoring strategies should reflect this. Periodically, exposures may need to be reassessed in order to update exposure profiles. Decisions concerning how frequently to repeat a survey should be based on professional judgment, taking into consideration toxicity of the material, effectiveness of controls, and variability of the process.

DOE and its contractors should document a procedure and schedule for conducting re-surveys of existing operations. Re-surveys may be appropriate for existing operations where there is a potential for employees to be exposed to hazardous agents. This review may be conducted as part of the periodic hazard re-evaluation required by DOE O 440.1. An example strategy for re-surveys might be:

- Industrial areas (e.g., research and development facilities, general industry areas, and craft shops) should be evaluated at least annually, and more often if the senior worker protection professional determines that potentially severe health hazards are present.

- Frequently changing work sites (e.g., construction sites and hazardous waste sites) where highly variable exposure potentials may occur should be evaluated as often as the senior worker protection professional determines necessary to obtain sufficient samples to characterize worker exposures.

- Low-hazard areas (e.g., offices and nonhazardous facilities) should be evaluated at least every 3 years. Unoccupied buildings should be evaluated initially and thereafter as frequently as deemed necessary by the senior worker protection professional.

- An exposure assessment should be conducted whenever there is a change in process; operations; work practices; chemical, physical or biological agents present; or personnel that could affect the exposure of employees. This should include a determination of the need for additional quantitative exposure monitoring or medical monitoring.

4.6 Uses for Exposure Assessment

4.6.1 Relationship to Performance Measures

Paragraph (e) of 48 CFR 970.5204-2 (the environment, safety and health DEAR clause) requires that "on an annual basis, the contractor shall review and update, for DOE approval, its safety performance objectives, performance measures, and commitments consistent with and in response to DOE's program and budget execution guidance and direction. Resources shall be identified and allocated to meet the safety objectives and performance commitments as well as maintain the integrity of the entire System."

The following questions focus on the goals and actions that DOE and contractor managers should consider in measuring the effectiveness of their exposure assessment activities:

- Are we identifying those workers with a significant risk and conducting exposure assessment on the highest-risk activities first?

- Are we identifying and evaluating contributing factors to exposures and implementing strategies to prevent and mitigate exposure based on significant risks and potential health effects to workers?

- Are we supplying to the occupational medical program data about exposures of individuals and groups in order to prioritize and target medical monitoring efforts?

- Are we retaining job, task, and hazard identification and risk-estimating information and making it available to workers and worker protection staff?

- Are we targeting exposure assessments to specific hazards and risks and measuring the exposure levels that may create a significant risk of illness? (This should be determined in concert with the occupational medical staff.)

- Are we trending exposure measurements and biological monitoring results and using them as performance measures? (These data can help workers and managers understand and improve working conditions.)

- Are we looking at high-risk tasks from the point of view of promoting safe acts and behaviors that reduce exposure? Are we also trending the improvement toward safe acts as an indicator of the success of our programs?

4.6.1.1 Performance Indicators

DOE and contractor managers and worker protection professionals should consider using performance indicators to help prioritize areas requiring improvement. Performance indicators should incorporate goals to achieve preventive and mitigation objectives. For chemical hazards, the following examples illustrate some typical goals that might be appropriate:

- Compliance with the OEL
- Arithmetic mean exposure of specific hazardous agents (such as chemical carcinogens) per SEG
- Number of exposure-related occupational illnesses shown on the OSHA 200 log
- Number of positive biological monitoring samples

Sites should determine the best indicators of performance in achieving these or similar goals, taking care to ensure that these indicators do not lead to under-reporting.

For more details about the use of performance measures, see DOE O 210.1, PERFORMANCE INDICATORS AND ANALYSIS OF OPERATIONS INFORMATION; DOE Standard 1048-92, PERFORMANCE INDICATOR GUIDANCE DOCUMENT; and other applicable standards and guidance.

