THYROID FUNCTION IN A GROUP OF FORMER WORKERS FROM A NUCLEAR WEAPONS RESEARCH AND DEVELOPMENT FACILITY

By

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Abstract

Objectives: The overall goal of this research was to investigate the relationship between exposures encountered while working at a Department of Energy nuclear weapons National Laboratory (LANL) and thyroid function in a sample of retired former workers.

Methods: The first phase of this work compared thyroid function in former workers from a nuclear weapons facility to that of participants in the Third National Health and Nutrition Examination Survey (NHANES III). Serum thyroid stimulating hormone (TSH) and thyroid medication use were combined to measure thyroid function. The second phase examined the association between workplace exposures, specifically radiation and solvents, and thyroid function. These exposures were characterized according to a cumulative exposure index based on reported frequency and duration of exposure. While a single measure was used to describe radiation exposure, solvents were classified as chlorinated, aromatic or "other." The association between these indices, controlling for demographic and work variables, and thyroid status was determined by means of regression analyses.

Results: The first set of analyses demonstrated that LANL former workers had an increased risk for abnormal TSH levels (> 4.5 mIU/L) and/or thyroid medication use as compared to the NHANES III sample. Of note was the finding that adjusted rates for the LANL group exceeded those of the NHANES III population, suggesting that occupational or environmental exposures may contribute to the risk for thyroid dysfunction. Further analyses showed an increased risk of abnormal TSH level (> 4.5 mIU/L) and/or thyroid medication use in male former workers who reported past chlorinated solvent exposure. Past radiation exposure was not significantly associated with thyroid dysfunction.

Conclusions: Extensive research has been done on cancer outcomes and all-cause health mortality and morbidity in radiation workers in the nuclear weapons and power generating industries in the U.S. and Europe. Relatively few have investigated the relationship between their workplace exposures and non-malignant thyroid dysfunction. Although radiation exposure was not a significant predictor of thyroid dysfunction, chlorinated solvents demonstrated a modest relationship. Causal relationships between thyroid dysfunction and occupational and environmental exposures should be further investigated to inform approaches for prevention of adverse thyroid outcomes.

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Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Introduction to the Research

The research described in this dissertation evolved from a medical screening program funded by the Department of Energy (DOE) as a result of a Congressional mandate. The overall objective of the medical screening program was to evaluate the health of former workers for adverse health outcomes related to the hazardous materials that they worked with during their employment at DOE sites and the Los Alamos National Laboratory (LANL). The Johns Hopkins Bloomberg School of Public Health (at that time, the Johns Hopkins School of Hygiene and Public Health) entered into a cooperative agreement with the DOE to conduct a needs assessment and to develop a medical screening program for former workers from LANL based on its findings. The "Medical Examination Program for Former Workers (FW) from LANL" began in April of 2000. Selected data from the Medical Examination Program served as the basis for the studies reported here.

One of the specific aims of the Medical Examination Program for Former Workers from LANL was to determine the burden of disease due to possible workplace exposures in this former worker population. The current work was designed to examine the level of thyroid dysfunction in this population and to assess associations between workplace exposures – particularly, ionizing radiation – and thyroid function. To accomplish this goal, two research studies were conducted. The first study compared the status of thyroid function in the LANL former worker population to thyroid function in the Third National Health and Nutrition Examination Survey (NHANES III) sample population, using thyroid stimulating hormone (TSH) levels stratified by gender, age and ethnicity. The second study examined the reported radiation exposures of the LANL former worker population to determine the association between thyroid function and workplace exposures – specifically, ionizing radiation and solvents.

The subjects of interest in this study were members of the workforce at LANL, including scientists, as well as the technical, administrative and scientific support staff who completed projects involving DOE weapons research. Additionally, employees who worked with LANL subcontractors were included. These workers were employees of the primary subcontractor to LANL that provided skilled and unskilled labor to the site (mainly members of the building and construction trades, e.g. plumbers, sheet metal workers, operating engineers, laborers, janitors and general service workers).

