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Development of a Medical Examination Program for Former Workers at a Department of Energy National Laboratory

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Background *As a part of the U.S. Department of Energy (DOE) Former Workers' Medical Surveillance Program, a Needs Assessment was conducted at Los Alamos National Laboratory (LANL). The objective was to identify former LANL employees who may be at significant risk for occupational disease and determine whether a medical examination program could reduce morbidity or mortality. We describe the needs assessment approach used at LANL.*

Methods *An algorithm was developed to make needs determinations. Information on factors including exposure, health impacts, size of exposed populations, and LANL worker concerns and recommendations were obtained. Each of these factors was scored from 1 to 3. The resulting factor sum was then multiplied by a binary (1 or 0) intervention suitability factor which was 1 if both of the following were available: (1) a screening test with acceptable sensitivity and specificity for the health outcome of concern; and (2) an intervention that decreases morbidity or mortality. This resulted in an Intervention Needs Score that was used to set priorities for the medical examination program for the estimated 35,000 former LANL workers.*

Results *Analysis of the algorithm output suggested that six exposure categories be recommended for consideration in a medical examination program. Beryllium, asbestos, and noise clearly warranted inclusion. Lead and ionizing radiation required careful consideration regarding availability of screening tests. Solvents were problematic due to the lack of screening tests and suitable intervention in formerly exposed workers.*

Conclusions *The algorithm approach to the needs assessment at LANL documented that six chemical and physical agents should be considered as candidates for inclusion in a medical examination program for former workers.* Am. J. Ind. Med. 42:443–454, 2002.

KEY WORDS: medical screening; surveillance; DOE

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INTRODUCTION

The Defense Authorization Act of 1993 directed the Secretary of the Department of Energy (DOE) to develop medical evaluation programs for former workers at risk for health problems from hazardous exposures they experienced while working at DOE weapons sites and national laboratories. As a result of this congressional mandate the DOE developed a Former Workers Medical Surveillance Program. Former Worker Medical Surveillance Programs have been established at nine different DOE sites including Hanford, Nevada Test Site, Rocky Flats, Portsmouth, Paducah, Oak Ridge, Savannah River Site, Los Alamos National Laboratory (LANL), and the Idaho National Engineering and Environmental Laboratory. Each program was initiated using a two-phased approach. During the first year (Phase I) each project focused on the need for and the feasibility of examining former workers for the consequence of their past exposures. Phase II efforts involve the development and implementation of an examination program. This work will present an approach to conducting, and the results of, the Phase I Needs Assessment at the Los Alamos National Laboratory.

Los Alamos National Laboratory

LANL is a large research facility with a long tradition of industrial hygiene monitoring and medical surveillance for workers. The Los Alamos Site, one of the original Manhattan Project Facilities, has been continuously in operation since 1943. The Laboratory's original mission to design, develop, and test nuclear weapon technologies has expanded over time to include broad-based programs in energy, nuclear safeguards, biomedical science, environmental protection and clean up, computational science, materials science, and other basic sciences. The University of California (UC) has been the employer for the majority of LANL employees since 1940s. The primary trades contractor for LANL was the Zia company from 1946–1986. This function was taken over by Pan Am World Services from 1986–1991, at which time the contract was awarded to Johnson Controls, Inc. (JCI), which holds the current contract. This company is now known as Johnson Controls of Northern New Mexico (JCNNM). The Los Alamos site draws its workforce from northern New Mexico resulting in a diverse group of employees, including Hispanics and Native Americans. In addition to cultural diversity, the LANL workforce includes a broad range of employees, including unskilled, skilled trades, administrative and professional. Both non-union and union employees are included, with the latter represented by 14 different unions.

METHODS

Needs Assessment Approach

The needs assessment was structured to address the following four questions:

1. What are the specific hazards (chemical, physical, and radiological) and the degree of potential exposure (duration and magnitude), and are they adequately documented?
2. What are the nature and extent of health impacts that are anticipated and are they well understood and appropriately characterized?
3. What is the size of the former worker target population(s)?
4. What are the concerns and recommendations of former workers?

The needs assessment was further complicated by two additional factors. The first was the requirement to prioritize, due to finite resources, the hazards or conditions that are targeted for inclusion in subsequent examination programs. The second was that the targeted hazards or conditions differ in the ability of medical screening tests to validly detect the associated health effects and in the availability of medical interventions that can decrease morbidity or mortality.

Development of Needs Assessment Algorithm

A semi-quantitative algorithm that addresses the four questions driving the needs assessment was developed so that decisions were transparent and thus could be evaluated thoroughly. Semi-quantitative algorithms are commonly used to provide a framework for reaching complex decisions. For example, the American Industrial Hygiene Association in their *Strategy for Occupational Exposure Assessment* manual utilized a similar approach to prioritizing exposure assessment needs [Mullhausen and Damiano, 1998]. In addition, the National Institute for Occupational Safety and Health has developed and utilized a complex computerized algorithm to estimate and prioritize health risks due to chemical exposures on a national scale [Pedersen and Hornung, 1986].