4.6.1.2 Exposure Reduction Goals

DOE and its contractors should consider establishing exposure reduction goals (ERGs) that are tracked for each significant risk group to help reduce exposures. This is not to say that ERGs are needed for all agents, but they should be considered for agents, exposures, and significant tasks that contribute to significant risks or exposure concerns (e.g., beryllium and other carcinogens). This should be done in concert with the use of feasible controls. Exposure reduction goals should be established with input from all affected individuals (workers, industrial hygienists, line mangers, occupational medicine staff, etc.). The following questions should be considered in measuring management's performance in conducting exposure assessment:

- Does upper management, with assistance from the industrial hygienist and the occupational medical physician, set targets and priorities for exposure reduction efforts?

- Does line management develop and implement action plans to reduce unacceptable exposures below the OEL or established goals?

- Does line management review performance in achieving the goals periodically (at least annually) or when the actual exposure exceeds a pre-established level, such as the ACL or OEL?

- Does line management prepare a summary of exposure reduction, mitigation, and control efforts, as well as progress in achieving the site or facility exposure control or reduction goals? This report may include:
  - Comparison of performance against goals and past measurements;
  - Analysis of exposure profiles of targeted groups;
  - Analysis of exposure mitigation recommendations;
  - Number of individuals exceeding the ACL and DOE-prescribed limits; and
  - Summary of any trends of occurrences.

- Does line management determine needed improvements and propose appropriate goals?

4.6.2 Role of Exposure Assessment in Occupational Medicine and Medical Monitoring

Occupational medicine plays a vital role in primary prevention of illness and injury through preplacement and other fitness-for-duty examinations aimed at ensuring that workers can perform their jobs without creating undue risk to themselves or others. Ready access to the information generated by exposure assessments can assist physicians in making more informed placement decisions. Secondary prevention of occupational disease is achieved through screening for early signs of disease, while intervention is still possible and effective. Exposure assessments also help physicians focus examinations and medical surveillance on detecting specific occupational health effects.

In turn, occupational medical programs contribute to exposure assessments through providing examination results and conducting bioassay programs. In addition, epidemiologic surveillance of the rates of morbidity and clinical findings occurring among workers, when combined with information on exposures, can be the first indicator of an unrecognized health hazard or a true measure of the effectiveness of health protection programs.

Two key data elements that make exposure assessments useful in the operation of occupational medical programs are links to rosters identifying exposed individuals and information about whether monitoring data are representative or actual exposures. Linking exposure data with medical data reduces the uncertainty about whether exposures are adequately controlled. It also provides direction for employee health counseling and training for controlling exposures and mitigating hazards.

Exposure assessments should be conducted in collaboration with occupational medical staff to determine the potential for health effects and the advisability of specialized medical monitoring, bioassays, and epidemiologic surveillance. When the potential for occupational health risks is significant, medical monitoring is important because it provides information needed to validate assumptions about presumed safe exposure levels. The effective integration of exposure assessments and occupational medical monitoring results helps to reduce uncertainties that are inherent to the risk assessments which are often used to establish health protection standards.

For more information about contractor occupational medical programs, see DOE G 440.1-4, CONTRACTOR OCCUPATIONAL MEDICAL PROGRAM. For Federal programs, see Chapter VIII of DOE O 3790.1B, FEDERAL EMPLOYEE OCCUPATIONAL SAFETY AND HEALTH PROGRAM.

4.6.3 Role of Exposure Assessment in Exposure Prevention and Hazard Control

Once individuals or exposure groups with potential for uncertain or unacceptable exposures have been identified and prioritized, engineering controls should be implemented, and workers should be protected in the interim until such long-term controls are in place. The decision-making process should take into account such control issues as short-term vs. long-term controls, feasibility and priority of controls, exposure levels, toxicity, and level of uncertainty. Intervention, prevention, employee training or counseling, and control measures should be implemented based on the analysis of data obtained through application of the exposure assessment strategy.

4.6.4 Occurrences

DOE and its contractors are required by DOE O 232.1A, OCCURRENCE REPORTING AND PROCESSING OF OPERATIONS INFORMATION, to use exposure assessment data to trigger the reporting of incidents. DOE and its contractors should consider establishing specific performance measures relating to control of hazards and future incidents and exposure reduction efforts. As required by DOE O 440.1, DOE and its contractors report and investigate accidents, injuries, and illnesses and analyze related data for trends and lessons learned. More specific hazard and exposure classification and reporting needs are contained in DOE O 232.1A.