The parent study, the Medical Examination Program for Former Workers from LANL, was designed to find occupationally related diseases and to recommend further testing and/or treatment. However, the two studies described herein examined a non-cancer health endpoint, thyroid dysfunction. This is in contrast to most of the reported research previously conducted on nuclear weapons industry workers, which has centered on mortality and morbidity endpoints of cancer or all-cause mortality (Gilbert et al. 1993; Richardson and Wing 1999; Ritz et al. 1999; Wing et al. 2004). European and Japanese studies involving radiation workers and radiologists have also focused primarily on cancer mortality and morbidity (Iwasaki et al. 2003; Telle-Lamberton et al. 2005; Yoshinaga et al. 2004; Zablotska et al. 2004). The studies reported in this dissertation are the first to look at a non-cancer outcome in radiation workers from a nuclear weapons facility. The findings of this study will elucidate the relationship between reported radiation exposure, as well as exposure to chlorinated, aromatic and other solvents, and thyroid dysfunction.

Most of our knowledge about the relationship between radiation exposure and health and, specifically, radiation and thyroid function, comes from studies of radiation treatment, exposure to atomic bombs, or nuclear accidents (although radiation doses of such magnitude are difficult to characterize in health outcome studies).

1.2 Specific Aims of the LANL Former Workers Study

The specific aims of this study include the following:

1. To examine the status of thyroid function in the sample of former workers at LANL, a nuclear weapons facility, and to make comparisons to a population-based sample (NHANES III); and
2. To examine whether reported exposures to radiation or to chlorinated, aromatic and other solvents are associated with thyroid function in this population of former workers.

1.3 Research Questions

1. Is there a difference between thyroid function as measured by TSH level in LANL former workers compared to the NHANES III cohort?
2. What are the demographic trends associated with thyroid dysfunction among former workers at LANL, and how do these compare to trends in the general population?
3. What is the relationship between radiation exposure and thyroid dysfunction in former workers at LANL?
4. What is the relationship between exposure to solvents and thyroid dysfunction in former workers at LANL?

5. Is there a dose response relationship between radiation exposure and thyroid dysfunction when those with high exposures levels are compared to those with lower levels?
6. What are the individual, job-related and exposure-related predictors of thyroid dysfunction in former LANL workers?

1.4 Overview of the Dissertation

Chapter 2 presents a review of the literature, concentrating on thyroid dysfunction and the individual, occupational and environmental risk factors that can affect normal thyroid homeostasis. The thyroid effects of radiation and other workplace exposures are also discussed.

Chapter 3 discusses the methods used in this research. This chapter addresses the design, populations, data collection methods, analyses, data management and human subject protection.

Chapter 4 presents the first manuscript, "Thyroid Dysfunction Among Former Workers from a Nuclear Weapons Facility Compared to a National Population Sample."

This report describes the study that compared the thyroid function in the LANL former workers to that of the NHANES III sample from the general population and presents its results.

Chapter 5 presents the second manuscript, "Thyroid Function and Workplace Exposures in Former Workers from a Nuclear Weapons Facility."

This paper examines the thyroid function of LANL former workers in relation to their reported radiation exposures, as well as other independent variables such as age, ethnicity, education levels and types of radiation protection methods that were used in their work.

Chapter 6 summarizes the overall findings, limitations and public health significance of this study.

Appendices include: 1) all of the data collection tools and materials used in the parent study, the Medical Examination Program for LANL former workers; 2) an overview of the original program, the Phase I Needs Assessment and the Development of the Medical Examination Program (Phase II); and 3) additional tables used in the analyses that were not included in the two manuscripts.

Chapter 2: Literature Review

2.1 Introduction

This chapter presents an overview of the literature concerning thyroid dysfunction and the occupational and environmental exposures that may contribute to disease, particularly with respect to the health effects of radiation exposure and other chemical exposures in the workplace. Additionally, environmental, demographic and lifestyle factors contributing to thyroid dysfunction will be reviewed.

