The NIOSH Occupational Energy Research Program

Evidence for the National Academies' "Review of the Worker and Public Health Activities Program Administered by the Department of Energy and the Department of Health and Human Services"

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

The NIOSH Occupational Energy Research Program

Evidence for the National Academies' "Review of the Worker and Public Health Activities Program Administered by the Department of Energy and the Department of Health and Human Services"

November 2005

Disclaimer

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). In addition, citations to Web sites do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these Web sites.

Ordering Information

To receive documents or other information about occupational safety and health topics, contact NIOSH at

NIOSH—Publications Dissemination
4676 Columbia Parkway
Cincinnati, Ohio 45226–1998
Telephone: **1–800–35–NIOSH** (1–800–356–4675)
Fax: 513–533–8573
E-mail: pubstaft@cdc.gov

or visit the NIOSH Web site at **www.cdc.gov/niosh**

Foreword

The purpose of this document is to provide an evidence package to the National Academies for its review of the CDC/NIOSH Occupational Energy Research Program. The OERP began under a Memorandum of Understanding with the Department of Energy in 1991 to study the health effects of workers at DOE facilities from exposure to ionizing radiation and other chemical and physical agents. This evidence package presents a comprehensive overview and history of the OERP, a detailed summary of completed research and communication products, and a rationale and plan for future research.

In developing this evidence package, NIOSH used an operational logic model (see p. iv) for describing the OERP process from inputs to outcomes. This model clarifies the driving need for health effects research at DOE facilities, the available DOE budget and data to support such research, and the research products such as journal articles and communication products. The model also clarifies the effect of these products on the scientific community, on national and international standards organizations, on compensation practice, and, most importantly, in reducing diseases such as cancer and other illnesses due to ionizing radiation and other workplace exposures.

As described in this evidence package, the NIOSH OERP has significantly moved forward the state of science for occupational radiation epidemiology and exposure assessment. This research will affect the well-being of more than 600,000 workers in the U.S. and more than 10 million worldwide. Much work, however, remains to be done in translating heath effects research into impact-driven practice for improving worker and public health. The National Academies' review of the OERP will help NIOSH set an optimal direction for future efforts to continue research and to move from research to practice in this area.

John Howard, MD
Director
National Institute for Occupational Safety and Health

NIOSH Occupational Energy Research Program Operational Model

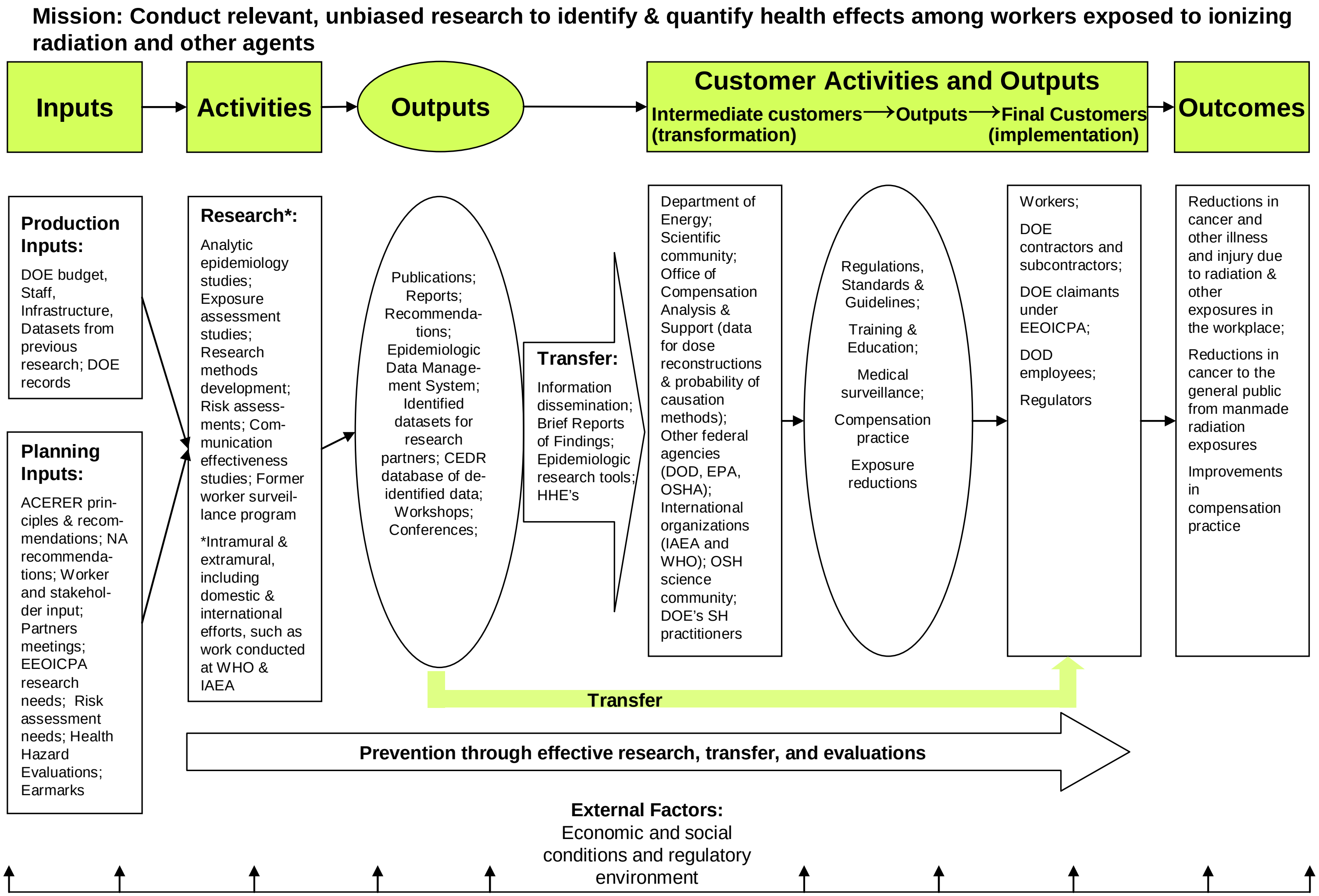

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

ACERER	Advisory Committee for Energy-Related Epidemiologic Research
ASA	American Statistical Association
ATSDR	Agency for Toxic Substances and Disease Registries
BEIR	Biological Effects of Ionizing Radiation
CDC	Centers for Disease Control and Prevention
CD-ROM	Compact Disc Read-Only Memory
CEDR	Comprehensive Epidemiologic Data Resource
CHP	Certified Health Physicist
CI	Confidence Interval
CIH	Certified Industrial Hygienist
CIO	Center, Institute or Office
CLL	Chronic Lymphocytic Leukemia
DHHS	Department of Health and Human Services
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	Department of Transportation
EAFS	Exposure Assessment Feasibility Study
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
EMF	Electromagnetic Fields
EPA	Environmental Protection Agency
ERR	Excess Relative Risk
FEMSP	Former workers Medical Surveillance Program
FY	Fiscal Year
HERB	Health-related Energy Research Branch
HHE	Health Hazard Evaluation
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
INEEL	Idaho National Engineering and Environmental Laboratory
INL	Idaho National Laboratory
IRB	Institutional Review Board
IWSB	Industry Wide Studies Branch
LANL	Los Alamos National Laboratory
LET	Linear Energy Transfer
LSS	Life Span Study
MoU	Memorandum of Understanding
NA	National Academies
NCEH	National Center for Environmental Health
NCRP	National Council of Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
OCAS	Office of Compensation Analysis and Support
OERP	Occupational Energy Research Program
OHS	Office of Health Studies

Acronyms and Abbreviations

OR	Odds Ratio
ORAU	Oak Ridge Associated Universities
OSHA	Occupational Safety and Health Administration
PGDP	Paducah Gaseous Diffusion Plant
PNNL	Battelle-Pacific Northwest National Laboratory
PNS	Portsmouth Naval Shipyard
POC	Point of Contact
RFA	Request for Application
SEC	Special Exposed Cohort
SES	Social Economic Status
SMR	Standardize Mortality Ratio
SOW	Statement of Work
SEC	Special Exposure Cohort
SPEERA	Secretarial Panel for the Evaluation of Epidemiologic Research Activities of the Department of Energy
Sv	Sievert (The special name for the System International unit of equivalent dose, effective dose, and the operational dose quantities: 1 Sv= 1 J kg-1)
TEC	Tennessee Eastman Corporation
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UV	Ultra-Violet
WHO	World Health Organization

Background and Scope

Since 1990, the U.S. Department of Energy (DOE) has sponsored research under the Worker and Public Health Activities Program conducted by the Department of Health and Human Services (DHHS). Within this program, energy-related health studies and public health activities are conducted by the National Center for Environmental Health (NCEH), the Agency for Toxic Substances and Disease Registry (ATSDR), and the National Institute for Occupational Safety and Health (NIOSH) under a Memorandum of Understanding (MoU) between DOE and DHHS.

Under the MoU, responsibilities for the occupational studies previously conducted by the DOE were delegated to NIOSH, an institute created by the Occupational Safety and Health Act of 1970. NIOSH was created to develop workplace exposure standards for consideration by the Occupational Safety and Health Administration, to conduct epidemiologic research related to health effects of workplace exposures, to provide technical assistance in investigating workplace hazards, and to support training for occupational safety and health professionals.

To carry out its responsibilities under the MoU, NIOSH created the Occupational Energy Research Program (OERP), which conducts occupational health research among workers at DOE and other energy-related facilities. This research assesses the incidence and prevalence of acute and chronic disease among nuclear workers, evaluates associations of work-related exposures and disease, and determines the nature and extent of occupational exposures to physical, chemical, and radiological agents in energy-related industries. OERP research is composed primarily of longitudinal records-based epidemiologic studies but also includes chemical and radiological exposure assessments. Findings from these studies are expected to be generalizable to others in the US and worldwide who are exposed to ionizing radiation in the workplace.

In July 2005, a committee of the National Academies (NA), led by the Nuclear and Radiation Studies Board (NRSB) initiated a critical review of the Worker and Public Health Activities Program, including the NIOSH OERP, under requests made by DOE (NSRB-O-05-01-A). According to its charge, the NA committee: "will assess and will recommend ways to enhance the program's scientific merit, focus, and effectiveness; its demonstrated impact on the agency's (DOE's) policies and decisions; and other benefits, such as relevance to DOE's missions, that are consistent with the objectives of this program."

NIOSH welcomes the opportunity to engage in this review as it relates to the OERP and looks forward to working with the NA committee members. NIOSH staff members are proud of the accomplishments of the OERP and are currently working with stakeholders to develop a future research agenda. As such, this review will provide constructive and timely feedback, which will aid NIOSH in carrying out the OERP mission. To assist the NA with its review, NIOSH has prepared this document summarizing the OERP and providing pertinent reference materials. The document is divided into the following three sections:

SECTION I. Program Orientation

In this opening section, we provide a brief history of the Occupational Energy Research Program (OERP), its mission and strategic goals, and management processes used to ensure that the research program is relevant, productive and of high quality. The intent of this Evidence Package is to demonstrate that NIOSH has conducted research that has moved the state of the science considerably forward in the area of occupational radiation epidemiology and exposure assessment. Although much has already been accomplished, more work remains to be done in protecting the large number of persons currently exposed to ionizing radiation in the workplace both in the U.S. and worldwide.

The Program's Beginnings

In 1989, DOE Secretary James Watkins announced that an independent advisory committee would be formed to advise him on the necessary restructuring of the DOE's epidemiologic research activities. The Secretarial Panel for the Evaluation of Epidemiologic Research Activities of the Department of Energy (SPEERA) was chartered on August 1, 1989, and issued its report early in 1990.[(1)] The report recommended that DOE enter into a MoU with the Department of Health and Human Services (DHHS). The report recommended that, under the MoU, DOE would fund and provide input on the research, and DHHS would carry out an independent program of analytic epidemiologic research related to DOE's activities. SPEERA recommended that the MoU include the following elements:

- DOE should continue to budget for analytic epidemiology with the funds to be allocated to DHHS.

- Current grants and contracts for analytic epidemiology should be continued. Research-in-progress should become subject to the DHHS' regular monitoring processes and should move toward open competition for grants and contracts. There should be a transition to a competitive system for project renewals and additional studies.

- DHHS should use its usual methods to set the research agenda, provide for peer review of research proposals, provide quality assurance for research-in-progress, and provide access to data to independent researchers.

- Several communication channels between DOE and DHHS should be established to share information about surveillance data, research findings, and policy implications. Information sharing should be routine and frequent.

- DHHS should adopt a method of promptly and effectively notifying workers and communities of results of studies which could affect them.

- DHHS should establish an advisory committee for the DOE's analytic epidemiologic research. Such an advisory committee should serve as a vehicle for public comments. Its members should represent all affected parties; including workers, communities, academicians, public health officials, and public interest groups.

SPEERA Panel Members

Kristine Gebbie, R.N., M.N., Chair
Molly Joel Coye, M.D., M.P.H.
Mark Cullen, M.D.
Clark Health, Jr., M.D.
Mark Rothstein, J.D.
Michael Silverstein, M.D., M.P.H.
Lee Stauffer, M.P.H.
Thomas Vernon, M.D.
Bailus Walker, Jr., Ph. D., M.P.H.

Also in 1989, DOE asked the National Academies (NA) to conduct a scientific review of its epidemiological research programs.(2) The NA report recommended that DOE enter into an agreement with DHHS to conduct epidemiologic research. Other recommendations of the NA report were:

- Efforts should be made to quantify exposures to and effects of agents in addition to ionizing radiation, because there will potentially be exposure, during cleanup and future work, to agents that might be toxic themselves or interact with radiation.

- Epidemiologic studies should be evaluated with respect to the appropriate inclusion of workers' family members, particularly children.

- Development and use of molecular markers of exposure to chemicals or ionizing radiation should be cautiously explored for use in future studies.

In 1990, DOE and DHHS entered into a five-year MoU. Its stated purpose was the execution of SPEERA recommendations for the management and conduct of energy-related analytic epidemiologic health research by DHHS. The responsibilities for conducting research activities were delegated to the Centers for Disease Control and Prevention (CDC), specifically NIOSH for occupational studies and the National Center for Environmental Health (NCEH) for dose reconstructions and community studies. Accompanying the implementation of this MoU were resource specifications for Fiscal Year (FY) 1991 and FY 1992. There have been two subsequent MoUs (1996 and 2000) that continued the work begun by the initial agreement. Currently there is no MoU in place, but a draft is in negotiation between the departments.

The OERP began as an activity within NIOSH's Division of Surveillance, Hazard Evaluations, and Field Studies in Cincinnati, Ohio, in 1991. Hiring of technical and administrative staff began immediately. Disciplines essential to the OERP include: epidemiologists, biostatisticians, health physicists, industrial hygienists, computer programmers, records specialists, and administrative personnel.

The initial OERP research agenda consisted of ongoing DOE studies that were transitioned to NIOSH under the first MoU. Beginning in fiscal year 1991, NIOSH assumed the responsibility for the conduct and management of the existing studies performed by the Oak Ridge Associated Universities (ORAU), Los Alamos National Laboratory (LANL), and the Battelle-Pacific Northwest National Laboratory (PNNL) under DOE direction. After careful consultation with research staff at the three DOE National Laboratories, only twenty of these studies were continued (Table I-1).

Table I-1. Previous studies with responsibilities assumed by NIOSH under the MoU

No.	Study	Principle Investigator
1	Oak Ridge National Laboratory [6]	ORAU
2	Mortality of workers at a nuclear materials production plant (Y12) in Oak Ridge, Tennessee [7]	ORAU
3	Oak Ridge Gaseous Diffusion Plant (K-25) Cohort Mortality Study [8]	ORAU
4	Combined Oak Ridge Facilities (Tennessee Eastman Corporation [TEC], Y-12, X-10, K-25) [9]	ORAU
5	Cohort Mortality Study of Welders at ORNL [10]	ORAU
6	Savannah River Site Cohort Mortality Study	ORAU
7	Fernald Feed Materials Cohort Mortality Study	ORAU
8	Uranium Dust Lung Cancer Case-Control [11]	ORAU
9	Mallinckrodt Chemical Works Cohort Mortality Study (12)	ORAU
10	5-Rem Study [13]	ORAU
11	Mound Facility Cohort Mortality Study [14,15]	LANL
12	Los Alamos National Laboratory Cohort Study [16]	LANL
13	Rocky Flats Nuclear Weapons Plant Cohort Mortality Study [17]	LANL
14	Zia Company Cohort Mortality Study [18]	LANL
15	Los Alamos “241 Cohort” Study [19]	LANL
16	Hanford Health and Mortality Study [20]	PNNL
17	Evaluation of Follow-Up for Hanford Workers	PNNL
18	Combined Data on Hanford and ORNL (21)	PNNL
19	External Radiation Dosimetry Data in Epidemiologic Analysis [22,23]	PNNL
20	Combined International Studies [24]	PNNL

The passage of the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) in late 2000 had substantial importance for the OERP. Under the Act, NIOSH was given three responsibilities related to compensation claims associated with ionizing radiation exposures of U.S. nuclear workers:

1. To develop guidelines for determining whether a claimant's cancer was "at least as likely as not" to have resulted from workplace exposure to ionizing radiation.

2. To conduct dose reconstructions for individual claimants.

3. To establish guidelines and consider petitions to expand the "Special Exposure Cohort" (SEC) of workers with certain cancers, who were deemed eligible for compensation provided they met certain length of employment criteria. The Congressionally mandated SECs included three DOE gaseous diffusion plants and the Amchitka nuclear test site.

The Office of Compensation Analysis and Support (OCAS) was established within NIOSH for this purpose. Some OERP staff were detailed to OCAS for extended periods of time to facilitate the start of this program. In addition, the goals of the OERP were affected by the responsibilities delegated to NIOSH under the EEOICPA.

OERP Mission

The mission of the OERP is:

- to conduct relevant, unbiased research to identify and quantify health effects among workers exposed to ionizing radiation and other agents
- to develop and refine exposure assessment methods
- to effectively communicate study results to workers, scientists, and the public
- to contribute scientific information for the prevention of occupational injury and illness
- to adhere to the highest standards of professional ethics and concern for workers' health, safety and privacy.

Strategic Goals

The OERP has established twenty strategic goals, categorized by activity related to the overall program, to specific research questions, or to communications. Most of these goals are published in the program book [3] and are listed below; however, two program goals (P.6 and P.7) have been added since the book was published, in response to new Congressional mandates for NIOSH. All OERP activities link to these goals. Furthermore, these strategic goals are aligned with the goals and mission of both NIOSH and the DOE, as illustrated in Figure I-1. The relationships of OERP goals to those of both NIOSH and DOE, and the success of the OERP in meeting these goals, are described further in Section III.

Program Goals

P.1) Assure that energy-related health research addresses pertinent occupational health questions and provides a framework for intervention.

P.2) Conduct research in an open environment with meaningful communication among all interested parties.

P.3) Capture the vanishing opportunities to study groups of people with unique exposure to radiation, chemical, and other stressors.

P.4) Develop improved methods for associating occupational exposures and consequent health risks.

P.5) Recommend improved protective measures for workers if scientific evidence indicates that regulations or practices are inadequate.

P.6) Provide scientific evidence to support the development of sound compensation policy for radiogenic cancers under the Energy Employees Occupational Illness Compensation Program Act.

P.7) Respond to Congressional and other special governmental requests for research addressing important public health and policy priorities.

Research Goals

Epidemiologic Research Goals

R.1) Evaluate possible relationships between workplace exposures and injury or disease using the best available methodologies.

R.2) Analyze combined populations to assess whether certain rare cancers are related to past occupational exposures.

R.3) Examine the relationships of mixed exposures and worker health.

R.4) Provide epidemiologic research findings which enhance the understanding of the effects of low-level protracted exposure to ionizing radiation in Department of Energy workers and others.

Exposure Assessment Goals

R.5) Improve exposure assessment methods to reduce uncertainty in mortality and morbidity studies.

R.6) Characterize the combined exposures experienced by Department of Energy workers for use in epidemiologic analyses.

R.7) Emphasize quantitative (vs. qualitative) relationships between exposure and health outcomes.

R.8) Evaluate the quality and validity of the available worker exposure data.

Communication Goals

C.1) Develop better mechanisms for generating research hypotheses by expanding the involvement of partners and actively seeking their input.

C.2) Conduct research in an open environment with attention to clear and accurate education of workers and the public.

C.3) Provide information that enhances the understanding of risks associated with radiation-induced health effects.

C.4) Solicit and consider worker interests and the public's concerns.

C.5) Provide relevant occupational exposure and health outcome information for public health research and policy.

NIOSH Strategic Goals	DOE Objectives for "Strategic Goal IV: Ensure the safety and health of workers at DOE facilities and the communities that surround them."			
	IV-1 Determine adverse health effects to workers and the public from exposures to chemical and radiological materials	IV-2 Ensure state-of-the-art worker safety and health policies are in place	IV-3 Detect and prevent work-related illness with an effective occupational health program	IV-4 …Provide information to …NIOSH to support their activities within the EEOICPA
1. Reductions in occupational illness, injuries, and fatalities for DOE, nuclear workers and entire US workforce	P.3, P.4, P.7 R.1, R.2, R.3, R.4, R.5, R.6, R.7 C.1, C.4		R.8	
2. Safe and healthy workplaces through interventions, recommendations and capacity building	P.1	P.5 C.2, C.3, C.5		
3. Enhanced global workplace safety and health through international collaborations	R.4	C.3, C.5		
4. Research information supporting the DOE workers' compensation program	R.3, R.4, R.7	P.6		R.6, R.8 C.5

Figure I-1. Alignment of OERP goals with NIOSH and DOE strategic goals.

Management Processes

Setting an Agenda for Research

During the first years of the OERP, its research agenda was established in close alignment with the recommendations of the SPEERA committee. In later years, the research agenda was guided by recommendations of the Federal advisory committee established to provide consensus advice to the new HHS programs covered under the MoU. More recently, the research agenda has been expanded by the scientific staff and program managers of the OERP through public and stakeholder meetings, as well as consultation with scientific experts on research needed in specific areas. This process as it has evolved through the years of the OERP is described more fully in the following paragraphs.

Following recommendations made by SPEERA, a workshop of approximately 150 scientists and stakeholders was convened in December 1991 to address the development of an analytic epidemiologic research agenda.[(4)] A number of presentations on issues and potential projects were made at the workshop, and five working groups were designated to identify strategies and methods for further evaluation of health risks potentially associated with exposures at DOE facilities. The focus of the workshop evolved into recommendations within five topic areas: communication and public involvement, epidemiology, exposure assessment, dose reconstruction, and other recommendations.

Some of the key recommendations related to the OERP research agenda were:

- To evaluate populations not included in previous cohorts
- To combine cohort data for increased statistical power
- To complete health studies for mercury and beryllium exposures
- To examine outcomes other than cancer such as reproductive health
- To continue follow-up of plutonium-exposed workers
- To evaluate emerging issues such as clean-up workers and Chernobyl liquidators
- To capture radiological and chemical exposure data and procedures
- To obtain institutional memory of site senior staff
- To assess additional chemical and non-ionizing exposures and risk.

Following the workshop, the Advisory Committee for Energy-Related Epidemiologic Research (ACERER) was formed with responsibilities to provide advice to the Secretary of DHHS on an overall research agenda. At the first meeting of the ACERER in early 1993, OERP staff presented a proposed research agenda [(5)], which consisted of the continued studies (Table I-1) and the proposed studies shown in Table I-2.

The ACERER continued to meet periodically between 1994 and 2000. A synopsis of its recommendations affecting NIOSH, produced at these subsequent meetings of the ACERER, is provided in the appendix.

Table I-2. Proposed Research at Initial Meeting of the ACERER

No.	Study and completed publications	Status as of November 2005
1	Mortality Among Nuclear Workers At The Portsmouth Naval Shipyard (25-30)	**Complete:** Cohort Mortality Study and Case-Control Study of Leukemia **Ongoing:** Case-Control study of Lung Cancer Mortality (PLUNG)
2	Mortality Patterns Among Uranium Conversion and Enrichment Workers (31)	Complete
3	Nuclear Complex Cleanup Workers (32-44)	Complete
4	A Study of Plutonium Workers Across DOE Facilities	**Not initiated:** A combined plutonium exposed cohort analysis is proposed in the current 5-year agenda http://www.cdc.gov/niosh/pdfs/hhsdoe_2005-2010-2.pdf (45)
5	Reproductive Health and Parental Occupational Exposure to Ionizing Radiation and Solvents (46)	Complete
6	Sellafield Study of Paternal Exposure and Childhood Leukemia (47)	Complete
7	Case-Control studies of Less Common Tumors at Combined DOE Sites: The Multiple Myeloma Component (48)	**Complete:** Multiple Myeloma Case-Control Study in Five DOE Cohorts **Ongoing:** Multiple Myeloma Case-Control Study at the K25 Uranium Enrichment Facility (K25K)
8	Chemical Exposure Assessment of DOE Workers	**Ongoing:** Chemical Laboratory Workers Cohort Mortality Study (CLWS).
9	Worker Exposure to Electromagnetic Fields at DOE Facilities (49-52)	Complete
10	Follow-Up Study of Mercury Exposed Workers at Y-12 (53,54)	Complete
11	Health Effects of Occupational Exposures to Beryllium Among ODE Workers (55-61)	Complete
12	Chernobyl Liquidation Workers (62)	Complete
13	Historical Health Physics Procedures to evaluate the bias, uncertainty, and selectivity of plutonium bioassay procedures used by DOE over time.	Complete
14	Radiation Exposure Measurement Error Issues (22,23,63-72)	**Ongoing:** This particular problem was recognized early in the program and continues to be focus in continuing epidemiologic studies.
15	Cancer Incidence at Rocky Flats Nuclear Weapons Plant (73-75)	Complete
16	Retrospective Mortality Study of Workers at the Idaho National Engineering Laboratory (76)	Complete

Stakeholder Input

Advisory committees to the research process also existed at various time periods at five DOE sites (see sidebar). They were called Citizens' Advisory Committees on Public Health Service Activities and Research at Department of Energy Sites (often referred to as the "site name" Health Effects Subcommittee). Their membership included scientists, community, labor, state and site representatives, medical professionals, and sometimes a former or retired worker from the site.

Citizens Advisory Committee on Public Health Service Activities and Research at Department of Energy Sites

Health Effects Subcommittee	Duration
Hanford	Sep 1994 to Jan 2004
Savannah River Site	Sep 1995 to Dec 2005
Idaho National Laboratory	Dec 1995 to Jun 2005
Fernald	Jun 1996 to Mar 2000
Oak Ridge Operations	Nov 2000 to Jul 2006

This committee consisted of approximately 180 members, permitting up to 30 members for each site. Members were selected by the Secretary, or designee, from individuals (to include technical experts) knowledgeable of site-specific research concerns, and from diverse community viewpoints and interests.

OERP staff also held research partner meetings in 1996, 1997, and 1998. The meetings provided an opportunity for exchange of research ideas, discussion of research challenges and sharing of lessons learned between OERP staff and its contractors, grantees, and cooperative agreement holders. Other meetings to obtain stakeholder input included:

- Workshop on energy-related epidemiologic research at CDC, Atlanta, Georgia (1991)
- "People of Color and Disenfranchised Communities Environmental Summit," Waveland, Mississippi (1997)
- Public meetings in Oak Ridge, Tennessee, Los Alamos, New Mexico, and Denver (1998)
- Combined Health Effects Subcommittee meeting, Salt Lake City (1998)
- Public meeting to gain expert opinion and public input on approaches to evaluate the radiogenicity of chronic lymphocytic leukemia (2004)
- Public meeting to gain input on future research agenda from stakeholders (2005)

OERP staff provided the occupational epidemiologic study component of the "Draft Agenda for Public Health Activities for Fiscal Years 1999 and 2000 at U.S. DOE Sites" prepared by the Agency for Toxic Substances and Disease Registry (ATSDR), NCEH, and NIOSH. Thirty of the received comments on the agenda were interpreted as having some applicability to occupational or worker concerns, and were considered by the OERP. The agenda was expanded into a five-year plan that was to be updated annually. The first five-year agenda covered fiscal years 2001 to 2006, and the fifth and most recent covers the period 2005 to 2010.

CDC and DOE send these annual updates to their respective stakeholders. Comments received are considered for incorporation into the next update. The most recent version, "Agenda for HHS Public Health Activities (For Fiscal Years 2005-2010) at U.S. Department of Energy Sites" is available at http://www.cdc.gov/niosh/pdfs/hhsdoe_2005-2010-2.pdf.[45] In the most recent years, this planning document has also been used by DOE as a congressional appropriations committee briefing book on the DHHS research agenda.

Ongoing Research Activities and Future Research Needs

Since 2001, the OERP has begun very few new epidemiologic studies, but instead has focused on completing existing studies, which were developed under the guidance of the SPEERA and ACERER recommendations. Beginning in January 2005, several new projects have been added to the public health agenda, which resulted from input provided to the OERP as part of earlier stakeholder meetings. Several other projects are proposed. OERP recently held two public meetings, in July 2004 and October 2005, to seek input from stakeholders and the general public on its proposed research agenda. Similar meetings will be held in the future. A list of recently completed, ongoing, and proposed OERP projects is shown in Table I-3.

The health research of the OERP and the research principles of SPEERA and the ACERER continue to be relevant given the large number of nuclear workers still employed in the U.S. and elsewhere and the recent impetus to invigorate the nuclear industry as a result of increasing energy demands worldwide. Findings from these studies are expected to be generalizable to other populations having chronic, low-level exposure to ionizing radiation. Ultimately, this research provides the cornerstone for future worker protection standards, which will draw directly from studies germane to occupational settings rather than rely solely on risk models developed from studies of persons exposed to high doses of radiation, such as atomic bomb survivors and patients exposed during radiotherapy, as is the case of existing standards.

Under the guiding principles of the SPEERA and ACERER recommendations, the body of OERP research has advanced the scientific understanding of risks associated with occupational exposures to ionizing radiation but many questions remain. Future OERP research will focus on answering the following primary questions:

1. Does low-level workplace exposure to low-LET radiation cause cancer (what kinds, and what is the quantitative risk per unit of dose)?

2. What are the relative effects of different types of ionizing radiation, e.g., alpha particles and neutron, compared to low-LET radiation?