5. ADDITIONAL INFORMATION

For site-specific questions concerning the implementation of DOE O 440.1, contact the DOE Operations Office's or DOE contractor organization's Worker Protection Manager. For additional information about the DOE Worker Protection Program, contact the Office of Worker Health and Safety (EH-5).

EH-5 also develops and disseminates interpretations of DOE worker protection Standards. A toll-free response line has been established to address requests for interpretations. Precedented requests for interpretations are maintained in a database and can usually be addressed in a matter

of minutes. Unprecedented requests are addressed with a written response, usually within 20 working days. The telephone number for the Standards Interpretation Response Line is 1-800-292-8061. Hours of operation are 8 a.m. to 4 p.m. (Eastern time) Monday through Friday.

For general questions regarding implementation of the occupational exposure assessment requirements of DOE O 440.1 or for questions concerning the contents of this Guide, contact David K. Pegram at 301-903-9840.

Appendix A. Acronyms

ABIH	American Board of Industrial Hygiene
ACGIH	American Conference of Governmental Industrial Hygienists
ACL	Administrative Control Level
AIHA	American Industrial Hygiene Association
CAIRS	Computerized Accident/Incident Reporting System
CFR	Code of Federal Regulations
CRD	Contractor Requirements Document
DAC	Derived Air Concentration
DEAR	Department of Energy Acquisition Regulations
DOE	U.S. Department of Energy
EA	Exposure Assessment
EJTA	Employee Job Task Analysis
EPA	Environmental Protection Agency
ERG	Exposure Reduction Goal
ES&H	Environment, Safety, and Health
EWP	Enhanced Work Planning
HASP	Health and Safety Plan
HEG	Homogeneous Exposure Group
HF	Hydrofluoric Acid
ISMS	Integrated Safety Management System
JHA	Job Hazard Analysis
JSA	Job Safety Analysis
LCAM	Life-Cycle Asset Management
MSDS	Material Safety Data Sheet
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational Exposure Limit
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
REMS	Radiation Exposure Monitoring System

SAR	Safety Analysis Report
SEG	Similarly Exposed Group
STEL	Short-Term Exposure Limit
TEDE	Total Effective Dose Equivalent
TLV	Threshold Limit Value
TWA	Time-Weighted Average
UF_6	Uranium Hexafluoride

Appendix B. Example Hazard Characterization for an Individual Worker

[NOTE: This appendix was adapted from the "Employee Job Task Analysis (EJTA) Process for Completion" used with Enhanced Work Planning projects at the Hanford site. The purpose of the EJTA is to collect information about job requirements and potential hazards in the workplace. It asks questions about different aspects of jobs which have been planned or which are currently being carried out. It represents only one approach that may be considered in implementing the hazards characterization element of the exposure assessment. The assumptions and professional judgements are those of the author and are offered to illustrate the process for discussion purposes only.]

The purpose of this portion of the EJTA is to estimate the potential for an employee to be exposed to a hazardous chemical, safety or health hazard so that he or she may be enrolled in the appropriate medical surveillance monitoring program(s). It will also be used to describe the overall exposure profile of the employee. This includes information on agents not currently monitored by the industrial hygiene monitoring program.

On the appropriate section of the EJTA form, list in the spaces provided any raw materials, intermediates, by-products, and products of processes conducted by the employee while performing essential functions. For example, an employee may potentially be exposed to uranium hexafluoride (UF_6) through inhalation while performing surveillance and monitoring functions on a gaseous diffusion stage. Since UF_6 exothermically reacts with water vapor to form corrosive hydrofluoric acid (HF), then HF must also be listed as a potential chemical agent if the installation is located in a non-arid area. If the supervisor cannot readily access needed information, the health and safety representative should assist in completing this section.

The information needed to complete this section can be obtained from the following sources (there may be other sources not listed):

-health and safety reports
-remedial investigation/feasibility studies
-baseline human health risk assessments
-dose reconstruction reports

-worker exposure evaluation

-safety analysis reports

-environmental impact statements

-industrial hygiene monitoring program data

-site or waste characterizations

-material safety data sheets

-programmatic environmental impact statement documents

Check only those characteristic hazards (if any) to which the employee may be exposed. Chemical-specific criteria are listed in Table 1.