2.2 Normal Physiology of the Thyroid Gland

The thyroid gland is an endocrine gland, located in the anterior neck, which is dependent on iodine for normal function. The thyroid produces two important hormones that are critical to the control of oxygen consumption and metabolism in the body: thyroxine (T_4) and triiodothyronine (T_3). T_4 is the main hormone released from the thyroid, and T_3, present in smaller amounts, is formed from the deiodination of T_4 in the peripheral circulation (Zoeller and Crofton 2000; DeVito 1999). Thyrotropin (also known as thyroid stimulating hormone, or TSH) is a pituitary hormone that controls the production and release of the thyroid hormones by stimulating the thyroid follicular cells (Zoeller and Crofton 2000). Many agents can interfere with the thyroid's normal function at different stages during hormone production, metabolism, and along elimination pathways.

As discussed by Zoeller and Crofton (2000), other important systems operate outside the thyroid to maintain the peripheral concentrations of the thyroid hormones. There is a negative feedback loop maintained by the concentrations of T_4 and T_3 in the blood; this negative feedback loop controls the release of thyrotropin-releasing hormone (TRH) from the hypothalamus and TSH from the pituitary. TRH stimulates the pituitary to release TSH, which regulates the synthesis and excretion of the thyroid hormones and controls the receptiveness of the pituitary gland to the negative feedback from the thyroid hormones.

According to Zoeller and Crofton (2000), most of the biological actions of thyroid hormone are mediated by nuclear thyroid hormone receptors (TRs) for T_3, and the TRs display a 10-fold greater affinity for T_3 than for T_4. There are four isoforms of TR derived from two genes. The T_3 receptors are part of the steroid/thyroid super family of ligand-dependent transcription factors, and "effects on gene expression mediate the majority of biological actions of thyroid hormone" (Zoeller and Crofton 2000). Two of these TRs demonstrate different profiles of binding to the thyroid hormone analogue desethylamioderone, and exogenous compounds, such as environmental chemicals, may bind differentially to these two TRs (Zoeller and Crofton 2000).

2.3 Thyroid Dysfunction

Numerous conditions can affect the thyroid gland, including malignancies and abnormal production of thyroid hormone. This review focuses on the latter, which is the outcome of interest in the study of LANL former workers described herein. Hypothyroidism, sometimes known as thyroid failure, results from the under secretion of thyroid hormone and is characterized by signs and symptoms that include goiter, fatigue, cold intolerance and coarseness of hair. In contrast, hyperthyroidism occurs as a result of over activity of the thyroid gland. This results in irritability, tachycardia, weight loss and a number of other outcomes. While clinical forms of both types of thyroid dysfunction exist, subclinical disease has also been recognized. Subclinical hypothyroidism and subclinical hyperthyroidism represent the earliest stages of thyroid dysfunction (Col et al. 2004).

The common symptoms of thyroid dysfunction are easily identifiable. Numerous health conditions may be associated with thyroid disease, including: past thyroid dysfunction; goiter; thyroid surgery or radiation to the thyroid, head, or neck; diabetes mellitus; vitiligo; pernicious anemia; a family history of thyroid disease; primary adrenal insufficiency; rheumatoid arthritis; medications; and other compounds (Ladenson et al. 2000). Other findings that may correlate with impaired thyroid function are: anemia; hypercholesterolemia; hyponatremia; elevations of creatine phosphokinase and lactate dehydrogenase; hyperprolactinemia; hypercalcemia; alkaline phosphatase elevation; and elevation of the hepatocellular enzyme (Ladenson et al. 2000).

According to the American Academy of Clinical Endocrinologists (AACE), as well as the American Thyroid Association (ATA), a TSH assay is the most valuable test for diagnosing clinical hypothyroidism and hyperthyroidism. Additional tests more relevant to subclinical forms and specific disorders such as Graves' disease include T_3, T_4, thyroid autoantibodies, thyroid scan and ultrasound (Ladenson et al. 2000; AACE 2002).

The diagnosis of subclinical thyroid disease is essentially a laboratory diagnosis that is based on a TSH level below or above the limits of normal, with T_4 and T_3 levels within the range of normal (Surks et al. 2004). Most individuals with subclinical thyroid dysfunction are mildly symptomatic or asymptomatic (Cooper 2001).