3. Does dose rate affect the level of cancer risk?

4. How does radiation interact or combine with other exposures (e.g., workplace exposures such as solvents, asbestos or heavy metals, or smoking) in causing cancer?

5. Do workers vary in their sensitivity to radiation, for example, by gender or age at exposure?

6. Does radiation cause chronic lymphocytic leukemia (CLL)? If so, what is the dose-response relation?

7. Do current exposure data and epidemiologic findings support the modification of occupational exposure limits for ionizing radiation?

To best answer these remaining questions, OERP researchers propose a research agenda that includes the epidemiologic study of exposure-based cohorts. Worker cohorts selected by exposure type (i.e. radiation type, exposure pathway) rather than facility maximizes cohort size while minimizing potential for confounding. This design promotes a reduction of uncertainty and increased statistical power. Cohorts could be assembled from the DOE workforce and other nuclear workers that would promote better understanding of the risks associated with internal high-LET radiation (e.g., uranium and/or plutonium exposed cohort), external high-LET radiation (neutron exposures), and external low-LET radiation exposure principally from gamma and x-ray radiations. For example, a “gold standard” for the occupational cancer risks associated with low-LET external radiation may be realized from studying a cohort of workers drawn from multiple nuclear shipyards combined with DOE workers with minimal potential for exposure to other forms of radiation. A nuclear shipyard cohort provides unique advantages over other occupationally exposed cohorts of comparable size. The data collection, abstraction, and exposure assessment phases of the project are greatly simplified given the similarities in radiation exposures and control among the various naval shipyards. The radiation exposures are limited to external whole-body gamma irradiation primarily from ^{60}Co, reducing uncertainties common to mixed radiations typical in fuel-cycle cohorts. Additionally, through their recent work with PNS, NIOSH staff has developed expertise in all phases of shipyard exposure assessment.

Furthermore, OERP research would pursue pooling data to incorporate similarly exposed cohorts examined by other researchers. For example, nuclear shipyard workers may be pooled with the combined cohorts of the IARC 15-country study or the recent study of U.S. nuclear power workers. These pooled analyses would further increase statistical power and relevance to the worldwide community of nuclear workers.

Most studies conducted to date in the OERP have been of cancers such as lung, multiple myeloma and leukemia (most subtypes), which have generally high case-fatality rates. For these health outcomes, cancer mortality is likely to be an adequate study endpoint. An additional avenue of promising research for the OERP, which was strongly recommended by the ACERER, consists of incidence studies for cancers with relatively low fatality rates (e.g., malignant melanoma, and prostate, breast, thyroid or bladder cancer). Feasibility studies conducted in the

OERP suggest that, due to the mobility of most DOE worker populations and retirees, a study with nationwide coverage would be required. Because most state cancer registries have been initiated relatively recently, a study of cancer incidence for most DOE populations would need to be prospective in nature, or would require individual follow-up by questionnaire in addition to linkage to these registries. An advantage of the latter approach would be the ability to capture information about confounding factors for study subjects; however, this approach is relatively expensive for large cohorts.

One area of research in which the ACERER recommendations have been more difficult to implement is the evaluation of current worker exposures and health effects. A feasibility study of the availability of demographic and exposure data to carry out such studies was completed by OERP researchers. It was determined that data collection by decommissioning and decontamination contractor employers was insufficient to support the development of exposure and epidemiologic studies. Recommendations were communicated to DOE to improve the collection of such information; these recommendations were supported by DOE's Office of the Inspector General (see example discussed in Section II, p. 42). It is likely that future NIOSH field investigations and Health Hazard Evaluations (a congressionally mandated program by which NIOSH investigates workplace exposures and potential health effects at the request of facility employees or management), as well as information provided by DOE's surveillance program among current workers, could improve the understanding of current worker exposures.

Table I-3. OERP Research Agenda

No.	Study Description	Study ID	Completed
1	All-Causes Cohort Mortality Study of Workers at INEEL	INEL	FY05
2	Mortality among Civilian Nuclear Workers at Portsmouth Naval Shipyard (PNS)	PNS	FY05
3	PNS Leukemia Nested Case-Control (PLCC)	PLCC	FY05
4	Chemical Laboratory Mortality Study	CLWS	Ongoing
5	Pantex Plant Mortality Study	PAMU	FY05
6	PNS Lung Cancer Nested Case-Control	PLUN	Ongoing
7	Multiple Myeloma at K-25 Plant	K25K	Ongoing
8	Leukemia and Ionizing Radiation Multisite Case Control (ORNL, SRS, Hanford, LANL/Zia, PNS)	LCCS	Ongoing
9	Fernald Cohort Mortality Update Study	FNUP	Ongoing
10	Hanford Mortality Study	HANF	FY05
11	International Agency for Research on Cancer (IARC) 15-Country Study	IARC	FY05
12	Health Effects of Uranium Milling Industry	HEUMI	FY05
13	Grants Program	GRNTP	FY06
14	HERB Epidemiological Database System	HEDS	Ongoing
16	Chronic Lymphocytic Leukemia Structured Review	CLLM	Ongoing
17	Other Chronic Lymphocytic Leukemia (CLL) Research	CLLE	Ongoing
18	Neutron Exposed Cohort Feasibility Study	NUTR	Proposed
19	Combined Uranium Workers Feasibility Study (FNUP & MALN)	CUWS	Proposed
20	Combined Plutonium Workers Feasibility Study	CPWS	Proposed

Quality Assurance Processes

OERP Research Protocol Development and Approval

Development of research protocols for the OERP follows the tri-partite model, which includes worker, management, and scientific peers in review. Knowledgeable scientists serve as peer reviewers by either a written review or in a meeting. DOE, worker representatives and site management are also invited to comment on the protocol. Final protocols are submitted to the NIOSH Human Subjects Review Board for approval. Additionally, DOE site institutional review boards for the respective study facilities approve research protocols. The process for the inter-departmental reviews was published in the Site Access Handbook [(77)], first printed in 1997. More details on the review procedures are found in the NIOSH Policies on external peer review of intramural projects.[(78)]

External Peer Review

External peer review is an integral part of OERP research. NIOSH policies have been in place for ensuring external peer review of projects since the inception of the OERP. The current NIOSH policy on external peer review was most recently revised in 2002 and 2005.[(78)] All OERP research projects are conducted in compliance with this policy, which also complies with the policies of DHHS and the Office of Management and Budget. The key requirements of the current policy are:

- Projects are subject to peer review by external experts at project inception, and at least every five years during the life of the project.
- Some projects, which do not have a research component and do not generate technical or scientific data, may be exempt from this policy, as determined on a case-by-case basis.
- Project review is to be conducted using, at a minimum, written reviews from two peer reviewers from outside of CDC.
- Large or complex projects or projects likely to have high public interest or impact require higher levels of review as appropriate for the specific project.
- All technical reports and manuscripts must be reviewed by at least two outside peer reviewers before communicated or submitted to a journal for publication.

Additional information on clearance procedures is located at the following web address: http://www.cdc.gov/od/foia/policies/clearance.htm. The typical process for clearing a NIOSH technical report is shown in Figure I-2. Extensive peer review, including at least two reviewers external to CDC (more for reports that are expected to be influential), is conducted for NIOSH-numbered reports, such as the OERP cohort mortality study of workers at the Idaho National Laboratory (INL) [(76)].

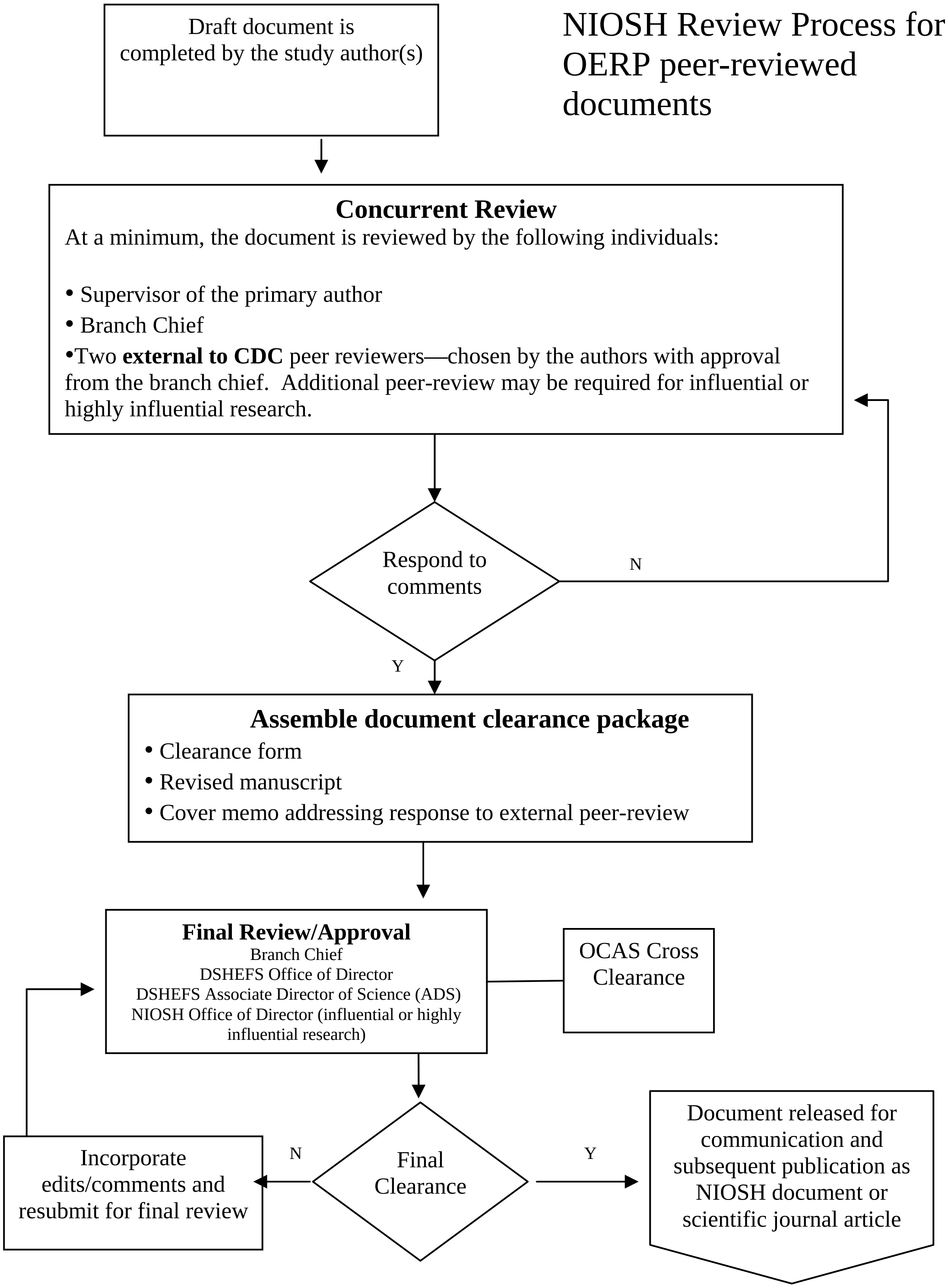

Figure I-2. Review and approval of OERP external peer-reviewed research document

Publications in Peer-Reviewed Literature

After going through the described peer review process including at least two reviewers external to CDC, OERP manuscripts intended for submission to peer-reviewed journals are cleared for submission by the Office of the Director of the Division of Surveillance, Hazard Evaluation, and Field Studies. Given the nature of OERP-related publications, cross-clearance by OCAS is often required. Manuscripts cross-cleared by NIOSH division managers do not necessarily need to be sent to the NIOSH Office of the Director, unless:

- They contain statements that have NIOSH policy implications
- They could be considered "influential" or addresses "sensitive" issues
- They include coauthors from another Center/Institute/Office (CIO) in CDC or ATSDR
- They contain policy statements (or implied policy statements) relevant to the mission of another CIO or comment directly on the programs of another CIO.

The typical process for clearing a publication in the peer-reviewed literature is shown in Figure I-2.

Communications with Workers, Management and Researchers

A primary value of the OERP is to conduct occupational research and communicate the findings in an open and meaningful way to workers, management and the scientific community. Cancer-related health communications have a strong research-based tradition (e.g., http://www.cancer.gov/pinkbook). Theory and evidence-based methods for communicating study findings are being applied in the OERP. These methods involve understanding intended audiences, segmenting those audiences, setting communication objectives for each segment, selecting messages and delivery channels for each audience, engaging the audience in two-way communications, and evaluating communications activities.

Five audience segments have been identified for the OERP: workers (*W*), their managers (*M*), DOE officials (*D*), the public (*P*), and peer-level scientists (*S*). To communicate effectively with this audience, the OERP established the following communication objectives, with input from both DOE and labor representatives (intended audience segments are indicated in parentheses):

1. Conduct NIOSH-sponsored OERP research meetings *(W, D, S)*
2. Use multiple channels to communicate with workers, site management and the public *(W, M, D, P)*
3. Communicate all study findings directly to workers and management *(W, M, D)*
4. Publish research methods and results in scientific peer-reviewed journals and present findings at scientific meetings *(D, S)*
5. Make data for OERP studies available in the DOE's Comprehensive Epidemiologic Data Resource (CEDR) *(D, S)*.

Objective 1: NIOSH/OERP sponsored research meetings

OERP-sponsored research meetings ("partners meetings") are held on a periodic basis at the NIOSH Hamilton Laboratory in Cincinnati. The meetings are coordinated with DOE and include primarily extramural research groups that have cooperative agreements, contracts, or grants with

NIOSH in energy-related epidemiologic research. The meetings provide an opportunity for scientific exchange, collaboration, and cooperation among the extramural research groups and DOE and OERP.

Objective 2: Use of multiple communication channels

OERP researchers use multiple channels to communicate with current and former workers about occupational research activities conducted at DOE sites. These include:

- Periodic conference calls and on-site meetings are conducted by OERP staff. The calls allow workers and site management to learn more about current and proposed OERP research and to discuss concerns about health problems and exposures.

- An extensive computerized list of labor, management, and human resources professionals, developed by OERP in coordination with DOE, allows for efficient communication with many current and former workers at several different DOE sites simultaneously.

- OERP materials that provide site-specific information about current and proposed research projects and the availability of OERP research information have been developed and distributed using this list.

- Complete information including technical reports and study summaries of all completed OERP studies and descriptions of current occupational research at all DOE sites is available on the NIOSH internet website. The web address is http://www.cdc.gov/niosh/2001-133.html.

- One-page study summaries (called "Brief Reports of Findings") have been developed that communicate the purpose, activities, and findings of OERP studies at the DOE sites. The format for these reports was prepared after extensive consultation with workers and management at DOE sites. The summaries are converted to a conventional file format (portable document file or pdf) so that they can be easily placed in site newsletters, on bulletin boards, and on Web sites. They are also distributed directly to workers individually or to worker representatives as an e-mail attachment.

Objective 3: Communicate findings to workers and management

When a study is completed under the OERP, study findings are reported to workers, DOE Headquarters and site managers, and site contractor management. To accomplish this, OERP researchers coordinate a sequence of communication activities described above with DOE headquarters, DOE site contacts, and labor representatives (see Figure I-3 and Figure I-4). Initially, study results were communicated to workers and worker representatives, DOE Headquarters and site management simultaneously. As a result of concerns expressed by DOE, the procedure was changed, and the Brief Report of Findings is communicated to DOE Headquarters three days before the communication to workers and site management.

Under the OERP, extramural investigators are strongly encouraged to communicate their study results to affected workers. For grantees willing to participate jointly with NIOSH in the communication of their study findings, OERP staff assist in the preparation of a Brief Report of Findings and work with the researcher to establish communications with workers and management. It is important to note that the extramural researchers' participation in communications is voluntary; a mechanism does not exist to require such participation given the need to ensure independence of the research. NIOSH does not communicate its own interpretation of extramural research findings in lieu of grantee participation. Instead, OERP staff will, to the extent practical, announce the completion of extramural research to workers and management through the existing communication channels.

OERP researchers do critically evaluate extramural research in the context of the body of scientific evidence when reviewing the literature (e.g., as was done in reviews of the radiogenicity of leukemia and chronic lymphocytic leukemia from occupational exposures to radiation). The OERP is also exploring with the NIOSH Office of Extramural Programs methods for ensuring that future grantees participate in communication of their study findings to workers and DOE management.

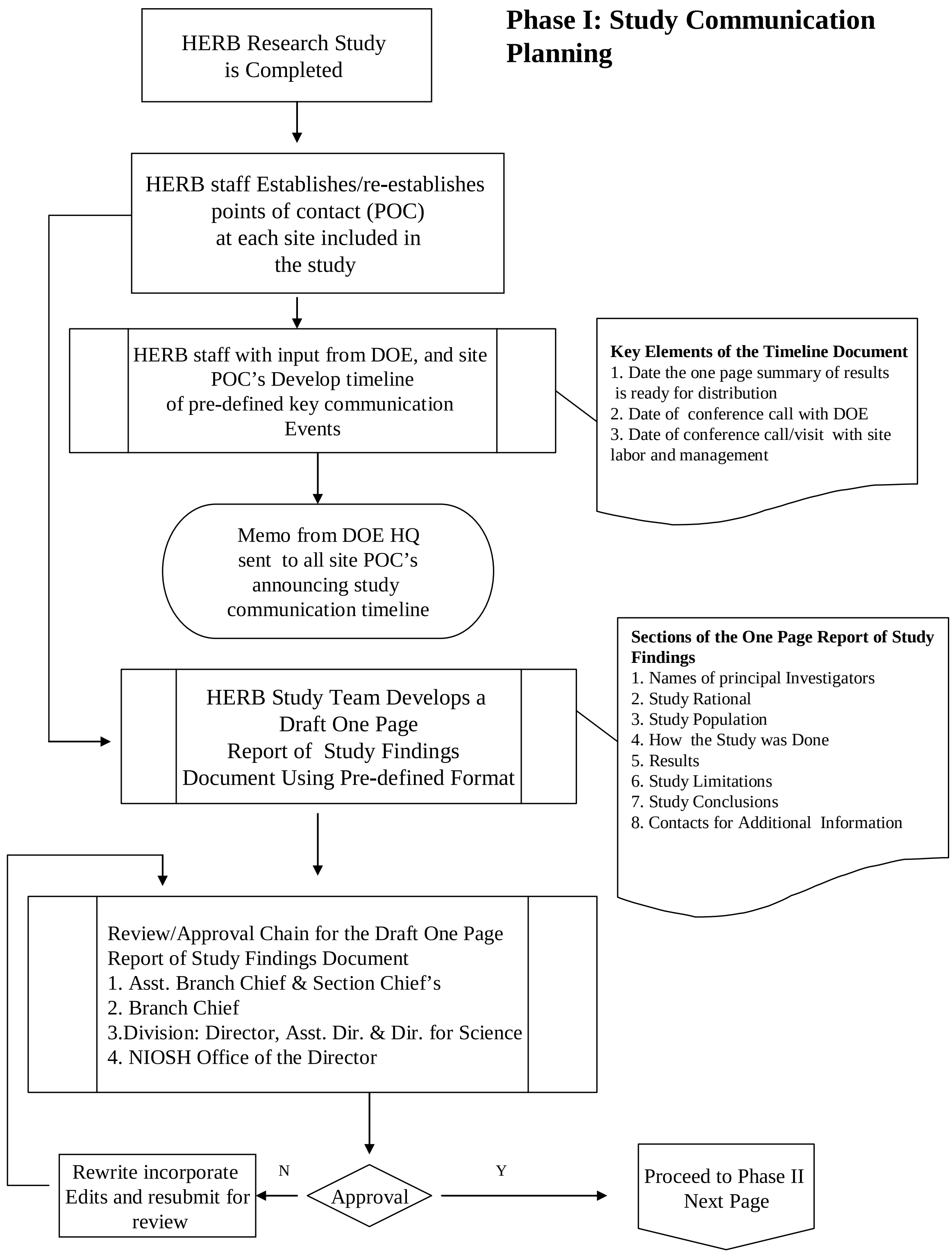

Figure I-3. OERP communications planning

Phase II: Communication of Study Findings with DOE and Site Labor and Management

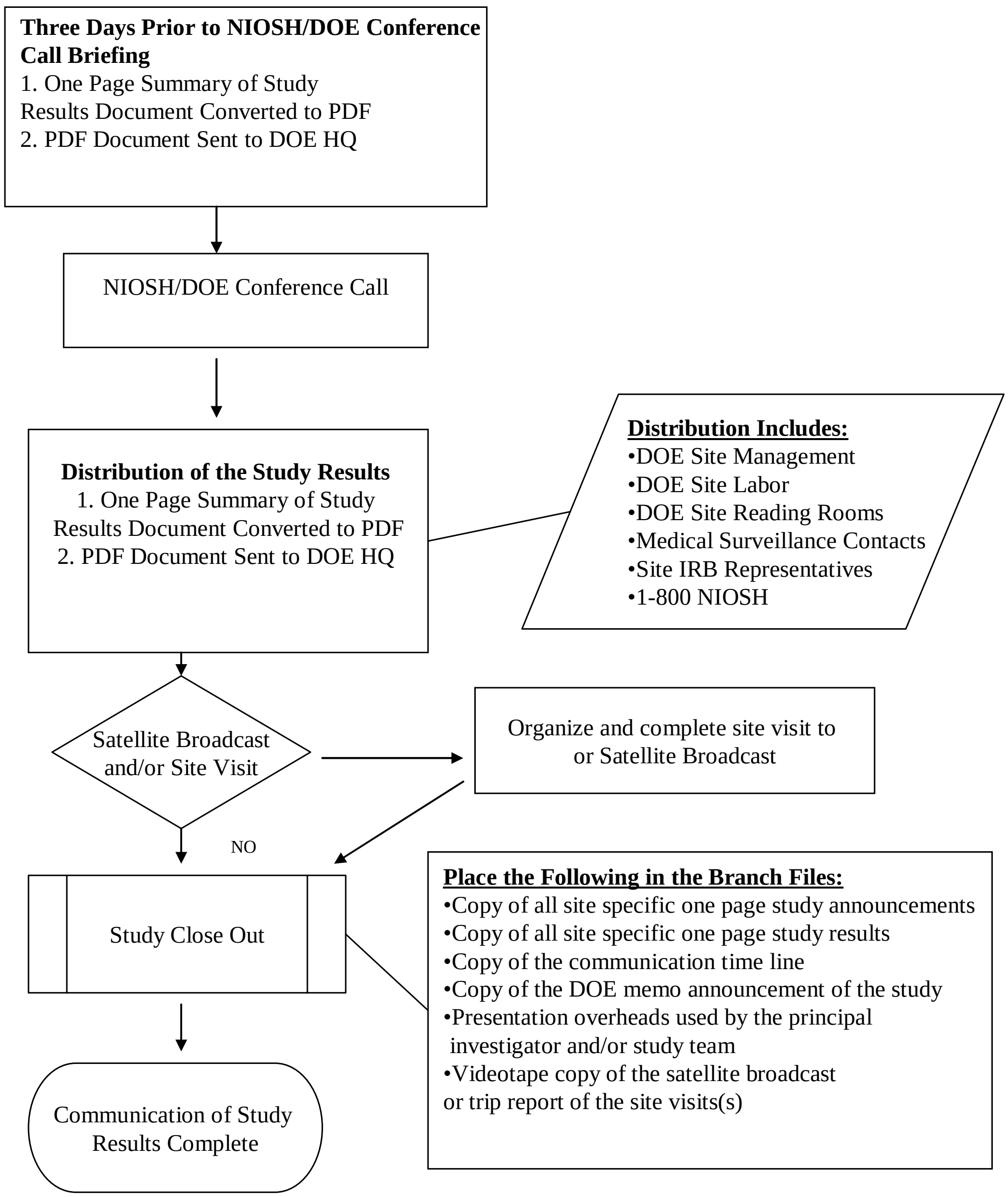

Figure I-4. OERP communication process

Objective 4: Publish research results in scientific peer-reviewed journals

OERP researchers are committed to publishing the results of their occupational research in peer-reviewed scientific journals and ensuring that all articles are of the highest quality and are useful to the intended audience. The peer-review procedure shown in Figure I-2 is the method by which this is achieved.

Objective 5: Make OERP data available in CEDR

A large volume (more than 18 million records) of de-identified data from OERP intramural and extramural studies has been placed into the DOE's CEDR database, so that independent researchers may access and conduct their own analyses of these data. This achievement is described more fully in Section III, under Strategic Goal I.

Resources

Staffing

OERP research staff is assigned to the Health-related Energy Research Branch (HERB) within DSHEFS. They possess a variety of credentials and backgrounds, contributing to the diversity and strength of the research program.

The primary fields of staff members are epidemiology, health physics, industrial hygiene, statistics, information technology, accounting and management support, and clerical work. Professional credentials held by staff members include: masters and doctoral degrees, Certified Health Physicist (CHP), and Certified Industrial Hygienist (CIH). The tenure among staff members in their respective disciplines ranges from a few years to over 20 years.

Additional scientists and support personnel are supplied on an "as needed" basis by external organizations by contracts under the OERP. The current organization, including subcontractor support, is shown in Figure I-5. The scientific staff is assigned to either the Epidemiology Team or the Exposure Assessment Team. As shown in Figure I-5, other support personnel with expertise in computer programming and information technology, communications, records management and branch administration are required for continuing research under the OERP.

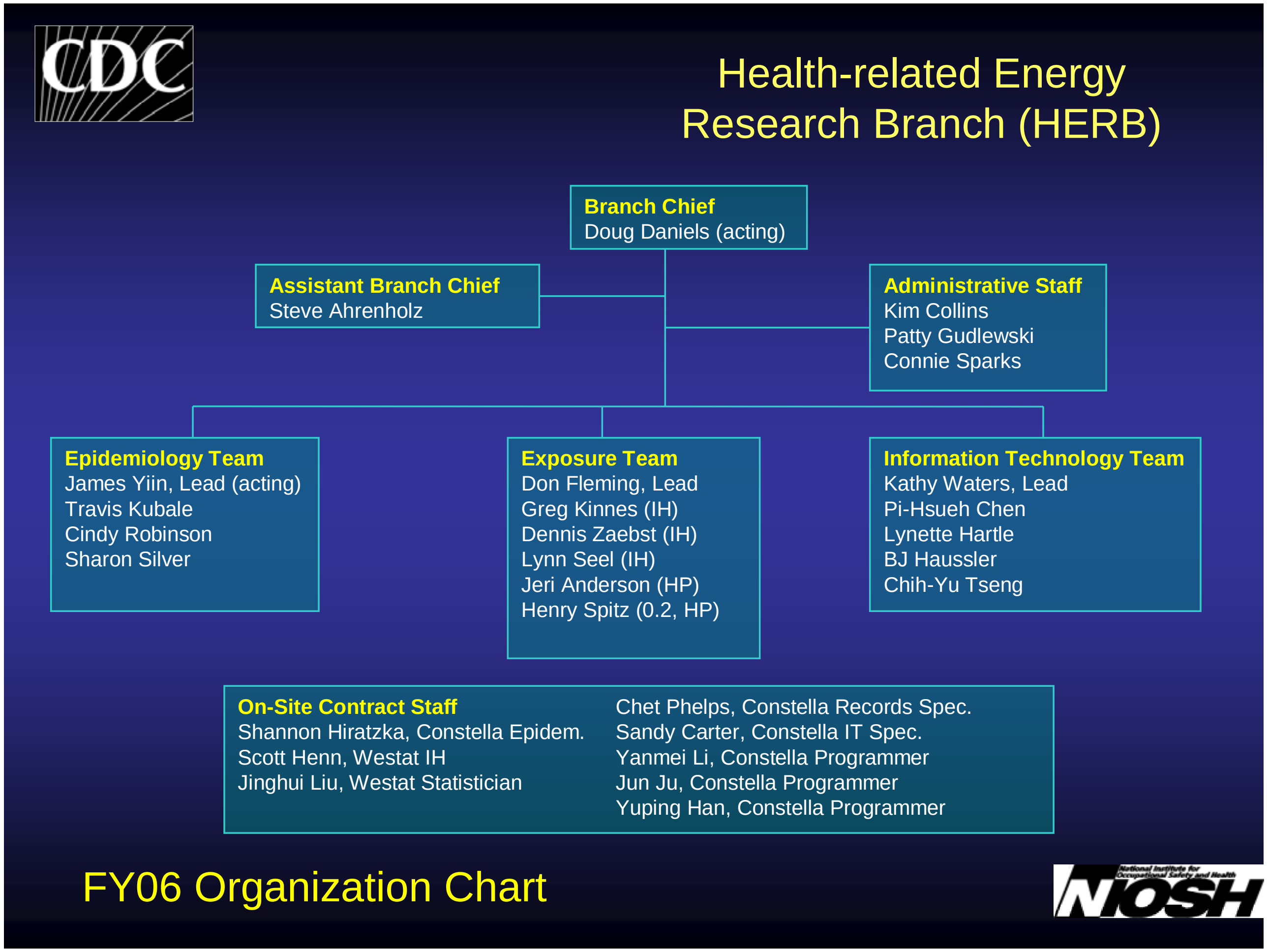

Figure I-5. 2006 Organization Chart for the Health-related Energy Research Branch

Epidemiology Section

The epidemiology staff design and conduct studies to assess acute and chronic health effects among workers from exposure to ionizing radiation and other physical, chemical, and biological agents in energy-related industries. These studies are highly quantitative in nature and emphasize complex statistical modeling of associations between exposures and disease or injury. The epidemiology staff also contributes to the development of epidemiologic methods for conducting retrospective studies of morbidity and mortality among workers.

Exposure Assessment Section

The exposure assessors are industrial hygienists and health physicists. They characterize and quantify worker exposures to ionizing radiation, physical, chemical, and biological agents to support epidemiologic studies of workers in energy-related industries. The exposure assessors develop methods and conduct tests to determine the validity of external and internal monitoring data from workers. They use these data to:

- Reconstruct workers' exposures to ionizing radiation
- Develop models for assessing internal deposition of radioactive materials based on bioassay data
- Develop methods to assess worker exposures to physical and chemical agents based on industrial hygiene data, biomonitoring data, manufacturing processes, procurement trends, and other available information
- Evaluate manufacturing operations and processes to identify materials and equipment used, products and by-products
- Conduct exposure monitoring of current processes, job practices, and engineering controls to characterize exposure potential.