The four questions listed above were addressed by developing a series of semi-quantitative Intervention Needs Factors (INF), referred to as X_1–X_5. These INFs, defined in Table I, were then incorporated into a decision algorithm (Fig. 1 and Eqn. 1) used to evaluate and prioritize former worker medical examination needs. INFs were assigned a numeric value that ranged from one to three and

TABLE I. Summary of Needs Assessment Factor Scores and Their Rationales

Intervention needs factor	Score	Rationale
Number of exposed workers-X_1	3	Exposures involving 5,387 or more workers (the upper tertile of the distribution of the number of potentially exposed workers)
	2	Exposures involving 3,226–5,386 workers (the middle tertile of the distribution of the number of potentially exposed workers)
	1	Exposures involving 3,225 or fewer workers (the lower tertile in the distribution of the number of potentially exposed workers)
Significance of exposure-X_2	3	Evidence of probable significant past exposures. Past exposures were considered to be significant if, based on historical data or judgement, these exposures would result in a large percentage of the exposed workers being included in an ongoing surveillance program if they occurred today
	2	Evidence of possible significant past exposures. Significant exposures were judged to be possible if documentary evidence was limited or in the judgement of the workshop participants these exposures would result in a small percentage of the exposed workers being included in an ongoing surveillance program if they occurred today
	1	This score indicates that significant exposures were unlikely
Documentation of health effect occurrence-X_3	3	Documented health effect is an inherent SHE(O) (e.g., asbestosis, chronic beryllium disease, and silicosis)
	2	Documented health effect is a non-inherent SHE(O) (e.g., noise-induced hearing loss, hepatitis, and various cancers). Therefore, there is suggestive evidence of a health effect that was caused by occupational exposure
	1	Limited evidence of an adverse health effect that could be linked to exposure
Outcome severity-X_4	3	Health conditions that could lead to death
	2	Health conditions that could lead to disability
	1	Health conditions that result in mild symptoms or effects only
Worker concern-X_5	3	Fifty percent or greater of the respondents expressed at least some concern
	2	Twenty-five to forty-nine percent of the respondents expressed at least some concern
	1	Less than 25% of the respondents expressed at least some concern

SHE(O), sentinel health event (occupational).

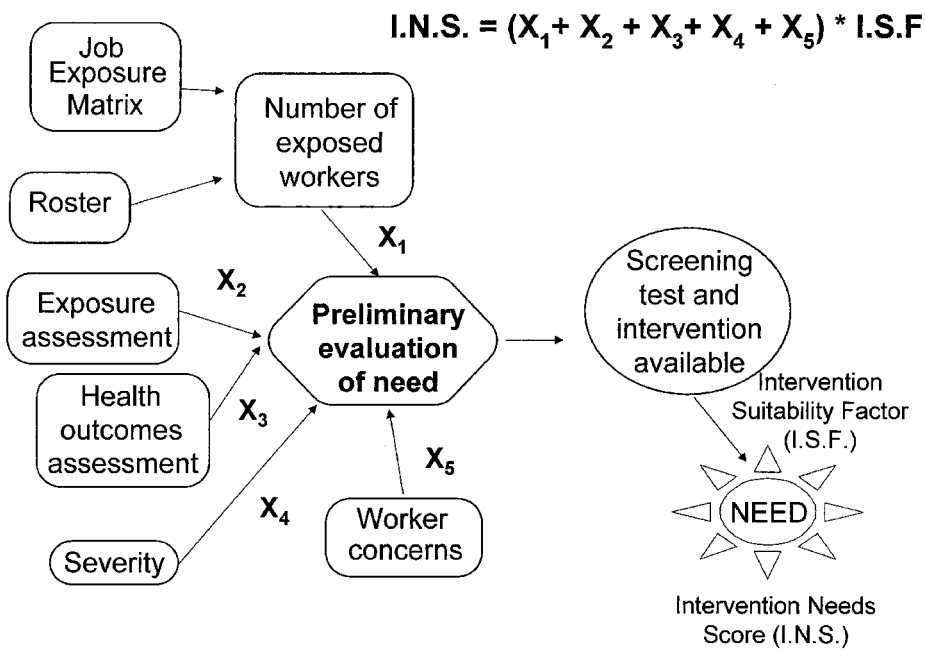

FIGURE 1. Overview of needs assessment process and intervention need factor algorithm.

were used to calculate Intervention Need Scores (INS) for each agent or agent category of concern according to Equation 1.

$$\mathrm{INS} = (X_1 + X_2 + X_3 + X_4 + X_5)\mathrm{ISF} \qquad (1)$$

where X_1 through X_5 are intervention needs factors (INFs) as defined in Table I, and ISF is a multiplier referred to as the intervention suitability factor (discussed below). The final INS results were used to prioritize agent exposure categories for the Phase II examination program.

Assignment of scores to X_1, number of exposed workers, was based on a frequency distribution of the number of exposed workers by specific agent developed from a Job-Exposure Matrix (JEM) constructed as a part of this project. The significance of historical exposures (X_2) was evaluated using historical records wherever feasible. When historical records were not available, judgments were based on professional opinion. To evaluate and score the occurrence of a health effect (X_3), the occurrence of any exposure-appropriate Sentinel Health Effect associated with occupational exposures [SHE(O)] was evaluated [Rutstein et al., 1983]. Outcome severity INF scores (X_4) were developed to help focus on outcomes that could lead to death or serious disability. Finally, worker concern (X_5) was based on information gathered from focus groups.