NOTE: EXPOSURE ABOVE ANY LISTED CRITERION DOES NOT NECESSARILY MANDATE ENROLLMENT INTO A MEDICAL SURVEILLANCE PROGRAM.

The procedure for completing this section is as follows:

- Check the box to the left of the agent if the employee is exposed or potentially exposed to the specific agent. Do not check if exposure is unlikely.

- Check box 1 if the employee is exposed or potentially exposed to the agent, but at levels below the specified criteria as indicated in Table 1.

- Check box 2 if the employee is exposed or potentially exposed to the agent at levels above the criteria but *less than 30 days* per year.

- Check box 3 if the employee is exposed or potentially exposed to the agent at levels above the criteria for *30 days or more* per year.

- Check box 4 if quantitative exposure data exist for the agent. Do not check if exposures are estimated based on qualitative analysis (i.e., integration of information and judgment).

Example:

If an employee is exposed to benzene at 0.6 ppm for 31 days per year as indicated by exposure monitoring data, then the following should be checked: the box to the left of benzene, box 3 and box 4. However, if the determination of benzene exposure was based on qualitative data or professional judgment, then check box 3 but not box 4.

NOTE: Not all agents have criteria to check boxes 1-3. In these cases, a checkmark in the box to the left of the agent should be made to designate potential exposure. Leaving the box blank indicates your judgment that exposure to that agent is considered unlikely.

Table 1

Exposure Criteria Triggering Potential for Entry into Medical Surveillance Programs

Agent	CAS Number	Exposure Action Level Criteria
Arsenic (Inorganic)	7440382	5.0 $\mu g/m^3$, 8-hour TWA, 30 or more days/year
Asbestos	----------	0.1 fiber/cm ^{3}, 8-hour TWA 1.0 fiber/cm ^{3}, 30-min TWA
Benzene	71432	0.5 ppm, 8-hour TWA, 30 or more days/year 1.0 ppm, 8-hour TWA, 10 or more days/year 5.0 ppm, 15-min. Avg., any period
Beryllium	7440417	0.5 $\mu g/m^3$, 8-hour TWA 3.0 $\mu g/m^3$, 15-min avg.
Cadmium	7440439	2.5 $\mu g/m^3$, 8-hour TWA, 30 or more days/year
Formaldehyde	50000	0.5 ppm, 8-hour TWA 2.0 ppm, 15-min. avg.
Lead	7439921	30.0 $\mu g/m^3$, 8-hour TWA, 30 or more days/year
Noise	N/A	1) Enrollment in a hearing conservation program is required where workers are exposed to continuous, intermittent, impact or impulse noise at or above 85 dBA as an 8 hour TWA regardless of the use of any hearing protection; and 2) Continuous or intermittent sound levels higher than 85 dBA may not exceed the exposure time dependent limits; and 3) No unprotected exposure to continuous, intermittent or impact noise in excess of C-weighted peak 140 dB is permitted. See WHC-CM-1-11, WKH 10.
Chlorine	7782-50-5	OSHA: 1 ppm PEL (ceiling)

PCBs	53469-21-9 (42%) 11097-69-1 (54%)	OSHA: 1 mg/m3 - 42% Chlorine OSHA: 0.5 mg/m3 - 54% Chlorine
Ammonia	7664-41-7	OSHA: 50 ppm PEL
Mercury	7439-97-6	ACGIH: 0.025 mg/m3
Particulates	NA	ACGIH: Total Particulates, 10 mg/m3 OSHA: Total Dust: 15 mg/m3 OSHA: Respirable: 5 mg/m3
Coal Dust	NA	Depends on respirable silica content
Synthetic Vitreous Fibers	NA	OSHA: Total Dust: 15 mg/m3 OSHA: Respirable: 5 mg/m3 ACGIH: Fiberglass: 10 mg/m3 (3 mg/m3 proposed) NAIMA: Mineral or Glass Wools & RCFs aka Refractory Ceramic Fibers: 1 f/cc 0.1 f/cc (action limit) ACGIH: Cristobalite (RCFs >1000 C.): 0.05 mg/m3 respirable
Lasers	NA	Employees who work with Class IIIB or Class IV lasers or laser systems.

