Surveillance of Respiratory Diseases Among Construction and Trade Workers at Department of Energy Nuclear Sites

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Background *Medical screening programs were begun in 1996 and 1997 at three Department of Energy (DOE) nuclear weapons facilities (Hanford Nuclear Reservation, Oak Ridge, and the Savannah River Site) to evaluate whether current and former construction workers are at significant risk for occupational illnesses. The focus of this report is pneumoconiosis associated with exposures to asbestos and silica among workers enrolled in the screening programs through September 30, 2001.*

Methods *Workers provided a detailed work and exposure history and underwent a respiratory examination, which included a respiratory history and symptom questionnaire, a posterior–anterior (P–A) chest radiograph, and spirometry. Both stratified and multivariate logistic regression analyses were used to explore the risk of disease by duration of DOE employment and frequency of exposure, while controlling for potential confounders such as age, race, sex, and other work in the construction and building trades.*

Results *Of the 2,602 workers, 25.2% showed one or more chest X-ray changes by ILO criteria and 42.7% demonstrated one or more pulmonary function defects. The overall prevalence of parenchymal changes by ILO criteria (profusion 1/0 or greater) was 5.4%. In the logistic regression models, the odds ratio for parenchymal disease was 2.6 (95% confidence interval (CI) = 1.0–6.6) for workers employed 6 to 20 years at Hanford or Savannah River and increased to 3.6 (95% CI = 1.1–11.6) for workers employed more than 35 years, with additional incremental risks for workers reporting routine exposures to asbestos or silica.*

Conclusions *Continued surveillance of workers is important given their increased risk of disease progression and their risk for asbestos related malignancies. Smoking cessation programs should also be high priority and continued abstinence for former smokers reinforced. Although the observed respiratory disease patterns are largely reflective of past exposures, these findings suggest that DOE needs to continue to review industrial hygiene control programs for work tasks involving maintenance, repair, renovation, and demolition.* Am. J. Ind. Med. 43:559–573, 2003. *© 2003 Wiley-Liss, Inc.*

KEY WORDS: DOE; Hanford; Oak Ridge; Savannah River; asbestos; silica; construction; trades; radiograph; parenchymal; pleural; surveillance

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BACKGROUND

In 1993, Congress added Section 3162 to the Defense Authorization Act, calling for the Department of Energy (DOE) to determine whether workers within the nuclear weapons facilities were at ''significant risk'' for work-related illnesses and if so, to provide them with medical surveillance. In 1996, DOE established six pilot programs, including two programs directed at construction workers at the Hanford Nuclear Reservation in Richland, Washington, and at the Oak Ridge Reservation in Oak Ridge, Tennessee. These programs are conducted by a consortium from the Center to Protect Workers' Rights, University of Cincinnati; Duke University; Medstar Research Foundation/Washington Hospital Center, and Zenith Administrators. In 1997, a program was initiated at the Savannah River Site (SRS) in Aiken, SC.

Construction trade workers employed at nuclear weapons facilities have potential exposures to a number of respiratory hazards during facility construction, maintenance, and renovation. Construction workers at Hanford, Savannah River, and Oak Ridge were mostly employed by sub-tier contractors and typically not considered to be 'permanent employees'. Therefore, work history and exposure information on them is either non-existent or very sporadic and unreliable and most were not included in site medical surveillance programs. Medical surveillance programs for construction trade workers at Hanford, Oak Ridge, and Savannah River were developed and implemented. The focus of this report is pneumoconiosis, based on chest radiographs and pulmonary function tests, associated with exposures to asbestos and silica among workers enrolled in the screening programs through September 30, 2001.

MATERIALS AND METHODS

Surveillance Program Overview

The surveillance programs at all sites were designed and implemented through a two-step process. Phase 1 consisted of needs assessment conducted over approximately 12 months. Available information characterizing site processes, work, and potential exposures was evaluated in order to determine whether workers had potentially experienced exposures sufficient to place them at significant disease risk. These needs assessments were subjected to an external review to determine whether the Phase 2 occupational medical screening process would be authorized; all three of these projects were approved for Phase 2 implementation.

Data from the Phase 1 needs assessments were used to develop appropriate surveillance instruments and protocols for workers participating in Phase 2. The screening uses a two-step design with the initial step consisting of a work history interview. The purpose of the interview is to determine whether a worker has sufficient evidence of exposures or health concerns to merit referral to step two of the screening. The work history interview is conducted in person or by telephone by trained project outreach staff interviewers, most of whom were retired trade and craft workers using computer-driven screens. Prior to the interview, workers are given a list of questions to help them recall their work at the sites. During the interview, extensive use is made of site-specific information such as site maps and process descriptions by building to help with recall [Bingham et al., 1998].

The work history focuses on the type of trade and whether the worker was engaged in, or subjected to hazards identified during Phase 1 and reported in the needs assessments. Workers are asked a detailed list of questions about: (1) working in or around high-hazard work tasks such as sand blasting or asbestos insulation application or removal; (2) working with or around high-hazard materials such as asbestos or silica; and (3) working in buildings or areas associated with potential exposures to hazardous materials or where known exposure incidents or emergencies occurred. For each component of the occupational exposure history, workers are asked to qualitatively estimate his/her extent of exposure to the task, material, or building. Each task or material exposure is assigned a qualitative frequency value by the interviewer based on responses provided by the worker as follows: (1) rarely, (2) few times per month, (3) couple of times per week, (4) daily or most days per week, (5) continuous.

We used information reported by workers relative to tasks and materials associated with exposures to asbestos, silica, or welding. These exposures are typical of construction and maintenance activities and not confined to any particular site building or work area. Data on buildings where these workers frequently worked are being used to define potential beryllium exposures and will be reported separately.

The medical screening examinations are performed under contract with local clinical providers who were selected by the program and required to adhere to a detailed protocol. The medical examination includes a detailed medical history, smoking history, limited physical examination, and tests for medical effects from specific hazards. The findings from each examination are reviewed by the project nurse coordinator and medical director (when necessary) before they are reported to the participant by the examining physician. Quality assurance is done through on-site visits, chart reviews, and periodic data evaluations to identify and explain unusual patterns. Workers completing the screening program are requested to complete a short questionnaire concerning program quality and participant satisfaction.