The sum of the INFs represents a preliminary evaluation of need. The final INS was calculated by multiplying the sum of the INFs by a binary (1 or 0) ISF. For ISF to be equal to 1, two criteria had to be met:

(1) screening tests with acceptable sensitivity and specificity (U.S. Preventive Service Task Force, 1996) are available for the health outcome associated with the specific exposure under consideration; and
(2) an intervention that decreases severity, morbidity, and/or mortality is available.

Using this approach, an INS score was greater than zero only if an acceptable screening test and a beneficial medical intervention was available for the particular exposure induced health outcome. In order to minimize effort the ISF scores were determined early in the process. ISF scores were assigned after agent exposures were determined (during the development the JEM and the determination of the X_1 scores). This allowed us to focus on those agents with ISF scores equal to 1.

It is important to note that the algorithm utilized in this Needs Assessment does not imply risk and is simply intended to incorporate judgments about exposures, potential health effects, and worker concerns in order to provide a relative quantification of former worker medical surveillance needs.

Data Sources

Information needed to score INFs X_1 through X_2 was obtained during extensive data gathering efforts conducted as part of the needs assessment. Data sources reviewed fall into several categories, including data from: (1) large epidemiologic studies performed at LANL [Voelz and Lawrence, 1991; Wiggs et al., 1994; Voelz et al., 1997]; (2) medical surveillance examinations; (3) industrial hygiene; (4) personnel department; (5) unions; (6) workers compensation; (7) radiation health; (8) published articles on LANL processes and health and safety activities; and (9) miscellaneous sources, including training and security records, and old telephone books from the site.

Worker concerns (X_5) were evaluated through a series of focus group interviews and a questionnaire mailing. Four focus groups were conducted during the needs assessment, with three focus groups recruited to be representative of former University of California (UC) workers, the largest employer at LANL, and a fourth group representing former craft workers from the trade unions. The three former UC focus groups represented the diverse workforce. One group included male scientists, researchers, and administrative level employees. The second group included machinists and mechanical technicians. The last UC employee focus group included retired female employees from any employment category (scientist, administrator, technicians, and general support staff). Volunteers for the scientist/administrator group and the women's group were recruited through an e-mail announcement that was sent out to members of the Los Alamos Retirement Group. Machinists were recruited via telephone through a list of former machinists at LANL. Members of the building and construction trade unions identified former members to participate in the craft worker focus group.

RESULTS

Development of a Job Exposure Matrix

An initial step in the needs assessment was the development of a job exposure matrix (JEM). The JEM was needed to identify the variety of historical, chemical, and physical agent exposures, to focus data gathering efforts, and to help determine the numbers of potentially exposed workers (X_1).

Information for the JEM was primarily obtained from a series of workshops involving study team members and current and former LANL employees familiar with production and health and safety activities. JEM development procedures are summarized in Figure 2 and included several steps. The first step involved classifying all job titles at LANL into a common classification scheme. The primary source of job title information was the epidemiologic rosters from which the first and last job titles of individuals employed