Security Clearance

Record searches and interviews require access to secure DOE facilities. OERP maintains an adequate number of scientists and program support personnel (approximately 6-8) with current security clearance to support site visits and assessment of data needs for research purposes.

Staffing Levels

Staffing increased in the early years (1991-1994) and then again in 1998 (Figure I-6). The initial increase facilitated data collection activities and study development, while the later increase addressed a need for computer programming skills and additional scientific staff to develop and complete studies and populate the OERP research database. Since 2003, there has been a slight reduction in the overall staffing level, reflecting reductions in funding support.

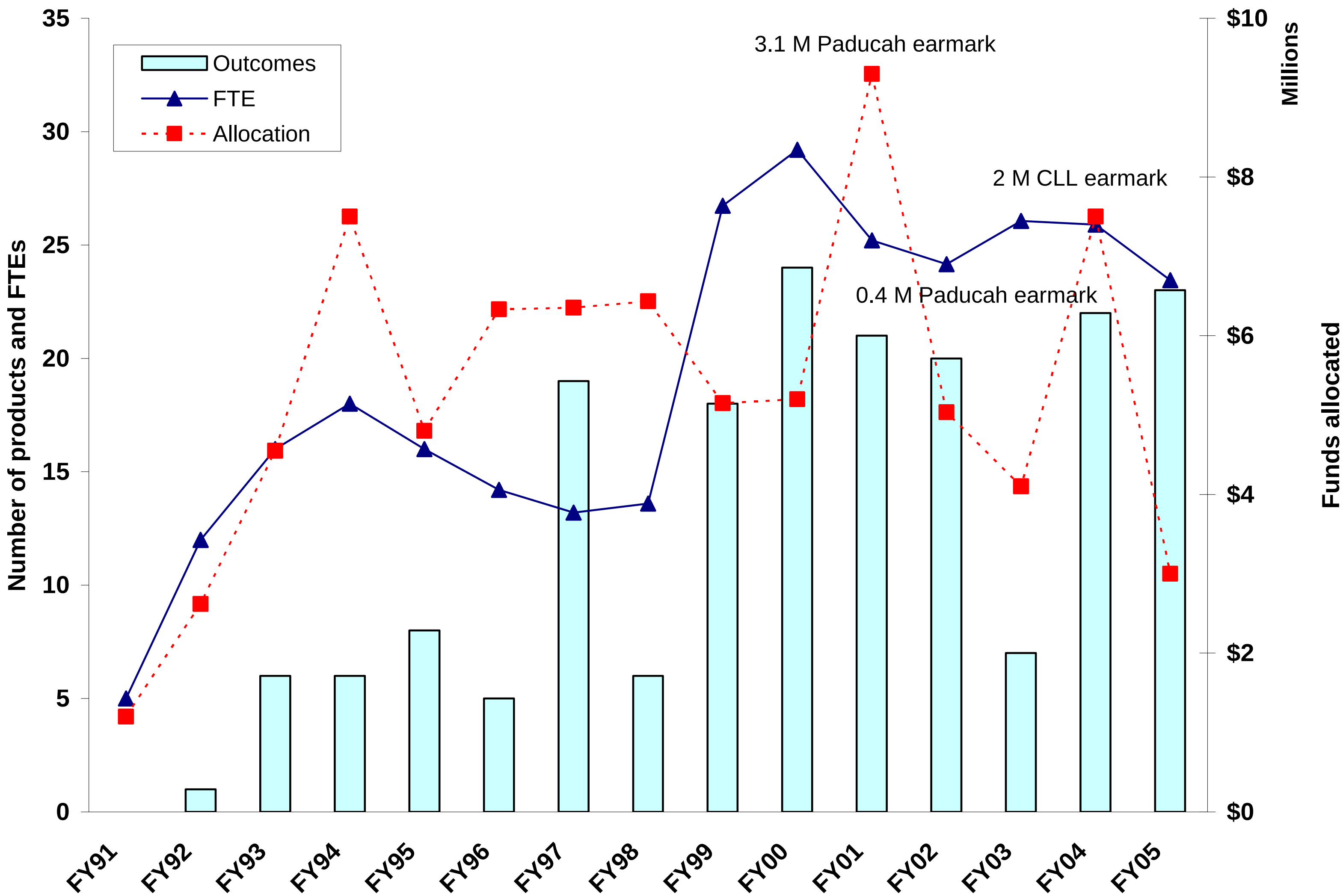

Figure I-6. OERP Funding

During 2001 and 2002, considerable turnover occurred among research staff assigned to the OERP. Although some of this turnover resulted from normal attrition, a portion was attributed to the startup of OCAS. During this time, a number of experienced OERP researchers were either temporarily assigned to, or accepted employment with this newly created compensation program, thus helping to ensure an effective startup. Although difficult to measure, the turnover led to a disruption of operations and delays in several studies. In part, this disruption may explain the reduction in FY03 research products observed in Figure I-6. Of the products shown, all seven resulted from extramural research in FY03.

Accessibility of DOE Records Required for Studies

Large quantities of records, including worker demographic information, work history, department and employment records, medical records, radiation monitoring data, information on production processes, chemical usage and monitoring data, are required to conduct retrospective epidemiology studies. Agreements have been negotiated between DOE and the programs under the MoU to permit access to these necessary records.

Funding

Funding levels for the OERP are also shown in Figure I-6. These figures exclude a total of approximately $11.2 million that was appropriated directly from DOE to the National Laboratories to complete existing occupational studies ($4.4 million in FY91, $3.9 million in FY92 and $2.9 million in FY93).

Annually, NIOSH (and the other CDC agencies) and DOE agree to a Statement of Work (SOW), including budget projections, detailing OERP project milestones and deliverables for the upcoming fiscal year. This information is also included in the "Five-year Budget Agenda" that is used by DOE to request Congressional budget appropriations.

In FY01 and FY04 OERP received Congressional earmarks for:

- A $3.5M grant awarded to the University of Louisville and the University of Kentucky for epidemiologic research at the Paducah Gaseous Diffusion Plant (PGDP).
- A $2.0M allocation to conduct epidemiologic research and other activities to evaluate the association between ionizing radiation exposure and the occurrence of chronic lymphocytic leukemia (CLL).

If one excludes these earmarks, the unadjusted funding levels for the OERP have been decreasing since 1998 (allocations, Figure I-6).

At the time of this report, the FY06 allocation for the OERP remains uncertain. However, available information suggests an FY06 allocation of between 2.0M and 2.4M, which is consistent with the decreasing trend observed in the preceding years (Figure I-6).

Figure I-7 shows a breakout of the OERP funding by year, indicating actual annual expenditures attributed to the program, including extramural grants, as well as the budget allocations. The large differences observed between expenditures and allocations in FY01 and FY04 are attributed to large earmarked obligations that were uncosted in the year of award.

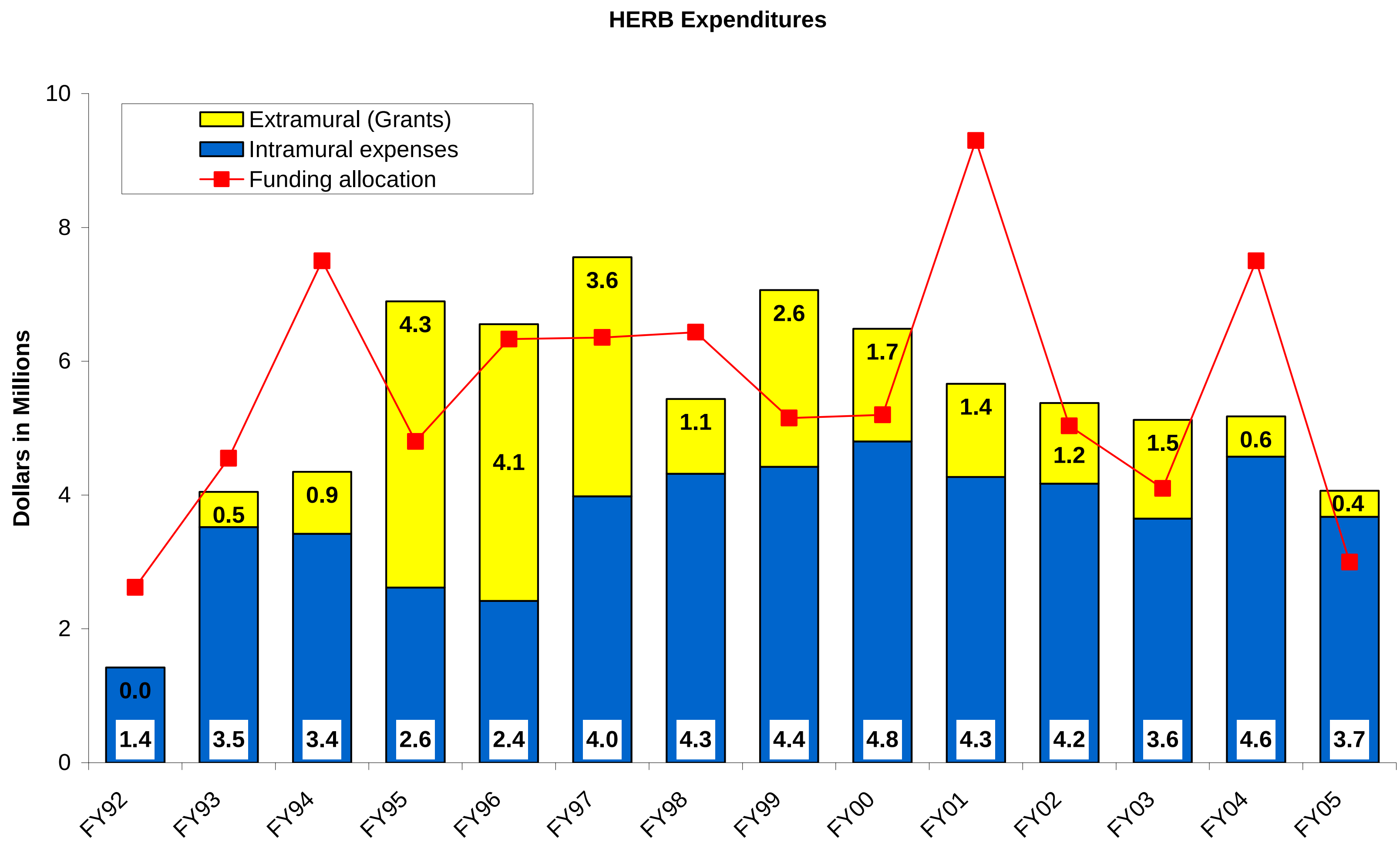

Figure I-7. Funding breakout of grants, intramural expenditures, and allocated funds

Addressing Challenges and External Factors

Since 1990, NIOSH has developed and refined several management processes for the conduct of the OERP. These processes include research protocol development and approval, peer review, conduct of research, communication of findings, and management of resources. Stewardship has meant aligning resources with priorities, increasing efficiency, strengthening management processes, ensuring accountability, and continually improving reporting requirements. Adherence to these key tenets has reduced the influence of external factors on the OERP during its execution.

However, several external factors have offered new challenges in carrying out the mission of the OERP. The following section provides some examples of factors affecting the OERP and the subsequent lessons learned by OERP researchers, which were instrumental in continuing the epidemiologic research on the health effects of radiation exposure among energy workers.

Epidemiology

Average external radiation doses within each cohort are generally low (10-30 mSv), with projected average risk of radiation-induced cancer near the limits of what is considered detectible by epidemiologic methods. This requires the use of large (often, combined) cohorts with minimal potential for confounding, in order to have sufficient statistical power to detect radiation-associated cancer risks at average or higher doses within the cohort.

The DOE workforce has been highly mobile overall. Assembling and following cohorts retrospectively for time periods before the National Death Index was created in 1979 is challenging. The OERP has addressed this through the use of complex tracing procedures to locate these workers in follow-up studies.

Worker information is often available in multiple databases at individual DOE sites, and data linkage is often hampered by incomplete or inaccurate information in these databases. Moreover, the mobility of the DOE workforce across multiple study sites has led to the need to resolve differences in worker data that may be present in individual databases at these sites. The difficulty of this issue has largely been resolved by the OERP through the creation of a DOE-wide study database linking workers across sites using a Master Roster.

Exposure Assessment

Exposure data relied upon for retrospective epidemiologic studies were not designed as such, but were drawn from monitoring programs developed to reasonably assure that worker exposures did not exceed prescribed protective limits. Protection programs varied over facilities and time, resulting in large differences in measurement capabilities and data reliability with respect to epidemiologic use.[68,79] For example, some nuclear workers deemed "not likely" to exceed protective limits were not monitored, thus researchers must estimate exposures based on monitored coworkers or a combination of available area monitoring data and work history information.[80,81] To improve epidemiologic research, OERP researchers developed and utilized methods to reduce bias and uncertainty in the exposure data derived from available site resources. Furthermore, to promote studies of combined cohorts, OERP exposure assessors developed methods to "normalize" exposures across facilities and time to provide consistency among the estimates used for epidemiologic analysis. Incorporating these improved exposure assessment methods into epidemiologic analyses reduces bias in the resulting risk estimates.

Assessment of doses from internal radiation sources has also proved challenging. Historical records of bioassay measurements usually contain only results from routine monitoring. Any special measurements that were performed in response to actual or suspected radiological incidents and accident evaluations are frequently stored in separate files. These files have been found to contain numbers of measurements for workers that may exceed the routine measurements. Lists of incidents provided by the site usually identify only exposures designated as “significant” according to management or compliance requirements. These incident files usually contain critical information beyond the bioassay measurements that are essential for epidemiological studies. Information in the incident file may include the type of decontamination process, isotopic composition of activity, particle size distribution, type and frequency of decontamination treatments, and the identity of others involved in the incident. Incident files may be located with medical records or special dosimetry files. Epidemiology studies require access to incident records to thoroughly categorize exposure for all workers. Retrieval of bioassay records must include all results including those collected for non-routine monitoring.

Frequently, work history and chemical exposure information was not as well organized or as thoroughly documented as the radiological exposure information. For example, industrial hygiene monitoring data in the records are almost always associated with building or other location descriptors yet work history information lists department assignments. For studies where chemical exposure assignments are made, linkages between locations and departments are assembled from the available records. This method is very complex since it usually must cover the entire historical period of site operations.

Understanding the main processes and support activities along with the associated chemical and physical hazards has proven to be difficult for some facilities. Not only have security classification issues been problematic but there is often a lack of available historical documents and knowledgeable industrial hygiene and health physics personnel familiar with the processes to provide the needed insight.

Communications

Initially, there was no established structure for the communication of study results to site management, workers, and former workers. Key site management and labor personnel had to be identified so that a comprehensive contacts list could be developed to facilitate communications to current and former workers and managers. Other stakeholders and research partners have since been added to the list of labor and management contacts. This list has proven to be an invaluable tool for continued communications of OERP research.

To improve communications, labor and management requested that the OERP develop a briefing document that could be sent electronically or mailed to workers throughout their respective sites, posted on websites, and attached to employee newsletters. The document needed to summarize study findings, report on the number of workers included, and define unusual terms in the text. In response, NIOSH developed a one-page communications document template using input from key DOE management and labor contacts at all the sites. The format for these Brief Reports of

Findings has been used to successfully communicate the findings of approximately thirty internal and external studies to some 300,000 current and former DOE workers. The OERP has received and incorporated feedback from workers on the utility of these Brief Reports of Findings.

Some OERP studies are conducted at single facilities, making it feasible to travel to the site for communication of study findings face-to-face with workers, management and the public. However, many of the studies conducted under the OERP include workers from multiple sites, and establishing methods to communicate simultaneously to these sites was a challenge. OERP staff and personnel at ten DOE sites worked jointly to develop and implement satellite communications capability, which allowed researchers to discuss study findings in real time with workers and management at multiple sites at once.

Access and Security Issues

Most records needed for OERP studies, particularly for facilities never previously studied, are stored at (or controlled by) individual DOE sites. These sites vary in their willingness and staffing to allow access to necessary records. Intramural and extramural OERP researchers have experienced substantial delays at some sites in receiving access to records. This can then lead to delays in completing projects.

Site access required extraordinary coordination that could only be effectively achieved through intervention by DOE Office of Health Studies (OHS) staff. On numerous occasions, OHS successfully assisted site contractor staff to identify available financial resources for records access. However, reconciliation of problems often resulted in delays in study progress. NIOSH increased its awareness of potential barriers to gaining site access, and worked with DOE in developing lines of communication among NIOSH, DOE program staff, and site staff to minimize further impacts. As described in the "Recordkeeping" section below, the development of an "Access Handbook" [77] to describe responsibilities of both OERP researchers and DOE has greatly facilitated this process.

There were several lessons learned while conducting retrospective research at secure DOE facilities. Security requirements would often complicate data retrieval and interpretations. "Top Secret" or Q-level security clearances are held by a number of OERP staff to facilitate the review and capture of records needed for studies (even many unclassified records require clearance for access, as they are stored in classified areas).

Coordination among the researchers, DOE field offices, site contractor personnel, and DOE Headquarters was often required to resolve data access issues. For example, each of the challenges below was overcome through negotiation between OERP researchers, DOE Headquarters, and site management personnel:

- Production and process flow information (along with the identification of contributing or supporting processes) frequently is either not available or cannot be readily obtained in a useable, declassified form.

- Coworkers within the same facility (and sometimes the same building) may have a very limited knowledge about who else worked at the site, where they worked, what they worked with, or what they did.

- The review and evaluation of records not containing classified information may still require a security clearance. This is common among records "born classified" during the earlier days of site operations but not yet declassified or in instances where declassified records are commingled among classified information.

- Special arrangements are needed to permit foreign nationals on the study team to visit the site, review records, or talk with site personnel, due to enhanced security requirements.

- Former workers and retirees as well as current workers may be refuse to discuss the site or their work with investigators who do not hold security clearances at the same level or higher than that of individual.

- The use of computers, scanners, or photocopiers for records collection can be problematic due to security requirements. For example, computer hard drives and storage media are prohibited or must undergo declassification review unless they are used exclusively outside of secured areas.

- Records and notes obtained from or generated at a secure DOE site require classified information review. Such review may take several weeks or months.

Recordkeeping

Development of cohort rosters, vital status ascertainment, and retrospective exposure assessment require access to and interpretation of DOE record holdings. Access and use of these records have been challenging to researchers given security requirements and past recordkeeping practices.

OERP researchers have developed methods to continue program research even when the ability to obtain data needed for assessing exposures is limited. In cases where exposure information is still classified, it has been possible to separate and obtain useful information by working with site document declassification procedures. When collections of monitoring results are not directly available, OERP researchers have concentrated on identifying other documents, such as site annual and quarterly reports and departmental progress reports, which sometimes identify the hazards associated with processes. In cases where documentary information is inadequate, the OERP has obtained necessary historical information by conducting interviews (within classification boundaries) with former and current workers possessing knowledge of the processes and hazards.

Some issues encountered with records are listed below. Most of the records access issues have been resolved through the creation of the Access Handbook in 1997.[77] This handbook, which was created jointly by DOE and DHHS programs covered under the MoU, documents procedures, responsibilities and timelines for obtaining records needed to conduct OERP studies.

- Records extraction from archived holdings requires considerable coordination of site resources. Research was often delayed until the appropriate contracting mechanisms within DOE were in place to cover costs incurred by its contractors in providing access to records needed for OERP studies.

- Some early record holdings were maintained as potentially contaminated. Decontamination and subsequent release of these records was problematic.

- Retention schedules vary for surrogate information that may assist in characterizing potential exposures. Information may be unavailable except as found in a cache of records that inadvertently weren't destroyed or happened to be misfiled (e.g., raw material purchases, chemical usage.).

- Data were likely to be migrated to several different storage formats as new recordkeeping protocols were developed over time. During data migration, sites often "corrected" results based on scientific or programmatic understanding of the time. With each data migration or manipulation, the potential for errors is introduced.

- Electronic data formats and files can be encountered that are obsolete and for which no equipment or trained personnel are any longer available to permit reading or converting the data files.

- Not all DOE records or contractor records relevant to a DOE site have been retained within the DOE system (e.g., previous contractors' orphaned record collections, individual researcher's files may exist).

- Administrative procedures for recording data, particularly for censored data or data below compliance limits varies over the decades and among site contractors.

Funding

Since the inception of the MoU, funds for extramural projects (grants and cooperative agreements) have comprised a large portion of the OERP research budget. As funds became available, a significant percentage of the funds was set aside for funding extramural projects. Since 1991, there have been approximately 33 projects funded at a cost of approximately $23.6M (not including the $11.4 million funded directly from DOE to the National Laboratories in FY91-FY93 for occupational studies).

Although many positive milestones have resulted from these projects, there have been some concerns raised about how these funds were disbursed and the possible detriment this could have on the program. Specifically, concerns were raised about the federal accounting regulations that must be adhered to by NIOSH in the administration of extramural funds, which are different from those of DOE. These regulations require the awarding agency to encumber (commit to spend) the funds needed for a project at the beginning of each budget period, but the awardee does not obligate the funds until they are actually spent on the project. Thus, for a grant or cooperative agreement, NIOSH would encumber funding for a project. An awardee would then take several years to obligate the funds, depending on how rapidly their research was progressing. This resulted in a situation in which NIOSH had encumbered all the research funds but DOE (which only tracked obligated funds) would report a significant uncosted balance for NIOSH. This unobligated (uncosted) balance or "carry over" has fueled a perception of over-allocation. Although this uncosted balance did not actually exist and was the result of accounting practices, it causes concern at DOE about the ability of NIOSH to manage the program budget. Despite many reports and explanations, DOE and NIOSH have not been able to develop a process for reconciling the differences in the federally mandated accounting system that must be used for extramural projects. Thus, the DOE perception that NIOSH is not able to adequately manage the extramural funds is a result of differences in the accounting systems that are used by the DOE and NIOSH, and is not based on the actual expenditure of funds.

NIOSH has also supported extramural funding through contracts. Because contracts are handled differently than grants, the program office has more control over expenditures and a rapid turnaround on obligations and disbursements is more likely. The program office and the contractor usually have a close working relationship, with agreements from the contractor to provide monthly reports and to meet deadlines for deliverables. A staggered invoicing plan is agreed upon as deliverables are received and approved. Contracting as a mechanism for conducting extramural studies has proven to reduce the amount of uncosted balances.

Staffing

Recruiting and retaining scientific staff for the OERP has presented a challenge, primarily as a result of the creation of the NIOSH Office of Compensation Analysis and Support in response to the Energy Employees Occupational Illness Compensation Program Act of 2000. This has made it difficult to retain qualified health physicists in the OERP. In addition, there has been relatively high turnover among epidemiological staff throughout the program, as this is a high-demand occupation. These challenges are being met through a merger of HERB with the Industry Wide Studies Branch (IWSB), which will increase the pool of available scientific and technical staff to accomplish the mission of the OERP.

SECTION II. Research Activities and Outputs

Research Project Examples

The following section summarizes examples of recently completed and ongoing research projects conducted under the OERP's intramural program. These projects exemplify how the OERP implemented recommendations of SPEERA and the ACERER; however, other intramural and extramural examples could have been selected to demonstrate this as well. Specific findings and objectives of the research projects are related to the strategic goals stated in the OERP program book and summarized in Section III of this document (see p. 71). Four separate research projects are discussed:

1. An ongoing multi-site leukemia case-control study of nuclear workers from the Portsmouth Naval Shipyard (PNS) in Kittery, Maine and four major DOE nuclear facilities: Hanford Site, Savannah River Site (SRS), Oak Ridge National Laboratory (ORNL), and the Los Alamos National Laboratory (LANL);

2. Recently completed and ongoing epidemiologic studies of workers (nuclear and non-nuclear) from a U.S. Naval Shipyard (PNS);

3. An assessment of the adequacy of existing records to accurately identify remediation workers within the DOE complex and to characterize their exposure, work history, and medical information for future epidemiologic research.

4. A large international study of cancer risks associated with occupational exposure to chronic, low-LET ionizing radiation exposure.

These examples, while conducted primarily intramurally, are representative of the entire OERP research portfolio.

Multi-Site Case-Control Study of Leukemia and Ionizing Radiation (LCCS)

Research Issues

The risk of leukemia following ionizing radiation exposure remains controversial when applied to the work environment. Most epidemiologic evidence that leukemia mortality is associated with external radiation derives from studies of persons experiencing acute irradiation resulting in relatively high doses when compared to exposures common to occupational sources. Studies of leukemia risk in individual facilities across the DOE complex have led to conflicting findings about the association.

Study objectives:

- Estimate the risk of fatal leukemia associated with low-level protracted exposure to whole body external ionizing radiation in the workplace (Strategic Goal P.1);

- Evaluate the appropriateness of the assumption that lower dose rates are less harmful per unit dose (Strategic Goal P.5);

- Investigate the nature of the dose-response relationship between exposure to external ionizing radiation and leukemia mortality (Strategic Goal P.4);
- Determine the effects of potential confounders or co-carcinogens, including internal emitters and chemical leukemogens (Strategic Goal P.4);
- Determine whether chronic lymphocytic leukemia mortality is related to occupational exposure to ionizing radiation (Strategic Goal P.6 and P.7).

Brief Description

Through this study, leukemia risks from exposure to chronic, low-level ionizing radiation in the workplace can be estimated with increased precision and used worldwide as a basis for occupational risk estimation.

A total of 257 leukemia cases have been identified from the combined cohort of radiation-monitored workers at four Department of Energy sites and one U.S. Navy nuclear shipyard included in this epidemiologic study. With 43 cases of chronic lymphocytic leukemia, this is one of the larger studies to evaluate the currently unknown association of radiation exposure with this type of leukemia. Four controls have been selected for each case, resulting in a study population of 1,269 workers drawn from an original cohort of 94,517 eligible workers. Exposure assessment methods are reported by Daniels *et al*., 2005.[68,79] Current studies of leukemia mortality and radiation exposure, with an overview of this study, are reported by Schubauer-Berigan and Wenzl.[82]

The study began with protocol development, peer review and approval. Records were obtained from all study sites; review and analysis are complete. Given current funding projections, the study is anticipated to be completed in FY06. Project staffing for FY06 is estimated at 2.1 FTEs. Tasks approaching completion consist of finalizing chemical exposure assessment publications, and completing the epidemiologic analyses, including publication and communication of final results. This study is linked to ongoing chronic lymphocytic leukemia research.

Relevance

The multi-site leukemia case-control study contributes essential knowledge to achieving a number of strategic goals of the Occupational Energy Research Program (OERP). Through this study, which combines populations from several DOE sites and one DOD site under a single protocol, leukemia risks from exposure to chronic, low-level ionizing radiation in the workplace can be estimated with increased precision, and thus the study may be more informative as a basis for occupational risk estimation worldwide (Strategic Goals P.1 and P.4). These results will add to the current body of knowledge, which may ultimately translate into revision of protective standards (Strategic Goal P.5).

By drawing cases from multiple facilities and adding follow-up for two facilities, this study has more leukemia cases (*n*=257) than were found in previous studies, and contributes a relatively large number for CLL (*n*=43). In comparison, the recent multinational study conducted by the International Agency for Research on Cancer (IARC) drew only 196 non-CLL leukemia cases from a combined cohort of 400,000 radiation-monitored workers.(83) This increased number of cases should result in improved power to detect a dose-response effect if one is present (Strategic Goals R.1 – R.4).

Table II-1. Current LCCS research products by strategic goal

No.	Citation	Goals
1	Schubauer-Berigan MK, Daniels RD, Fleming D, Markey A, Couch J, Ahrenholz S, Burphy JL, Anderson J, Tseng C-Y [*forthcoming*]. Risk of chronic lymphocytic leukemia mortality following exposure to ionizing radiation among workers at four U.S. nuclear weapons facilities and a nuclear naval shipyard. *In preparation.*	R.1-R.4
2	Schubauer-Berigan MK, Daniels RD, Fleming D, Markey A, Couch J, Ahrenholz S, Burphy JL, Anderson J, Tseng C-Y [*forthcoming*]. Risk of non-CLL leukemia mortality following exposure to ionizing radiation among workers at four U.S. nuclear weapons facilities and a nuclear naval shipyard. *In preparation.*	R.1-R.4
3	Fleming D. *et al*. [*forthcoming*]. Benzene and carbon tetrachloride assessment for a multi-site study of leukemia risk at four DOE facilities and a nuclear naval shipyard. *In preparation.*	R.5, R.6
4	Anderson JL, Daniels RD [*in press*]. Bone marrow dose estimates from work-related medical X-ray examinations given between 1943 and 1966 for personnel from five U.S. nuclear facilities. Health Phys 2005. *In press.*	P.4, R.5 – R.8
5	Daniels, RD, Lodwick, CJ, Schubauer-Berigan, MK and Spitz, HB [2005]. Assessment of plutonium exposures for an epidemiological study of US nuclear workers. Radiat Prot Dosimetry.	P.4, R.5 – R.8
6	Daniels, RD and Schubauer-Berigan, MK [2005]. Bias and uncertainty of penetrating photon dose measured by film dosemeters in an epidemiological study of US nuclear workers. Radiat Prot Dosimetry 113 (3) 275-89.	P.4, R.5 – R.8
7	Schubauer-Berigan, MK and Wenzl, TB [2001]. Leukemia mortality among radiation-exposed workers. Occup Med 16 (2) 271-87.	R.4

Portsmouth Naval Shipyard Cohort Mortality and Leukemia and Lung Cancer Case-Control Studies

Research Issues

It is difficult to separate the health effects of chronic exposures to low-LET radiation from the confounding effects of other radiation exposures among nuclear worker populations (Strategic Goal P.1). Shipyard cohorts may offer a unique opportunity to address this problem. Studies of U.S. Naval shipyard cohorts provide unique advantages over studies of other occupationally exposed cohorts of comparable size. The data collection, abstraction, and exposure assessment phases of the shipyard studies are greatly simplified given the record-keeping practices and similarities in radiation exposures and control among the various naval shipyards. The radiation exposures common to shipyard workers are limited to external whole-body irradiation, primarily from ^{60}Co gamma emissions, which result under common exposure conditions during the overhaul and repair of nuclear-powered submarines. These similarities in exposure sources and geometries minimize dosimetric uncertainties and act to reduce the potential for confounding that is often observed among mixed-field and fuel-cycle cohorts, such as in the DOE workforce.