Recommendations vary with regard to the levels and ranges of TSH values considered to be normal. In describing the prevalence of thyroid dysfunction in a U.S. national sample (described below), Hollowell et al. (2002) defined a TSH value of 0.4 mIU/L as the lower limit of normal and 4.5 mIU/L as the upper. In a consensus development conference in 2002, representatives from the ATA, AACE and the

Endocrine Society defined the reference range of normal TSH concentration as 0.45 to 4.5 mIU/L (Surks et al., 2004; Col et al. 2004). Surks and colleagues (2004) further state that most individuals with subclinical hypothyroidism will have TSH levels between 4.5 and 10 mIU/L, and that subclinical hyperthyroidism is characterized by levels from 0.1 to 0.45 mIU/L.

Two studies of the same cohort were done in the United Kingdom to define the prevalence and the natural history of thyroid disease in that country. A community survey was done in Whickham, County Durham, by Tunbridge et al. (1977) from 1972-1974. This study estimated the prevalence of hyperthyroidism as 1.6/1000 for males and 19/1000 for females, and the prevalence of hypothyroidism was estimated at <1/1000 in males and 14/1000 for females. In individuals with TSH levels ≥6 mIU/L, thyroid cytoplasmic antibodies were present in 40% of males and 67% of females, but in individuals with normal TSH levels, antibodies were present in only 2.2% of males and 8.0% of females. The investigators concluded that there was a large pool of autoimmune thyroid dysfunction in the general community at the time this report was published, and only the cases of overt hypothyroidism and hyperthyroidism were detected by the screening methods available at the time.

In a 20-year follow-up of the original Whickham cohort, Vanderpump et al. (1995) found that the incidence of spontaneous hypothyroidism in this cohort was 3.5/1000 female survivors/year (C.I. 2.8-4.5), and that this increased to 4.1/1000 survivors/year (C.I. 3.3-5.0) for all causes of hypothyroidism in women, including individuals who had destructive therapy for thyrotoxicosis (Vanderpump et al. 1995). The mean incidence rate for hypothyroidism in males in this cohort was 0.6/1000 survivors/year (C.I. 0.3-1.2). The incidence of hyperthyroidism was 0.8/1000 for female survivors/year (C.I. 0.5-1.4), and the mean incidence rate for hyperthyroidism in males was negligible (Vanderpump et al. 1995). Incidence rates were calculated in the deceased members of the cohort and were found to be comparable (Vanderpump et al. 1995). In both men and women, the odds of developing overt hypothyroidism were increased for individuals with either an elevated TSH level or the presence of antithyroid antibodies in the earlier study. And, for both genders, for those with both elevated TSH and antithyroid antibodies, the odds of developing hypothyroidism were even greater (Vanderpump et al. 1995).

As discussed below, thyroid dysfunction has been associated with numerous factors (Ladenson et al. 2000). The National Center for Health Statistics (NCHS) conducts a periodic survey designed to gather information on the health and nutrition of adults and children in the U.S. civilian non-institutionalized population, titled the Third National Health and Nutrition Examination Survey (NHANES III). The data for NHANES III were collected from 1988 through 1994 in two parts that included a home interview and a health examination. The sampling strategy for NHANES III is designed to allow the estimation of population parameters. A more complete description of the data collected for NHANES III can be found on-line at http://www.cdc.gov/nchs.

Hollowell et al. (2002) reported on the status of thyroid function in the U.S. population based on an analysis of the NHANES III data. They estimated the prevalence of hyperthyroidism in the United States to be 1.2%, further subdivided into 0.5% prevalence of clinical hyperthyroidism and 0.7% prevalence of subclinical hyperthyroidism. The prevalence of hypothyroidism in the United States is estimated to be 4.6%, and is further subdivided into clinical hypothyroidism (0.3%) and subclinical hypothyroidism (4.3%) (Hollowell et al. 2002).The prevalence of thyroid dysfunction in workers has not been well characterized, but two thyroid screening programs were conducted in large, but non-representative, European groups (Pirich et al. 2000; Schaaf et al. 1993). In the first (Schaaf et al. 1993), participants were clearly not representative of all workers; the exposures of these healthy working males were not described and no information was provided about environmental or other exposures. Additionally, the parameters for defining thyroid dysfunction were not presented. It is therefore difficult to interpret the results, which indicated that the prevalence of overt and subclinical hyperthyroidism exceeded rates of overt and subclinical hypothyroidism. The second screening effort addressed males and females who worked in a large Viennese banking operation. Among these healthy workers aged 30 to 48 years, only 1.1% had a TSH level >4.0 mIU/L (subclinical hypothyroidism) and 0.8% had a level <0.1 mIU/L (subclinical hyperthyroidism); subclinical hypothyroidism was more common in women (1.6%) than men (0.6%). Because a goal of the program was to look at associations between thyroid function and cardiac risk factors, the investigators also concluded that subclinical hyperthyroidism was not related to any form of hyperlipidemia and, thus, that thyroid screening programs should not specifically target this group (Pirich et al. 2000).