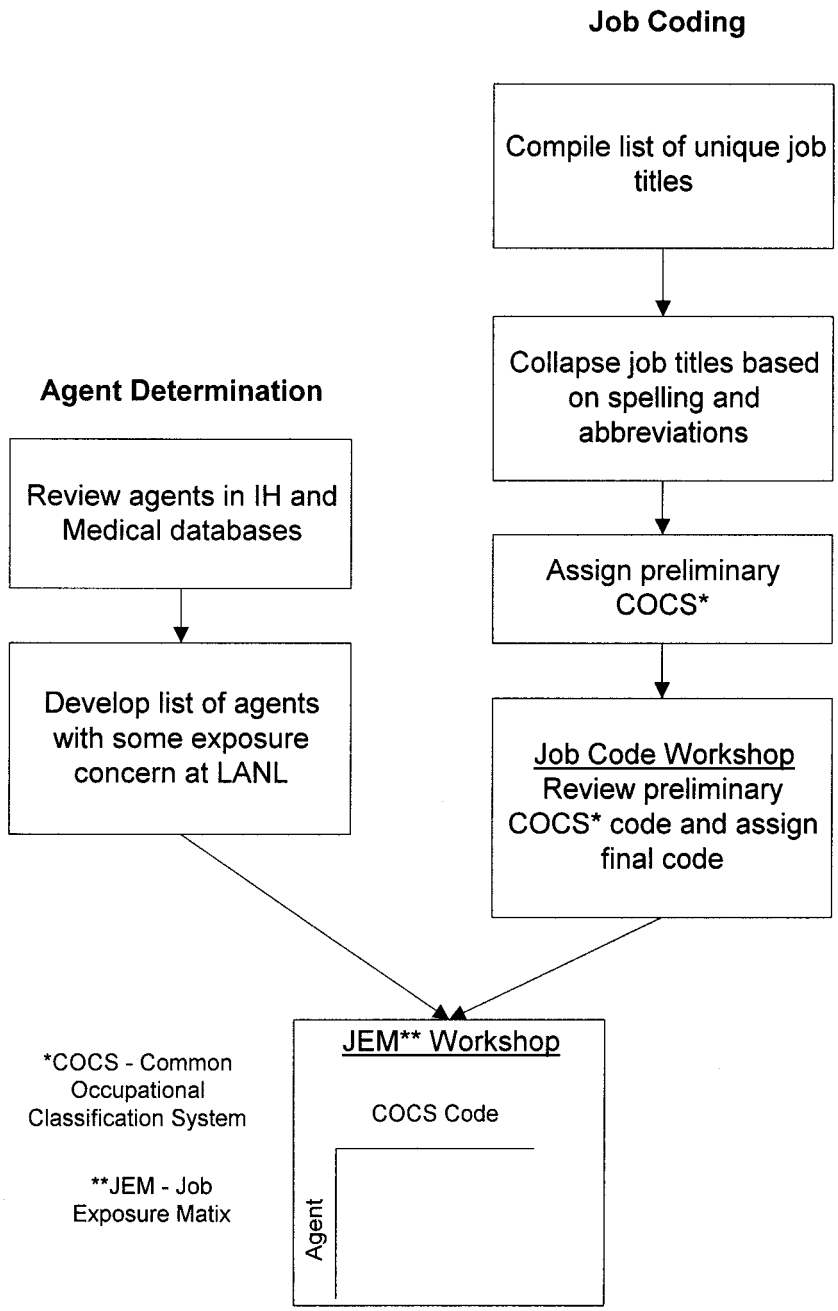

FIGURE 2. Summary of the procedure used to develop a job exposure matrix at LANL.

from the mid 1940s to the late 1970s were obtained. Once extracted, the job title database was sorted, cleaned, and condensed resulting in the collapsing of approximately 12,000 job titles into 2,000 titles. This collapsing was primarily based on combining different job title abbreviations and spellings. For example, the original database had the job title "secretary" listed in multiple ways including: SEC, SEC., SECRETARY, and SEC1. These job titles were all combined into a single secretary job title.

The next step involved assigning a common code based on a standard job title classification scheme. The Common Occupation Classification System (COCS) [Stahlman and Lewis, 1996] was chosen to code LANL job titles because they were developed for the DOE and have been used by other DOE-sponsored Medical Surveillance Needs Assessments. Job titles were assigned unique COCS codes at a two-day job title coding workshop. Primary COCS code categories, which were slightly modified for LANL, are

TABLE II. Description of Primary COCS Code Categories Used to Construct the Job Exposure Matrix

COCS code	Description
A000	Unknown job title
C000	Crafts
E000	Engineers
G000	General administrative, secretarial, and clerical support staff
L000	Laborers and general service workers
M000	General managers, executives, first line supervisors, and program/project managers
N000	Nevada test site workers
P000	Professional administrative and related occupations
R000	Operators
S000	Scientists
T000	Technicians
Y000	Staff members
Z000	Faculty, students, and visitors

listed in Table II. In order to create the other axis of the JEM, the LANL industrial hygiene air sampling databases were queried to provide a listing of all agents sampled from 1990 to present (i.e., the time period for which these electronic databases are active). These queries resulted in a preliminary listing of agents for the JEM that included 39 different agents or agent categories including metals, solvents, and radioactive materials and physical agents such as noise and ultraviolet radiation.

A second two-day workshop resulted in the binary assignment of exposure (yes or no) for each of the agent categories and COCS job codes in the JEM. A given job title was assigned an associated exposure if, in the consensus of the workshop participants, the majority of individuals having that job title were likely to be exposed to that agent. This decision was made based on the collective expertise of the workshop participants. A number of job titles (primarily craft-related) were recognized to be mobile in nature. As a result, exposures of plumbers, electricians, or construction workers would be extensive and vary depending on job task and location within the Laboratory. It was decided to assign these jobs a wide range of possible exposures and to include exposure to asbestos or radioactive materials where it was reasonable to assume that there was an opportunity for exposure to these agents. For example, all construction workers were assigned asbestos and radiation exposure.

Size of Former Worker Population (X_1)

A roster of former workers was used to determine the total number of employees potentially eligible for medical screening, and the number of former employees in COCS codes that had specific exposures. The epidemiology databases at LANL, which formed the basis for developing a roster of former workers, divided the information into two separate rosters, one for the UC former employees and one for the major subcontractor (Zia/Pan Am/JCI). The two rosters were kept separate since major differences in job activities existed between the two employers. The epidemiology databases consist of information only through 1977 with vital status to 1990 for UC employees and through 1978 with vital status to 1990 for Zia/Pan Am/JCI (referred to as JCI roster). Therefore, additional personnel databases were used to update the rosters to include former workers from the late 1970s to the present.

The UC epidemiology roster, which contains the original epidemiology database, covering workers from 1943–1977, was updated using personnel records covering UC workers from 1981 to 1998. A 3-year gap remained for UC workers whose employment was limited to 1978–1980 time period. Only workers whose employment period is wholly contained during those 3 years have been missed. Workers with such short employment durations are not likely to be at a high risk for occupational diseases. In addition, there was a hiring freeze during part of this time period further reducing the number of workers that might have been missed.

The JCI roster includes the original epidemiologic database covering workers employed by the Zia Company from its inception in 1946 through 1978, and information from a computerized human resources database covering all workers employed from 1991 to the present. Therefore, workers hired and terminated between 1978–1991 were not included in the JCI roster.