Table I shows the number of construction workers at risk, and the number of participants who have completed the screening program through September 30, 2001; a combined

TABLE I. Project Characteristics, DOE Construction Workers

Parameter	Hanford	Savannah River	Oak Ridge
Date site opened	1943	1949	1943
Approximate number of workers ever employed	109,000	67,000	—
Number of workers potentially available for screening	30,000	37,000	8,000
Number of workers screened	1,652	1,227	1,088

Note: Data in this table were taken from the Phase 1 needs assessment for each site.

total of 3,967 workers. Because participation in the program is voluntary, and workers may chose to accept only parts of the protocol, there are potential selection biases, both with regard to selection into the screening program, and in terms of the tests that participants have agreed to accept once they are in the program. Data in this table was derived from the Phase 1 needs assessments at each site.

Respiratory Disease Surveillance

The respiratory examination focuses on pneumoconiosis screening and includes a respiratory history and symptom questionnaire, chest radiograph, and spirometry. The respiratory history and symptom questionnaire was adapted from the American Thoracic Society (ATS) DLD-78 questionnaire [Ferris, 1978]. Workers included in the respiratory examination receive a posterior–anterior (P–A) chest radiograph, classified by a local B-reader according to International Labor Office [ILO, 1980] Classification of Radiographs of Pneumoconiosis [ILO, 1980]. For purposes of the analyses presented in this report, a parenchymal abnormality is defined as a profusion score of 1/0 or greater for any shape or size of small opacity. A pleural abnormality is defined as presence of any notations of positive findings in sections 3A-D of the NIOSH ILO coding form.

Spirometry is obtained according to the local provider's standard practices for pulmonary function tests, with ATS standards serving as the acceptable benchmark [American Thoracic Society, 1987]. An effort is made to obtain a minimum of three acceptable tracings with reproducibility of forced expiratory volume in 1 sec (FEV_1) and forced vital capacity (FVC) within 5% between the two best efforts; however, no spirometric tests are rejected based on poor reproducibility alone, as recommended by Eisen et al. [1984]. For the present analyses, abnormal spirometry results were identified using the prediction equations of Crapo et al. [1981] and the 95% confidence interval (CI) calculation procedures associated with these equations. Individual pulmonary function tests were placed into categories as follows:

- normal lung function: FVC $\geq$ 95% CI for predicted value and FEV_1/FVC $\geq$ 95% CI;
- obstructive disease: FEV_1/FVC $<$ 95% CI and FVC $\geq$ 95% CI;
- restrictive disease: FVC $<$ 95% CI and FEV_1/FVC $\geq$ 95% CI;
- mixed obstructive/restrictive disease: FEV_1/FVC $<$ 95% CI and FVC $<$ 95% CI.

A small number of workers (1.1%) were missing race information and these were assumed to be Caucasian for purposes of calculating expected PFT values.

Data presented in this report are for 2,602 workers who had completed both the chest radiograph and spirometry components of the medical examinations through September 30, 2001. These data are thus a subset of all workers who have been examined by these programs. All data collected by these programs are stored in Microsoft Access data management systems (DMS). In addition to providing data storage and management capability, the DMS is used extensively for program management, quality control, and reporting. For these analyses, custom queries were developed to extract appropriate demographic, work history, exposure history, and medical information. These data were converted to SAS data sets for statistical analyses. All analyses presented in this report were conducted using PC SAS Version 8 [SAS Institute, Inc., 1999].

Both descriptive and multivariate analysis methods were used. Demographic data were summarized by calculation of means and standard deviations of study parameters such as age, DOE work time, etc. Stratified analyses were used to explore trends in disease frequency by age, employment duration, and cigarette smoking history. Unconditional logistic regression was used to further explore the risk of disease by duration of DOE employment and frequency of exposure to asbestos, silica, or welding while controlling for potential confounders such as age, race, sex, and other work in the construction and building trades at non-DOE sites.

Separate regression models were developed for parenchymal and pleural X-ray changes only. In the parenchymal model, all workers with an ILO profusion score of 1/0 or greater for small opacities were classified as a case. For the pleural only model, a case was defined as workers with any pleural X-ray change marked in section 3 A-D of the NIOSH ILO coding form. Workers with normal chest X-rays were used as the internal referent group for both models. In order to generate the best parsimonious risk estimates, both models included covariates for sex, race (white and non-white), age (categories <45, 45–54, 55–64, 65+), and smoking (ever versus never smoked). Duration of DOE site work was used as a surrogate of exposure duration in the models and was introduced as a categorical variable (≤5, 6–20, 21–35, and >35 years). Workers with fewer than five years of DOE work were thus used as the referent category for calculation of adjusted odds ratios. Using a similar approach, risk associated with non-DOE trade work was estimated using a categorical variable for duration of trade work (≤5, 6–20, 21–35, and >35 years).

In addition to use of duration of work as an exposure surrogate, qualitative exposure category data for asbestos, silica, and welding/cutting from the occupational history data was summarized and introduced into the regression models. For these analyses, additional effects of reporting having been exposed to ''constantly'' (i.e., frequency category 5) were explored. For each material, workers were assigned the maximum category based on either reported tasks or materials. A dichotomous variable was introduced into models reflecting whether or not a worker achieved a frequency category of five.

RESULTS

Descriptive and Stratified Analyses

The frequency of tasks and material exposures for craft and trade workers at all three sites are summarized in Figure 1. For each worker, the list of tasks and materials resulting in potential exposures to asbestos and silica was reviewed, as these were the primary exposures likely related to the risk of pneumoconiosis among these workers. Welding/cutting fume exposures also were reviewed as some studies have shown intense welding exposures to be associated with an increased risk of interstitial pulmonary fibrosis [Buerke et al., 2002]. In many instances, a worker reported multiple tasks or materials, which would generate an exposure. For example, many workers reported working with asbestos thermal insulation products, as well as other asbestos containing materials such as asbestos cement products, gaskets, or valve packings. These workers might also report having applied or removed asbestos insulation. Data in Figure 1 presents the maximum exposure category report by workers combining both task and materials. These data show that most workers completing the work history and the respiratory disease component of surveillance examinations reported exposures to asbestos and silica on most days or nearly constantly. The frequency of reported exposures to welding/cutting fumes among these workers is interesting given the small number of workers in this cohort classified as welders. This is largely due to craft and trade workers working in close proximity to each other at the job sites. Our review of reported welding/cutting tasks among these workers found that the task of welding and cutting is not well confined to workers classified as welders. For example, most pipe trade workers identified welding/cutting as a task which they commonly performed.