2.4 Individual Factors

2.4.1 Age

Because thyroid dysfunction is associated with both age and gender, it is difficult to discuss these risk factors independently. Most studies of thyroid dysfunction in the general population by age and gender have indicated a pattern of increased prevalence of hypothyroidism by age; however, the prevalence among females is consistently higher across all age groups. For example, thyroid measures among those over age 60 in the Framingham Study cohort were classified according to serum TSH – those with normal levels (<5 mIU/L), slightly elevated TSH levels (5-10 mIU/L) and clearly elevated TSH levels (>10 mIU/L) were compared by age and gender. The prevalence of both categories of elevated TSH increased for men over the age of 80, although men's rates were lower than those of women. The proportion of men with clearly elevated TSH levels (>10 mIU/L) increased fourfold compared to those in the two younger decades (6.6% vs. 2.0%) (Sawin et al. 1985).

In an extensive review of literature on subclinical thyroid disease, Surks et al. (2004) noted that the prevalence of subclinical hypothyroidism increases with age, and can be as high as 20% in women over 60 years of age. Prevalence also increases among men who are older than 65, but the data are less consistent. The same review identified the elderly as experiencing increased rates of subclinical hyperthyroidism (Surks et al. 2004). In the 20-year follow-up of the original Whickham cohort, 21% of the women aged 55 to 65 had developed antithyroid antibodies since their original evaluations at age 35 to 45 years, and the presence of the antibodies occurred at the same time as menopause (Vanderpump et al. 1995).

The Colorado Thyroid Disease Prevalence Study screened 25,862 individuals to determine the prevalence of abnormal thyroid function, the relationship between thyroid dysfunction and abnormal lipid levels, and the relationship between thyroid dysfunction and hypothyroidism symptoms (Canaris et al. 2000). With regard to trends by age, the proportions with elevated TSH levels increased over all age groups. Consistent with other studies of demographic trends, TSH levels were higher in women. For women, rates of hypothyroidism, TSH >5 mIU/L, ranged from 4% in the 18- to 24-year age group to 21% in the greater than 74-year age group. In men, these elevations of TSH levels ranged from 3% in the 18- to 24-year age group to 16% in the greater than 74-year age group (Canaris et al. 2000).

Hollowell et al. (2002) used data from the NHANES III survey population to determine the prevalence of thyroid dysfunction in the U.S. population. The investigators found that significantly more females aged 50-59 years and 60-69 years had subclinical or clinical hypothyroidism. There was also an age-related increase in TSH levels in both men and women, but women had higher levels of TSH than men in most age groups, particularly after age 39 (Hollowell et al. 2002). The prevalence of thyroid antibodies was higher in females than in males, and the prevalence of thyroid antibodies increased with age, mainly in women (Hollowell et al. 2002).

The Study of Women's Health Across the Nation (SWAN), a community-based multiethnic cohort study of the natural history of menopausal transition, evaluated TSH concentrations in women from five ethnic groups aged 42 to 52 years (n = 3242) (Sowers et al. 2003). Investigators found that TSH concentrations increased with age and, for every five-year increase in age, TSH levels rose by 3.5% (Sowers et al. 2003).

2.4.2 Gender

As mentioned above and found consistently in other studies, hypothyroidism, hyperthyroidism and their subclinical forms are more common in women than in men (Helfand 2004; Sowers et al. 2003; Hollowell et al. 2002; Vanderpump and Tunbridge 2002). For example, the original Whickham study estimated the prevalence of hypothyroidism to be between 1.4% and 1.9% in females and less than 1% in males (Tunbridge et al. 1977). Additionally, average TSH levels are higher for women in the same population-based studies. As expected, undetected thyroid disease is more common in women (Helfand 2004).