The rosters, while not entirely complete, include a total of 55,600 individuals prior to removal of deceased and current workers. Demographic information for the former workers is presented in Table III. After removal of currently employed individuals and the deceased, the exposures of 25,140 UC former workers and 11,273 Zia/Pan Am/JCI former workers were determined after defining their COCS codes linkage to the JEM. UC former workers were 65% male and had a mean age of 56 years (Table III). In contrast, former Zia/Pan AM/JCI workers were older with a mean age of 70 years and among workers for whom gender information was available, a larger proportion were male.

After definition of the COCS codes and linkage to the JEM, the number of exposed workers could be estimated for 39 different agents (Table IV). Among the former Zia/Pan Am/JCI workers, the three agents with the largest number of potentially exposed individuals were asbestos (N = 6614), noise (N = 4547) and, external radiation (N = 3799). For former UC workers, the three agents with the largest number of exposed individuals were lead (N = 5072), external radiation (N = 4895), and other solvents (N = 4532).

These are initial estimates of the number of exposed workers for several reasons. First, if workers in a particular COCS code were exposed only during some decades, all workers in that code were considered exposed. Second, the

TABLE III. Summary of Demographic Information for Former LANL Workers

	UC (n = 25,140)	Zia/Pan Am/JCI total n = 11,273
Mean age in 1998[a]	**56 years (n = 25,040)**	**70 years (n = 9,328)**
Gender		
Males	65.2%	55.5%
Females	34.2%	9.0%
Missing	0.6%	35.5%
Race (male employees)		
White	75.6%	82%
Oriental/Pacific Island	2.5%	0.03%
Native American	0.9%	1.2%
Black	1.1%	0.2%
Missing	19.9%	16.5%
Race (female employees)		
White	81.8%	76.1%
Oriental/Pacific Island	1.7%	0.1%
Native American	1.5%	1.4%
Black	1.4%	0.1%
Unknown	13.5%	22.3%

[a]Age data available for 25,040 and 9,328 UC and Zia/Pan Am/JCI former workers, respectively.
UC, University of California employees; Zia/Pan Am/JCI, major former worker subcontractors; Zia Company, Pan Am World Services and Johnson Controls.

exposures of workers in the mobile COCS categories without specific job locations were difficult to estimate with any certainty. As described earlier, a mobile COCS job category is any craft worker whose job tasks will require him/her to be in areas where there is the possibility of exposure to a wide range of agents including asbestos and radioactive materials. The assignment of a variety of exposures to these mobile job titles was a deliberate attempt to cast a broad net in order to be as inclusive as possible. Existing rosters provided an important starting point for this effort. It is recognized that these rosters are not complete. Future efforts will focus on filling in the JCI roster and expanding the rosters to include more recently retired workers.

Determination of Intervention Suitability Factors

The JEM contained information on 39 different agents or agent categories grouped as metals, solvents, radioactive materials, non-radioactive physical agents, and other agents. In order to efficiently focus further data gathering efforts, the next step in the process was to assign each agent an ISF. Agents assigned ISFs equal to 0 were removed from consideration for inclusion in the medical screening program and as a result were subject to less intense data gathering efforts.

TABLE IV. Target Population Size Estimates by Agent Exposure Categories in the Job Exposure Matrix (JEM)

Agent	ZIA/JCI/Pan Am roster	UC roster	Total
General categories			
All metals	3655	5174	8829
All radiation	4118	4917	9035
All solvents	1839	4599	6438
Specific agents			
Americium	3316	4306	7622
Arsenic	378	1753	2131
Asbestos	6614	4184	10798
Benzene	563	2662	3225
Beryllium	3186	4196	7382
Cadmium	1839	3793	5632
Carbon tetrachloride	114	3133	3247
Chlorinated solvents	1030	4356	5386
Chromium	1013	3287	4300
Cobalt	378	1753	2131
Degreasers	1104	3364	4468
External radiation	3799	4895	8694
Fiberglass	2103	398	2501
Glycol ethers	113	2926	3039
Isocyanates	335	89	424
Lasers	134	1226	1360
Lead	2727	5072	7799
Manganese	536	921	1457
Mercury	980	2676	3656
Metal working fluids	962	3242	4204
MOCA	0	86	86
Nickel	681	3285	3966
Noise	4547	4405	8952
Other aromatic solvents	1182	3337	4519
Other isotopes	3316	4306	7622
Other metals	805	3512	4317
Other solvents	1839	4532	6371
PBB/PCB	1762	2443	4205
Pesticides/herbicides	1605	1051	2656
Plutonium	3316	4306	7622
Polonium	3278	3315	6593
Radiofrequency/microwaves	1044	2779	3823
Rock dust/silica	2258	2275	4533
Uranium	2976	963	3939
UV radiation	3636	4411	8047
Vanadium	427	2708	3135
Vibration	2151	3370	5521
Welding fumes	1526	2605	4131

Zia/Pan Am/JCI, major former worker subcontractors; Zia company, Pan Am World Services and Johnson Controls; UC, University of California employees; MOCA-4, 4′-methylene bis(4-cyclo-hexylisocyanate); PBB, polybrominated biphenyl; PCB, polychlorinated biphenyl.