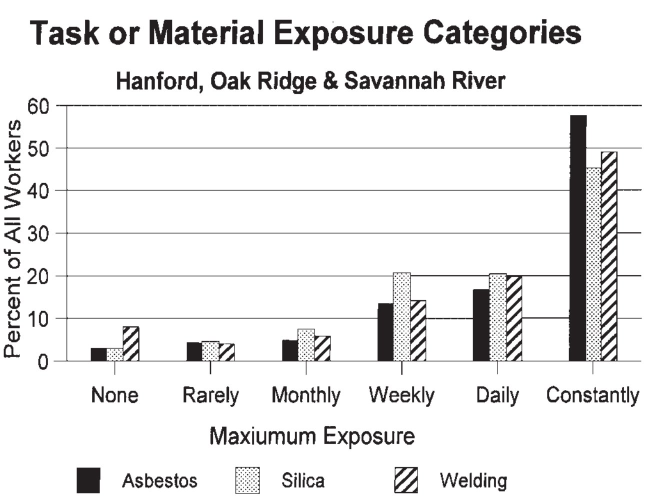

FIGURE 1. Construction worker exposure categories.

Demographic data for 2,602 workers are summarized in Table II. Mean age for all participants was 58.2 years. Overall, 95.7% of the work force was male and 83.3% of participants were Caucasian; however, 25% of Savannah River participants were African-American. On average, these workers were employed 14.5 years. For Hanford and Savannah River, an additional variable was recorded which showed that workers were employed an average of 24.2–28.6 years in their trades.

The study population included a wide variety of trades as shown in Table III with the highest numbers being pipefitters (n = 501), electricians (n = 474), laborers (n = 406), and carpenters (n = 220). However, the distribution by trade varied somewhat by site, as the proportion of pipefitters was lower at Oak Ridge while the number in ''all other trades'' was higher.

Cigarette smoking status for the study population is summarized in Table IV. Consistent with other data for building trade workers, a high proportion had ever smoked and only 33.4% of workers reported to have never smoked [Nelson et al., 1994; Bang and Kim, 2001]. The prevalence of current smokers ranged from 17.4 to 22.0% and the average number of cigarettes smoked per day by these workers was 19.1. A similar level of smoking was reported by former smokers. Former smokers had stopped smoking an average of 19.4 years prior to the current examinations.

Table V presents results of the chest radiographs by site and for all sites combined. The prevalence of one or more X-ray abnormalities using the ILO classification system was 25.2% for all sites combined with a range of 12.1–42.3% across sites. For all sites, the prevalence of parenchymal only changes (profusion ≥1/0) was 2.2% (range 1.7–3.1%) and the prevalence of pleural and parenchymal changes was 3.2%

TABLE II. Demographic Characteristics of Construction and Craft Workers, DOE Construction Workers*

Parameter	Hanford	Savannah River	Oak Ridge	All sites
Number with PFT & B-readers	977	980	646	2,602
Age[a]				
Mean (SD)	61.2 (12.5)	53.6 (12.0)	60.7 (12.7)	58.2 (12.7)
Sex				
Male (%)	968 (99.1%)	890 (90.8%)	634 (98.1%)	2,491 (95.7%)
Female (%)	9 (0.9%)	90 (9.2%)	12 (1.9%)	111 (4.3%)
Race				
Caucasian (%)	887 (90.8%)	705 (71.9%)	602 (93.3%)	2,194 (83.3%)
African-American (%)	27 (2.8%)	245 (25.0%)	30 (4.6%)	302 (11.6%)
Hispanic (%)	23 (2.4%)	5 (0.5%)	1 (0.2%)	29 (1.1%)
Asian/Hispanic (%)	3 (0.3%)	1 (0.1%)	0	4 (0.2%)
Alaskan/Indian (%)	12 (1.2%)	6 (0.6%)	5 (0.8%)	23 (0.9%)
Other of missing (%)	25 (2.6%)	18 (1.8%)	7 (1.1%)	50 (1.9%)
Years at DOE site				
Mean (SD)	13.9 (10.1)	13.5 (8.4)	16.9 (11.5)	14.5 (10.0)
Years in trades[c]				
Mean (SD)	28.6 (12.5)	24.2 (11.3)	N/A[b]	N/A

*Workers completing medical exams though September 30, 2001.
[a]Demographics and other data in this report are for workers completing both the PFT and chest X-rays (B-readers).
[b]Total trade years not available for workers at Oak Ridge.
[c]Years in trades includes both DOE and non-DOE work.

(range 2.0–4.2%). The prevalence of pleural only changes was much higher at Hanford (36.6%) compared to the other two sites (8.4–11.9%).

We evaluated the performance of B readers involved at each site through our quality control programs. The B reader at Hanford reported higher rates of pleural disease. We asked the Hanford reader, the SRS reader, and a third B reader to each read the same set of 30 films and found a high concordance on parenchymal abnormalities, and that the Hanford reader reported more pleural disease than

TABLE III. Trades of Construction and Craft Workers by Site, DOE Construction Workers

Longest trade	Hanford	Savannah River	Oak Ridge	All sites number (%)
Asbestos workers	11	28	8	47 (1.8)
Boilermaker	34	23	9	66 (2.5)
Carpenters	69	73	79	220 (8.5)
Cement masons/finishers	10	11	5	26 (0.9)
Electricians	127	212	135	474 (18.2)
Insulator	8	13	3	24 (0.9)
Ironworkers	81	43	36	160 (6.1)
Laborers	124	161	121	406 (15.6)
Machinists	6	9	5	20 (0.8)
Millwrights	41	23	12	76 (2.9)
Operating engineers	65	49	25	139 (5.3)
Painters	33	37	19	89 (3.4)
Pipefitters	219	211	72	501 (19.3)
Plumbers/steam fitters	77	6	13	96 (3.7)
Sheetmetal workers	41	45	46	132 (5.1)
Teamsters/truck driver	30	29	25	83 (3.2)
Welders	2	5	7	14 (0.5)
All other trades	1	2	26	29 (1.1)

TABLE IV. Smoking Status of Construction and Craft Workers,[a] DOE Construction Workers

Parameter	Hanford	Savannah River	Oak Ridge	All sites
Smoking status				
Never (%)	285 (29.8%)	365 (38.4%)	191 (31.1%)	840 (33.4%)
Former (%)	504 (52.8%)	406 (42.7%)	288 (46.9%)	1,198 (47.6%)
Current (%)	166 (17.4%)	179 (18.8%)	135 (22.0%)	480 (19.1%)
Smoking unknown	22 (2.3%)	30 (3.1%)	32 (5.0%)	84 (3.2%)
Pack-years				
Current, mean (SD)	33.3 (23.7)	26.1 (24.1)	32.1 (22.4)	30.3 (23.6)
Former, mean (SD)	29.3 (24.4)	21.7 (24.7)	16.5 (12.8)	23.3 (24.1)
Cigarettes per day				
Current, mean (SD)	19.2 (9.5)	19.1 (10.9)	18.9 (10.3)	19.1 (10.2)
Former, mean (SD)	21.2 (10.9)	22.3 (13.7)	16.0 (12.8)	20.2 (12.6)
Former smokers, years quit				
Mean (SD)	20.3 (13.9)	16.6 (12.5)	21.9 (14.8)	19.4 (13.8)

[a]Reliable smoking status not available for 84 workers with B-reader and PFT data.

the other two readers. However, we cannot conclude from this small trial that our Hanford reader is incorrect in his assessment, but we can conclude he is more likely to report pleural changes consistent with asbestos related disease.