Study Objectives

- To evaluate the causes of death for all PNS workers and to evaluate whether an association exists between low-level external ionizing radiation exposures and death from certain cancers (Strategic Goal P.2).

- To conduct a modeling-based cohort analysis that incorporates multiple covariates to explore the dose-response relationship between external radiation exposure and the causes of death including lung cancer and leukemia (Strategic Goal P.4).

- To determine if there is an association between occupational exposure to external ionizing radiation and lung cancer among PNS workers after controlling for confounders and effect modifiers such as asbestos exposure, smoking, race, sex, and age are considered (Strategic Goal P.1).

- To examine the association between occupational exposure to external ionizing radiation and leukemia mortality among civilian PNS workers after potential confounders and effect modifiers such as solvent exposure and time since exposure are considered (Strategic Goal P.1).

Brief Description

The Portsmouth Naval Shipyard (PNS) cohort offers an opportunity to study the health effects of chronic exposures to low-LET radiation without the confounding effects of other radiation exposures. Similarities in exposure characteristics among workers over time aid researchers in reducing bias and uncertainty in exposure estimates. Several previous studies of PNS workers have been carried out by NIOSH and others, with inconsistent results. Thus, researchers were afforded opportunities to improve on exposure assessments and assess analytic methods, to add more recent workers, and to examine effects of additional follow-up time. Studies completed to date indicate a significant positive association between external radiation and leukemia.

Study Population: The 37,853 civilian workers employed at PNS for at least one day between January 1, 1952 and December 31, 1992. This cohort was subdivided into three groups: exposed radiation workers, unexposed radiation workers, and non-monitored workers. The study is divided into three separate efforts:

1. Cohort mortality study including modeling-based analysis of the radiation monitored workers to examine dose response characteristics and the potential effects of confounding exposures;

2. Nested case-control study of the association of leukemia mortality and exposures to ionizing radiation, assessing in detail the potential for confounding by other leukemogens such as solvents;

3. Nested case-control study of the association of lung cancer mortality and exposures to ionizing radiation, assessing in detail the potential for confounding by other lung carcinogens such as smoking, asbestos, and welding fumes.

Cohort Mortality Study: The association between exposure to low-level external ionizing radiation and all causes of death among civilian workers at the PNS was evaluated in two separate analyses. A life table analysis was used to compare mortality among different groups of workers to each other and to the general U.S. population. Specific analyses were used to determine if exposure to external ionizing radiation is associated with lung cancer or leukemia mortality while adjusting for other factors such as socioeconomic status (SES), smoking, and exposures to asbestos, welding fume and solvents. The two types of analyses are reported in separate publications: Silver *et al*., 2004 [(25)]; Yiin *et al*., 2005.[(26)] The radiation exposure assessment methods supporting these studies are reported in a separate publication by Daniels *et al*., 2004.[(29)]

The study found slightly fewer total deaths occurred in the full cohort than expected based on comparisons with the U.S. population (SMR=0.95, 95% CI 0.93-0.96). Fewer deaths than expected were observed for tuberculosis, diseases of the heart, circulatory system, digestive system, and for accidents and violence. More deaths than expected occurred for all cancers combined, and for cancers of the lung and esophagus. Leukemia deaths for the entire cohort were close to the number expected (SMR=1.01, 95% CI 0.84-1.22). However, excess leukemia deaths were observed in the more highly exposed radiation-monitored workers, and a significant positive linear trend was observed in the leukemia mortality rate with increasing dose.

Lung cancer mortality among the entire cohort was elevated compared to the U.S. population, and for radiation-monitored workers it was positively associated with SES categories (a measure of smoking prevalence) and welding fume and asbestos exposures. After including these factors in the analysis, a positive relationship between cumulative radiation dose and lung cancer was no longer observed. Non-monitored workers had excess deaths from causes historically associated with smoking, such as lung cancer and emphysema.

Leukemia Case-Control Study: This study included an in-depth analysis of the association of leukemia mortality with external ionizing radiation exposures within the PNS cohort. Both workplace exposure measured by radiation badges and work-related medical x-rays were included as a source of external ionizing radiation exposure. Other factors such as potential solvent exposure and radiation worker status were also considered. Results were consistent with the cohort analysis and indicated a significantly positive dose-response association between leukemia deaths and external ionizing whole-body radiation exposure [odds ratio (OR) =1.08 at 10 mSv, compared to workers receiving <1 mSv; 95% CI-1.01, 1.16] with solvent exposure duration factored into the analysis. Also, a significantly positive exposure-response relation was observed between duration of employment in solvent-exposed jobs and leukemia mortality (OR=1.03 at one year of exposure; 95% CI=1.01, 1.06). Work-related medical x-ray doses did not change the leukemia risk estimate per 10 mSv radiation exposures. The results of the case-control study and the work-related x-ray exposure assessment are reported by Kubale *et al*., 2005 [(28)] and Daniels *et al*., 2004 [(30)], respectively.

Lung Cancer Case-Control Study: The relation between lung cancer mortality and exposure to external ionizing radiation in civilian workers at PNS is being further evaluated with a case-control analysis. A thorough examination of additional industrial hygiene and medical records data will facilitate evaluation of the role of co-exposures in the observed excess lung cancer risk.

This study is ongoing and is projected to be completed in FY06. The staff allocation for FY06 is 2.4 FTEs. The remaining tasks consist of finalizing chemical exposure assessment publications, and completing the epidemiologic analyses, including publication and communication of final results.

Conclusions: Overall mortality for the PNS cohort was slightly less than expected. However, some causes of death were elevated within subgroups. For example, elevations in asbestosis deaths were observed only in radiation workers, and higher risk of death was observed for several smoking-related causes among the non-radiation workers. Cohort analyses, adjusted for confounding, found a radiation dose response for leukemia but not for lung cancer. The nested case-control study of leukemia mortality confirmed the cohort analyses, which indicated PNS workers with higher cumulative radiation doses have an increased risk of leukemia compared to unexposed workers. Also, workers potentially exposed to benzene or carbon tetrachloride appear to have elevated risk for leukemia. There was no evidence of effect modification of radiation risk by solvent exposure level (on a multiplicative scale). Uncertainty in the estimated risk is attributed to the relatively small number of leukemia deaths (34) among radiation-monitored workers and exposure estimates for chemicals based on job titles and shops.

Relevance

Studies of workers at PNS directly contribute to several strategic goals of the Occupational Energy Research Program. PNS, located in Kittery, Maine, is a large industrial complex employing workers from a variety of trades such as welding, insulating, pipefitting, painting, engineering, rigging, steel fabrication, electrical, and machining (Strategic Goal P.3). These studies involve an expansion of a cohort studied previously by NIOSH and others.[(84-86)] These earlier studies were limited in power due to cohort size and short follow-up. In continuing to study these workers, researchers are afforded opportunities to improve and assess analytic methods, to add more recent workers, and to examine the effects of additional follow up time (Strategic Goal P.4). Although this cohort of nuclear workers is relatively small (~14,000 radiation workers) compared to the combined cohort of ~400,000 radiation-monitored workers in a recent study by Cardis *et al*.[(83)], the age of the cohort is much greater, resulting in a relatively large number of deaths in the study period.

Although PNS is not a DOE site, the findings of studies of PNS workers are highly generalizable to the DOE workforce and to other workers exposed to external ionizing radiation. The nuclear shipyard workforce is particularly important to study because the potential for exposure misclassification is minimized by the excellent recordkeeping of the Navy's nuclear program, and the lack of exposure to internal sources of radiation.

Table II-2. Current Portsmouth Naval Shipyard studies outcomes by strategic goal

No.	Citation	Goals
1	Daniels RD, Taulbee TD, Chen P [2004]. Radiation exposure assessment for Portsmouth Naval Shipyard health studies. Radiat Prot Dosimetry; 111(2):139-50.	P.4, R.5 – R.8
2	Silver SR, Daniels RD, Taulbee TD, Zaebst DD, Kinnes GM, Couch JR, Kubale TL, Yiin JH, Schubauer-Berigan MK, Chen PH [2004]. Differences in mortality by radiation monitoring status in an expanded cohort of Portsmouth Naval Shipyard workers. J Occup Environ Med; 46(7):677-90.	P.3, R.1-R.4
3	Yiin JH, Schubauer-Berigan MK, Silver SR, Daniels RD, Kinnes GM, Zaebst DD, Couch JR, Kubale TL, Chen PH [2005]. Risk of lung cancer and leukemia from exposure to ionizing radiation and potential confounders among workers at the Portsmouth Naval Shipyard. Radiat Res; 163(6):603-13.	P.3, R.1-R.4
4	Daniels RD, Kubale TL, Spitz HB [2005]. Radiation exposure from work-related medical X-rays at the Portsmouth Naval Shipyard. Am J Ind Med; 47(3):206-16.	P.4, R.5 – R.8
5	NIOSH [2004]. A nested case-control study of leukemia and ionizing radiation at the Portsmouth Naval Shipyard. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; DHHS (NIOSH) Publication No. 2005-104; 182 pgs.	P.3, P.6, R.1-R.4
6	Kubale TL, Daniels RD, Yiin JH, Couch J, Schubauer-Berigan MK, Kinnes GM, Silver SR, Nowlin SJ, Chen PH [2005]. A nested case-control study of leukemia mortality and ionizing radiation at the Portsmouth Naval Shipyard. Radiation Res; 164(6) 810-19	P.3, P.6, R.1-R.4

Exposure Assessment of Hazardous Waste, Decontamination and Decommissioning, and Cleanup Workers - Phase I

Research Issues

Many DOE facilities have shifted from weapons development to site remediation and environmental restoration activities. Workers involved in site remediation processes encounter diverse exposure scenarios not faced by site production workers. In addition, remediation workers are typically not drawn from a long-standing DOE workforce but are subcontracted personnel. Recordkeeping practices for remediation workers may lack the rigor for comprehensive epidemiologic, exposure assessment, or hazard surveillance studies.

Study Objectives

- Locate records systems that identify the hands-on remediation workforce (Strategic Goal P.1, P.3).
- Examine remediation activities and technologies (Strategic Goal P.3).
- Identify electronic records systems that could be used to obtain demographic, exposure (chemical and radiological), and medical data on remediation workers (Strategic Goal P.3).

Brief Description

Assessment of seven DOE sites showed that the current environment of decentralized management and increased subcontracting at DOE sites has led to fragmented and inconsistent data collection and maintenance. Given identified gaps in data critical to assessing risks to remediation workers, NIOSH recommended that DOE develop a comprehensive worker information system to identify remediation workers and their work activities, exposure potentials and medical information for risk reduction efforts and future epidemiologic study.

Two OERP projects, the Exposure Assessment Feasibility Study (EAFS) and the Integrated Health, Work History, and Exposure Database for DOE Site Remediation Workers, focused on assessing the availability of information about remediation workers and their activities at seven DOE facilities: Fernald, Mound, Rocky Flats, Savannah River Site, Hanford, Oak Ridge, and INL. The assessment findings and recommendations results were published in a NIOSH technical report [32] and discussed extensively with DOE and workers.

Conclusions

It was found that the current environment of decentralized management and increased subcontracting at DOE sites has led to fragmented and inconsistent data collection and maintenance. Rosters of remediation workers were rarely maintained by DOE or its Contractors and are difficult to compile from other sources of site data. In addition, the availability of exposure data varies across disciplines. Radiation monitoring practices are standardized throughout the complex, leading to reasonably comprehensive exposure data. However, industrial hygiene monitoring and data collection requirements are not standardized and tend to be incomplete. Given the identified gaps in data critical to assessing risks to remediation workers, NIOSH recommended that DOE establish a centralized collection of a standardized core of data throughout the DOE complex for use in their occupational health program and for future research. In 2001, this recommendation was evaluated by the DOE's Office of the Inspector General, which concurred with the NIOSH findings.[87]

Relevance

Both future epidemiologic studies and risk reduction efforts depend on the ability to identify workers and assess their work history, exposure, and medical data (Strategic Goal P.1). A comprehensive worker information system is needed to identify remediation workers and their work activities, exposure potentials, and medical information for risk reduction efforts and future epidemiologic study (Strategic Goal P.5).

Table II-3. Remediation worker assessment outcomes by strategic goal

No.	Citation	Goals
1	Silver SR, Robinson CF, Kinnes G, Taulbee T, Ahrenholz S [2000]. Evaluation of data for DOE site remediation workers ("White paper"). Cincinnati, OH: National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, 37 pgs.	P.1, P.3, and P.5
2	Back DA and Stevens GW [1998]. Remediation workers' exposure assessment feasibility study at the Department of Energy's Rocky Flats site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati, OH, 218 pgs.	P.1, P.3, and P.5
3	Stevens GW and Back DA [1997]. Remediation workers' exposure assessment feasibility study at the Department of Energy's Mound site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 218 pgs.	P.1, P.3, and P.5
4	Stevens GW and Back DA [1996]. Hazardous waste, decontamination and decommissioning, and clean-up workers exposure assessment feasibility study at the Department of Energy's Fernald site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 156 pgs.	P.1, P.3, and P.5
5	Tankersley WG, West CM and Gray FE [1998]. Hazardous waste, decontamination and decommissioning and clean-up workers exposure assessment feasibility study at the Department of Energy's Savannah River site, Contract 200-93-2695 for National Institute for Occupational Safety and Health, Cincinnati OH, 142 pgs.	P.1, P.3, and P.5
6	Tankersley WG, West CM and Gray FE [1999]. Hazardous waste, deactivation, dismantlement, and cleanup workers exposure assessment feasibility study at the Department of Energy Oak Ridge reservation, Contract 200-93-2695 for National Institute for Occupational Safety and Health, Cincinnati OH, 134 pgs.	P.1, P.3, and P.5
7	Zimmerman TD [1999]. Remediation workers exposure assessment feasibility study at the Department of Energy's Hanford site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 204 pgs.	P.1, P.3, and P.5
8	Zimmerman TD, and Moore AM [2000]. Remediation workers exposure assessment feasibility study at the Department of Energy's INEEL site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 217 pgs.	P.1, P.3, and P.5

Combined International Nuclear Worker Study

Research Issues

Radiation protection standards are mainly based on cancer risk estimates from studies of the Japanese atomic bomb survivors, who unlike typical nuclear workers, were exposed to relatively high doses at one point in time. The effects of low-dose chronic exposures common to the workplace have been studied previously, but relatively small sample sizes have resulted in limited precision in risk estimates. This study was conducted in an international collaborative study of cancer risk among radiation workers from 15 countries. The increased size of the cohort (~400,000) is intended to improve the precision of estimated risk from protracted low dose exposures and to strengthen the scientific basis of radiation protection.

Study objectives

- To provide direct estimates of cancer risk following protracted exposure to low-level, external ionizing radiation in the workplace (Strategic Goals P.3, P.4, P.6, P.7)
- To strengthen the scientific basis of radiation protection standards which are largely based on acute exposures to relatively high levels of radiation (Strategic Goals P.1, P.5)
- To incorporate uncertainties in radiation dose measurements into the estimates of radiation-related risk (Strategic Goals P.4, P.6)

Brief Description

> Results of this study provide radiation risk estimates from the largest study of nuclear industry workers ever conducted. It suggests that there is a small increase in cancer risk even at the low doses and dose rates typically received by nuclear workers in this study. The risk estimates per unit dose from the study are statistically similar to those of the atomic bomb survivor data, but the uncertainty in the estimates suggests cancer risk could be up to five times greater than indicated by the atomic bomb survivors study, at a given dose.

OERP researchers collaborated with IARC to study nuclear industry workers in 15 countries. Three DOE cohorts were included in the study (Hanford Site, Oak Ridge National Laboratory, and INL). OERP scientists served on the sub-committees directing the study on epidemiology and dosimetry issues. The study results were recently published by Cardis *et al*. [(83)]

The 407,391 workers in the study, most of whom were men, were employed for at least one year in nuclear power production facilities, or in specialized nuclear activities including research, waste management, and production of fuel, isotopes, and weapons. Workers were monitored for external radiation exposure and were followed for 13 years on average. Workers who had substantial neutron or internal (for example, plutonium) exposure were excluded. The study includes 29,332 Hanford Site workers employed between 1944 and 1978, 25,570 INL workers employed between 1949 and 1991, and 5245 Oak Ridge National Laboratory employees who worked between 1943 and 1972.

Risk estimates per level of radiation dose were then calculated for deaths from all cancers excluding leukemia and from leukemia excluding chronic lymphocytic leukemia. Factors such as age, duration of employment, and socioeconomic status were taken into account. Doses were lagged for two years for leukemia and ten years for other cancers.

Only about 6% of the overall cohort was found to be deceased. The excess relative risk (ERR) for all cancers excluding leukemia was elevated at 0.97 per Sv, with a 95% confidence interval (CI) of 0.14 to 1.97. When lung and pleura cancers were also excluded along with leukemias, the ERR was 0.59 (95% CI, -0.29, 1.7) per Sv. For leukemias other than chronic lymphocytic, the ERR was 1.93 per Sv with a very wide 95% confidence interval (<0, 8.47). The study estimated that cumulative exposure of 100 mSv would lead to a 10% increased rate of mortality from all cancers excluding leukemia and a 19% increased rate of mortality from leukemia excluding chronic lymphocytic leukemia. On the basis of these estimates, the study suggests that 1-2% of deaths from cancer among workers in this study may be attributable to radiation.

Relevance

Results from this study provide radiation risk estimates from the largest study of nuclear industry workers ever conducted (R.1, R.2, and R.4). They suggest that there is a small increase in cancer risk even at the low doses and dose-rates typically received by nuclear workers in this study. The use of a common set of methods across facilities and countries helps to ensure the accuracy of the risk estimates. This study was restricted only to workers with relatively well-measured radiation exposures, which reduces possible error from poor measurement of other exposures, such as neutrons and internal radiation.

The risk estimates per unit dose from this study are statistically similar to those of the atomic bomb survivor data, but the uncertainty in the estimates suggests cancer risk could be up to five times greater than indicated by the A-bomb study at a given dose. A major limitation of the study is the low overall mortality within the combined cohort, due to the young age distribution of the cohort. Plans are underway to continue following up this very important combined cohort, so that an improved understanding may be gained of their cancer risk related to occupational exposure.

Table II-4. Current IARC research products by strategic goal

No.	Citation	Goals
1	Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, Howe G, Kaldor J, Muirhead CR, Schubauer-Berigan MK, Yoshimura T, and the international study group [2005]. Risk of cancer after low doses of ionising radiation—retrospective cohort study in 15 countries. Brit Med J; 327:765-8 doi:10.1136/bmj.37939.736944.87 (full text published online 29 June 2005); also BMJ 331:77-80; 2005.	P.3, P.4, R.1-R.4
2	Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, Howe G, Kaldor J, Muirhead CR, Schubauer-Berigan MK, Yoshimura T, and the international study group [*forthcoming*]. Effects of low doses of ionizing radiation: results of the 15-country study of nuclear industry workers. *In preparation.*	P.3, P.4, R.1-R.4
3	Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, Howe G, Kaldor J, Muirhead CR, Schubauer-Berigan MK, Yoshimura T, and the international study group [*forthcoming*]. The 15-Country Collaborative Study of Cancer Risk Among Radiation Workers in the Nuclear Industry: Design, Epidemiological Methods, and Descriptive Results; *in preparation.*	R.1-R.4

Research Output and Products

OERP research products are documented in the scientific literature, such as peer-reviewed journal articles and peer-reviewed NIOSH reports. These documents form the basis for communications to workers, the public and the scientific community. The collection of scientific works originating from the OERP effectively demonstrates:

- Novel research methods and applications conceptualized, developed, and used to enhance understanding of exposures and health effects in the DOE workforce. For example, of 88 OERP-related articles published in peer-reviewed scientific journals (Table II-5 and Table II-11), 38 publications focus on exposure assessment and 50 publications address health effects.

- New cancer risk estimates for chronic, low-level exposure to ionizing radiation.

- The breadth of study findings, publication of significant results, and effective communication of study conclusions to DOE management, affected workers, and the scientific community.

- The quality and range of research projects and number of research partners engaged in the program. For example, a total of 119 reports and articles have resulted from the many extramural research grants and cooperative agreements conducted under the OERP (Table II-11 and Table II-12).

To illustrate the depth and breadth of OERP publications, a comprehensive bibliography of both extramural and intramural publications and reports is provided in the following tables:

- Table II-5. Intramural peer-reviewed journal articles
- Table II-6. Intramural proceedings and extended abstracts
- Table II-7. NIOSH numbered reports
- Table II-8. Unnumbered Intramural reports
- Table II-9. NIOSH Health Hazard Evaluations (HHE) within the OERP
- Table II-10. Works in progress
- Table II-11. Extramural peer-reviewed journal articles
- Table II-12. Extramural reports

The bibliography was constructed from review of OERP record holdings, interviews of OERP staff and research partners, and structured searches of the open literature. It is important to note that the majority of extramural research was conducted under a grants program, which promoted but did not specifically require researchers to publish results or notify NIOSH of resulting publications. In some cases, publications were added to or removed from the bibliography following a vetting process on OERP applicability.

Figure II-1 shows a plot of OERP research publications over time. This graph demonstrates a necessary balance between intramural and extramural research and provides a measure of overall output. Over the years, the OERP has contributed greatly to the body of scientific literature regarding occupational radioepidemiology and exposure assessment for epidemiologic studies. This research is drawn upon by other researcher and scientific bodies, such as the National Academies' Committee on the Biological Effects of Ionizing Radiations (NA/BEIR) for a better understanding the risk associated with ionizing radiation exposure and for providing recommendation for radiation protection standards.

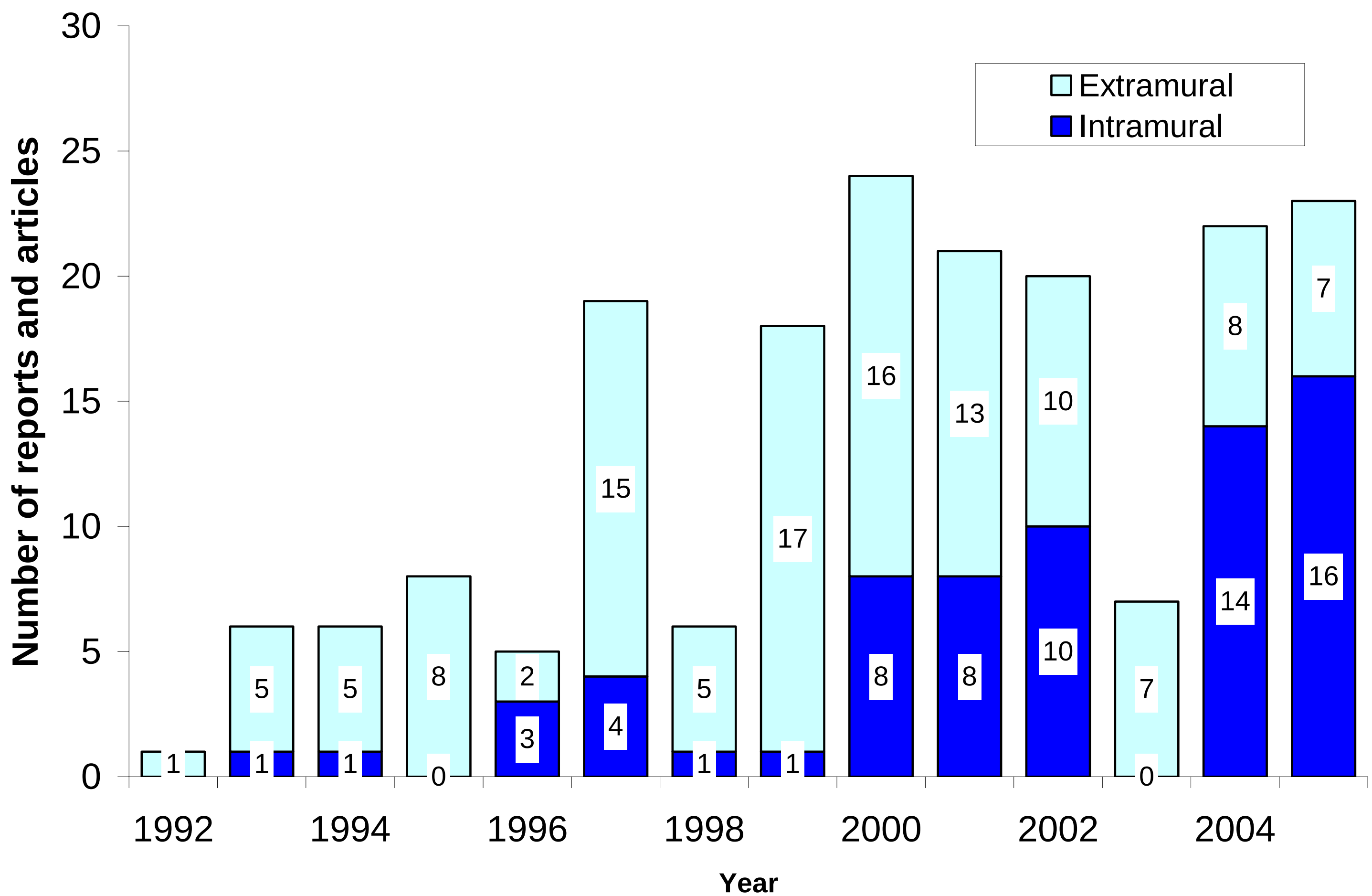

Figure II-1. Number of Occupational Energy Research Program reports and articles

Intramural Research Publications

Table II-5. Intramural peer-reviewed journal articles

No.	Citation	Year
1	Cardarelli J, Spitz H, Rice C, Buncher R, Elson H, Succop P [2002]. Significance of radiation exposure from work-related chest X-rays for epidemiological studies of radiation workers. Am J Ind Med; 42(6):490-501.	2002
2	Cardarelli, Elliott L, Hornung R, Chang WP [1997]. Proposed model for estimating dose to inhabitants of 60Co contaminated buildings. Health Phys; 72(3):351-60.	1997
3	Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, Howe G, Kaldor J, Muirhead CR, Schubauer-Berigan MK, Yoshimura T, and the international study group [2005]. Risk of cancer after low doses of ionising radiation--retrospective cohort study in 15 countries. Brit Med J; 327:765-8 doi:10.1136/bmj.37939.736944.87 (full text published online 29 June 2005); also BMJ 331:77-80.	2005
4	Daniels RD, Kubale TL, Spitz HB [2005]. Radiation exposure from work-related medical X-rays at the Portsmouth Naval Shipyard. Am J Ind Med; 47(3):206-16.	2005
5	Daniels RD, Lodwick CJ, Schubauer-Berigan MK, Spitz HB [2005]. Assessment of plutonium exposures for an epidemiological study of US nuclear workers. Radiat Prot Dosimetry.	2005
6	Daniels RD, Schubauer-Berigan MK [2005]. Bias and uncertainty of penetrating photon dose measured by film dosemeters in an epidemiological study of US nuclear workers. Radiat Prot Dosimetry; 113(3):275-89.	2005
7	Daniels RD, Taulbee TD, Chen P [2004]. Radiation exposure assessment for Portsmouth Naval Shipyard health studies. Radiat Prot Dosimetry; 111(2):139-50.	2004
8	Kubale TL, Daniels RD, Yiin JH, Couch J, Schubauer-Berigan MK, Kinnes, GH, Silver SR, Nowlin SJ, and Chen P [2005]. A nested case-control study of leukemia mortality and ionizing radiation at the Portsmouth Naval Shipyard. Radiat Res; 164(6): 810-19	2005
9	Methner MM, Feng HA, Utterback DF [2001]. Use of historical uranium air sampling data to estimate worker exposure potential to airborne radioactive particulate in a uranium processing facility. Appl Occup Environ Hyg; 16(12):1150-7.	2001
10	Methner MM [2004]. Identification of potential sources of arsenic exposure during scrapyard work at a former uranium enrichment facility. J Occup Environ Hyg; 1(9):D96-D100.	2004

continued

Table II-5. Intramural peer-reviewed journal articles

No.	Citation	Year
11	Robinson C, Cardarelli J, Spitz HB, Utterback DF [2002]. Re: Diagnostic radiation and the risk of multiple myeloma (United States). Cancer Causes Control; 13(10):975; author reply 977.	2002
12	Schubauer-Berigan MK, Wenzl TB [2001]. Leukemia mortality among radiation-exposed workers. Occup Med; 30; 16(2):271-87.	2001
13	Silver SR, Daniels RD, Taulbee TD, Zaebst DD, Kinnes GM, Couch JR, Kubale TL, Yiin JH, Schubauer-Berigan MK, Chen PH [2004]. Differences in mortality by radiation monitoring status in an expanded cohort of Portsmouth Naval Shipyard workers. J Occup Environ Med; 46(7):677-90.	2004
14	Wenzl TB [1997]. Estimating magnetic field exposures of rail maintenance workers. Am Ind Hyg Assoc J; 58(9):667-71.	1997
15	Wenzl TB [1999]. Assessment of magnetic field exposures for a mortality study at a uranium enrichment plant. Am Ind Hyg Assoc J; 60(6):818-24.	1999
16	Yiin JH, Schubauer-Berigan MK, Silver SR, Daniels RD, Kinnes GM, Zaebst DD, Couch JR, Kubale TL, Chen PH [2005]. Risk of lung cancer and leukemia from exposure to ionizing radiation and potential confounders among workers at the Portsmouth Naval Shipyard. Radiat Res; 163(6):603-13.	2005