TABLE V. Rationale for Assigning ISF = 1

Hazard	Screening test[a]	Intervention (other than exposure cessation)
Asbestos	Chest X-ray, spirometry	Smoking cessation, pulmonary rehabilitation, influenza and pneumococcal vaccines, correct diagnosis decreases additional diagnostic intervention
Beryllium	Lymphocyte proliferation test, chest X-ray	Steroids and other interventions noted for asbestos
Cobalt	Chest X-ray, spirometry	Steroids and other interventions noted for asbestos
Lead	Clinical neurologic exam, BUN, creatinine	Consider therapeutic chelation if at least moderately increased chelatable lead level[b]
4,4′-Methylene bis(4-cyclo-hexylisocyanate)	Urine cytology	Early diagnosis and surgical intervention
Noise	Audiometry	Hearing aids
Ionizing radiation	Complete blood count, thyroid stimulating hormone, chest X-ray	Dictated by test abnormality; i.e., medication for thyroid disease
Rock dust/silica	Chest X-ray, spirometry	Tuberculosis screening, other interventions as for asbestos
Solvents	Clinical neurologic exam, liver function tests	Dependent on test abnormality
UV radiation	Clinical skin exam	Surgical intervention

[a]The selection of the screening tests in this program were arrived at by consensus of the investigators in the Former Worker Programs.
[b]Lin et al. [2001].
See text for further discussion.
BUN, blood urea nitrogen.

Nine of the 41 agents contained in the JEM were assigned ISFs equal to 1. Table V summarizes the rationale for assigning ISF = 1 for these agents.

Numerous carcinogens were not recommended for inclusion in the medical screening program because effective screening tests and interventions for most cancers are not available. For example, screening for leukemia in formerly exposed benzene workers was not felt to meet both criteria for the ISF since there is no accepted screening test for leukemia (i.e., high positive predictive value in early disease) and the myelodysplastic and aplastic syndromes were not thought to be suitable for screening after exposure has already ceased since they are thought to occur during active exposure.

In general, selection of screening tests and interventions that are valid for currently exposed workers, in terms of the sensitivity and specificity of screening tests or the value of intervention, may not be applicable to workers whose exposures have ceased. This is due to the fact that exposure cessation is often the most important intervention in current workers, but has no role in former workers, assuming workers have not taken jobs after termination of employment with LANL that involve similar exposures. This was a particular problem for solvents. The consensus screening tests included a clinical neurologic examination of the central and peripheral nervous systems and liver function tests. However, a high false positive rate is a limiting factor for these tests when performed in workers who are no longer exposed. The utility of serum bile acids and liver ultrasound was evaluated, but these tests were ultimately not included since they are currently considered appropriate only for research applications.

Evaluation of Specific Hazards (X_2)

Exposures to agents with ISF scores equal to 1 were assessed by reviewing and summarizing readily available quantitative monitoring information using industrial hygiene databases, and relying on the professional judgement of industrial hygienist familiar with historical activities. In most cases, with the exception of beryllium and noise, historical exposure data were not stored in electronic format and were therefore not accessible for this needs assessment due to the relatively short duration, 1 year, of the effort.

In general, agents were given INFs (see Table I) equal to three if, based on direct evidence or professional opinion, a significant number of exposed workers would be included in a medical surveillance program if their exposures occurred today. When exposure to a specific agent was judged to be possible but not likely to result in large numbers of individuals in surveillance programs a score of two was given. Finally, an INF score of 1 was assigned when significant exposures were unlikely. Agents with a significant number of exposed workers given an X_1 equal to three included asbestos, beryllium, lead, noise, and ionizing radiation.

Not surprisingly, asbestos was widely used at LANL. A recent survey for asbestos-containing materials (ACM) conducted at the laboratory identified a wide variety of materials including thermal insulation on pipes and boilers, acoustic surface treatments, floor coverings, gaskets, friction

products, and transite wall board. ACM are present in every technical area (TA, a work area within LANL) with some TAs having ACM in every building. Although historical exposure data were not accessible for this needs assessment, it is reasonable to assume that exposures to employees in a variety of craft occupations (such as, plumbers and pipefitters, insulation workers, and construction workers) were likely. In addition, asbestos worker is a job title at LANL. Former workers reported that metallurgists made their own asbestos ovens and aprons in the past, resulting in asbestos exposure to workers in this job title.

Beryllium has been a health hazard concern at LANL since the 1940s. Dr. Harriet Hardy, an early beryllium expert and pioneer in US occupational health, was employed at LANL as head of the Occupational Health Program in the late 1940s. Many exposure controls were recommended by her as early as 1948 [Mitchell and Hyatt, 1957]. Publications from the 1950s discuss monitoring results and show examples of early exposure control methods [Mitchell and Hyatt, 1957]. For example, Hyatt and Milligan [1953] reported that beryllium metal was processed in the shops and metallurgical labs and soluble beryllium salts were handled in the chemical labs.

In addition to the published literature, industrial hygiene records and interviews with current LANL workers familiar with historical aspects of beryllium operations at the site were used to develop an understanding of beryllium use at LANL beginning in the late 1940s. A total of 4,528 airborne beryllium sampling results were extracted from the LANL air sampling database. These records indicate that activities involving beryllium have been performed at 20 technical areas (TAs) between 1948 and 1980 with airborne beryllium levels averaging 1.67 mg/m^3.