As can be seen in Table VI, among workers who were found to have a parenchymal abnormality consistent with pneumoconiosis, 65.8% of all recorded parenchymal changes were of profusion 1/0 or greater for small opacities and the highest recorded profusion score was 3/2 in one worker. Among workers with a profusion score of 1/0 or greater for small opacities, 94% showed irregular opacities (ILO s, t, or u), consistent with exposure to asbestos.

Data from the pulmonary function tests (PFT) and the respiratory history questionnaires are summarized in Table VII. For all sites combined, 42.7% of all workers demonstrated a PFT defect (20.5% restrictive, 12.2% obstructive, 10.0% mixed). The prevalence of restrictive defects was higher at Oak Ridge (32.0%) compared to the other two sites (11.1 and 22.4%). Restrictive defects are strongly associated with asbestos and silica exposures; therefore, the higher prevalence of restriction at Oak Ridge is consistent with the slightly higher prevalence of parenchymal chest X-ray changes (Table V). It is interesting to compare Oak Ridge and Hanford workers with regard to their distribution of profusion scores (Table VI). Approximately, 50% of Hanford workers noted to have any parenchymal changes had a profusion score less than 1/0 compared to only about 30% at Oak Ridge. Our data suggest greater exposure to asbestos among the Oak Ridge cohort as demonstrated by higher profusion scores and PFT changes showing restriction. The highest prevalence of obstruction was observed for Hanford workers. Oak Ridge workers were found to have the highest prevalence dyspnea, consistent with the higher prevalence of parenchymal X-ray changes and restrictive PFT defects among these workers.

A cross-tabulation of chest X-ray and PFT results is presented in Table VIII and several interesting patterns emerge. Among workers with a normal chest X-ray, 39% were found to have an abnormal PFT. Likewise, 20.3% of workers with normal PFTs were found to have one or more chest X-ray abnormalities, with pleural changes being highly predominant. Among workers with only pleural changes by X-ray, 23.8% showed restriction, 14.8% showed obstruction, and 14.2% had mixed obstruction/restriction. A simple χ^2 statistical test of association between PFT and X-ray findings was highly significant.

Tables IX presents stratified analyses of chest X-ray data by age and duration of DOE site work. The prevalence

TABLE V. Distribution of Parenchymal and Pleural Abnormalities, DOE Construction Workers

Chest radiograph result	Hanford	Savannah River	Oak Ridge	All sites
Negative (%)	563 (57.6%)	861 (87.9%)	522 (80.8%)	1,945 (74.8%)
Positive parenchymal only (%)[a]	20 (2.1%)	17 (1.7%)	20 (3.1%)	57 (2.2%)
Positive pleural only (%)[b]	358 (36.6%)	82 (8.4%)	77 (11.9%)	517 (19.9%)
Both positive (%)	36 (3.7%)	20 (2.0%)	27 (4.2%)	83 (3.2%)

[a]ILO profusion score of 1/0 or greater.
[b]Any pleural abnormality based on ILO criteria.

TABLE VI. Distribution of ILO Profusion Scores for Small Opacities Among Workers Reported as Having any Parenchymal Abnormality, DOE Construction Workers

ILO score	Hanford	Savannah River	Oak Ridge	All sites (%)
0/1	49	4	20	73 (34.2)
1/0	23	13	19	55 (25.8)
1/1	20	19	18	57 (26.7)
1/2	5	2	4	11 (5.2)
2/1	5	1	2	8 (3.8)
2/2	0	2	3	5 (2.3)
2/3	2	0	1	3 (1.4)
3/2	1	0	0	1 (0.5)
3/3	0	0	0	0 (0.00)
3/+	0	0	0	0 (0.00)

of radiographic abnormalities increased strongly with increasing age. The strongest trend with duration of DOE was observed for parenchymal X-ray changes where the prevalence of any parenchymal change (profusion 1/0 or greater) was 4.0% among workers employed at DOE sites less than 5 years and increased to 9.7% among workers employed 35 or more years.

Stratified analyses of the PFT data by age and duration of DOE work are shown in Table X. The prevalence of all PFT changes increased with age with the strongest trend being observed for mixed PFT defects. No consistent trend was observed with increasing duration of DOE site work for any of the PFT categories.

Results of chest X-rays and PFTs by smoking category are shown in Tables XI and XII. Past smokers were found to have a higher prevalence of pleural only changes while the prevalence of parenchymal only and parenchymal plus pleural changes was reasonably consistent across smoking category. Workers who reported to have never smoked were found to have a higher proportion of normal PFTs. Obstructive and mixed PFT defects increased by smoking category whereas the prevalence of restrictive defects demonstrated no trend.

The prevalence of chest X-ray changes and PFT defects by trade was analyzed and is shown in Tables XIII and XIV. These analyses were restricted to trades with 25 or more workers in order to generate reasonably stable estimates of prevalence. Millwrights, asbestos workers, sheetmetal workers, and ironworkers were found to have a higher prevalence of parenchymal changes whereas plumbers/steam fitters and asbestos workers had a higher prevalence of pleural changes. PFT data by trade demonstrated reasonably consistent prevalence values for obstruction and restriction across trades. Exceptions were a higher prevalence of restriction among sheetmetal and asbestos workers, as expected, and a lower prevalence of obstruction for these same trades. Mixed PFT defect prevalence was more variable