Table II-6. Intramural proceedings and extended abstracts

No.	Citation	Year
1	Ahrenholz S [2000]. NIOSH Sponsored Research Addressing the DOE Workforce, Boston, MA. American Public Health Association, Occupational Safety and Health Session, 2000	2000
2	Ahrenholz S, Kubale T [2002]. Simultaneous Communication of Study Results to Workers and Management at Multiple Locations. Am Ind Hyg Conf Expo, AIHA :72	2002
3	Ahrenholz SH [2005]. An overview of the NIOSH health-related energy research branch occupational radioepidemiology program. Health Phys; 89(1)(Suppl S):S61-S61	2005
4	Burphy JS, Silver SR, Hiratzka S, Schubauer-Berigan MK, Waters KM [2004]. Mortality update for the Pantex Weapons Facility. American Public Health Association Conference.	2004
5	Cardarelli J, Elliott L, Chang W [1995]. Poster Presentation: Epidemiologic Study of Buildings Contaminated with Cobalt-60: Exposure Assessment Model, The Annual Conference on the International Society for Environmental Epidemiology and the International Society for Exposure Analysis, Noordwijkerhout, The Netherlands, 30 August - 1 September, 1995.	1995
6	Cardarelli J., Rinsky R.A., Hornung R., Ahrenholz S.H., Reeder D., and Dill P [1997]. Oral Presentation: The Development of a Job Exposure Matrix Using Uranium Alpha-Count Data in Epidemiology. Health Physics. 72(6): S82.	1997
7	Cardarelli J, Spitz H, Rice C, Buncher CR, Elson H, Succop P [2001]. Significance of Radiation Exposure from Work-Related Chest X-rays for Epidemiologic Studies of Radiation Workers. Exposure Assessment in Epidemiology and Practice Conference, Göteborg, Sweden. June 10-13, 2001.	2001
8	Cardarelli JJ, Spitz HB, Rice C, Buncher CR, Elson H, Succop P, Daniels RD, Kubale-T [2002]. Evaluation of work-related medical x-rays in epidemiological studies of nuclear workers Radiat Res, 158(6):807-808.	2002
9	Couch J, Fleming D, Herman A [2005]. A retrospective chemical exposure assessment of benzene and carbon tetrachloride for a United States naval shipyard. American Industrial Hygiene Conference and Expo, May 21-26, 2005, Anaheim, California. Fairfax, VA: American Industrial Hygiene Association, p. 73.	2005
10	Daniels RD [2005]. Radiation exposure assessment for epidemiologic studies. Health Phys 2005 Jul; 89(1) (Suppl S):S61-S61.	2005
11	Daniels R, Kubale T, Spitz H [2005]. Radiation exposure from work-related medical x-rays at the Portsmouth Naval Shipyard. Occ Environ Med 62(11):e25.	2005
12	Elliott, L.J., T. Katz, J. Neton, M. Schubauer-Berigan [2002]. United States Energy Employees Occupational Illness Compensation Program: adjudication of radiation-related cancer claims utilizing dose reconstruction and probability of causation procedures. Proceedings of International Conference on Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation. Geneva, Switzerland; IAEA-CN-91, pgs. 572-575.	2002
13	Fleming D, Markey A [2004]. A chemical exposure assessment strategy developed to analyze solvent exposures at the Department of Energy Hanford Site. American Industrial Hygiene Conference and Expo, May 8-13, 2004, Atlanta, Georgia. Fairfax, VA: American Industrial Hygiene Association, p. 87.	2004

continued

Table II-6. Intramural proceedings and extended abstracts

No.	Citation	Year
14	Foster SO, Schubauer-Berigan MK, Waters KM [2000]. The specificity of the National Death Index and Social Security Administration death master file when information on Social Security Number is lacking. Am J Epidemiol. 151(11): 170 (Suppl S).	2000
15	Henn S, Tankersley W, Utterback D [2004]. Retrospective chemical exposure assessment of laboratory workers at three department of energy sites in Oak Ridge, Tennessee. American Industrial Hygiene Conference and Expo, May 8-13, 2004, Atlanta, Georgia. Fairfax, VA: American Industrial Hygiene Association pp. 4-5	2004
16	Kinnes G, Silver S, Taulbee T, Ahrenholz S, Robinson C [2002]. U.S. Department of Energy Site Remediation Workers: Assessing the Availability of Worker, Exposure, and Medical History Information. Am Ind Hyg Conf Expo, 2002 Jun AIHA :82-83.	2002
17	Kubale T, Daniels R, Yiin J, Kinnes G, Couch J, Schubauer-Berigan M, Silver S, Nowlin S, Chen P [2005]. A nested case-control study of leukaemia and ionising radiation at the Portsmouth Naval Shipyard. Occ Environ Med 62(11):e25.	2005
18	Kubale TL, Daniels RD, Yiin JH, Kinnes GM, Couch JR, Schubauer-Berigan MK [2005]. A nested case-control study of leukemia and ionizing radiation at the Portsmouth naval shipyard. Health Phys; 89(1)(Suppl S):S77-S77	2005
19	Markey A, Fleming D [2004]. A historical chemical exposure strategy developed to analyze solvent exposures of workers at the Savannah River Site. American Industrial Hygiene Conference and Expo, May 8-13, 2004, Atlanta, Georgia. Fairfax, VA: American Industrial Hygiene Association, p. 87.	2004
20	Neton J, Flora J, Spitz H, Taulbee T [2000]. Retrospective internal radiation exposure assessment in occupational epidemiology. Tenth International Congress of the International Radiation Protection Association. Hiroshima, Japan. May, 2000.	2000
21	Neton JW, Wenzl TB, Ju J, Cardarelli J, Doody MM, Freeman DM, Mohan AK, Alexander BH [2001]. External radiation exposure in a cohort of US radiologic technologists (1977 - 1998). Health Physics. 80(6): S117.	2001
22	Neton J, Wenzl T, Cardarelli J, Utterback-D [2002]. Retrospective exposure assessment for radiological technologists Radiat Res, 158(6):804-805	2002
23	Rinsky R, Thomas DC [2000]. Resolved: The probability of causation can be used in an equitable manner to resolve radiation tort claims and design probability of compensation schemes. Radiat. Res. 154:717-718.	2000
24	Schubauer-Berigan M, Elliott LJ, Katz T, Neton J [2002]. Guidelines for determining the probability of causation under the US Energy Employees Occupational Illness Compensation Program Act of 2000. Proceedings of International Conference on Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation. Geneva, Switzerland. IAEA-CN-91, pgs. 581-584.	2002
25	Schubauer-Berigan MK, Utterback DF, Macievic G, Tseng C-Y [2004]. Cancer & other mortality in the US Idaho National Engineering and Environmental Laboratory, a large nuclear research facility. Occ Environ Med 61(11):e18.	2004

continued

Table II-6. Intramural proceedings and extended abstracts

No.	Citation	Year
26	Schubauer-Berigan MK, Macievic GV, Utterback DF, Tseng-CY [2005]. Non-Hodgkin lymphoma and hematopoietic cancer mortality among Idaho National Engineering and Environmental Laboratory workers. Health Phys; 89(1) (Suppl S):S77-S78.	2005
27	Schubauer-Berigan, MK [2002]. Medical radiation exposures in occupational studies: Discussion. In: Proceedings of the American Statistical Association Conference on Radiation and Health, Deerfield Beach, Florida, June 23-26, 2002. Radiat. Res. 158:808.	2002
28	Schubauer-Berigan MK, Raudabaugh R, Ruder AM, Hein MJ, Silver SR, Chen B, Laber P, Spaeth S, Steenland K [2005]. LTAS.NET: A NIOSH Life Table Analysis System For The Windows Environment. AEP Vol. 15, No. 8:pp 630–665.	2005
29	Silver, SR, Daniels RD, Schubauer-Berigan MK [2004]. Differences in mortality by radiation monitoring status in Portsmouth Naval Shipyard Workers. American Public Health Association Conference.	2004
30	Simon SL, Weinstock RM, Doody MM, Neton J, Wenzl T, Stewart P, Mohan AK, Yoder C, Hauptmann M, Freedman M, Cardarelli J, Feng HA, Bouville A, Linet M [2004]. Status Report On Estimating Historical Radiation Doses to a Cohort of U.S. Radiologic Technologists. In Proceedings of 11th International Congress of the International Radiation Protection Association, 23-28 May, 2004, Madrid, Spain. Available on CD-ROM and at http://www.irpa11.com/new/pdfs/5f39.pdf	2004
31	Zaebst DD [2005]. The importance of industrial hygiene exposure assessment in radioepidemiology. Health Phys; 89(1)(Suppl S):S77-S77	2005
32	Zaebst, D.D. *et al*. [2001]. A Field Evaluation of Techniques Used to Construct a Quantitative Job Exposure Matrix. X2001, Exposure Assessment in Epidemiology and Practice, Gothenburg, Sweden, p. 172.	2001
33	Zaebst, DD *et al*. [2004] Estimation of Historical Exposure to Asbestos in a Nested Case-control Study of Radiation and Lung Cancer at a Naval Shipyard. X-2004, Exposure Assessment in a Changing Environment; Utrecht, The Netherlands.	2004

Table II-7. NIOSH numbered reports

No.	Citation	Year
1	Cardarelli, J, Spitz H, Elliott L [1993]. NIOSH research issues workshop: epidemiologic use of nondetectable values in radiation exposure measurements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health/Health-Related Energy Research Branch; DHHS (NIOSH) Publication No. 224647; 27 pgs.	1993
2	NIOSH [2004]. A nested case-control study of leukemia and ionizing radiation at the Portsmouth Naval Shipyard. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-104; 182 pgs.	2004
3	NIOSH [2001]. NIOSH Occupational Energy Research Program. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 2001-133, pgs.	2001
4	NIOSH [2005]. Report of Public Meeting to Seek Input on Gaps in Chronic Lymphocytic Leukemia (CLL) Radiogenicity Research Held July 21, 2004. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 2006-100, 104 pgs.	2005
5	NIOSH [2005]. An epidemiologic study of mortality and radiation-related risk of cancer among workers at the Idaho National Engineering and Environmental Laboratory, a U.S. Department of Energy Facility. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-131, 224 pgs.	2004
6	NIOSH [2005]. Mortality update for the Pantex weapons facility: Final report. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-124, 24 pgs.	2004

Table II-8. Unnumbered Intramural reports

No.	Citation	Year
1	Foster S, Espinoza R [2000]. Cancer incidence and sentinel event registries. Cincinnati, OH: National Institute for Occupational Safety and Health/Health-Related Energy Research Program; 107 pgs.	2000
2	Foster SO, Schubauer-Berigan MK, Waters KM [2000]. The specificity of the National Death Index and Social Security Administration Death Master File when information on Social Security Number is lacking.	2000
3	Massoudi BL [1996]. Adverse reproductive outcomes among females employed at Department of Energy facilities: The feasibility of epidemiologic studies. Available from the National Institute for Occupational Safety and Health/Health-related Energy Research Branch, Cincinnati, OH. [Final Report] Unpublished. 18 pg.	1996
4	Murray B [1997]. Dosimetry data compilation for international radiation worker study: Final report. IARC Collaborative Study; Cincinnati, OH: National Institute for Occupational Safety and Health/Health-Related Energy Research Branch; 52 pgs.	1997
5	Rinsky R, Cardarelli J, Ahrenholz S, Wenzl T, Hornung R, Reeder D, Waters K, Dill P. [2001]. Final technical report: Mortality patterns among uranium enrichment workers at the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio. Cincinnati, OH: Cincinnati, OH: National Institute for Occupational Safety and Health/Health-Related Energy Research Branch; 179 pgs.	2001
6	Rinsky R and Taulbee T [1998]. Report to Deputy Assistant Secretary, U.S. Department of Energy. Feasibility assessment. Epidemiologic study of personnel involved in the underground nuclear detonation, Cannikin site, Amchitka, Alaska. Cincinnati, OH: National Institute for Occupational Safety and Health/Health-Related Energy Research Branch; 18 pgs.	1998
7	Silver SR, Robinson CF, Kinnes G, Taulbee T, Ahrenholz S [2000]. Evaluation of data for DOE site remediation workers ("White paper"). Cincinnati, OH: National Institute for Occupational Safety and Health/Health-Related Energy Research Branch; 37 pgs.	2000
8	Schmid E, Keith S, TenfordeT, Alberth D, Cloeren M, Kramp R, *et al.* [2001]. Depleted Uranium: Sources, Exposure and Health Effects. Dept Prot Hum Env 2001 Apr :1-209	2001
9	Wenzl TB, Mills P, Murray WE [1996]. Electromagnetic Fields [EMF] and rail maintenance workers: Final report of an exposure survey and feasibility investigation. Cincinnati, OH: National Institute for Occupational Safety and Health/Health-Related Energy Research Program; 7 pgs.	1996

Table II-9. NIOSH Health Hazard Evaluations (HHE) within the OERP

No.	Citation	Year
1	NIOSH [1994]. Hazard evaluation and technical assistance report: Protection Technology Idaho Inc., Idaho Falls, Idaho. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 93-0740, 19 pages.	1994
2	NIOSH [1996] Hazard evaluation and technical assistance report: Lockheed Martin Utility Services, Inc., Piketon, Ohio. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 94-0077-2568, 41 pages.	1996
3	NIOSH [1998]. Hazard evaluation and technical assistance report: Los Alamos National Laboratory, Los Alamos, NM. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 98-0240, 6 pages.	1998
4	NIOSH [2000]. Hazard evaluation and technical assistance report: Portsmouth Gaseous Diffusion Plant, Piketon, Ohio. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 96-0198-2651, 1-36.	2000

Table II-10. Works in progress

No.	Citation
1	Anderson JL, Daniels RD [*in press*]. Bone marrow dose estimates from work-related medical X-ray examinations given between 1943 and 1966 for personnel from five U.S. nuclear facilities. Health Phys 2005.
2	Burphy JS, Schubauer-Berigan MK, Utterback DF [*forthcoming*]. Evaluating the association between U.S. State of Origin and Mormon Religious Affiliation in a records-based cohort mortality study.
3	Daniels RD, Yiin J. Estimation of less than detectable ionizing radiation exposures. *Submitted to Radiation Protection Dosimetry*.
4	Fleming DA, (other team members will be added at a later date) [*forthcoming*]. A chemical exposure assessment strategy developed to analyze solvent exposures at five sites.
5	Henn SA, Utterback DF, Markey AM, Waters KM, Tankersley WG. Task and time-dependent weighting factors in a retrospective exposure assessment of chemical laboratory workers. *Submitted to the Journal of Occupational and Environmental Hygiene.*
6	Hiratzka S, Silver SR [*forthcoming*]. Chronic lymphocytic leukemia radiogenicity: a systematic review.
7	Markey AM, Couch JR, Fleming DA, Ahrenholz SH, Tseng C [*forthcoming*]. A multi-site comparison of a retrospective chemical exposure assessment strategy utilizing Department of Energy and Department of Defense facilities.
8	Nestle DR [*forthcoming*]. Diagnostic X-ray spectrum modeling: derivation of constant-potential and single-phase spectra. In external peer review for clearance.
9	Schubauer-Berigan MK, Daniels RD, Fleming D, Markey A, Couch J, Ahrenholz S, Burphy JL, Anderson J, Tseng C-Y [*forthcoming*]. Risk of chronic lymphocytic leukemia mortality following exposure to ionizing radiation among workers at four U.S. nuclear weapons facilities and a nuclear naval shipyard.
10	Seel L, Zaebst D, Chen B [*forthcoming*]. Reconstruction of historical exposures to asbestos and welding fumes at the Portsmouth Naval Shipyard Part II: methods.
11	Spitz HB and Anderson JL [*forthcoming*]. Evaluation of Occupational Exposure to Uranium at a Former Enrichment Facility.
12	Taulbee T, Spitz H, Neton J, Chen P [*forthcoming*]. Dose rate as a parameter in occupational radiation epidemiologic studies.
13	Zaebst D, Seel L, Chen B, Liu J [*forthcoming*]. Reconstruction of historical exposures to asbestos and welding fumes at a nuclear naval shipyard part I: description of site & exposures.

Extramural Research publications

Table II-11. Extramural peer-reviewed journal articles

No.	Citation	Year
1	Baillargeon J, Wilkinson GS [1999]. Characteristics of the healthy survivor effect among male and female Hanford workers. Am J Ind Med, 35(4):343-7.	1999
2	Baillargeon J, Wilkinson G, Rudkin L, Baillargeon G, Ray L [1998]. Characteristics of the healthy worker effect: a comparison of male and female occupational cohorts. J Occup Environ Med, 40(4):368-73.	1998
3	Bigbee WL, Jensen RH, Veidebaum T, Tekkel M, Rahu M, Stengrevics A, Auvinen A, Hakulinen T, Servomaa K, Rytomaa T, *et al*. [1997] Biodosimetry of Chernobyl cleanup workers from Estonia and Latvia using the glycophorin A in vivo somatic cell mutation assay. Radiat Res,147(2):215-24.	1997
4	Brodkin CA, Moon JD, Camp J, Echeverria D, Redlich CA, Willson RA, Checkoway H [2001]. Serum hepatic biochemical activity in two populations of workers exposed to styrene. Occup Environ Med, 58(2):95-102.	2001
5	Brown SC, Schonbeck MF, McClure D, Baron AE, Navidi WC, Byers T, Ruttenber AJ [2004]. Lung cancer and internal lung doses among plutonium workers at the Rocky Flats Plant: a case-control study. Am J Epidemiol, 15; 160(2):163-72.	2004
6	Brown SC, Ruttenber AJ [2005]. Lung cancer and plutonium exposure in rocky flats workers. Radiat Res, 163 (6): 696-697.	2005
7	Cardis E, Gilbert ES, Carpenter L, Howe G, Kato I, Levé EC, Armstrong BK [1994]. Direct estimates of cancer mortality due to low doses of ionising radiation: an international study. IARC Study Group on Cancer Risk among Nuclear Industry Workers. Lancet. 344(8929):1039-43	1994
8	Cardis E, Gilbert ES, Carpenter L, Howe G, Kato I, Armstrong BK, Beral V, Cowper G, Douglas A, Fix J, *et al*. [1995]. Effects of low doses and low dose rates of external ionizing radiation: cancer mortality among nuclear industry workers in three countries. Radiat Res,142(2):117-32.	1995
9	Dimarco JH, Wilkinson GS [1995]. Case-control study of brain-tumors and ionizing-radiation nested within a cohort of nuclear workers. Am J Epidemiol 141 (11): S30-S30 Suppl. S.	1995
10	Dunning K, LeMasters G, Levin L, Bhattacharya A, Alterman T, Lordo K [2003]. Falls in workers during pregnancy: risk factors, job hazards, and high risk occupations. Am J Ind Med, 44(6):664-72.	2003
11	Dupree EA, Watkins JP, Ingle JN, Wallace PW, West CM, Tankersley WG [1995]. Uranium dust exposure and lung cancer risk in four uranium processing operations. Epidemiology, 6(4):370-5.	1995

continued

Table II-11. Extramural peer-reviewed journal articles

No.	Citation	Year
12	Dupree-Ellis E, Watkins J, Ingle JN, Phillips J [2000]. External radiation exposure and mortality in a cohort of uranium processing workers. Am J Epidemiol, 152(1):91-5.	2000
13	Frome EL, Cragle DL, Watkins JP, Wing S, Shy CM, Tankersley WG, West CM [1997]. A mortality study of employees of the nuclear industry in Oak Ridge, Tennessee. Radiat Res, 148(1):64-80.	1997
14	Fry SA, Cragle DL, Crawford-Brown DJ, Dupree EA, Frome EL, Gilbert ES, Petersen GR, Shy CH, Tankersley WG, Voelz GL, Wallace PW, Watkins JP, Watson JE, Wiggs LD [1995]. Health and mortality among contractor employees at US Department of Energy facilities. Radiation and Public Perception; Adv Chem, 243:239-258.	1995
15	Gilbert ES, Cragle DL, Wiggs LD [1993]. Updated analyses of combined mortality data for workers at the Hanford Site, Oak Ridge National Laboratory, and Rocky Flats Weapons Plant. Radiat Res, 136(3):408-21.	1993
16	Gilbert ES, Fix JJ, Baumgartner WV [1996]. An approach to evaluating bias and uncertainty in estimates of external dose obtained from personal dosimeters. Health Phys, 70(3):336-45.	1996
17	Gilbert ES, Fix JJ [1995]. Accounting for bias in dose estimates in analyses of data from nuclear worker mortality studies. Health Phys, 68(5):650-60.	1995
18	Gilbert ES, Omohundro E, Buchanan JA, Holter NA [1993]. Mortality of workers at the Hanford site: 1945-1986. Health Phys, 64(6):577-90.	1993
19	Jensen RH, Langlois RG, Bigbee WL, Grant SG, Moore D 2nd, Pilinskaya M, Vorobtsova I, Pleshanov P [1995]. Elevated frequency of glycophorin A mutations in erythrocytes from Chernobyl accident victims. Radiat Res, 141(2):129-35.	1995
20	Jensen RH, Reynolds JC, Robbins J, Bigbee WL, Grant SG, Langlois RG, Pineda JD, Lee T, Barker WC [1997]. Glycophorin A as a biological dosimeter for radiation dose to the bone marrow from iodine-131. Radiat Res, 147(6):747-52.	1997
21	Kelleher PC, Martyny JW, Mroz MM, Maier LA, Ruttenber AJ, Young DA, Newman LS [2001]. Beryllium particulate exposure and disease relations in a beryllium machining plant. J Occup Environ Med, 43(3):238-49.	2001
22	Kesniiniene A, Cardis E, Tenet V, Ivanov VK, Kurtinaitis J, Malakhova I, Stengrevics A, Tekkel M [2002]. Studies of cancer risk among Chernobyl liquidators: materials and methods. J Radiol Prot, 22(3A):A137-41.	2002
23	LaMontagne AD, Ruttenber AJ, Wegman DH [2000]. Exposure surveillance for chemical and physical hazards. In Maizlish N, ed. Workplace Health Surveillance: Principles & Practice. New York: Oxford University Press, pgs. 219-234.	2000

continued

Table II-11. Extramural peer-reviewed journal articles

No.	Citation	Year
24	LaMontagne AD, Herrick RF, Van Dyke MV, Martyny JW, Ruttenber AJ [2002]. Exposure databases and exposure surveillance: promise and practice. AIHA J (Fairfax, VA), 63(2):205-12.	2002
25	LaMontagne AD, Van Dyke MV, Martyny JW, Ruttenber AJ [2001]. Cleanup worker exposures to hazardous chemicals at a former nuclear weapons plant: piloting of an exposure surveillance system. Appl Occup Environ Hyg, 16(2):284-90.	2001
26	LaMontagne AD, Van Dyke MV, Martyny JW, Simpson MW, Holwager LA, Clausen BM, Ruttenber AJ[2002]. Development and piloting of an exposure database and surveillance system for DOE cleanup operations. Department of Energy. AIHA J (Fairfax, VA), 63(2):213-24.	2002
27	Langholz B, Thomas D, Xiang A, Stram D [1999]. Latency analysis in epidemiologic studies of occupational exposures: application to the Colorado Plateau uranium miners cohort. Am J Ind Med, 35(3):246-56.	1999
28	Letz R, Gerr F, Cragle D, Green RC, Watkins J, Fidler AT [2000]. Residual neurologic deficits 30 years after occupational exposure to elemental mercury. Neurotoxicology, 21(4):459-74.	2000
29	Lindholm C, Murphy BP, Bigbee WL, Bersimbaev RI, Hulten MA, Dubrova YE, Salomaa S [2004]. Glycophorin A somatic cell mutations in a population living in the proximity of the Semipalatinsk nuclear test site. Radiat Res, 162(2):164-70.	2004
30	Martyny JW, Hoover MD, Mroz MM, Ellis K, Maier LA, Sheff KL, Newman LS [2000]. Aerosols generated during beryllium machining. J Occup Environ Med, 42(1):8-18.	2000
31	Mitchell TJ, Ostrouchov G, Frome EL, Kerr GD [1997]. A method for estimating occupational radiation dose to individuals, using weekly dosimetry data. Radiat Res, 147(2):195-207.	1997
32	Newman LS, Mroz MM, Balkissoon R, Maier LA [2005]. Beryllium sensitization progresses to chronic beryllium disease: a longitudinal study of disease risk. Am J Respir Crit Care, 171(1):54-60.	2005
33	Newman LS, Mroz MM, Maier LA, Daniloff EM, Balkissoon R [2001]. Efficacy of serial medical surveillance for chronic beryllium disease in a beryllium machining plant. J Occup Environ Med, 43(3):231-7.	2001
34	Newman LS, Mroz MM, Ruttenber AJ [2005]. Lung fibrosis in plutonium workers. Radiat Res, 164(2):123-31.	2005
35	Pepper L, Messinger M, Weinberg J, Campbell R [2003]. Downsizing and health at the United States Department of Energy. Am J Ind Med, 44(5):481-91.	2003
36	Richardson D, Wing S, Steenland K, McKelvey W [2004]. Time-related aspects of the healthy worker survivor effect. Ann Epidemiol, 14(9):633-9.	2004

continued

Table II-11. Extramural peer-reviewed journal articles

No.	Citation	Year
37	Richardson D, Wing S, Watson J, Wolf S [2000]. Evaluation of annual external radiation doses at values near minimum detection levels of dosimeters at the Hanford nuclear facility. J Expo Anal Environ Epidemiol, 10(1):27-35.	2000
38	Richardson D, Wing S, Watson J, Wolf S [1999]. Missing annual external radiation dosimetry data among Hanford workers. J Expo Anal Environ Epidemiol, 9(6):575-85.	1999
39	Richardson DB, Wing S [1999]. Greater sensitivity to ionizing radiation at older age: follow-up of workers at Oak Ridge National Laboratory through 1990. Int J Epidemiol, 28(3):428-36.	1999
40	Richardson DB, Wing S [1998]. Methods for investigating age differences in the effects of prolonged exposures. Am J Ind Med, 33(2):123-30.	1998
41	Richardson DB, Wing S [1999]. Radiation and mortality of workers at Oak Ridge National Laboratory: positive associations for doses received at older ages. Environ Health Perspect, 107(8):649-56.	1999
42	Ritz B [1999]. Radiation exposure and cancer mortality in uranium processing workers. Epidemiology, 10(5):531-8.	1999
43	Rosenman K, Hertzberg V, Rice C, Reilly MJ, Aronchick J, Parker JE, Regovich J, Rossman M [2005]. Chronic beryllium disease and sensitization at a beryllium processing facility. Environ Health Perspect, 113(10):1366-72	2005
44	Ruttenber AJ, McCrea JS, Wade TD, Schonbeck MF, LaMontagne AD, Van Dyke MV, Martyny JW [2001]. Integrating workplace exposure databases for occupational medicine services and epidemiologic studies at a former nuclear weapons facility. Appl Occup Environ Hyg, 16(2):192-200.	2001
45	Ruttenber AJ, Schonbeck M, McCrea J, McClure D, Martyny J [2001]. Improving estimates of exposures for epidemiologic studies of plutonium workers. Occup Med, 16(2):239-58.	2001
46	Salazar MK, Takaro TK, Ertell K, Gochfeld M, O'Neill S, Connon C, Barnhart S [1999]. Structure and function of occupational health services within selected Department of Energy sites. J Occup Environ Med, 41(12):1072-8.	1999
47	Salazar MK, Connon C, Takaro TK, Beaudet N, Barnhart S [2001]. An evaluation of factors affecting hazardous waste workers' use of respiratory protective equipment. AIHAJ, 62(2):236-45.	2001
48	Salazar MK, Takaro TK, Connon C, Ertell K, Pappas G, Barnhart S [1999]. A description of factors affecting hazardous waste workers' use of respiratory protective equipment. Appl Occup Environ Hyg, 14(7):470-8.	1999
49	Sanderson WT, Henneberger PK, Martyny J, Ellis K, Mroz MM, Newman LS [1999]. Beryllium contamination inside vehicles of machine shop workers. Appl Occup Environ Hyg, 14(4):223-30.	1999

continued

Table II-11. Extramural peer-reviewed journal articles

No.	Citation	Year
50	Sanderson WT, Henneberger PK, Martyny J, Ellis K, Mroz MM, Newman LS [1999]. Beryllium contamination inside vehicles of machine shop workers. Am J Ind Med, Suppl 1:72-4.	1999
51	Sawyer RT, Maier LA, Kittle LA, Newman LS [2002]. Chronic beryllium disease: a model interaction between innate and acquired immunity. Int Immunopharmacol, 2(2-3):249-61.	2002
52	Sibley RF, Moscato BS, Wilkinson GS, Natarajan N [2003]. Nested case-control study of external ionizing radiation dose and mortality from dementia within a pooled cohort of female nuclear weapons workers. Am J Ind Med, 44(4):351-8.	2003
53	Stram DO, Huberman M, Langholz B [2000]. Correcting for exposure measurement error in uranium miners studies: impact on inverse dose-rate effects. Radiat Res, 154(6):738-9; discussion 739-40.	2000
54	Stram DO, Kopecky KJ [2003]. Power and uncertainty analysis of epidemiological studies of radiation-related disease risk in which dose estimates are based on a complex dosimetry system: some observations. Radiat Res, 160(4):408-17.	2003
55	Stram DO, Langholz B, Huberman M, Thomas DC [1999]. Correcting for exposure measurement error in a reanalysis of lung cancer mortality for the Colorado Plateau Uranium Miners cohort. Health Phys, 77(3):265-75.	1999
56	Takaro TK, Ertell K, Salazar MK, Beaudet N, Stover B, Hagopian A, Omenn G, Barnhart S [2000]. Barriers and solutions in implementing occupational health and safety services at a large nuclear weapons facility. J Healthc Qual, 22(6):29-37.	2000
57	Thierry-Chef I, Cardis E, Ciampi A, Delacroix D, Marshall M, Amoros E, Bermann F [2001]. A method to assess predominant energies of exposure in a nuclear research centre—Saclay (France). Radiat Prot Dosimetry, 94(3):215-25.	2001
58	Thierry-Chef I, Pernicka F, Marshall M, Cardis E, Andreo P [2002]. Study of a selection of 10 historical types of dosemeter: variation of the response to Hp(10) with photon energy and geometry of exposure. Radiat Prot Dosimetry, 102(2):101-13.	2002
59	Van Dyke MV, LaMontagne AD, Martyny JW, Ruttenber AJ [2001]. Development of an exposure database and surveillance system for use by practicing OSH professionals. Appl Occup Environ Hyg, 16(2):135-43.	2001
60	Watkins JP, Cragle, DL, Frome EL, Reagan JL, West CM, Crawford-Brown D, and Tankersley WG [1997]. Collection validation, and treatment of data for a mortality study of nuclear workers. Appl. Occup. Environ. Hyg, 12, no. 3: 195-205.	1997
61	Watkins JP, Frome EL, and Cragle DL [2005]. "Age-Based Methods to Explore Time-Related Variables in Occupational Epidemiology Studies," 2005 Proceedings of the American Statistical Association, Section on Statistics in Epidemiology [CD-ROM], Alexandria, VA: American Statistical Association.	2005

continued

Table II-11. Extramural peer-reviewed journal articles

No.	Citation	Year
62	Wiggs LD, Johnson ER, Cox-DeVore CA, Voelz GL [1994]. Mortality through 1990 among white male workers at the Los Alamos National Laboratory: considering exposures to plutonium and external ionizing radiation. Health Phys, 67(6):577-88.	1994
63	Wilkinson GS [1997]. Invited commentary: are low radiation doses or occupational exposures really risk factors for malignant melanoma? Am J Epidemiol, 15;145(6):532	1997
64	Wilkinson GS, Morgenstern H [1995]. Internal comparisons do not always control for the healthy worker effect. Am J Epidemiol, 141 (11): S58	1995
65	Wilkinson GS, Baillargeon J, Ray L, Baillargeon G, Trieff N [1997]. Cancer mortality among plutonium and radiation workers. Am J Epidemiol, 145 (11): 158	1997
66	Wing S, Richardson D, Wolf S, Mihlan G, Crawford-Brown D, Wood J [2000]. A case control study of multiple myeloma at four nuclear facilities. Ann Epidemiol, 10(3):144-53.	2000
67	Wing S, Richardson D, Wolf S, Mihlan G [2004]. Plutonium-related work and cause-specific mortality at the United States Department of Energy Hanford Site. Am J Ind Med, 45(2):153-64.	2004
68	Wing S, Richardson DB [2005]. Age at exposure to ionising radiation and cancer mortality among Hanford workers: follow up through 1994. Occup Environ Med, 62(7):465-72.	2005
69	Woo JG, Pinney SM [2002]. Retrospective smoking history data collection for deceased workers: completeness and accuracy of surrogate reports. J Occup Environ Med, 44(10):915-23.	2002
70	Wu JD, Milton DK, Hammond SK, Spear RC [1999]. Hierarchical cluster analysis applied to workers' exposures in fiberglass insulation manufacturing. Ann Occup Hyg, 43(1):43-55.	1999
71	Xue X, Shore RE, Ye X, Kim MY [2004]. Estimating the dose response relationship for occupational radiation exposure measured with minimum detection level. Health Phys, 87(4):397-404.	2004
72	Xue X, Shore RE [2003]. A method for estimating occupational radiation doses subject to minimum detection levels. Health Phys, 84(1):61-71.	2003