The use of lead at LANL parallels its regulatory history. As more restrictive control measures were implemented through federal legislation the Laboratory activities utilizing lead and lead containing materials diminished. The Laboratory used numerous lead products, for example, lead foil, powders, bricks, blocks, wool, and sheets and other types of shielding. Lead powder was used by the ceramics and metallurgy sections and lead was machined and formed in the machine shops.

Over a 40-year period, there were also several foundry operations where lead products were made and recycled. At the foundry, workers melted and cast lead ingots and lead materials used for radiation shielding for use in various Laboratory programs. Lead recycling and smelting operations (ingot production) were also conducted in a foundry operated by ZIA company. Lead was also used in the explosives research conducted at multiple sites throughout the Laboratory. Pipefitters worked with lead throughout the Laboratory conducting typical maintenance work that included maintaining sewerage piping (cast iron with lead joints and seals) and performing lead soldering. In addition, lead-based paints were used by painters and other construction workers and were also removed from surfaces by a variety of craft workers. Other operations involving lead included using gas torches to melt lead and the use of lead-acid batteries. Finally, LANL security force employs a live fire range for target practice and training exercises. An armory is operated for the maintenance of firearms.

Computerized noise monitoring data between 1983 and 1987 were reviewed as a part of this needs assessment. Noise exposure monitoring at LANL focused on the shops (machine, wood), the compressed gas facility, test firing, drilling and grinding operations, injection molding and construction work. These results indicate that noise exposures greater than 85 dBA were common among workers employed in these activities.

Los Alamos workers have worked with many different types of radiation, with the most common being external whole body radiation (including tritium) and plutonium. In addition, Los Alamos workers have handled americium, polonium, uranium, cesium, and other radioactive materials. Exposures to these substances have been monitored since the 1940s using pocket chambers, film badges, thermoluminescent dosimeters, urine bioassays, whole body counting, area monitoring, and other methods.

The widespread use of radioactivity at LANL is well documented. Practically ''every conventional industrial process encompassed laboratory and manufacturing operations involving radioisotopes'' [Hyatt and Milligan, 1953]. The levels of exposures have varied widely, ranging from below detection to three fatalities occurring in separate radiation criticality accidents. Exposures activities range from routine maintenance work to fires and explosions involving pyrophoric metals, and reactor and other source leaks.

Nature and Extent of Health Impacts (X_3, X_4)

The nature and extent of the health impacts were evaluated by documenting their occurrence and assessing their severity. Multiple sources of information were utilized to evaluate the occurrence of health effects that could be work related. Existing medical surveillance data (e.g., International Classification of Diseases, 9th edition [ICD-9] diagnoses, chemistry, X-ray, spirometry and audiogram databases) as well as workers compensation records and illness and injury logs were extensively analyzed as a part of this assessment. Other sources include interviews with current and past LANL physicians and current and former workers, as well as published information.

In order to identify occupational disease, a sentinel health event (occupational) [SHE(O)] approach was used [Rutstein et al., 1983]. We focused our search for health outcomes to those adverse health effects that are known, or suspected to be, caused by the exposures to agents with ISF scores equal to 1. There are several important limitations of

this approach. For example, (1) many occupational medical surveillance programs do not evaluate the occurrence of important health effects associated with some of these exposures (i.e., central or peripheral nervous system effects of solvents or lead); (2) the available screening tests for some occupational diseases are insensitive and non-specific (i.e., BUN and creatinine for renal disease); (3) recognition of the work-relatedness of occupational diseases can be difficult, due to long latency, non-specificity of presentation, and multifactorial etiology (i.e., peripheral neuropathy, certain cancers); and (4) the use of existing data sources is inherently limited by what was looked for, diagnosed, and reported in the past.

Because of these limitations, documented occurrence of any inherent SHE(O) (e.g., asbestosis, mesothelioma, and chronic beryllium disease) was taken as strong evidence that disease was caused by past occupational exposure. The documented occurrence of a non-inherent SHE(O) (e.g., noise-induced hearing loss and leukemia) was taken as suggestive evidence that disease was caused by past occupational exposure. This assessment did not include the calculation of epidemiologic effect measures (i.e., incidence, prevalence, relative risk) because the existing data were inadequate in this regard; thus, our determination does not hinge on numbers of cases, attributable risk of disease, observed to expected numbers, or other epidemiologic measures.

As an example, the data reviewed and the rationale for assignment of INF(X_3) for beryllium is briefly reviewed. Due to the known toxicity of beryllium, a chronic beryllium disease (CBD) case tracking system, involving physician review of medical records, is used at LANL. In contrast to disease prevalence at other DOE sites, CBD has been an uncommon diagnosis at LANL. Of the seven known cases, two received their beryllium exposure prior to working at LANL and most were diagnosed in the early decades of LANL operation. In comparison, CBD has been diagnosed in 1–2% of workers at some DOE sites and up to 8.5% in high risk groups such as beryllium machinists at Rocky Flats [Pavlova et al., 1998; Stange et al., 2001]. Y-12 at Oak Ridge has a total of 25 workers with CBD and Rocky Flats has 83 as of April 1998 [Pavlova et al., 1998].