TABLE VII. Pulmonary Function and Respiratory Symptoms, DOE Construction Workers

Parameter	Hanford	Savannah River	Oak Ridge	All sites
Pulmonary function, mean % predicted and (standard deviation)				
Mean FVC, L	89.9 (20.4)	84.1 (16.9)	78.2 (17.0)	84.8 (18.9)
Mean FEV_1, L	84.4 (23.7)	81.8 (19.2)	76.9 (20.6)	81.6 (21.6)
Pattern, frequency, and (%) by site				
Normal (%)	588 (60.2%)	593 (60.5%)	310 (48.0%)	1,491 (57.3%)
Obstructive defect (%)	173 (17.7%)	93 (9.5%)	51 (7.9%)	317 (12.2%)
Restrictive defect (%)	108 (11.1%)	219 (22.4%)	207 (32.0%)	533 (20.5%)
Mixed obstructive/restrictive defect (%)	108 (11.1%)	75 (7.7%)	78 (12.1%)	261 (10.0%)
Symptoms, frequency, and (%) by site				
Cough (%)	257 (26.3%)	236 (24.1%)	213 (33.0%)	706 (21.1%)
Phlegm (%)	286 (29.2%)	249 (25.4%)	211 (32.7%)	746 (28.7%)
Dyspnea				
At least Grade 1 (%)	462 (47.2%)	493 (50.3%)	410 (64.5%)	1,365 (52.5%)
Grade 2+ or higher (%)	283 (28.9%)	328 (33.5%)	300 (46.5%)	911 (35.0%)

Cough—“Yes” to “Do you usually have a cough?” and “Yes” to “Do you usually cough like this on most days for three consecutive months or more during the year?”
Phlegm—“Yes” to “Do you usually bring up phlegm from your chest?” and “Yes” to “Do you bring up phlegm like this on most days for 3 consecutive months or more during the year?”
Dyspnea Grade 1—“Yes” to “Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill?”
Dyspnea Grade 2+—“Yes” to “Do you have to walk slower than people of your age because of breathlessness?” or questions showing a more severe dyspnea.

TABLE VIII. Cross Tabulation—Pulmonary Function and ILO Chest Radiograph Results, DOE Construction Workers

PFT category	Normal X-ray (%)	Parenchymal changes only 1/0 or greater (%)	Parenchymal & pleural changes (%)	Pleural changes only (%)	Total
Normal PFT	1,187 (61.0)	27 (47.4)	33 (39.8)	244 (47.2)	1,491
Obstructive PFT	223 (11.5)	12 (21.1)	9 (10.8)	73 (14.2)	317
Restrictive PFT	373 (19.2)	12 (21.1)	25 (30.1)	123 (23.8)	533
Mixed PFT	162 (8.3)	6 (10.5)	16 (19.3)	77 (14.8)	261
Total	1,945	57	83	517	2,602

Note: Percentages are for the columns. Statistical test of association between PFT and X-ray findings ($\chi^2 = 58.6$, df $= 9$, $P < 0.00001$).

across trades, ranging from 3.0 to 15.0%. Trades with a higher prevalence of mixed PFT defects included carpenters and asbestos workers.

Logistic Regression Analyses

Unconditional logistic regression models were developed and used to explore trends in lung disease with employment variables, while controlling potential confounders (e.g., age, race, sex, non-DOE work). These analyses were restricted to data from Hanford and Savannah River for several reasons. First, the occupational exposure history questionnaires for these two sites were nearly identical with regard to questions on exposure tasks and materials, which allowed combination. Secondly, many workers (24%) in the Oak Ridge program and 3–9% at Hanford and Savannah River had recently undergone an asbestos disease screening as part of medical/legal actions and reported a prior asbestos related disease diagnosis. Consistent with good medical practice, chest X-rays and PFTs were not repeated for workers for whom the tests were done within approximately one year. A summary of prior asbestos related disease diagnoses reported by site is shown in Table XV. As can be seen in this table, high proportions of workers with a prior diagnosis were given a chest X-ray examination by the Hanford and Savannah River medical screening programs (>85%) compared to less than 45% at Oak Ridge. It was considered important to limit the logistic regression analyses to the Hanford and Savannah River population in order to minimize selection bias.

Our initial regression models demonstrated age and duration of trade work to be highly correlated. Likewise, age and duration of DOE site work were correlated, although less so than age and trade work duration. In order to partially account for data correlation, a separate model was developed restricted to workers older than 55 years. The cut point of 55 years was chosen as this was the approximate median age for Hanford and Savannah River workers used for model development and others have shown that the prevalence of small opacities using the ILO system is higher for workers older than 50 years and unexposed to dusts occupationally [Meyer et al., 1997].

Results of the regression analyses for any parenchymal change (profusion 1/0 or greater) and pleural only changes are shown in Tables XVI and XVII. In these tables, both the full model with age categories as well as the model restricted

TABLE IX. ILO Chest Radiograph Results by Age and Duration of DOE Site Work, DOE Construction Workers

Category (in years)	Normal X-ray (%)	Parenchymal changes only 1/0 or greater (%)	Parenchymal and pleural changes (%)	Pleural changes only (%)
Age				
<50	702 (94.1)	4 (0.5)	1 (0.1)	39 (5.2)
50–59	564 (81.0)	12 (1.7)	15 (2.2)	105 (15.1)
60–69	366 (65.7)	20 (3.6)	22 (4.0)	149 (26.8)
70–79	250 (52.3)	14 (2.9)	32 (6.7)	182 (38.1)
≥80	63 (50.4)	7 (5.6)	13 (10.4)	42 (33.6)
DOE work				
<5	305 (76.1)	3 (0.8)	13 (3.2)	80 (19.9)
5–19	1,123 (77.2)	31 (2.1)	39 (2.7)	261 (18.0)
20–34	438 (71.5)	17 (2.8)	24 (3.9)	134 (21.9)
≥35	79 (59.0)	6 (4.5)	7 (5.2)	42 (31.3)
Total by X-ray category	1,945	57	83	517

TABLE X. Pulmonary Function Results by Age and Duration of DOE Site Work, DOE Construction Workers

Age category	Normal PFT (%)	Obstructive (%)	Restrictive (%)	Mixed (%)
Age (years)				
<50	530 (71.1)	83 (11.1)	104 (13.9)	29 (3.9)
50–59	433 (62.2)	77 (11.1)	143 (20.6)	43 (6.2)
60–69	266 (47.8)	69 (12.4)	140 (25.1)	82 (14.7)
70–79	211 (44.1)	68 (14.2)	119 (24.9)	80 (16.7)
≥80	51 (40.8)	20 (16.0)	27 (21.6)	27 (21.6)
DOE work (years)				
<5	224 (55.9)	54 (13.5)	75 (18.7)	48 (12.0)
5–9	857 (58.9)	165 (11.4)	291 (20.0)	141 (9.7)
20–34	345 (56.3)	78 (12.7)	134 (21.9)	56 (9.1)
≥35	65 (48.5)	20 (14.9)	33 (24.6)	16 (11.9)
Total by PFT category	1,491	317	533	261