Table II-12. Extramural reports

No.	Citation	Year
1	Back DA and Stevens GW [1998]. Remediation workers' exposure assessment feasibility study at the Department of Energy's Rocky Flats site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati, OH.	1998
2	Bigbee WL, Brown ML, Burmeister LA, Carty SE, Swanson D, Watson CG [1998]. Final performance report: Glycophorin A (GPA) biodosimetry in I-131 treated patients. Pittsburgh, PA: Center for Environmental and Occupational Health and Toxicology, Department of Environmental and Occupational Health, Graduate School of Public Health, University of Pittsburgh; 36 pgs. (DHHS Grant # 5 RO1 OH03276)	1998
3	Bingham E. Rice C [1999]. Work histories – evaluating new participatory methods. Cincinnati, OH: Department of Environmental Health, University of Cincinnati; 21 pgs. (NIOSH Grant #5R01 CCR512026-03)	1999
4	Brodkin CA, Checkoway H, Bushley A, Stover Bert, McDonald G, Lee S, Wang K, Carpenter K, Dubinsky T, Green D [2001]. Surveillance methods for solvent-related hepatotoxicity. Seattle, Washington: University of Washington; (NIOSH Grant SERCA 1 K01 OH00165-01, Technical Report) Available from the National Institute for Occupational Safety and Health/Health-related Energy Research Branch, Cincinnati, OH, 7 pg.	2001
5	Cardis E, Krjuchkov VP, Anspaugh L, Bouville A, Chumak VV, Drozdovich V, Gavrilin Y, Golovanov I, Hubert P, Illychev S, Ivanov VK, Kesminiene A, Kurtinaitis J, Maceika E, Malakhova IV, Mirhaidarov AK, Pitkevitch VA, Stengrevics A, Tekkel M, Tenet V, Tsykalo A [2003]. Reconstruction of doses for Chernobyl liquidators (Final Performance Report). Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 53 pgs.	2003
6	Cardis E, Martuzzi M, Amoros E [1997]. International collaborative study of cancer risk among radiation workers in the nuclear industry – II procedures document 1997 Revision. Lyon, France: International Agency for Research on Cancer, World Health Organization; 102 pgs.	1997
7	Cragle DL, Watkins JP, Ingle JN, Robertson-Demers K, Tankersley WG, West CM [1995]. Mortality among a cohort of white male workers at a uranium processing plant: Fernald Feed Materials Production Center, 1951-1989. Oak Ridge, TN: Center for Epidemiologic Research, Oak Ridge Institute for Science and Education. Unpublished. 29 pg.	1995

continued

Table II-12. Extramural reports

No.	Citation	Year
8	Departments of Behavioral Sciences and Health Education and of Environmental and Occupational Health; Rollins School of Public Health of Emory University, and The Center for Epidemiologic Research Environmental and Health Sciences Division; Oak Ridge Associated Universities, [Undated]. A study of the health effects of exposure to elemental mercury: a followup of mercury exposed workers at the Y-12 plant in Oak Ridge, Tennessee. (DHHS Contract 200-93-2629, Final Technical Report.) Available from the National Institute for Occupational Safety and Health/Health-related Energy Research Branch, Cincinnati, OH, 134 pg.	1994
9	Dupree EA, Wells SM, Watkins JP, Wallace PW, Davis NC [1994]. Mortality among workers employed between 1945 and 1984 at a uranium gaseous diffusion facility. Oak Ridge, TN: Center for Epidemiologic Research Medical Sciences Division; Oak Ridge Institute for Science and Education; (DOE Contract DE-AC05-760R00033, Final report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 24 pg.	1994
10	Ertell K, Takaro T, Shorter C, Stover B, Beaudet N, Barnhart S, Rabito F, White LE [2000]. Results of employee job task analysis (EJTA) quality assessment: Combined analysis for fourteen Hanford contractors. Seattle, WA: University of Washington; 34 pgs. (NIOSH Grant # 1R01 CC12031)	2000
11	Factors EM [1999]. Study of occupational magnetic-field personal exposures associated with Seattle metro transit's electric trolley system. Richland, WA: EM Factors; (CDC NIOSH Contract 200-94-2837, Contractor report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 67 pg.	1999
12	Fix JJ [2001]. Interim final report: Evaluation of dosimetry data for National Institute for Occupational Safety and Health (NIOSH) Collaboration with the International Agency for Research on Cancer (IARC) Nuclear Worker Study. Richland, WA: Pacific Northwest National Laboratory (PNNL); 65 pgs.	2001
13	Fix JJ, Scherpelz RI, Strom DJ, Traub RJ [2005]. Dose validation for NIOSH/HERB multi-site leukemia case control study. PNWD-3538. Richland WA: Battelle Pacific Northwest Division 218 pg.	2005
14	Galke GA, Johnson ER, Tietjen GL [1992]. Mortality in an ethnically diverse radiation exposed occupational cohort. Los Alamos, NM: Los Alamos National Laboratory; Unpublished. 70 pg.	1992
15	Kaune WT [1999]. Study of occupational magnetic-field personal exposures of non-flying airline employees. Richland, WA: EM Factors; (CDC NIOSH Contract 200-94-2837, Contractor report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 52 pg.	1999

continued

Table II-12. Extramural reports

No.	Citation	Year
16	Mitchell RJ, Ostrouchov G, Frome EL, Kerr GD [1993]. A method for estimating occupational radiation dose to individuals, using weekly dosimetry data. Oak Ridge, TN: Oak Ridge National Laboratory; 46 pgs. (DOE Contract # DE-AC-05-84OR21400)	1993
17	Newman LS [2002]. Final performance report: Beryllium disease natural history and exposure-response. Denver, CO: Division of Environmental and Occupational Health Sciences, National Jewish Medical and Research Center, Department of Medicine and Department of Preventive Medicine and Biometrics, University of Colorado School of Medicine; 17 pgs. (Cooperative Agreement # U60/CCU812221-05)	2002
18	Newman LS, Mroz MM, Ruttenber JA [2002]. Lung fibrosis in plutonium workers. Division of Environmental and Occupational Health Sciences; National Jewish Medical and Research Center, Denver, CO. (DHHS Grant R01 811855. Revised final performance report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 19 pg.	2002
19	Newman LS, Ruttenber JA, Mroz MM [1999]. Lung fibrosis in plutonium workers. Denver, CO: Division of Environmental and Occupational Health Sciences; National Jewish Medical and Research Center; 19 pgs. (DHHS Grant # R01 CCR 811855) One-pager included.	1999
20	Omohundro E, Gilbert E [1993]. An evaluation of the adequacy of vital status follow-up in the Hanford Worker Mortality Study. Richland, WA: Hanford Environmental Health Foundation; (DOE Contract DE-AC06-76RLO 1830, report prepared for the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH). Available from NTIS, Springfield, VA; DE94005179, 40 pg.	1993
21	Ostrouchov G, Frome EL, Kerr GD [1998]. Dose estimation from daily and weekly dosimetry data. Oak Ridge, TN: Oak Ridge National Laboratory; (CDC-NIOSH Grant RO1 OH12956)	1998
22	Pepper L [2000]. The health effects of downsizing in the nuclear industry: findings at the Idaho National Engineering and Environmental Laboratory. Boston, MA: Department of Environmental Health, Boston University School of Public Health; (CDC Cooperative Agreement U60 CCU 112215, Final Report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 129 pg.	2000

continued

Table II-12. Extramural reports

No.	Citation	Year
23	Pepper L [2000]. The health effects of downsizing in the nuclear industry: findings at the Los Alamos National Laboratory. Boston, MA: Department of Environmental Health, Boston University School of Public Health; (CDC Cooperative Agreement U60 CCU 112215, Final Report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 135 pg.	2000
24	Pepper L [2000]. The health effects of downsizing in the nuclear industry: findings at the Nevada Test Site. Boston, MA: Department of Environmental Health, Boston University School of Public Health; (CDC Cooperative Agreement U60 CCU 112215, Final Report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 125 pg.	2000
25	Pepper L [2000]. The health effects of downsizing in the nuclear industry: Pantex. Boston, MA: Department of Environmental Health, Boston University School of Public Health; (CDC Cooperative Agreement U60 CCU 112215, Final Report.) Available from the National Institute for Occupational Safety and Health/Health-related Energy Research Branch, Cincinnati, OH, 133 pg.	2000
26	Pepper L [2000]. The health effects of downsizing in the nuclear industry: findings at the Y-12 Plant, Oak Ridge Reservation. Boston, MA: Department of Environmental Health, Boston University School of Public Health; (CDC Cooperative Agreement U60 CCU 112215, Final Report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 129 pg.	2000
27	Pinney S [2004]. Radon and cigarette smoking assessment in Fernald workers. Cincinnati, OH: University of Cincinnati; 103 pgs. (Grant # 5 R01 CC5 15748-02)	2004
28	Rosenman KD, Gardiner J, Cameron W, Anger KW [2000] United Brotherhood of Carpenters Health and Safety Fund. (DHHS Grant 5 R01 CCR311859, Final performance report.) Available from the National Institute for Occupational Safety and Health/Health-related Energy Research Branch, Cincinnati, Ohio, 76 pg.	2000
29	Rosenman KD, Hertzberg VS, Rice C, Rossman M. Final performance report: Chronic beryllium disease among beryllium-exposed workers cooperative agreement; 25 pgs. (Award #UCO CCU512218)	2001
30	Ruttenber AJ, LaMontagne AD, Van Dyke MV, Martyny JW [2004]. Final performance report: Sentinel exposure event surveillance and evaluation for DOE sites. Denver, CO: Department of Preventive Medicine & Biometrics, University of Colorado Health Sciences Center; 5 pgs. (NIOSH Grant # 1 R01 CCR8120044).	2004

continued

Table II-12. Extramural reports

No.	Citation	Year
31	Ruttenber AJ, Schonbeck M, Brown S, Wells T, McClure D, McCrea J, Popken D, Martyny J [2003]. Report of epidemiologic analyses performed for Rocky Flats production workers employed between 1952-1989: Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH. [Final Report] Unpublished. 75 pgs.	2003
32	Sever LE, Gilbert ES, Tucker K, Greaves J, Greaves C, Buchanan J [1997]. Epidemiologic evaluation of childhood leukemia and paternal exposure to ionizing radiation. Seattle, WA: Battelle Memorial Institute; (CDC Cooperative Agreement U50/CCU012545-01, Final Report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 51 pgs.	1997
33	Shy C, Wing S [1994]. A report on mortality among workers at Oak Ridge National Laboratory: followup through 1990. (PO 3C-70837, Final Report). Oak Ridge, TN: Oak Ridge Associated Universities, 21 pg.	1994
34	Stevens GW and Back DA, [1996]. Hazardous waste, decontamination and decommissioning, and clean-up workers exposure assessment feasibility study at the Department of Energy's Fernald site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 156 pgs.	1996
35	Stevens GW and Back DA, [1997]. remediation workers' exposure assessment feasibility study at the Department of Energy's Mound site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 218 pgs.	1997
36	Stram DO. Measurement error methods for underground miner studies. (DHHS Contract R01 CCR11869-06, Final Report). Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 4 pgs.	2002
37	Tankersley WG [1997]. Potential exposure profile system (PEPS) users guide. Oak Ridge, TN: Oak Ridge Associated Universities; 34 pgs. (CDC Grant R01/CCR412029)	1997
38	Tankersley WG [1997]. Worker exposure surveillance system (WESS) users guide, Oak Ridge, TN: Oak Ridge Associated Universities, 38 pgs. (CDC Grant R01/CCR412029)	1997
39	Tankersley WG, West CM and Gray FE [1998]. Hazardous waste, decontamination and decommissioning and clean-up workers exposure assessment feasibility study at the Department of Energy's Savannah River site, Contract 200-93-2695 for National Institute for Occupational Safety and Health, Cincinnati OH, 142 pgs.	1998

continued

Table II-12. Extramural reports

No.	Citation	Year
40	Tankersley WG, West CM and Gray FE [1999]. Hazardous waste, deactivation, dismantlement, and cleanup workers exposure assessment feasibility study at the Department of Energy Oak Ridge reservation, Contract 200-93-2695 for National Institute for Occupational Safety and Health, Cincinnati OH, 134 pgs.	1999
41	Voelz GL, Johnson ER, Lawrence JNP [1993]. Mortality of 244 male workers exposed to plutonium. Los Alamos, NM: Los Alamos National Laboratory; Unpublished. 16 pg.	1993
42	Wald N, Day R, Shekhter-Levin S, Vergona R, Aimin Z [2001]. acute radiation syndrome in Russian nuclear workers. Pittsburgh, PA: University of Pittsburgh; (NIOSH Grant #1 R01 CCR312952-01, Final Report) Available from the National Institute for Occupational Safety and Health/Health-related Energy Research Branch, Cincinnati, OH, 59 pg.	2001
43	Watkins JP, Frome EL, Cragle DL [2004]. Evaluating time-related variables in occupational epidemiology studies. Final project report. April 2004, Oak Ridge Associated Universities. 57 pp + 3 appendices.	2004
44	West CM, Rutherford BF, Tankersley WG [1997]. Current programs for estimating dose and chemical exposure: Volume I. Oak Ridge, TN: Oak Ridge Associated Universities; 124 pgs. (CDC Grant # R01/CCR412029)	1997
45	West CM, Rutherford BF, Tankersley WG [1997]. Current programs for estimating dose and chemical exposure: Volume II. Oak Ridge, TN: Oak Ridge Associated Universities; 107 pgs. (CDC Grant #R01/CCR412029)	1997
46	Wilkinson GS, Trieff, N, Graham, R [2000]. Study of mortality among workers exposed to ionizing radiation and other physical and chemical agents. Chapel Hill, NC: University of North Carolina at Chapel Hill, School of Public Health; 203 pgs. (DHHS Contract # 200-93-2628)	1997
47	Xue X. Correcting for measurement errors in radiation exposure. (DHHS Contract 1R01 CCR215746, Final Performance Report.) Available from the National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH, 16 pgs.	2002
48	Zimmerman TD [1999]. Remediation workers exposure assessment feasibility study at the Department of Energy's Hanford site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 204 pgs.	1999
49	Zimmerman TD, and Moore AM [2000]. Remediation workers exposure assessment feasibility study at the Department of Energy's INEEL Site - Phase I: Report, Contract 200-98-2006 for National Institute for Occupational Safety and Health, Cincinnati OH, 217 pgs.	2000

SECTION III. Key Outcomes

The strategic goals of NIOSH are to conduct research that will reduce illness, injury and death among workers in the U.S. and worldwide, and to promote healthy and safe workplaces (http://www.cdc.gov/niosh/about.html). NIOSH has also been delegated responsibility by Congress and the President to develop compensation-related policy for DOE site workers with cancer. As shown in Section I and below, the OERP contributes to each of these desired outcomes as they apply to nuclear workers within the U.S. and throughout the world:

I. ***Conduct research to reduce work-related illnesses and injuries.*** A primary mission of the OERP is to conduct research that will contribute to the reduction of work-related injuries, illness and death. Quantification of risk is an important element of reduction efforts. Although the OERP research is still in its early stages, it is anticipated that its findings will be influential in the refinement of state, federal and international radiation exposure standards (See p. 72).

II. ***Promote safe and healthy workplaces through interventions, recommendations and capacity building.*** The OERP has made specific recommendations about workplace practices to DOE as a result of its research studies. The OERP has also contributed to the development of surveillance programs for former and current workers at numerous DOE worksites. NIOSH has conducted health hazard evaluations at several DOE sites to address concerns about health and safety of current workers (See p. 83).

III. ***Enhance global workplace safety and health through international collaborations.*** The OERP has established several important collaborative efforts with international organizations. Researchers are working with IARC on an influential study of cancer deaths occurring among a population of nearly half-million nuclear workers in fifteen countries to evaluate risks associated with low-level exposure to ionizing radiation. OERP researchers contributed invited sessions to an international workshop sponsored by the International Atomic Energy Agency (IAEA) on occupational radiation protection, and to a document on depleted uranium exposures developed by the World Health Organization (See p. 87)

IV. ***Contribute research information to the DOE workers' compensation program on dose reconstruction methodology and the proportion of workers' cancer that is attributable to occupational exposures to ionizing radiation.*** In addition to the strategic goals outlined above, Congress has mandated a role for health studies of nuclear workers in guiding compensation policy, as described in EEOICPA. Section 7384n. (c)(3)(C) of the Act states that "Such guidelines [for establishing the probability that a cancer for an individual worker with cancer was caused by employment in a DOE facility] shall… take into consideration…information on the risk of developing a radiation-related cancer from workplace exposure…". The OERP directly contributes to this effort through its etiologic studies of the association between workplace exposure to ionizing radiation and the risk of cancer. These studies may contribute to assigned share ("probability of causation") calculations for EEOICPA and other compensation programs. The OERP has also contributed data and methods for dose reconstruction, as mandated under EEOICPA. (See p. 88)

Contributions of the OERP toward achieving each of these goals (and supporting intermediate outcomes) are described on the following pages. The success of the OERP in achieving these goals depends on many factors, including the public health importance of the projects in the OERP portfolio; sufficient funding resources; the validity of the scientific methods used in the studies; the ability to communicate key findings effectively to workers, the scientific community and institutions; and a mechanism for ensuring that these recommendations are implemented by organizations with the mandate to do so. This section concludes with a discussion of the rationale for continued epidemiologic and exposure assessment research among DOE worker populations.

Strategic Goal I

Target outcome: reductions in occupational illness, injuries, and fatalities for DOE, nuclear workers and entire US workforce

Public health importance of OERP research

The purpose of this section is to place the research questions addressed by the OERP into a public health context, first by estimating the number and worksites of those occupationally exposed to radiation. Risks among this workforce are then projected based on previous research in acutely exposed non-occupational cohorts, assuming both average exposures and exposures at the current occupational standards. These risks are then compared to more familiar workplace hazards.

The radiation-exposed workforce

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimates that 11 million workers worldwide are monitored for exposure to ionizing radiation.[88] Determining the number of U.S. workers currently exposed to ionizing radiation in the workplace is difficult, however, as there is no central registry of radiation workers or their dosimetry. The only available picture comes from estimates by industry sector.

- A large number of workers are employed in nuclear facilities operated by DOE, DOD, and the commercial nuclear power industry. Approximately 345,000 nuclear workers have been studied within the OERP (Table III-1), with 67,000 workers most recently added from the K25 and Y12 sites at Oak Ridge and the Fernald facility in Ohio. This workforce is among the most extensively radiation-monitored in the U.S.
- An estimated 42% of U.S. workers who receive a measurable radiation dose at work are employed in the medical or dental field.[89] However, many of these workers have not been monitored for exposure to ionizing radiation, although monitoring frequencies have increased over time.
- Airplane crews, a population that is largely unmonitored, are exposed to ionizing radiation at fairly substantial levels [estimated at 0.2 to 5 mSv per year [90]].

Table III-1. Distribution of workers at sites studied by the NIOSH OERP

Site	Location	Number of workers	Percent of total
Idaho National Laboratory (NL)	Idaho Falls, ID	99778	28.9%
Y12*	Oak Ridge, TN	53880	15.6%
Portsmouth Naval Shipyard	Kittery, ME	38377	11.1%
Hanford	Richland, WA	34255	9.9%
K25 Gaseous Diffusion Plant (GDF)	Oak Ridge, TN	29879	8.7%
X10	Oak Ridge, TN	17995	5.2%
Los Alamos NL†	Los Alamos, NM	16050	4.7%
SRS	Aiken, SC	13175	3.8%
Portsmouth GDF	Portsmouth, OH	8822	2.6%
Fernald	Ross, OH	7027	2.0%
Pantex	Amarillo, TX	5336	1.5%
Multiple sites		20866	6.0%
Total		**345440**	**100%**

*Includes Tennessee Eastman Corporation workers

†Includes Zia workers

Projected risks of radiation-induced cancer based on high-dose studies

Workplace exposures to radiation have been estimated in risk assessments to confer substantial risk. For example, a recent study projected cancer risks for workers exposed over a working lifetime to levels of radiation equivalent to both the average in the nuclear industry (1.75 mSv per year) and to the maximum dose limit recommended by the International Commission on Radiological Protection (ICRP) [20 mSv per year (91)]. These projected risks, which are based on extrapolations from high-dose studies of atomic-bomb survivors and medically exposed populations, are shown in Table III-2.

Table III-2. Fatal cancer risk per 35 years of occupational ionizing radiation exposure.(91)

Exposure	Lifetime risk	Average annual risk
Average medical occupation: 0.33 mSv per year	4.6×10^{-4}	7.7×10^{-6}
Average nuclear industry: 1.75 mSv per year	25×10^{-4}	41×10^{-6}
Dose limit: 20 mSv per year	280×10^{-4}	470×10^{-6}

The same study estimated these projected annual fatal cancer risks for nuclear workers at the average dose level in the industry to be comparable to the annual occupational risk of fatal injury for U.S. workers in the manufacturing sector and in all sectors combined. In addition, the projected annual risk among workers exposed for a working lifetime at the maximum dose limit was estimated to be 2.5 times greater than the annual fatal injury risk among U.S. construction workers.[(91)]

From the preceding paragraphs it is clear that:

1. A large group of workers in the U.S. and worldwide is exposed to potentially harmful levels of ionizing radiation in the workplace

2. For this group of workers, projected fatal cancer risks associated with workplace radiation appear to be similar to current risks of injury in U.S. industries, presuming that risk in those occupationally exposed is comparable, per unit of dose, to that observed in high-dose populations.

Rationale for studies of nuclear workers

A key question, therefore, is whether cancer risk per unit of dose extrapolated from high-dose studies reflects the actual risk experienced by workers. This assumption has been questioned by many investigators, some of whom assume that dose protraction reduces risk, and others who assert that risks among workers may be underestimated from high-dose studies.

The most legitimate way to identify and directly quantify risks to workers is clearly through well-conducted epidemiologic studies of workers. It is also highly likely that the public health impact of non-occupational exposures, generally lower than those of workers, may also be better understood through the study of risks in nuclear workers. In addition, DOE workers face health risks from exposures other than ionizing radiation. A public health research program at DOE sites should address questions related to health effects from on-site exposures to chemicals and physical hazards, and possible synergistic effects of radiation with some of these exposures.

The work of the OERP is directed toward achieving the following impacts:

- Development of radiation protection standards based on direct evidence from studies of nuclear workers
- Reductions in exposures to radiation leading to reductions in cancer among nuclear workers
- Reductions in exposures to radiation leading to reductions in cancer among the general public, if warranted

The contribution of the NIOSH OERP to the desired outcome of reductions in illness and deaths associated with workplace exposures may be best understood through consideration of intermediate outcomes—contributions to the body of science that is used to create exposure standards, contributions to the DOE mission, and influence on policy-making groups in the U.S. The relation of the NIOSH OERP to each of these intermediate outcomes is described below.

Contributions to science, including exposure assessment and epidemiologic methods

The importance of continued studies of nuclear workers has been emphasized by the National Academies in the recent report by its Committee on the Biological Effects of Ionizing Radiation (BEIR VII). Although it was anticipated that the BEIR VII report would expand the basis of its risk estimates to include findings from studies in the occupationally relevant dose range, this did not occur due to the cutoff date of 2004 given by the BEIR VII committee for quantitative analyses in its report. However, information on the combined international nuclear workers study supported by OERP funding and research expertise was presented as important, direct evidence of risks associated with low-level occupational exposures. In addition, recommendations were made in the BEIR VII report regarding the importance of continued epidemiologic studies of workers exposed to ionizing radiation (see text box).

Research Needs Identified in the BEIR VII Report Regarding the Health Effects of Ionizing Radiation

- Determination of the level of various molecular markers of DNA damage as a function of low dose ionizing radiation
- Determination of DNA repair fidelity, especially double and multiple strand breaks at low doses, and whether repair capacity is independent of dose
- Evaluation of the relevance of adaptation, low-dose hypersensitivity, bystander effect, hormesis, and genomic instability for radiation carcinogenesis
- Identification of molecular mechanisms for postulated hormetic effects at low doses
- Reduction of current uncertainties on the specific role of radiation in how tumors form
- Studies on the genetic factors that influence radiation response and cancer risk
- Studies on the heritable genetic effects of radiation
- Continued medical radiation and occupational radiation studies
- Continued follow-up health studies of the Japanese atomic-bomb survivors, 45% of whom were still alive in 2000
- Epidemiologic studies to supplement studies of atomic-bomb survivors, for example studies of nuclear industry workers and persons exposed in countries of the former Soviet Union

Recent OERP studies of nuclear workers have also contributed to the basic understanding of health risks associated with low-dose radiation exposures, particularly for diseases such as multiple myeloma [20,48], leukemia [25,26,28], and brain tumors [76,92]. An OERP study of the effects of plutonium on lung cancer risk at Rocky Flats suggests higher risk than predicted based on models derived from low-LET exposures.[74] A second study of Rocky Flats workers showed a plutonium-related risk of lung fibrosis, the first evidence for such an association among U.S. workers.[73] The newly published study of risk among nuclear workers in fifteen countries [83] was also considered to be very informative in the recent publication of BEIR VII and has recently been cited in a *Science* [93] editorial about the effects of low-dose radiation exposure.

Methods for conducting exposure assessment and epidemiologic studies have also benefited from studies conducted by the OERP:

- The importance of evaluating work-required x-rays in occupational epidemiology studies [30,94,95]
- Novel methods of measuring bias and uncertainty in external doses [66-68,96,97]
- Techniques for estimating organ dose from internal emitters using bioassay data [79]
- The importance of time-related factors such as age at exposure and birth cohort in elucidating risk [98-100]
- Methods of successful follow-up of DOE workers with limited demographic information [101]

Citations in the literature reference many studies conducted intramurally or extramurally by the OERP (see sidebar). For example, there are 12 OERP-related citations in the recently published BEIR VII Report [102] and 11 citations in UNSCEAR 2000.[88] Many of the most informative studies with respect to the carcinogenicity of occupational radiation exposures are very recent; citations of this work will likely accelerate in the future.

Search results of OERP publication citations among the open literature using ISI Web of Science® (http://www.isinet.com/).

	Intramural publications	Extramural publications	**Total**
Number of citations	37	713	**750**
Number of OERP documents cited	9	51	**60**

For many years, researchers from the OERP have been active participants in planning the biennial American Statistical Association (ASA) Conference on Radiation and Health, one of the premiere meetings in the field, which brings together epidemiologists, biologists, exposure assessors and statisticians to present and discuss the latest research on the health effects of radiation exposures. Many studies deriving from the OERP have been presented at this conference, including effects of age at exposure on radiation-induced cancer risks among workers, the contribution of work-required x-rays to occupational radiation doses, and effects of low-dose plutonium and photon exposures on lung cancer and leukemia risk, respectively.

Contributions to DOE mission

DOE regulations

OERP studies of DOE workers may make important contributions to the regulations that DOE sets for its workforce to protect against adverse effects (primarily cancer) from exposures to ionizing radiation. NIOSH has commented in the past on such regulations promulgated by DOE. For example, federal regulation 10 CFR 835, "Occupational Radiation Protection", establishes limits on occupational radiation exposures for DOE workers was first promulgated in 1993.[103]

In a letter to the DOE Office of Health in 1992 (104), NIOSH commented on this proposed new regulation. DOE monitoring data for 1987 indicated that 1,540 workers received doses in excess of 10 mSv with no workers receiving a dose greater than 40 mSv. NIOSH calculated lifetime risk estimates for excess fatalities. In its comments, NIOSH stated that "for each 1 rem (10 mSv) reduction in exposure for this population of 1,540 workers, 44.3 excess cancers among this population would be prevented over a working lifetime according to the BEIR V Committee estimates." DOE monitoring data for 1988 indicated that 536 workers received doses in excess of 10 mSv with no workers receiving a dose greater than 30 mSv. Hence, NIOSH concluded "These data imply that it is feasible for DOE to reduce the specified exposure level to 'occupational workers' to below 5 rem (50 mSv)."

In this same document, NIOSH calculated risk estimates for workers exposed annually to ionizing radiation at the level allowed by a proposed occupational limit of 50 mSv over a working lifetime of 45 years. Using the risk estimate from ICRP 60, NIOSH calculated that 90 deaths per 1000 workers could occur which "is much greater than the risk generally accepted in setting regulatory standards for occupational hazards." For perspective, NIOSH then quotes the Supreme Court language which concluded that "at an incidence rate of 1 death per 1000 'a reasonable person might well consider the risk significant and take appropriate steps to decrease or control it.'" [Industrial Union Department v. American Petroleum Institute 448 US 607 (1980)].