In addition to a targeted history and physical, surveillance participants at LANL have spirometric testing and chest X-rays, and lymphocyte proliferation testing. Surveillance test results have been computerized since 1980 and information on workers is kept in the database even after they leave employment at LANL. As on April 1998, test results from 147 former and 305 current workers were contained in the database. The use of lymphocyte proliferation testing (LPT) in beryllium exposed workers can improve medical screening for CBD by identifying those workers who have become sensitized to beryllium and are at increased risk for developing CBD [Maier and Newman, 1998]. At the time of this Needs Assessment, 87 current LANL employees have had blood sent for LPT testing. Two of them have had abnormal LPTs. One of these subjects has undergone clinical evaluation and there was no evidence in support of a diagnosis of CBD.

The LANL Medical Surveillance and Examination Database was also utilized in the assessment of possible health effects from beryllium. For beryllium, we assessed whether other cases of CBD were present in addition to those noted in the beryllium case registry. This database contains four individuals with ICD-9 code for beryllium related diagnoses and 18 with sarcoidosis, that prior to LPT testing, was a potential CBD misdiagnosis.

In summary, these data provide evidence of an inherent SHE(O) from beryllium at LANL. Therefore, $X_3 = 3$ for use in Equation1.

In addition to the occurrence of occupational diseases, the final determination of need incorporated an assessment of severity (X_4). Severity of adverse health outcome was based on accepted occupational health principles. Health conditions that could lead to death were given the highest priority, followed by conditions that could lead to disability and those that resulted in mild symptoms or effects only.

Assessment of Former Worker Concerns (X_5)

Assessment of former worker concerns is a critical portion of the Needs Assessment. Several strategies were used to assess the health and exposure concerns of former LANL workers. Initial efforts involved disseminating information about the program through newspaper, newsletter, and web page articles, laboratory bulletins, meetings with unions, and other worker groups. Current workers were also included to ensure that they would be aware of the project when they become former workers and because family members may have worked at LANL. A Steering Committee comprised of both current and former workers as well as community members was constituted to provide ongoing advice to the project.

The concerns of former workers were ascertained by conducting focus groups with former LANL workers in New Mexico. Three former UC-worker focus groups and a fourth focus group of former craft workers from the trade unions were recruited. A total of 30 former workers participated. Each session lasted for approximately 2 hr. Demographically, the focus groups consisted of 80% males, 77% white, ranging in age from 44 to 83 years.

Themes covered with the focus groups included:

- the health and exposure concerns of former workers;
- the medical surveillance program, what services should be offered, who should be included, and the most important benefits;

- barriers to participate in such a program;
- questions about health related to the workplace, who should answer workers' questions, and how health information gets to workers;
- how should the individual information be given to workers; and
- ways to locate and communicate with former LANL workers.

In order to obtain additional information and to encourage individuals to offer opinions that they may not offer in a group, a questionnaire was developed for use at the end of the focus group discussion period. The questionnaire was used to collect demographic and work history information as well as information on common medical conditions and exposure concerns.

When asked to mention concerns about specific exposures, radiation exposures were mentioned most frequently. The other major exposures included asbestos and lead with about one-quarter of the former workers mentioning these agents. The primary health concerns were arthritis and various types of cancer. There was an underlying theme in several groups reflecting a cynicism or distrust about the collection of information to be used to actually help workers.

Questionnaire data were used to rank agents by level of concern. The percentages of individuals expressing concern were used to score INF(X_5). If more than 50% of focus group members expressed concern about an agent and $X_5 = 3$ was assigned.

Final Determination of Need

The final intervention needs scores that were possible based on Equation 1 are 0 and 5–15. Exposures with INS scores of 11–15, in the upper half of the INS range, were recommended for inclusion in the screening program. Using this approach beryllium, asbestos, and noise are clearly included. Lead, solvents, and ionizing radiation were also included after careful consideration regarding availability of screening tests and interventions as well as worker concerns. However, the solvent category remains problematic due to the lack of an effective screening test since liver function tests are not useful after exposure has ceased.

It is important to note that exposures to agents in categories with a final score below the initial cut-off could be included in later years of Phase II if new information is identified to change the final score. Such information could include increased worker concerns and results of our initial screening efforts. Alternatively, Phase II may reveal that medical screening for some agents, we have selected, will not be of enough benefit to continue that screening.

CONCLUSIONS

Through their Former Worker Medical Surveillance Program the DOE is recognizing the responsibility to extend occupational medical surveillance beyond currently employed workers to include former workers. Development of such a program is difficult because (1) former worker populations are not typically enumerated or tracked once they leave employment at the DOE laboratories; (2) historical exposure and surveillance data are not easily accessible; and (3) traditional medical surveillance concepts, designed for current workers, can not always be directly translated to former workers. Given these limitations and difficulties, we have presented a needs assessment approach that represents the first step in developing a former worker surveillance program. The needs assessment approach presented in this article is a structured evaluation of the historical hazards present, the nature and extent of health impacts resulting from those exposures, the numbers of potentially impacted former workers, and an assessment of former worker concerns. It is important to reiterate that the algorithm utilized in this Needs Assessment does not imply risk and is simply intended to incorporate judgments about exposures, potential health effects and worker concerns in order to provide a relative quantification of former worker medical surveillance needs. There are many gaps in our understanding of historical exposures and health effects that have necessitated simplifying assumptions.

Based on this approach, we have identified exposure categories for which previously exposed former workers are recommended for inclusion in a screening program. We envision the needs assessment approach as an iterative process where new information is continually sought and decisions about inclusion or exclusion are periodically re-evaluated.

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