NOTE: For chemical agents not listed in Table 1 or not regulated under a substance specific OSHA standard, the exposure criterion is defined as the OSHA action level, the ACGIH TLV, or half the OEL, whichever is less.

The figure on the following page is an example of one of the computer screens that is generated by the Hanford EJTA software.

Potential Exposure Hazards

EJTA ID	Last Name:	First Name:	Middle Name:
JTA	PLACEHOLDER	MY	RECORD

1 2 3 4 1 2 3 4

Regulated:

- Arsenic Inorganic:
- Asbestos:
- Benzene:
- Beryllium:
- Cadmium Inorganic:
- Formaldehyde:
- Lead Inorganic:
- Noise:

Paint/Resins:

- Lead:
- Chromium:

Solvents:

1. List
2. List
3. List

Welding:

- Nickel (SS):
- Chromium (SS):
- Metal Fumes:

1. List
2. List
3. List

Carcinogens (List if not checked elsewhere.):

A1 or OSHA:

1. List
2. List
3. List

Other Carcinogens:

1. List
2. List
3. List

Other Chemicals (List if not checked elsewhere)

Chlorinated Solvents:

1. List 1,1,1-Trichloroethane
2. List 1,1,1-Trichloroethane

Other Solvents/Vapors:

1. List
2. List

Corrosives:

1. List
2. List

- Isocyanates:
- Epichlorohydrin:
- Chlorine:
- PCBs:
- Ammonia:
- Mercury:

Chemicals:

1. Other
2. Other

Hazardous Waste (List if not checked elsewhere.):

1. List
2. List
3. List

Particulates:

- Coal Dust:
- Synthetic Vitreous Fibers:

1. Other
2. Other
3. Other

- Laser Light:

Appendix C. References

(Unless otherwise noted, the most recent version of the reference document should be used.)

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2. U. S. Department of Labor, Title 29 Code of Federal Regulations Part 1960, *Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters.*

3. United States Code, 42 USC Sect. 7274i, *Program to Monitor Department of Energy Workers Exposed to Hazardous and Radioactive Substances.*

4. U.S. Department of Energy, Title 10 Code of Federal Regulations Part 835, *Occupational Radiation Protection,* and its implementation guides (b through l) .

5. U.S. Department of Energy, DOE G 440.1-1, WORKER PROTECTION MANAGEMENT FOR DOE FEDERAL AND CONTRACTOR EMPLOYEES.

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7. U.S. Department of Energy, DOE G 440.1-4, CONTRACTOR OCCUPATIONAL MEDICAL PROGRAM.

8. U.S. Department of Energy, DOE G 440.1-5, FIRE SAFETY PROGRAM.

9. U.S. Department of Energy, DOE G 440.1-6, IMPLEMENTATION GUIDE FOR USE WITH SUSPECT/COUNTERFEIT ITEMS REQUIREMENTS OF DOE O 440.1, WORKER PROTECTION MANAGEMENT; 10 CFR 830.120; and DOE 5700.6C, QUALITY ASSURANCE.

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26. U.S. Department of Labor, Occupational Safety and Health Administration, *Technical Manual*.

27. U.S. Environmental Protection Agency, *Guidelines for Exposure Assessment.*

28. National Institute for Occupational Safety and Health, *Manual of Analytical Methods.*

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30. U.S. Department of Energy, *Handbook for Occupational Health and Safety During Hazardous Waste Activities* (June 1996).

31. U.S. Department of Energy, Title 48 Code of Federal Regulations Part 970.5204-2, *Integrating Environment, Safety, and Health into Work Planning and Execution.*

32. U.S. Department of Energy, DOE P 450.4, INTEGRATED SAFETY MANAGEMENT SYSTEM.

33. M. Corn and N. A. Esmen, "Workplace Exposure Zones for Classification of Employee Exposures to Physical and Chemical Agents," *J. Am. Ind. Hygiene Assoc.,* 40:47 (1979).

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35. U.S. Department of Energy, DOE O 430.1, LIFE-CYCLE ASSET MANAGEMENT (LCAM).

36. U.S. Department of Energy, DOE G 430.1-3, DEACTIVATION IMPLEMENTATION GUIDE.

37. U.S. Department of Energy, DOE G 430.1-4, DECOMMISSIONING IMPLEMENTATION GUIDE.

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