NIOSH also commented on the proposed rule for planned overexposures. "The [monitoring] data submitted by DOE and the more recent exposure data strongly imply that there is no need for a 'planned overexposure' to a 5 rem (50 mSv) limit. NIOSH states, "It has been a repeated experience in occupational safety and health that, where protection exposure limits are established and enforced, employers have readily succeeded in overcoming challenges in achieving lower worker exposure concentrations than were previously believed to be infeasible on a technical or economic basis."

The NIOSH recommendations did not result in changes to DOE's proposed occupational standards, which currently remain in effect. These recommendations predated much of the OERP's research program development and publications. As important OERP epidemiologic studies are completed, these recommendations are revisited as NIOSH continues to provide input to DOE and other regulators.

DOE's Strategic Goals

Like many groups, the DOE Environmental Health and Safety group has developed strategic goals by which its progress in accomplishing its mission may be judged. (http://www.eh.doe.gov/EH_Strategic_Plan2003_2006.pdf). The NIOSH OERP contributes primarily to Goal IV (Table III-3). The overall NIOSH and OERP program and research goals are placed into context of the DOE goals in Figure I-1 of Section I, while the following paragraphs describe this in more detail.

The OERP contributes directly to a number of DOE's Goal IV strategies, including the development, conduct and communication to workers of health studies among DOE workers (Strategies IV-1.1 and IV-3.5), and making de-identified study data available in CEDR [http://cedr.lbl.gov/]. The contributions of the OERP to these first three areas are detailed in Section II of this document.

DOE made its database available in 1992 after several years of planning and development. CEDR is "a public-use data base with the goal of broadening independent access to data collected during studies of the health effects of exposure to radiation and other physical agents associated with the production and use of energy" (CEDR Catalog, 1995). OERP epidemiologic and exposure assessment staff assisted DOE in the development of CEDR. The requirement for research organizations to submit epidemiologic data sets to CEDR was included in the first MoU. Both extramural and intramural investigators have submitted data sets, although this was not always a requirement of the grants program. Even with this requirement, it has proven difficult to enforce submission to CEDR with some grants recipients. OERP managers are working with the HHS Office of Extramural Programs to identify ways to be more effective in this area.

The majority of analytic files available in CEDR result from research conducted under the MoU. Recent intramural studies submitted to CEDR include the Portsmouth Gaseous Diffusion Plant mortality study, the Pantex mortality update, the PNS cohort mortality study, the PNS leukemia case control study, and the INL cohort mortality study. According to the DOE, the CEDR website is accessed about 500 times per day by scientists conducting epidemiologic, environmental and health-related research. The recent increase in the volume of records provided to researchers is shown in Figure III-1 (Courtesy DOE web page: http://www.eh.doe.gov/health/hstudies/volume.html).

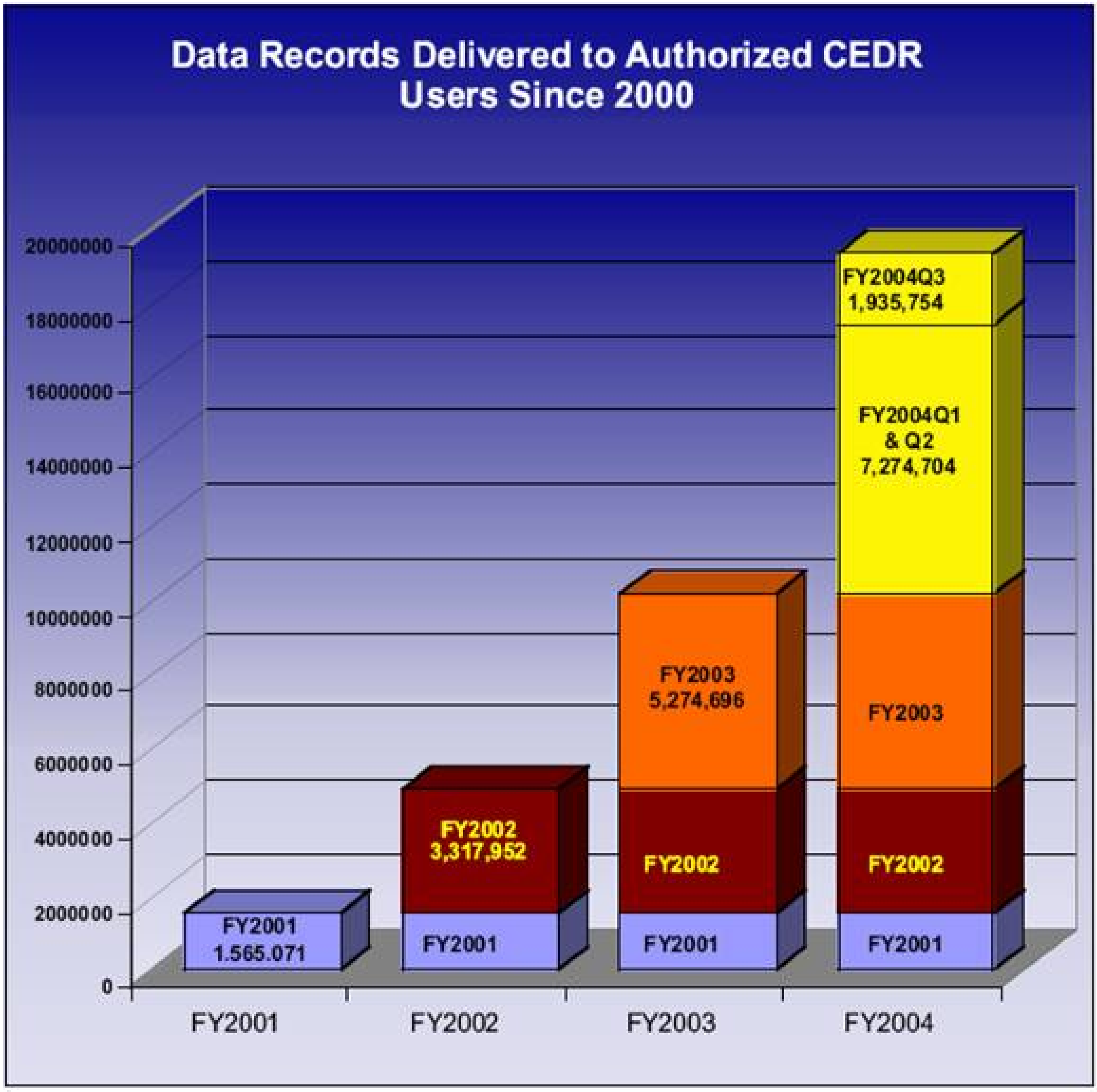

Figure III-1. Record volumes provided to CEDR users between FY01 and FY04 (from DOE web page: http://www.eh.doe.gov/health/hstudies/volume.html).

Influence on U.S. policy-making groups

As described above, research conducted under the OERP adds to the body of scientific knowledge used in setting radiation protection standards. Currently, comprehensive scientific reports such as those produced by the NA BEIR Committees and UNSCEAR rely on information collected from ongoing radiation research programs like the OERP to provide a quantitative basis for limiting radiation exposures.

BEIR Committees and UNSCEAR establish risk estimates as the bases for protection limits recommended by international bodies, such as the ICRP and the IAEA, and U.S. organizations such as the National Council on Radiation Protection and Measurements (NCRP). In turn, these recommendations are relied upon by U.S. regulatory bodies, such as the Environmental Protection Agency (EPA), the NRC, DOE, the Occupational Safety and Health Administration

(OSHA), and Department of Transportation (DOT) for the development and oversight of radiation protection regulations. Given its focus on quantitative exposure estimation in the epidemiologic studies of nuclear workers, the research conducted under the OERP is highly relevant and appropriate for current and future decisions regarding occupational radiation protection standards, which ultimately serves as the cornerstone in nuclear worker protection.

OSHA has recently requested information from NIOSH regarding the health effects of ionizing radiation exposures. It is anticipated that information from key OERP studies will be informative in the standard-setting process that may be undertaken by OSHA.

Table III-3. Contributions of NIOSH-OERP to DOE-EH Strategic Goal IV *

DOE Strategies	Description	NIOSH OERP contributes?	Strategic Impacts for DOE Program
Objective IV-1	Determine adverse health effects to workers and the public from exposures to chemical and radiological materials	Directly	Worker protection programs and policies are based on sound scientific evidence Accurate, reliable information wins the public's trust
Strategy IV-1.1	Conduct health studies to establish the health effects of exposure to chemical and radiological materials	Directly	
Strategy IV-1.2	Maintain a health studies plan that includes DOE site health and risk profiles to guide and inform the need for future studies	Indirectly	
Strategy IV-1.3	Support basic research on the uptake and distribution of transuranics in the body	No	
Strategy IV-1.4	Maintain the beryllium worker and health outcomes exposure registry to determine the prevalence of disease and document the progression of health effects associated with beryllium exposures	Indirectly (advisors to FWMSP)	
Strategy IV-1.5	Make health studies data available to the research community through the Comprehensive Epidemiologic Data Resource	Directly	
Objective IV-2	Ensure state-of-the-art worker safety and health policies are in place	Indirectly	Worker safety and health programs are tailored to the hazards present and workers are on the job in support of DOE mission essential work, thus avoiding lost work days from accidents and injuries, and worker compensation costs. Lost work days and worker compensation costs will be significantly reduced.
Strategy IV-2.1	Actively engage with national and international standards-setting bodies to maintain current knowledge on the scientific basis used by these organizations in developing their standards and revise DOE policies accordingly.	Indirectly	
Strategy IV-2.2	Proactively search the literature and studies concerning the health effects associated with DOE workplace hazards, determine their implications to existing DOE policies and revise policies, as necessary to keep DOE worker safety and health policies current	Indirectly	
Strategy IV-2.3	Maintain relations with appropriate offices in DOE to ensure that the policies are incorporated in contracts, as appropriate to the hazards present.	No[†]	
Strategy IV-2.4	Team with DOE line management and contractor organizations to take actions that result in the efficient and cost-effective implementation of the policies	No[†]	
Strategy IV-2.5	Manage and conduct the EH Federal Employee Occupational Safety and Health (FEOSH) program	No[†]	

* Ensure the safety and health of workers at DOE facilities and the communities that surround them. From DOE EH website http://www.eh.doe.gov/EH_Strategic_Plan2003_2006.pdf

† Outside the scope of the current Memorandum of Understanding with DOE

continued

Table III-3. Contributions of NIOSH-OERP to DOE-EH Strategic Goal IV *

DOE Strategies	Description	NIOSH OERP contributes?	Strategic Impacts for DOE Program
Objective IV-3	Detect and prevent work-related illness with an effective occupational health program	Directly	DOE workers are healthier, resulting in savings in worker compensation costs The adequacy of worker safety and health policy to provide appropriate protection is validated
Strategy IV-3.1	Publish performance expectations for the operation of preventive occupational health programs	No†	
Strategy IV-3.2	Maintain relations with appropriate offices in DOE to assure that the occupational health program policy and model contract language is incorporated in contracts	Indirectly	
Strategy IV-3.3	Team with DOE line management and contractor organizations to take actions that result in the efficient and cost effective implementation of the occupational program policy and model contract language	Indirectly	
Strategy IV-3.4	Proactively engage with DOE line management, contractor management and the occupational medicine physicians across the DOE to ensure continuous improvement in preventive occupational health programs	No†	
Strategy IV-3.5	Proactively communicate health effects information, to include the results of health studies and their implications, to workers and other interested DOE stakeholders	Directly	
Objective IV-4	Process applications for Subpart D of the Energy Employees Occupational Illness Compensation Program Act of 2000 and provide information to the Department of Labor and the Department of Health and Human Services (NIOSH) to support their activities within the EEOICPA	No†	Applicants noted of Physicians Panel outcomes in a timely manner DOE data is not a controlling factor in the DOL/NIOSH, subpart B processing

* Ensure the safety and health of workers at DOE facilities and the communities that surround them. From DOE EH website http://www.eh.doe.gov/EH_Strategic_Plan2003_2006.pdf

† Outside the scope of the current Memorandum of Understanding with DOE

Strategic Goal II.

Target outcome: safe and healthy workplaces through interventions, recommendations and capacity building

Direct recommendations to DOE and its contractors

Through the OERP, NIOSH has made recommendations to improve the capabilities to assess exposures and health outcomes for workers taking part in decommissioning, decontamination and cleanup of DOE weapons laboratories and facilities.[32] Seven DOE facilities undergoing decommissioning and decontamination were assessed (Fernald, Mound, Rocky Flats, Hanford, INL, Oak Ridge, and Savannah River Site), and it was concluded that most of these activities were conducted by multi-tiered contractors and subcontractors with inconsistent monitoring and data collection practices. Information systems were inadequate to capture identities and likely exposures of workers conducting this non-traditional work, complicating attempts to identify hazardous exposures or to study workers in the future. This also reduces the ability to inform workers of any risks associated with their DOE site work. NIOSH communicated these findings to DOE Headquarters and to the relevant sites, and received very positive feedback from both DOE and from worker representatives involved in site cleanup activities. In the five years since this recommendation was presented and discussed with DOE and the individual sites, it is not clear that appropriate actions have been taken. The Office of the Inspector General of DOE reviewed the NIOSH assessment, conducted its own survey of the current workforce at three DOE locations, and issued a report concurring with the NIOSH recommendations.[87]

Prevention of illness and injury through former worker surveillance program

The NIOSH OERP has played an advisory role in several phases of DOE's Former Worker Medical Surveillance Program (FWMSP), which was designed to identify workers at risk of adverse health effects due to workplace exposures (Phase I) and to provide medical monitoring for these workers (Phase II). The FWMSP addresses OERP Program Goals P.3-P.5, and also has provided informative research publications.

Examples of site-specific FWMSP programs include screening for pulmonary fibrosis among Rocky Flats workers with lung burdens of plutonium[73] and screening for bladder cancer in workers at the Oak Ridge K-25 facility; programs common to multiple sites are identification of workers with elevated risk for health effects from exposures to asbestos, beryllium, solvents, and noise. OERP staff reviewed and provided comments on each of the FWMSP projects.

The beryllium screening program for Nevada Test Site (NTS) workers exemplifies how these programs address the NIOSH goal of conducting research to reduce work-related illnesses and injury while supporting the DOE EH strategic plan Goal IV, Objective IV-1. Strategy IV-1.4 of this plan involves ensuring the safety and health of workers at DOE facilities with respect to beryllium exposure. The NTS FWMSP program identifies workers potentially exposed to beryllium and tests them for beryllium sensitivity. Identifying and following sensitized workers allows researchers to evaluate whether removal from exposed conditions can forestall progression to chronic beryllium disease, while detection of workers who already have chronic beryllium disease leads to entry into compensation and lifetime medical treatment programs.

The OERP reviewed all Phase I former worker surveillance project proposals as well as the Phase I project reports, and also participated in meetings with DOE and its surveillance partners. The OERP's review comments were summarized by its Surveillance Activity Coordinator and submitted to DOE. Comments about the Phase I project reports included recommendations about whether to fund Phase II of each project and suggested changes to the scope and/or methods used in Phase I that could enhance the efficacy and efficiency of Phase II projects. Examples of OERP recommendations include: methods for effectively identifying potentially exposed workers, based on knowledge gained through the OERP of site industrial hygiene and health physics data sources; methods for improving outreach to ensure that targeted former workers are aware of screening programs through resources such as community groups and organized labor rolls; and ensuring that screening programs do not duplicate efforts already in place.

While most of these programs are geared to secondary and tertiary prevention through early detection and prevention of disease progression, the information gathered about workplace hazards can have utility for primary prevention among active workers at the sites.

Some researchers working on FWMSP grants were also funded for research at these sites under the OERP's grants program. One such grant included a study of the health effects of downsizing on the workforce at the NTS, which produced a set of recommendations to reduce impacts of downsizing on worker health (see sidebar).[(105)]

Recommended interventions to prevent adverse health effects from downsizing at Nevada Test Site:

- Implement processes and policies that emphasize fair procedures, and open, timely and honest communication to employees in all work units
- Assess workload demands following significant changes to a work unit or department
- Implement regular surveys of the organization, with particular attention to communication, workload, and management relations with the DOE

Health hazard evaluations for workers at DOE facilities

One of the mechanisms developed by statute within NIOSH for evaluating health risks at worksites is the Health Hazard Evaluation (HHE) program. The goal of the HHE program is to reduce injury and illness among workers through evaluation of health effects and exposures at specific facilities and technical assistance for methods to mitigate or reduce exposures. Since 1991, NIOSH has conducted several HHEs in response to requests by workers or site managers at DOE facilities (Table III-4). OERP scientists have participated in many of these investigations, including those at the Paducah facility and the Portsmouth Gaseous Diffusion Plants, INL, and LANL, for a variety of chemical and physical agents including arsenic, lead, fluoride, hexafluoride, noise and UV, EMF and neutron radiation.

Most HHEs at DOE facilities have resulted in a published report. Recommendations and guidance for methods of reducing worker exposures have been routinely shared with managers at workers at the affected sites, as a result of these NIOSH investigations (Table III-4). These recommendations have frequently focused on methods to monitor and reduce exposures to specific non-radiological hazards. Further medical monitoring of potentially affected workers has also been recommended in some investigations. In other instances (e.g., suspected autoimmune disease at a facility within the INL), the fact that no workplace association was detected or likely was also communicated to workers and managers at the facility.

Table III-4. Health Hazard Evaluations (HHEs) conducted by NIOSH at DOE facilities (1991-2005)*

DOE Site	Year	Report ID	Problem or Agent of Interest	Requested by:	NIOSH recommendations or findings
Sandia National Laboratories	1991	HETA 91-260 (106)	Chemicals, UV and EMF radiation in a specific building	Employee representative	Improvements in exhaust ventilation and monitoring; training improvements; UV-protective glasses; ergonomic improvements
Knolls Atomic Power Laboratory	1992	HETA 92-0059 (107)	Asbestos, radiation, lead;	Employee representative	Contractor requests NY Department of Health to perform epidemiologic study.
Paducah Gaseous Diffusion Plant (PGDP)	1993	Not assigned (108)	Carcinogenicity of perfluoroisobutylene (chlorofluorocarbon replacement)	Employee(s)	Improvements in air monitoring and control methods; worker exposure monitoring in affected areas
Idaho National Laboratory (INL)	1993	HETA 93-0740 (109)	Noise, lead	Site and DOE management	Air supply reconfiguration; Substitution of copper-jacketed bullets; handwashing and use of barriers to prevent lead exposures; medical surveillance; use of both earmuffs and plugs.
Portsmouth Gaseous Diffusion Plant (PORTS)	1994	HETA 94-0369 (110)	Fluoride, hexafluoride (HF); unexplained	Employee(s)	Process changes to reduce exposures; better training & exposure monitoring of nearby employees; use of NIOSH sampling methods for HF; rapid treatment of exposed workers.
PORTS	1994	HETA 94-0077 (111)	Arsenic	Employee representative	Use of supplied-air respiratory protection and protective clothing in non-radiological areas; increased exposure monitoring and control
Oak Ridge Y-12 Plant (Y-12)	1994	HETA 94-0181 (112)	Mercury		An epidemiologic study of mercury exposures at Y-12 was completed (54) and is cited in the closeout documentation.
Oak Ridge K-25 Site (K25)	1996	HETA- 96-0071-2584 (113)	Cyanide	Employee(s)	Improvement in risk communication efforts and evaluation of procedures.
PORTS	1996	HETA 96-0198-2651 (114)	Neutron exposures from "slow cooker" process	Employee representative	Potential for substantial neutron exposures exists in this process; specific improvements recommended for monitoring of neutrons
LANL	1998	HETA 98-0240 (115)	Sheet metal work; removal of contaminant controls (lab hoods & ducts)	Employee representative	Incomplete; requested information to close-out investigation was not provided by DOE.
PORTS	2002	HETA 02-0351-2903 (116)	Arsenic, cutting scrap	Management & employee(s)	Improve respirator cleaning and vent methods; continue air & urine monitoring; require respirators
HANFORD	2004	HETA 04-0145-2941 (117)	Tank farm contents	Employee(s)	Provide respirators for workers in tank farms; monitor real-time exposures in head space and breathing zone; medical monitoring of vapor exposed persons
INL	2005	HETA 05-0034 (118)	Auto-immune disease	Employee representative	No apparent connection with workplace.

* Non-OERP funds contributed to many of these HHEs.

Strategic Goal III.

Target outcome: enhanced global workplace safety and health through international collaborations.

The OERP has collaborated on several activities with international organizations, with the expectation of improving global health in the workplace by reducing harmful effects from occupational radiation exposures. These activities include the contribution of research to the global understanding of occupational radiation risks, direct collaboration on international studies, and participation on topics related to global workplace protections.

Research completed under the OERP has been cited by international organizations such as the ICRP and UNSCEAR, which are responsible for establishing recommended limits for occupational exposure to radiation. As the research findings continue to evolve from the occupational studies within the OERP, it is anticipated that such contributions will increase in the future.

Researchers from the NIOSH OERP participated in a recent working group with IARC, which developed a monograph on the evaluation of carcinogenic risks from x-rays, gamma-radiation and neutrons.[(119)] Evidence and determinations provided in these monographs are considered highly influential by standards-setting organizations.

OERP researchers participated in a recent conference coordinated by the IAEA (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1145_web.pdf), the International Labour Organization, and the World Health Organization (WHO), with the goal of developing approaches to protect workers against exposure to ionizing radiation in the workplace.[(120)] Several recommendations to the international standard-setting bodies were made as a result of this conference, including improved identification of exposures among transient clean-up workers, which reflect recommendations made to DOE by OERP itself.

Researchers within the OERP have collaborated with IARC in recently published studies of risks of cancer associated with occupational radiation exposures among nuclear workers in fifteen countries.[(83)] The strength of these studies lies in the use of a combined protocol that reduces the potential for confounding by lifestyle-related and other occupational exposures; however, mortality follow-up is only 94% complete across these cohorts. These studies, which show a small but meaningful elevation of cancer risk associated with workplace radiation exposure, are expected to continue into the future to capture the increase in mortality that will be experienced by this workforce. The DOE cohorts in particular, which are among the largest, oldest and best monitored, will be critical in contributing information to this important international study.

Strategic Goal IV.

Target outcome: research information supporting the DOE workers' compensation program on dose reconstruction methodology and the proportion of workers' cancers attributable to occupational exposures to ionizing radiation

In addition to the contributions to science and to improvements in worker health and safety at the DOE facilities outlined above, nuclear worker studies conducted by the OERP may also affect compensation policy and practices for nuclear workers. Congress has mandated a role for health studies of nuclear workers in guiding compensation policy, as described in the EEOICPA. Section 7384n. (c)(3)(C) states that "Such guidelines [for establishing the probability that a cancer for an individual worker with cancer was caused by employment in a DOE facility] shall… take into consideration…information on the risk of developing a radiation-related cancer from workplace exposure…". The OERP directly contributes to this intended outcome through its etiologic studies of the association between workplace exposure to ionizing radiation and the risk of cancer, as described below. OERP researchers have also contributed to international guidance in development with the IAEA. EEOICPA also mandated that NIOSH develop methods for dose reconstruction within the compensation program, and OERP research has directly contributed to the establishment of these methods.

Contributions to compensation policy under EEOICPA

One of the NIOSH-mandated roles in the compensation program was the development of regulations for determining a DOE worker's cancer to be considered "at least as likely as not" to be related to his or her exposure in the workplace. OERP researchers contributed substantially to the development of the technical basis for this regulation [121,122], which included information specific to the types of exposure experienced by the DOE workforce.

Within the NIOSH compensation program, it is recognized that information from worker studies may be influential on compensation policies. Although most of the risk models underlying the compensation policies are based on analyses among Japanese atomic bomb survivors (http://www.cdc.gov/niosh/ocas/ocasfaqs.html#irep), there are some cancers such as malignant melanoma and chronic lymphocytic leukemia (CLL), for which direct evidence from nuclear worker studies would be more informative, due to the rarity of the diseases in the Japanese population. Several special evaluations of CLL's radiogenicity among nuclear workers are expected to be completed within the next few months, and it is anticipated that these will be highly informative for the compensation program.

In addition, future studies proposed within the OERP have the objective to answer specific questions posed by the compensation program, such as the effects of exposures at older ages among workers, which have been suggested by some worker studies to be higher than at younger ages. Direct studies of combined cohorts of workers exposed to agents not experienced by the atomic bomb survivors, such as plutonium, uranium and neutrons, are expected to address several important questions regarding cancer risk from these exposures, and how it may affect compensability of certain cancers.

OERP research affected dose reconstruction practice for the compensation program, as well. The recognition within the compensation program that work-required medical x-ray doses were potentially significant and should be included in dose reconstruction methodology derived from research conducted within the OERP.[95] In addition, dosimetry data and work history record and data systems developed by OERP were of assistance in the putting the compensation program's dose reconstruction methods into practice.

Development of international guidance for compensation programs

At the request of the IAEA and the International Labour Organization, the OERP participated in a small working group to develop scientific and technical guidance for nations or groups interested in initiating programs to compensate workers for occupational radiation exposures that may have caused cancer or other diseases.[123] It is expected that this report will be presented at a joint committee of these organizations and to the United Nations for consideration by worker representatives and member nations.

Rationale for Continued OERP Research

Despite the volume of research conducted over the past several decades, essential questions remain in assessing health risks from radiation exposures in the workplace. The magnitude of risks associated with chronic low-level radiation exposure is the subject of much scientific and policy debate. Within the past three months, the National Academies' Committee on the Biological Effects of Ionizing Radiations (NA/BEIR) published its BEIR VII Report.[102] It provides comprehensive risk estimates for cancer and other health effects from exposure to low-level ionizing radiation. The Committee evaluated available biological, biophysical, and epidemiologic data during its examination of adverse health effects from ionizing radiation exposures. However, because of the remaining uncertainty in risk estimates from occupational studies, the Committee concluded that current occupational studies, although directly relevant to the estimation of effects of low-dose protracted exposures, are not sufficiently precise to form the sole basis for radiation risk estimates. Therefore, the current risk models continue to rely on the results of the Life Span Study (LSS) cohort of Japanese atomic bomb survivors.

Although the BEIR VII risk models are not currently based on occupational studies, the Committee recognized that studies of occupational radiation exposures, in particular among nuclear industry workers, are well suited for the direct assessment of the carcinogenic effects of long-term, low-level radiation exposure in humans. In its report, the Committee recommends the continued study of nuclear industry workers. It also recommends that data from the LSS should be supplemented with data on populations exposed to low doses and/or dose rates, especially those with large enough doses to allow risks to be estimated with reasonable precision. In addition to the National Academies, other influential bodies [124] and groups of researchers [88] have recommended continued studies of risks associated with occupational radiation exposures.

For many important reasons, the next decade is the best possible time to continue epidemiologic studies of DOE workers. With few exceptions, studies published to date are based upon relatively short follow-up periods, and most workers were still young at the end of follow-up. Continued follow-up into the next decades will result in older cohorts and increased mortality rates. Larger numbers of deaths in mortality studies mean greater power to detect meaningful changes in cancer risk that might be associated with radiation and chemical exposures. OERP researchers have been working to improve the reliability of epidemiologic studies by incorporating detailed and accurate exposure metrics into the study design and analyses. The OERP has developed advanced data management systems that increase the ability to combine records from an array of sources and perform analyses that were previously impractical. Also, radiation monitoring and recordkeeping practices have improved over time, thus reducing bias and uncertainty in recent monitoring data and simplifying future research. Risk estimates based on continuing analysis of these mature cohorts will substantially reduce uncertainty and may suggest changes in exposure limits.

References

1. DOE [1990]. Report to the secretary: The secretarial panel for the evaluation of epidemiologic research activities for the U. S. Department of Energy. U.S. Department of Energy (DOE), Washington DC.

2. NRC [1994]. Epidemiologic research programs at the Department of Energy: Looking into the future. National Research Council. National Academy Press, Washington, DC.

3. NIOSH [2001]. Occupational energy research program. 3 ed. Cincinnati OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 2001-133.

4. CDC [1991]. A workshop on energy related epidemiologic research agenda. Atlanta, GA: U.S. Department of Health and Human Services (DHHS), Center for Disease Control and Prevention (CDC).

5. CDC [1993]. Advisory committee for energy-related epidemiologic research. Minutes of the meeting held January 12 and 13, 1993, at the Centers for Disease Control and Prevention, Chamblee Facility, Building 101. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention (CDC).

6. Shy C and Wing S [1994]. A report on mortality among workers at Oak Ridge National Laboratory: followup through 1990. Oak Ridge Associated Universities, Oak Ridge, TN.

7. Loomis DP and Wolf SH [1996]. Mortality of workers at a nuclear materials production plant at Oak Ridge, Tennessee, 1947-1990. Am J Ind Med 29 (2) 131-41.

8. Dupree EA, Wells SM, Watkins JP, Wallace P, and Davis NC [1994]. Mortality among workers employed between 1945 and 1984 at a uranium gaseous diffusion facility. Center for Epidemiologic Research Medical Sciences Division; Oak Ridge Institute for Science and Education (ORISE), Oak Ridge, TN.

9. Frome EL, Cragle DL, Watkins JP, Wing S, Shy CM, Tankersley WG and West CM [1997]. A mortality study of employees of the nuclear industry in Oak Ridge, Tennessee. Radiat Res 148 (1) 64-80.

10. Wells SM, Cragle DL and Tankersley WG [Undated]. An update of mortality among welders, including a group exposed to metal oxides. Oak Ridge Associated Universities, Oak Ridge Institute for Science and Education (ORISE) Center for Epidemiologic Research; Oak Ridge, TN.

11. Dupree EA, Watkins JP, Ingle JN, Wallace PW, West CM and Tankersley WG [1995]. Uranium dust exposure and lung cancer risk in four uranium processing operations. Epidemiology 6 (4) 370-5.

12. Dupree-Ellis E, Watkins J, Ingle JN, and Phillips J [2000]. External radiation exposure and mortality in a cohort of uranium processing workers. Am J Epidemiol 152 (1) 91-5.