to workers 55 and older is shown. Both tables demonstrate a strong trend in disease risk with age; however, the magnitude of the age association is exaggerated due to the correlation of age with other model parameters. The best estimates of effects of employment variables on respiratory disease risks are the models restricted to older workers in these tables. The odds-ratio for parenchymal X-ray changes demonstrated a statistically significant association with DOE site work, with an increasing trend of disease risk with work duration. The highest risk was observed for workers employed more than 35 years (OR = 3.6, 95% CI = 1.1–11.6). Non-DOE trade work also increased the risk of parenchymal changes with the highest risk being for 35 years or more of other trade work (OR = 1.8, 95% CI = 0.7–4.5). Having ever smoked cigarettes also was significantly related to parenchymal disease risk (OR = 2.0, 95% CI = 1.1–3.7). In addition to risks associated with work duration, workers who reported regular exposures to asbestos and silica were found to be at higher risk of parenchymal disease, although the covariates for these parameters did not achieve statistical significance. Welding did not increase the risk of parenchymal disease in these models.

The regression models for pleural only X-ray changes demonstrated a pattern similar to that found with parenchymal disease. In the model restricted to workers 55 years of age and older, the odds-ratio for DOE work increased with years of work and was highest for workers having worked at DOE sites 35 years and longer (OR = 2.2, 95% CI = 1.2–4.2). Duration of non-DOE trade work also was significantly associated with disease risk and was highest among workers having worked in trades 35 years and longer (OR = 2.1, 95% CI = 1.3–3.5). Regular exposures to silica, asbestos, and welding were found to increase the risk of pleural disease. Having ever smoked was associated with a slight increase in pleural disease (OR = 1.3, 95% CI = 1.0–1.7) although the risk was of borderline statistical significance.

The association between DOE work and the risk of parenchymal disease was further investigated by restricting the logistic regression model to the 431 workers in our study population who had only done trade work at Hanford or Savannah River. Although the parameter estimates were less stable than the model based on all workers, due to the smaller number of workers and cases, the odds-ratios for DOE work demonstrated the same trends. For example, the odds-ratio for workers 55 years or older and having worked trade work only at DOE for 35 or more years was 1.8 compared to 3.6 in the model which included all workers (Table XVI). The risk of parenchymal changes associated with regular

TABLE XI. ILO Chest Radiograph Results by Smoking Category, DOE Construction Workers

Smoking category[a]	Normal X-ray (%)	Parenchymal changes only 1/0 or greater (%)	Parenchymal and pleural changes (%)	Pleural changes only (%)
Never smoked	387 (80.6)	15 (3.1)	15 (3.1)	63 (13.1)
Past smoker	805 (67.2)	30 (2.5)	52 (4.3)	311 (26.0)
Current smoker	387 (80.6)	15 (3.1)	15 (3.1)	63 (12.7)
Total[a]	1,883	55	82	498

[a]Smoking data missing for 84 workers.

TABLE XII. Pulmonary Function Results by Smoking Category, DOE Construction Workers

Smoking category[a]	Normal PFT (%)	Obstruction (%)	Restriction (%)	Mixed (%)
Never smoked	560 (66.7)	75 (8.9)	168 (20.0)	37 (4.4)
Past smoker	659 (55.0)	143 (11.9)	256 (21.4)	140 (11.7)
Current smoker	228 (47.5)	91 (19.0)	86 (17.9)	75 (15.6)
Total[a]	1,447	309	510	252

[a]Smoking data missing for 84 workers.

exposure to asbestos and silica also was somewhat higher in the model restricted to DOE only workers (OR = 2.3 and 3.2, respectively) and welding did not increase the risk of parenchymal disease (OR = 0.8).

DISCUSSION

Construction workers are mostly employed by sub-tier contractors and typically not considered to be 'permanent employees,' therefore, work history and exposure information on them is either non-existent or very sporadic and unreliable at Hanford, Savannah River, and Oak Ridge. In order to provide meaningful medical surveillance programs for these workers, procedures have been developed for obtaining occupational and exposure histories through detailed interviews, incorporating maps, photos, and other site-specific materials intended to assist with recall. The work and exposure history process was developed to establish qualitative categories of exposure frequency, where possible.

Data from worker interviews as well as site characterization data by building and work area are used to determine worker eligibility for the medical screening programs and to select the appropriate medical screening tests to be administered for each participant. While these procedures have proven useful for triage, worker recall of exposures at these sites is no doubt less than complete; therefore, we have used reasonably inclusive program entrance criteria in order not to exclude workers with potentially hazardous site exposures.

The most commonly reported respiratory exposures associated with changes in X-ray or PFT among these workers have been asbestos and silica. Welding also has been associated with increased risk of interstitial pulmonary fibrosis in some populations [Buerke et al., 2002]. While other site exposures such as internal radiation could have contributed to these disease patterns, we have found it difficult to capture and quantify radiation exposures; therefore, we are currently initiating a special study to better address radiation exposures. Among the 2,602 workers included in the current report, approximately half reported nearly constant exposures to asbestos, silica, or welding during some portion of their work history. More than 80% of workers reported exposures to these materials on a weekly basis or more often. These exposure patterns were not unexpected, as workers were required to have significant exposures to these substances in order to be included in the medical screening programs.

This report includes data for a subset of workers at Hanford, Savannah River, and Oak Ridge who had completed

TABLE XIII. ILO Chest Radiograph Results for Trades With 25 or More Exams, DOE Construction Workers

Longest trade	Normal X-ray (%)	Parenchymal changes only 1/0 or greater (%)	Parenchymal and pleural changes (%)	Pleural changes only (%)	Any X-ray abnormality (%)
Asbestos workers	28 (59.6)	1 (2.1)	3 (6.4)	15 (31.9)	19 (40.4)
Boilermaker	47 (71.2)	0 (0.0)	4 (6.1)	15 (22.7)	19 (28.9)
Carpenters	178 (80.9)	6 (2.7)	3 (1.4)	33 (15.0)	42 (19.1)
Electricians	352 (74.3)	8 (1.7)	15 (3.2)	99 (20.9)	122 (25.7)
Ironworkers	121 (75.6)	3 (1.9)	9 (5.6)	27 (16.7)	39 (24.4)
Laborers	329 (81.0)	13 (3.2)	8 (2.0)	56 (13.8)	77 (19.0)
Millwrights	51 (67.1)	5 (6.6)	3 (4.0)	17 (22.4)	25 (32.9)
Operating engineers	103 (74.1)	3 (2.2)	5 (3.6)	28 (20.1)	36 (25.9)
Painters	72 (80.9)	0 (0.0)	0 (0.0)	17 (19.1)	17 (19.1)
Pipefitters	358 (71.4)	9 (1.8)	20 (4.0)	114 (22.1)	143 (28.5)
Plumbers/steam fitters	54 (56.3)	1 (1.0)	2 (2.1)	39 (40.6)	42 (43.8)
Sheetmetal workers	96 (72.7)	5 (3.8)	5 (3.8)	26 (19.7)	36 (27.3)
Teamsters	61 (81.4)	2 (2.7)	3 (4.1)	8 (10.8)	13 (17.8)