When the specific category of autoimmune thyroid diseases is considered, women continue to manifest higher rates. In Graves' disease and Hashimoto's thyroiditis, the female-to-male ratio is 5-10-1. Prummel et al. (2004) have suggested that hormonal influences may affect the induction of these autoimmune diseases. In the 20-

year follow-up of the original Whickham cohort, 17% of all women in the cohort had developed antithyroid antibodies since their first visit, compared to only 7% of men (Vanderpump et al. 1995).

2.4.3 Race and Ethnicity

Most information regarding ethnic and racial differences in thyroid function comes from the estimates made by Hollowell et al. (2002), who evaluated the NHANES III data. They found whites to have the highest prevalence of clinical (0.4%) and subclinical (4.8%) hypothyroidism, compared to Mexican Americans (0.2% and 3.9%), African Americans (0.1% and 1.6%) and the remaining ethnic groups (0.2% and 4.0%). Whites had the highest prevalence of clinical (0.6%) and subclinical hyperthyroidism (0.8%), compared to Mexican Americans (0.2% and 0.5%), African Americans (0.5% and 0.6%) and the remaining ethnic groups (0.4% and 0.3%). Thus, the prevalence of hyperthyroidism in African Americans was much closer to that of whites. In the same population, whites had the highest TSH levels (mean 1.53 mIU/L, SE 0.02), compared to African Americans (mean 1.17 mIU/L, SE 0.02) and Mexican Americans (mean 1.43 mIU/L, SE 0.03). Following the same trend, the proportion with TSH levels >4.5 mIU/L in whites was 5.2%, compared to 1.7% in African Americans and 4.2% in Mexican Americans. For low TSH levels, however, African Americans demonstrated the greatest proportion, with TSH levels <0.4 mIU/L (4.6%), compared to 3.0% in whites and 2.6% in Mexican Americans. Whites were found to have a higher prevalence of antithyroid antibodies than Mexican Americans, and African Americans had the lowest prevalence.

The SWAN study of women over the age of 42 analyzed TSH levels of five ethnic groups (Sowers et al. 2003). Among women who were not taking thyroid medication, African American women had the highest proportion of TSH levels <0.5 mIU/ml (3.4%), followed by Japanese women (2.9%). The ethnic groups with the greatest proportion of women whose TSH levels were >5.0 mIU/L were Caucasians (7.5%), Hispanics (6.2%) and Chinese (5.3%)

2.4.4 Genetics

Brix et al. (1999) studied Danish twins in order to evaluate the role of genes and environment in the etiology of autoimmune thyroid disorders. Their findings suggested that a genetic susceptibility may be necessary for development of simple goiter in women, with environmental factors determining progression to a clinically overt goiter. In another study that examined the relationship between genetic and environmental factors in the development of Graves' disease, the investigators reached the same conclusion: a genetic predisposition may be necessary for the development of Graves' disease, but, again, environmental factors control progression to overt disease (Brix et al. 2001). In both studies, genetics explained a high percentage of the risk for the development of disease, compared to the contribution of environmental factors (Brix et al. 2001).

In a study designed to look at the contribution of environmental factors in the pathogenesis of autoimmune thyroid disease, Strieder et al. (2003) noted that Graves' hyperthyroidism and Hashimoto's disease often were found within the same families, suggesting that these two different types of autoimmune thyroid diseases may have a common genetic background (Strieder et al. 2003). They showed that, in healthy subjects, 27% of those with a family history of autoimmune thyroid disease had positive antithyroid antibodies, 5.5% had an abnormal TSH level, 3.6% had hypothyroidism and 1.9% had hyperthyroidism. After considering the role of other factors, such as age, smoking and estrogen use, the authors concluded that environmental factors may influence the development of thyroid dysfunction in an individual with a certain genetic make-up. Roberts and Ladenson (2004) reported that a genetic predisposition to autoimmune thyroiditis appears to be an autosomal dominant expression of the gene.