13. Fry SA, Dupree EA, Sipe AH, Seiler DL, and Wallace PW [1996]. A study of mortality and morbidity among persons occupationally exposed to >50mSv in a year: phase I, mortality through 1984. Appl Occup Environ Hyg 11 (4) 334-43.

14. Wiggs LD, Cox-DeVore CA, Wilkinson GS and Reyes M [1991]. Mortality among workers exposed to external ionizing radiation at a nuclear facility in Ohio. J Occup Med 33 (5) 632-7.

15. Wiggs LD, Cox-DeVore CA, and Voelz GL [1991]. Mortality among a cohort of workers monitored for 210Po exposure: 1944-1972. Health Phys 61 (1) 71-6.

16. Wiggs LD, Johnson ER, Cox-DeVore CA, and Voelz GL [1994]. Mortality through 1990 among white male workers at the Los Alamos National Laboratory: considering exposures to plutonium and external ionizing radiation. Health Phys 67 (6) 577-88.

17. Wilkinson GS, Tietjen GL, Wiggs LD, Galke WA, Acquavella JF, Reyes M, Voelz GL, and Waxweiler RJ [1987]. Mortality among plutonium and other radiation workers at a plutonium weapons facility. Am J Epidemiol 125 (2) 231-50.

18. Galke GA, Johnson ER, and Tietjen GL [1992]. Mortality in an ethnically diverse radiation exposed occupational cohort. Los Alamos National Laboratory (LANL), Los Alamos, NM.

19. Voelz GL, Johnson ER, and Lawrence JNP [1993]. Mortality of 244 male workers exposed to plutonium. Los Alamos National Laboratory (LANL), Los Alamos, NM.

20. Gilbert ES, Omohundro E, Buchanan JA, and Holter NA [1993]. Mortality of workers at the Hanford site: 1945-1986. Health Phys 64 (6) 577-90.

21. Gilbert ES, Cragle DL, and Wiggs LD [1993]. Updated analyses of combined mortality data for workers at the Hanford Site, Oak Ridge National Laboratory, and Rocky Flats Weapons Plant. Radiat Res 136 (3) 408-21.

22. Gilbert ES and Fix JJ [1995]. Accounting for bias in dose estimates in analyses of data from nuclear worker mortality studies. Health Phys 68 (5) 650-60.

23. Gilbert ES, Fix JJ, and Baumgartner WV [1996]. An approach to evaluating bias and uncertainty in estimates of external dose obtained from personal dosimeters. Health Phys 70 (3) 336-45.

24. Cardis E, Gilbert ES, Carpenter L, Howe G, Kato I, Armstrong BK, Beral V, Cowper G, Douglas A, Fix J, *et al*. [1995]. Effects of low doses and low dose rates of external ionizing radiation: cancer mortality among nuclear industry workers in three countries. Radiat Res 142 (2) 117-32.

25. Silver SR, Daniels RD, Taulbee TD, Zaebst DD, Kinnes GM, Couch JR, Kubale TL, Yiin JH, Schubauer-Berigan MK, and Chen PH [2004]. Differences in mortality by radiation monitoring status in an expanded cohort of Portsmouth Naval Shipyard workers. J Occup Environ Med 46 (7) 677-90.

26. Yiin JH, Schubauer-Berigan MK, Silver SR, Daniels RD, Kinnes GM, Zaebst DD, Couch JR, Kubale TL, and Chen PH [2005]. Risk of lung cancer and leukemia from exposure to ionizing radiation and potential confounders among workers at the Portsmouth Naval Shipyard. Radiat Res 163 (6) 603-13.

27. NIOSH [2004]. A nested case-control study of leukemia and ionizing radiation at the Portsmouth Naval Shipyard. A nested case-control study of leukemia and ionizing radiation at the Portsmouth Naval Shipyard. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HHS (NIOSH) Publication No. 2005-104.

28. Kubale TL, Daniels RD, Yiin JH, Couch J, Schubauer-Berigan MK, Kinnes GM, Silver SR, Nowlin SJ, and Chen PH [2005]. A nested case-control study of leukemia mortality and ionizing radiation at the Portsmouth Naval Shipyard. Radiat Res 164 (6) 810-9.

29. Daniels RD, Taulbee TD, and Chen P [2004]. Radiation exposure assessment for Portsmouth Naval Shipyard health studies. Radiat Prot Dosimetry 111 (2) 139-50.

30. Daniels RD, Kubale TL, and Spitz HB [2005]. Radiation exposure from work-related medical X-rays at the Portsmouth Naval Shipyard. Am J Ind Med 47 (3) 206-16.

31. Rinsky R, Cardarelli J, Ahrenholz S, Wenzl T, Hornung R, Reeder D, Waters K, and Dill P [2001]. Mortality patterns among uranium enrichment workers at the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio. U.S. Department of Health and Human Services; Public Health Service; Centers for Disease Control and Prevention; National Institute for Occupational Safety and Health; Division of Surveillance, Hazard Evaluations and Field Studies; Health-Related Energy Research Branch, Cincinnati, OH.

32. Silver SR, Robinson CF, Kinnes G, Taulbee T, and Ahrenholz S [2000]. Evaluation of data for DOE site remediation workers. National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH.

33. LaMontagne AD, Van Dyke MV, Martyny JW, Simpson MW, Holwager LA, Clausen B. M, and Ruttenber AJ [2002]. Development and piloting of an exposure database and surveillance system for DOE cleanup operations. Department of Energy. AIHA J (Fairfax, VA) 63 (2) 213-24.

34. LaMontagne AD, Herrick RF, Van Dyke MV, Martyny JW, and Ruttenber AJ [2002]. Exposure databases and exposure surveillance: promise and practice. AIHA J (Fairfax, VA) 63 (2) 205-12.

35. LaMontagne AD, Van Dyke MV, Martyny JW, and Ruttenber AJ [2001]. Cleanup worker exposures to hazardous chemicals at a former nuclear weapons plant: piloting of an exposure surveillance system. Appl Occup Environ Hyg 16 (2) 284-90.

36. Ruttenber AJ, McCrea JS, Wade TD, Schonbeck MF, LaMontagne AD, Van Dyke MV, and Martyny JW [2001]. Integrating workplace exposure databases for occupational medicine services and epidemiologic studies at a former nuclear weapons facility. Appl Occup Environ Hyg 16 (2) 192-200.

37. Van Dyke MV, LaMontagne AD, Martyny JW, and Ruttenber AJ [2001]. Development of an exposure database and surveillance system for use by practicing OSH professionals. Appl Occup Environ Hyg 16 (2) 135-43.

38. Back DA and Stevens GW [1998]. Remediation Workers' Exposure Assessment Feasibility Study at the Department of Energy's Rocky Flats Site - Phase I: Report. Contract 200-98-2006. National Institute for Occupational Safety and Health, Cincinnati, OH.

39. Stevens GW and Back DA [1996]. Hazardous waste, decontamination and decommissioning, and clean-up workers exposure assessment feasibility study at the Department of Energy's Fernald Site - Phase I. Contract 200-98-2006. National Institute for Occupational Safety and Health, Cincinnati OH.

40. Stevens GW and Back DA [1997]. Remediation workers' exposure assessment feasibility study at the Department of Energy's Mound Site - phase I: report. Contract 200-98-2006. National Institute for Occupational Safety and Health, Cincinnati OH.

41. Tankersley WG, West CM, and Gray FE [1998]. Hazardous waste, decontamination and decommissioning and clean-up workers exposure assessment feasibility study at the Department of Energy's Savannah River Site. Contract 200-93-2695. National Institute for Occupational Safety and Health, Cincinnati OH.

42. Tankersley WG, West CM, and Gray FE [1999]. Hazardous waste, deactivation, dismantlement, and cleanup workers exposure assessment feasibility study at the Department of Energy Oak Ridge Reservation. Contract 200-93-2695. National Institute for Occupational Safety and Health, Cincinnati OH.

43. Zimmerman TD [1999]. Remediation workers exposure assessment feasibility study at the Department of Energy's Hanford Site - phase I: report. Contract 200-98-2006. National Institute for Occupational Safety and Health, Cincinnati OH.

44. Zimmerman TD and Moore AM [2000]. Remediation workers exposure assessment feasibility study at the Department of Energy's INEEL Site - phase I: report. Contract 200-98-2006. National Institute for Occupational Safety and Health, Cincinnati OH.

45. DHHS [2005]. Agenda for HHS public health activities for fiscal years 2005-2010 at U.S. Department of Energy sites. US DOE and US DHHS, Washington, DC. U.S. Department of Energy and U.S. Department of Health and Human Services.

46. Wilkinson GS, Trieff N and Graham R [2000]. Study of mortality among female nuclear weapons workers. DHHS Grant Numbers: 1R01 OHO3274, R01/CCR214546, R01/CCR61 2934-01. Department of Social and Preventative Medicine, School of Medicine and Biomedical Sciences, University of Buffalo, State University of New York, Buffalo, NY.

47. Sever LE, Gilbert ES, Tucker K, Greaves J, Greaves C and Buchanan J [1997]. Epidemiologic evaluation of childhood leukemia and paternal exposure to ionizing radiation. CDC Cooperative Agreement U50/CCU012545-01. Battelle Memorial Institute, Seattle, WA.

48. Wing S, Richardson D, Wolf S, Mihlan G, Crawford-Brown D and Wood J [2000]. A case control study of multiple myeloma at four nuclear facilities. Ann Epidemiol 10 (3) 144-53.

49. Kaune WT [1999]. Study of occupational magnetic-field personal exposures of non-flying airline employees. CDC NIOSH Contract 200-94-2837, Contractor report. Battelle Institute, Richland, WA.

50. Factors EM [1999]. Study of occupational magnetic-field personal exposures associated with Seattle metro transit's electric trolley system. CDC NIOSH Contract 200-94-2837, Contractor report. Battelle Institute, Richland, WA.

51. Wenzl TB [1997]. Estimating magnetic field exposures of rail maintenance workers. Am Ind Hyg Assoc J 58 (9) 667-71.

52. Wenzl TB [1999]. Assessment of magnetic field exposures for a mortality study at a uranium enrichment plant. Am Ind Hyg Assoc J 60 (6) 818-24.

53. Letz R, Gerr F, Cragle D, Green RC, Watkins J and Fidler AT [2000]. Residual neurologic deficits 30 years after occupational exposure to elemental mercury. Neurotoxicology 21 (4) 459-74.

54. Rollins School of Public Health of Emory University and Oak Ridge Associated Universities [1994]. A study of the health effects of exposure to elemental mercury: a followup of mercury exposed workers at the Y-12 plant in Oak Ridge, Tennessee. DHHS Contract 200-93-2629, Final Technical Report. Oak Ridge Associated Universities (ORAU), Oak Ridge, TN.

55. Rosenman KD, Hertzberg VS, Rice C and Rossman M [2001]. Final performance report: Chronic beryllium disease among beryllium-exposed workers. Cooperative Agreement #UCO CCU512218. Michigan State University, East Lansing, MI.

56. Newman LS, Mroz MM, Balkissoon R and Maier LA [2005]. Beryllium sensitization progresses to chronic beryllium disease: a longitudinal study of disease risk. Am J Respir Crit Care Med 171 (1) 54-60.

57. Kelleher PC, Martyny JW, Mroz MM, Maier LA, Ruttenber A J, Young DA. and Newman LS [2001]. Beryllium particulate exposure and disease relations in a beryllium machining plant. J Occup Environ Med 43 (3) 238-49.

58. Newman LS, Mroz MM, Maier LA, Daniloff EM and Balkissoon R [2001]. Efficacy of serial medical surveillance for chronic beryllium disease in a beryllium machining plant. J Occup Environ Med 43 (3) 231-7.

59. Martyny JW, Hoover MD, Mroz MM, Ellis K, Maier LA, Sheff KL and Newman LS [2000]. Aerosols generated during beryllium machining. J Occup Environ Med 42 (1) 8-18.

60. Sanderson WT, Henneberger PK, Martyny J, Ellis K, Mroz MM and Newman LS [1999]. Beryllium contamination inside vehicles of machine shop workers. Am J Ind Med Suppl 1 72-4.

61. Newman LS [2002]. Final performance report: Beryllium disease natural history and exposure-response. Cooperative Agreement # U60/CCU812221-05. Division of Environmental and Occupational Health Sciences, National Jewish Medical and Research Center, Department of Medicine and Department of Preventive Medicine and Biometrics, University of Colorado School of Medicine; Denver, CO.

62. Kesniiniene A, Cardis E, Tenet V, Ivanov VK, Kurtinaitis J, Malakhova I, Stengrevics A and Tekkel M [2002]. Studies of cancer risk among Chernobyl liquidators: materials and methods. J Radiol Prot 22 (3A) A137-41.

63. Mitchell TJ, Ostrouchov G, Frome EL and Kerr GD [1997]. A method for estimating occupational radiation dose to individuals, using weekly dosimetry data. Radiat Res 147 (2) 195-207.

64. Ostrouchov G, Frome EL and Kerr GD [1998]. Dose estimation from daily and weekly dosimetry data. CDC-NIOSH Grant RO1 OH12956, Final Draft. Oak Ridge National Laboratory, Oak Ridge, TN.

65. Mitchell RJ, Ostrouchov G, Frome EL and Kerr GD [1993]. A method for estimating occupational radiation dose to individuals, using weekly dosimetry data. DOE Contract # DE-AC-05-84OR21400. Oak Ridge National Laboratory, Oak Ridge, TN.

66. Xue X, Shore RE, Ye X and Kim MY [2004]. Estimating the dose response relationship for occupational radiation exposure measured with minimum detection level. Health Phys 87 (4) 397-404.

67. Xue X and Shore RE [2003]. A method for estimating occupational radiation doses subject to minimum detection levels. Health Phys 84 (1) 61-71.

68. Daniels RD and Schubauer-Berigan, MK [2005]. Bias and uncertainty of penetrating photon dose measured by film dosemeters in an epidemiological study of US nuclear workers. Radiat Prot Dosimetry 113 (3) 275-89.

69. Richardson D, Wing S, Watson J and Wolf S [2000]. Evaluation of annual external radiation doses at values near minimum detection levels of dosimeters at the Hanford nuclear facility. J Expo Anal Environ Epidemiol 10 (1) 27-35.

70. Richardson D, Wing S, Watson J and Wolf S [1999]. Missing annual external radiation dosimetry data among Hanford workers. J Expo Anal Environ Epidemiol 9 (6) 575-85.

71. Stram DO, Huberman M and Langholz B [2000]. Correcting for exposure measurement error in uranium miners studies: impact on inverse dose-rate effects. Radiat Res 154 (6) 738-9; discussion 739-40.

72. Stram DO, Langholz B, Huberman M and Thomas DC [1999]. Correcting for exposure measurement error in a reanalysis of lung cancer mortality for the Colorado Plateau Uranium Miners cohort. Health Phys 77 (3) 265-75.

73. Newman LS, Mroz MM and Ruttenber AJ [2005]. Lung fibrosis in plutonium workers. Radiat Res 164 (2) 123-31.

74. Brown SC, Schonbeck MF, McClure D, Baron AE, Navidi WC, Byers T and Ruttenber AJ [2004]. Lung cancer and internal lung doses among plutonium workers at the Rocky Flats Plant: a case-control study. Am J Epidemiol 160 (2) 163-72.

75. Ruttenber AJ, Schonbeck M, McCrea J, McClure D and Martyny J [2001]. Improving estimates of exposures for epidemiologic studies of plutonium workers. Occup Med 16 (2) 239-58.

76. Schubauer-Berigan MK, Macievic GV, Utterback DF, Tseng CY and Flora JT [2005]. An Epidemiologic Study of Mortality and Radiation-Related Risk of Cancer Among Workers at the Idaho National Engineering and Environmental Laboratory, a U.S. Department of Energy Facility. 2005-131. National Institute for Occupational Safety and Health/Health-Related Energy Research Branch, Cincinnati, OH.

77. DOE [1997]. Access handbook for conducting studies at Department of Energy sites. DOE-EH-0556. U. S. Department of r Energy (DOE), Office of Epidemiologic Studies, Washington, DC.

78. NIOSH [2005]. NIOSH policy on peer-review of intramural projects. National Institute for Occupational Safety and Health (NIOSH), Washington, DC.

79. Daniels RD, Lodwick CJ, Schubauer-Berigan MK and Spitz HB [2005]. Assessment of plutonium exposures for an epidemiological study of US nuclear workers. Radiat Prot Dosimetry, August 4, [Epub ahead of print]; doi:10.1093/rpd/nci330.

80. Watkins JP, Cragle DL, Frome EL, Reagan JL, West CM, Crawford-Brown D and Tankersley WG [1997]. Collection validation, and treatment of data for a mortality study of nuclear workers. Appl. Occup. Environ. Hyg 12 (3) 195-205.

81. Tankersley WG, West CM, Watson JE and Reagan JL [1996]. Retrospective assessment of radiation exposures at or below the minimum detectable level at a federal nuclear reactor facility. Appl. Occup. Environ. Hyg. 11 (4) 330-3.

82. Schubauer-Berigan MK and Wenzl TB [2001]. Leukemia mortality among radiation-exposed workers. Occup Med 16 (2) 271-87.

83. Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, Howe G, Kaldor J, Muirhead CR, Schubauer-Berigan M, et al [2005]. Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. BMJ 331 (7508) 77.

84. Rinsky RA, Zumwalde RD, Waxweiler RJ, Murray WE, Bierbaum, PJ, Landrigan PJ, Terpilak M and Cox C [1981]. Cancer mortality at a Naval Nuclear Shipyard. Lancet 1 (8214) 231-5.

85. Stern FB, Waxweiler RA, Beaumont JJ, Lee ST, Rinsky RA, Zumwalde RD, Halperin WE, Bierbaum PJ, Landrigan PJ and Murray WE [1986]. Jr A case-control study of leukemia at a naval nuclear shipyard. Am J Epidemiol 123 (6) 980-92.

86. Matanoski GM [1991]. Health effects of low-level radiation in shipyard workers. DOE DE-AC02-79 EV10095. John Hopkins University, Baltimore MD.

87. Doggett FD [2001]. Memorandum of September 7, 2001 from Frederick D. Doggett, Manager, Capital Regional Audit Office, Office of Inspector General, U.S. Department of Energy to Assistant Secretary for Environmental Management, EM-1.

88. UNSCSCEAR [2000]. United Nations Scientific Committee on the Effects of Atomic Radiation. Epidemiological evaluation of radiation-induced cancer. Annex I in: Sources and Effects of Ionizing Radiation. United Nations, New York, NY.

89. Kumazawa S, Nelson DR and Richardson AC [1984]. Occupational exposures to ionizing radiation in the United States: a comprehensive review of the year 1980 and a summary of trends for the years 1960-1985. EPA/520/1-8-005. U.S. Government Printing Office, Washington DC.

90. Waters M, Bloom TF and Grajewski B [2000]. The NIOSH/FAA Working Women's Health Study: evaluation of the cosmic-radiation exposures of flight attendants. Federal Aviation Administration. Health Phys 79 (5) 553-9.

91. Lochard J [2003]. Radiation risks in the workplace in perspective. pgs. 143-152 in Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation. Proceedings of an international conference on occupational radiation protection: protecting workers against exposure to ionizing radiation. International Atomic Energy Agency (IAEA), Austria.

92. Ruttenber AJ, Schonbeck M, Brown S, Wells T, McClure D, McCrea J, Popken D and Martyny J [2003]. Report of Epidemiologic Analyses Performed for Rocky Flats Production Workers Employed Between 1952-1989. Colorado Department of Public Health and Environment, Denver, CO.

93. Stone R [2005]. Epidemiology. Russian cancer study adds to the indictment of low-dose radiation. Science 310 (5750) 959.

94. Anderson JL and Daniels RD [in press]. Bone marrow dose estimates from work-related medical X-ray examinations given between 1943 and 1966 for personnel from five U.S. nuclear facilities. Health Phys.

95. Cardarelli J, Spitz H, Rice C, Buncher R, Elson H and Succop P [2002]. Significance of radiation exposure from work-related chest X-rays for epidemiological studies of radiation workers. Am J Ind Med 42 (6) 490-501.

96. Thierry-Chef I, Cardis E, Ciampi A, Delacroix D, Marshall M, Amoros E and Bermann F [2001]. A method to assess predominant energies of exposure in a nuclear research centre--Saclay (France). Radiat Prot Dosimetry 94 (3) 215-25.

97. Thierry-Chef I, Pernicka F, Marshall M, Cardis E and Andreo, P [2002]. Study of a selection of 10 historical types of dosemeter: variation of the response to Hp(10) with photon energy and geometry of exposure. Radiat Prot Dosimetry 102 (2) 101-13.

98. Richardson DB and Wing S [1999]. Radiation and mortality of workers at Oak Ridge National Laboratory: positive associations for doses received at older ages. Environ Health Perspect 107 (8) 649-56.

99. Wing S and Richardson DB [2005]. Age at exposure to ionising radiation and cancer mortality among Hanford workers: follow up through 1994. Occup Environ Med 62 (7) 465-72.

100. Watkins JP, Frome EL and Cragle DL [2005]. Age-based methods to explore time-related variables in occupational epidemiology studies. Proc. Am. Stat. Assoc.

101. Foster SO, Schubauer-Berigan MK and Waters KM [2000]. The specificity of the National Death Index and Social Security Administration death master file when information on social security number is lacking. Am. J. Epidemiol 151 (S) 43.

102. National Academy of Sciences [2005]. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2. National Academies Press, Washington, DC.

103. 10 CFR Part 835. Occupational Radiation Protection. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

104. Niemeier RW [1992]. Memorandum of March 25, 1992 from R. W. Niemeier, Division of Standards Development and Technology Transfer, National Institute for Occupational Safety and Health to R. Thomas Bell, Office of Health (EH-40) U.S. Department of Energy.

105. Pepper L, Messinger M, Weinberg J and Campbell R [2003]. Downsizing and health at the United States Department of Energy. Am J Ind Med 44 (5) 481-91.

106. NIOSH [1991]. Hazard evaluation and technical assistance report: Sandia National Laboratory, Albuquerque, NM. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 91-260.

107. NIOSH [1994]. Hazard evaluation and technical assistance report: Department of Energy, Knolls Atomic Power Laboratory, Schenectady, NY. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No 92-0059.

108. NIOSH [1993]. Hazard evaluation and technical assistance report: Paducah Gaseous Diffusion Plant, Paducah, KY. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. [unassigned].

109. NIOSH [1994]. Hazard evaluation and technical assistance report: Live Fire Range at Protection Technology, Idaho Falls, ID. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 93-0740.

110. NIOSH [1995]. Hazard evaluation and technical assistance report: Martin Marietta, Piketon, OH. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No 94-0369.

111. NIOSH [1996]. Hazard evaluation and technical assistance report: Martin Marietta, Piketon, OH. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 94-0077.

112. NIOSH [2000]. Hazard evaluation and technical assistance report: Martin Marietta Y-12, Oak Ridge, TN. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 94-0181.

113. NIOSH [1996]. Hazard evaluation and technical assistance report: Department of Energy, Lockheed Martin Energy Systems, Inc., K-25 site, Oak Ridge, TN. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 96-0071-2584.

114. NIOSH [1996]. Hazard evaluation and technical assistance report: Portsmouth Gaseous Diffusion Plant/Lockheed Martin Utility Services Inc., Piketon, OH. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 96-0198.

115. NIOSH [2005]. Hazard evaluation and technical assistance report: Johnson Controls Northern New Mexico, Los Alamos, NM. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 98-0240.

116. NIOSH [2003]. Hazard evaluation and technical assistance report: Bechtel Jacobs Co, LLC, Piketon, OH. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 02-0351.

117. NIOSH [2004]. Hazard evaluation and technical assistance report: Department of Energy, Office of River Protection, Richland, WA. Denver, CO: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 04-0145.

118. NIOSH [2005]. Hazard evaluation and technical assistance report: Department of Energy - Idaho Operations Office, Idaho Falls, ID. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 05-0034. NIOSH, Cincinnati, OH (2005).

119. IARC [2000]. IARC Working group on the evaluation of carcinogenic risks to humans: ionizing radiation, Part I, X- and gamma- radiation and neutrons. Lyon, France, 26 May-2 June 1999. IARC Monogr Eval Carcinog Risks Hum 75 Pt 1 1-448.

120. IAEA [2003]. Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation Proceedings of an International Conference in Geneva, Switzerland, 26-30 August 2002. STI/PUB/1145. International Atomic Energy Agency, Vienna, Austria.

121. NIOSH [2002]. NIOSH-Interactive Radioepidemiological Program (NIOSH-IREP) Technical Documentation. Final Report NIOSH Office of Compensation Analysis and Support, Cincinnati, OH.

122. Schubauer-Berigan MK, Elliott LJ, Katz T and Neton J [2003]. Guidelines for determining the probability of causation under the US Energy Employees Occupational Illness Compensation Program Act of 2000. Extended abstract published in International Conference on Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation. Geneva, Switzerland. August 2002. IAEA-CN-91. International Atomic Energy Agency, Vienna, Austria.

123. Gentner N, Gustafsson M, Kutkov V, Land C, Lewis M, Neton J, Schubauer-Berigan M and Wakeford R [2004]. Attributing radiation-linked disease to occupational exposure. Draft Report to the United Nations. International Atomic Energy Agency (IAEA), Vienna, Austria.

124. Matanoski GM, Boice JD, Brown SL, Gilbert ES, Puskin JS and O'Toole T [2001]. Radiation exposure and cancer: case study. Am J Epidemiol 154 (12 Suppl) S91-8.

APPENDIX A
ACERER committee recommendations having impact on the OERP

Table A-I. Advisory Committee on Energy Related Epidemiologic Research (ACERER) Recommendations or Action Items Directed Toward NIOSH OERP or Impacting NIOSH Research Activities

Meeting Date	Recommendation or Action Item	Comments
July 1994	Scope of advisory committee: "The advisory committee will solicit information necessary to its development of an appropriate research agenda, and make its recommendations to the Secretary of HHS and that these recommendations are shared with the Secretary of DOE on all health research issues associated with DOE operations: 1) Epidemiologic research and exposure assessment of workers at federal nuclear facilities and the collection of surveillance monitoring data for epidemiologic purposes." 2) …(relating to community health studies) 3) "The committee shall encourage the continued involvement of workers and communities in the planning , conduct, and discussion of such research. In addition, where related to the scope of the committee's work as defined above, the committee may request and consider information provided by the HHS agencies on matters such as studies of health service needs and resources for communities affected by DOE operations, public health consultations and assessments, and studies on chemical, biological or physical agents that may have public health significance."	The three motions for these changes passed unanimously: • Removed language in scope definition that had ACERER reporting to both Secretaries of DHHS and DOE; • Included language that recommendations to the Secretary of HHS are shared with the Secretary of DOE; • Inclusion of an exposure assessment element for worker studies, providing parallel activities with community health studies (which included an assessment of exposure.)
July 1994	Research addressed by the committee: Drop the "analytic" delineation from the type of epidemiology addressed by the committee.	Committee unanimously agreed to this change due to the difficulty in distinguishing between analytic and descriptive epidemiology.

continued

Meeting Date	Recommendation or Action Item	Comments
October 1994	Creation of a cleanup worker registry including a tracking mechanism, by whatever mechanism deemed appropriate (identification card, etc.) Follow-up discussion clarified intent that motion not be too open-ended, risking that nothing might be accomplished. Specification of an agency to address the work would initiate action and NIOSH could come back to the committee and report that they had insufficient resources to do this. NIOSH would report back in a few meetings. The ACERER Chair requested implementation of this recommendation by no later than the second meeting from this one. (April 1996 would be the second meeting.)	Committee unanimously approved this motion. The ACERER Chair, when questioned as to whom the motion to establish a registry was directed, NIOSH or DHHS, clarified that the committee advises DHHS. The committee would let the agencies determine the best way to implement the recommendation. Dr. Seligman of DOE summarized committee's intent as a call to address how to track and support worker, possibly through a surveillance program.
October 1994	Recommend that DHHS recommend to DOE that Regulations 85/85A be incorporated into any new DOE contracts.	Committee unanimously approved motion and sought to provide a mechanism to address access issues NIOSH encountered in obtaining records, data, and cooperation from DOE sites and contractors to initiate and conduct studies.
April 1996	CDC should work with DOE/EH and NCI to seek collaboration on all national and international activities in which results of research may complement informative needs of CDC for sites at which dose reconstruction is ongoing or planned. Activities of particular interest would be:…(issues 1 and 2 dealt with non-occupational exposures) 3. dose reconstructions of inhalation or ingestion of plutonium, strontium and I^{131} at the Techa River, Chelyabinsk, and the Mayak facility of Russia.	Committee discussed research activities supported by DOE outside of the MOU within the U.S. (Center for Risk Evaluation and Stakeholder Participation or CRESP) and international studies.

continued

Meeting Date	Recommendation or Action Item	Comments
July 1997	"The DHHS Advisory Committee on Energy-Related Epidemiologic Research shall request that the Secretary of DHHS ask the Secretary of DOE to provide a mechanism to ensure that DOE contractors adopt and follow NIOSH procedures for research as contained in CFR 42, 85 and 85A."	Resolution unanimously passed. Sought to address the existence of extensive access delays, while acknowledging (in the preamble) that some progress had been made.
December 1997	A proposal to include in ACERER's purview DOE activities in the areas of health research, worker monitoring, etc. Move sought to amend a sentence in the draft charter to read: "ACERER will provide advice to the Secretary of DHHS to assure appropriate interaction between ACERER and DOE regarding the direction DHHS should take in establishing the research agenda, developing the research plan, and for effectively resolving issues concerning the respective roles of DOE and DHHS in commissioning and managing health-related activities."	Committee unanimously approved this motion.
December 1999	Action Item: NIOSH Research/Worker Right to Know Policy: That NIOSH work with ACERER in developing a 'worker right to know' policy regarding the potential health risks associated with occupational exposure to workplace contaminants. Policy should be extended to conditions in which epidemiological studies are either not feasible or are likely to be inconclusive. Efforts to communicate with the worker community should commence at the earliest opportunity. The exposed employee should be made aware of the range of uncertainty associated with the individual and cohort risk estimates.	Response to ACERER request for information on processes NIOSH uses to inform workers of study results. Previous ACERER discussions had also sought information on how NIOSH obtains worker input on its studies and for its research agenda.