TABLE XIV. Pulmonary Function Results for Trades With 25 or More Exams, DOE Construction Workers

Longest trade	Normal PFT (%)	Obstruction (%)	Restriction (%)	Mixed (%)	Any PFT abmormality (%)
Asbestos workers	26 (55.3)	3 (6.4)	11 (23.4)	7 (14.9)	21 (44.7)
Boilermaker	44 (66.7)	8 (12.1)	12 (18.1)	2 (3.0)	22 (33.3)
Carpenters	118 (53.6)	27 (12.3)	42 (19.1)	33 (15.0)	102 (46.4)
Electricians	274 (57.8)	57 (12.0)	106 (22.4)	37 (7.8)	200 (42.2)
Ironworkers	106 (66.3)	13 (8.13)	25 (15.6)	16 (10.0)	54 (33.8)
Laborers	221 (54.4)	49 (12.1)	94 (23.2)	42 (10.3)	185 (45.6)
Millwrights	40 (52.6)	12 (15.8)	15 (19.7)	9 (11.8)	36 (47.4)
Operating engineers	79 (56.8)	17 (12.2)	28 (20.1)	15 (10.8)	60 (43.2)
Painters	44 (49.4)	13 (14.6)	21 (23.6)	11 (12.4)	45 (50.6)
Pipefitters	307 (61.3)	68 (13.6)	77 (15.4)	49 (9.8)	194 (38.7)
Plumbers/steam fitters	55 (57.3)	12 (12.5)	19 (19.8)	10 (10.4)	41 (42.7)
Sheetmetal workers	72 (54.6)	13 (9.5)	37 (28.0)	10 (7.6)	60 (45.5)
Teamsters	40 (54.1)	12 (16.2)	16 (21.6)	6 (8.1)	34 (46.6)

both a chest X-ray and a PFT through September 30, 2001. Overall, 25.2% of workers showed one or more chest X-ray changes by ILO criteria and 42.7% demonstrated a pulmonary function defect. These data likely underestimate the prevalence of disease among all construction workers as many workers, particularly at Oak Ridge, had prior lung disease diagnoses and were not re-examined by the current screening programs. The possibility of self-selection of diseased workers into the screening programs cannot be directly evaluated; however, 582 workers participated in the work history and exposure history component but chose not to undergo the medical examination. Exposure categories for asbestos, silica, and welding were reviewed for these workers and compared to that for the 2,602 workers included in these analyses. The overall exposure patterns as well as patterns for each site were found to be very similar. While not conclusive, these data do not suggest a strong pattern of self-selection, which would bias disease prevalence estimates.

Both stratified and multivariate analyses found parenchymal chest X-ray changes by ILO criteria (profusion 1/0 or greater) to be most strongly associated with DOE work. The overall prevalence of parenchymal changes was 5.4% for all sites combined, with a slightly higher prevalence (7.3%) being seen at Oak Ridge. Stratified analyses found reasonably strong trends of increasing parenchymal disease risk with increasing age and duration of DOE site work. Logistic regression models using data for Hanford and Savannah River, controlling for age, race, sex, smoking, and other trade work, found excess risk associated with DOE site work. The odds ratio for parenchymal disease was 1.8 (95% CI = 0.8–4.1) for workers employed 5–19 years and increased to 3.6 (95% CI = 1.1–11.6) for workers employed 35 years or more. These models also found additional risks for workers who ever smoked or reporting regular exposures to asbestos or silica. The logistic models for pleural only changes demonstrated disease associations and patterns similar to those found for parenchymal changes. The risk of any X-ray change by ILO criteria indicative of pneumoconiosis was found to be significantly associated with DOE work duration. Restricting the models to workers who only did trade work at a DOE site further substantiated the lung disease risk associated with DOE work.

The logistic regression models for chest X-ray abnormalities likely underestimate the risk associated with DOE work for several reasons. First, all workers included

TABLE XV. Prior Diagnoses of Asbestos Related Diseases by DOE Site, DOE Construction Workers

DOE site	No. medical exams[a]	No. reporting a prior diagnosis	No. given chest X-ray by program	Prevalence of pleural or parenchymal changes (%)[b]
Hanford	1,149	100	85	91.8
Savannah River	1,059	32	30	46.7
Oak Ridge	890	218	98	75.5

[a]Medical examinations through September 30, 2001.
[b]ILO profusion score of 1/0 or greater or any pleural abnormality based on ILO criteria.

TABLE XVI. Logistic Regression Results for ILO Chest Radiographs, Hanford and SRS[a], Parenchymal Changes (Profusion ≥1/0), DOE Construction Workers

	Full model	Restricted model
Model parameter	**All workers**	**Workers ≥ 55 years**
Age (years)		
<45	1.0	
45–54	2.8 (0.6–12.9)	
55–64	8.0 (1.8–35.2)	
≥65	25.0 (5.7–108.9)	
Duration of DOE work (years)		
<5	1.0	1.0
5–19	2.0 (0.9–4.6)	1.8 (0.8–4.1)
20–34	2.0 (0.8–5.1)	2.6 (1.0–6.6)
≥35	2.4 (0.8–7.9)	3.6 (1.1–11.6)
Years of non-DOE trade work		
<5	1.0	1.0
5–19	1.5 (0.9–2.7)	1.2 (0.6–2.4)
20–34	0.9 (0.5–1.8)	1.0 (0.5–2.1)
≥35	1.3 (0.5–3.1)	1.8 (0.7–4.4)
Cigarette smoking history		
Never smoked	1.0	1.0
Ever smoked	1.7 (1.0–3.0)	2.0 (1.1–3.7)
Asbestos exposure regularly	1.2 (0.7–2.2)	1.2 (0.6–2.3)
Silica exposure regularly	1.2 (0.7–2.1)	1.6 (0.9–2.8)
Welding exposure regularly	1.1 (0.6–1.8)	0.8 (0.5–1.4)

[a]Unconditional logistic regression model odds-ratios and 95% confidence intervals (CIs) controlling for age, race, sex, and other model covariates as shown.

TABLE XVII. Logistic Regression Results for ILO Chest Radiographs, Hanford and SRS[a] Pleural Only Cases, DOE Construction Workers

	Full model	Restricted model
Model parameter	**All workers**	**Workers ≥ 55 years**
Age (years)		
<45	1.0	
45–54	2.6 (1.3–5.4)	
55–64	8.8 (4.4–17.5)	
≥65	20.8 (10.4–41.5)	
Duration of DOE work (years)		
<5	1.0	1.0
5–19	0.9 (0.5–1.2)	1.1 (0.8–1.7)
20–34	1.0 (0.7–1.6)	1.8 (1.1–2.8)
>35	1.0 (0.5–1.9)	2.2 (1.2–4.2)
Years of non-DOE trade work		
<5	1.0	1.0
5–19	1.5 (1.1–2.0)	1.4 (1.0–1.9)
20–34	1.3 (0.9–1.9)	1.4 (0.9–2.0)
>35	1.3 (0.8–2.1)	2.1 (1.3–3.5)
Cigarette smoking history		
Never smoked	1.0	1.0
Ever smoked	1.4 (1.1–1.9)	1.3 (1.0–1.7)
Asbestos exposure regularly	1.2 (0.9–1.7)	1.3 (0.9–1.8)
Silica exposure regularly	1.3 (1.0–1.8)	1.3 (1.0–1.8)
Welding exposure regularly	1.7 (1.3–2.3)	1.6 (1.2–2.1)

[a]Unconditional logistic regression model odds-ratios and 95% CIs controlling for age, race, sex, and other model covariates as shown.

in these analyses reported an occupational history showing exposures to asbestos and silica; therefore, the internal comparison group (i.e., workers with less than five years of DOE site work) also was exposed. Secondly, the model demonstrated a strong trend of increasing parenchymal disease risk with age, which also is correlated with duration of DOE work. Correlation of age and work duration results in an underestimation of risk attributable to DOE work time in the full models. Restricting the logistic models to workers 55 and older and dropping age from the model changes the parameter estimates for DOE work duration only moderately. The age-restricted models represent the best estimates of the effects of occupational exposures in these analyses.

The prevalence of any pleural change by ILO criteria was 23.1% for all sites combined and much higher at Hanford. Our programs used different certified B-readers for each site; therefore, some of the variability by site is likely due to differences in interpretations among the local readers used for these programs. Nevertheless, reasonably strong disease trends were noted for duration of DOE site work and a reasonably strong trend with age. Among workers with only pleural changes by X-ray, 23.7% showed restriction, 14.1% showed obstruction, and 14.9% had mixed obstruction/restriction. The mean age for these workers (65.8 years) was slightly higher than the overall average. Others have shown a significant association between pleural plaques and restriction [Oliver et al., 1988; Rosenstock et al., 1988; Kouris et al., 1991; Miller et al., 1992]. In addition, Garcia-Closas and Christiani [1995] observed a significant association between pleural plaques and mixed PFT impairment in construction carpenters.

The prevalence of chest X-ray abnormalities among DOE workers at Hanford, Oak Ridge, and Savannah River is compared to other asbestos-exposed populations in Table XVIII. The prevalence of pleural changes among these DOE workers is similar to other reported data for construction trade workers whereas the prevalence of parenchymal changes is lower. Data for these workers is most similar to that for carpenters [Garcia-Closas and Christiani, 1995] and sheetmetal workers [Welch et al., 1994]. This is to be expected, given the wide range of crafts and trades included in the current study and their patterns of exposures.

TABLE XVIII. Comparison Results for ILO Chest Radiographs With Other Asbestos Exposed Cohorts, DOE Construction Workers

Cohort	No. of workers	Parenchymal changes only (1/0 or greater)	Pleural changes only	Both pleural and parenchymal changes
DOE workers [current report]	2,602	2%	20%	3%
CARET [Barnhart et al., 1997]	4,060	18	27	21
Carpenters [Garcia-Closas and Christiani, 1995]	564	3	10	7
Shipyard [Kilburn et al., 1985]	339	18	24	23
Shipyard [Selikoff et al., 1980]	284	32	7	47
Insulation [Lilis et al., 1986]	1,117	12	18	26
Sheetmetal [Selikoff and Lilis, 1991]	1,016	16	28	19
Sheetmetal [Welch et al., 1994]	9,605	7	19	6
Plumbers/pipefitters [Rosenstock et al., 1988]	684	7	17	12

CONCLUSIONS

A very high percentage of workers interviewed expressed concern about having been exposed to hazards while working at DOE sites and most were concerned that their health had been harmed by these exposures. The medical findings from the screening programs generally confirm these concerns, and show a clear pattern between duration of work at DOE sites and the risk of respiratory disease by chest X-ray and spirometry. Thus, although retrospective recollection of exposure details may be vague in some aspects, the aggregate concerns expressed by workers are generally confirmed. These data also demonstrate the value of occupational and exposure history information that can be gleaned from carefully designed work history interviews. Although the observed respiratory disease patterns are largely reflective of past exposures, these findings suggest that DOE needs to continue to review whether workers are adequately protected during work tasks involving maintenance, repair, renovation and demolition.

Continued surveillance of DOE craft and trade workers will be important as those workers who have sufficient exposure to asbestos to cause radiographic changes consistent with clinical asbestosis are at extremely high risk of lung cancer [Huuskonen, 1978; Liddell and McDonald, 1980; Berry, 1981; Finkelstein et al., 1981; Cookson et al., 1985; Coutts and Turner Warwich, 1987; Roggli, 1990]. Increased risk of lung cancer also has been shown among exposed workers without radiological evidence of parenchymal asbestosis [Wilkinson et al., 1995; Finkelstein, 1997]. Further, workers without parenchymal fibrosis who have asbestos-related pleural changes by X-ray have been shown to be at elevated risk of lung cancer [Loomis et al., 1989; Hillerdal, 1994]. The interactive effects of smoking and asbestos exposures to greatly magnify the risk of lung cancer also is important for these workers as 67% of the study population have ever smoked and approximately 19% of workers examined by these programs are current smokers. Smoking cessation programs for these workers should be a high priority. Smoking cessation programs have been shown to be highly effective for construction workers provided that they are designed for the needs and environment of these workers [Ringen et al., 2002]. The helical CT has not been fully developed for early screening of lung cancer; however, this technique has shown promise [Tiitola et al., 2002] and is currently being evaluated in one DOE population. Decisions on expansion to workers with a history of asbestos exposure and pneumoconiosis should await publication of results from this trial.

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