2.4.5 Diet

As previously discussed, iodine is an important dietary component. A case-control study conducted in Sweden (iodine-deficient region) and Norway (iodine-rich diet) assessed the relationship between dietary habits and risk of thyroid cancer. Data came from the national cancer registry and from self-reported exposures. Investigators found: an increased risk for thyroid cancer related to high consumption of butter (OR = 1.6; C.I. 1.3-4.9) and cheese (OR = 1.5; C.I. 1.0-2.4); an increased risk of thyroid cancer in women in Sweden who lived in areas of endemic goiter (OR = 2.5; C.I. 1.3-4.9); and, for those in Northern Norway and women who used iodized salt in adolescence, a negative association between salt use and thyroid cancer (OR = 0.6; C.I. 0.6-1.0) (Galanti et al. 1997)

A few studies have looked at essential vitamins and minerals that can influence thyroid function. Selenium, a trace metal that is known to influence the immune system, plays an essential role in thyroid hormone production (Prummel et al. 2004). Like iodine, selenium is essential for normal thyroid function and thyroid hormone homeostasis. Selenium supplementation of 200 µg/day was used in a randomized, prospective, blinded study of individuals with autoimmune thyroiditis; after three months, thyroid (peroxidase) specific antibodies (TPOAb) decreased from 100% to 63.6%. Additionally, TPOAb concentrations normalized in 9 of 36 patients (Gartner et al 2002).

Deficiencies in vitamin A and iron compound the effects of iodine deficiency and, therefore, may disturb thyroid hormone production and metabolism (Dunn 2002). In a double-blind randomized trial in Morocco (an area of endemic goiter), iodized salt and a vitamin A supplement improved thyroid measures in children and decreased the goiter rate (Zimmermann et al. 2004).

Food sources have been directly linked to thyroid function. Thiocyanate from cassava and goiter-producing compounds found in millet (both of which are food staples in developing countries) can block thyroid hormone synthesis and can worsen the course of hypothyroidism or goiter (Dunn 2002). Deficiencies of iodine, iron, and vitamin A are the three most common micronutrient deficiencies in developing countries, where control programs can be effective if they are appropriately put into practice (Elnour et al. 2000). In a study conducted in Sudan, 984 children aged 1 to 6 years were assessed and 22% were found to have goiter; also, 44% of the children had TSH levels above normal, 32% had low concentrations of retinol binding protein, and 88% had low hemoglobin concentrations (Elnour et al. 2000). The study concluded that, even though the area had sufficient iodine, goiter was endemic, and that vitamin A deficiency, protein-energy malnutrition and consumption of millet may be possible causes of these health problems. Some additional plant products can also inhibit TPOs, including turnips and other cruciferous vegetables that contain goitrin and flavonoids (DeVito et al. 1999).

2.4.6 Medications

Many drugs can modify thyroid function or thyroid test results, and some can cause autoimmune or destructive thyroiditis (Pearce et al. 2003). A number of serious effects are seen with amiodarone, which contains 37% iodine and is used to treat cardiovascular disorders. Mechanisms include inhibition of type I 5'-deiodinase and type II 5'-deiodinase, inhibiting thyroid access into peripheral tissues and TSH synthesis in the pituitary (and thus increasing T_4 and decreasing T_3). In animal studies, amiodarone and its metabolites have been shown to have direct cytotoxic effects on the thyroid cells.

Additionally, there is ongoing debate over the relationship between thyroid autoimmunity and amiodarone, possibly targeting a susceptible subgroup of individuals who have pre-existing autoimmune thyroiditis and resulting in amiodarone-induced thyrotoxicosis, particularly in iodine-deficient areas (Pearce et al. 2003). In individuals with pre-existing thyroid autoimmune disease, lithium may increase the concentration of serum thyroid antibodies and may lead to subclinical or overt hypothyroidism (Pearce et al. 2003). There is a 10-to-33% prevalence of high serum antibodies in individuals on long-term lithium treatment, and lithium has direct toxic effects on thyroid cells that may result in thyrotoxicosis or painless sporadic thyroiditis (Pearce et al. 2003).

During treatment with interferon alfa, up to 15% of individuals without previous thyroid autoimmunity will develop high serum peroxidase antibody levels or thyroid dysfunction (Pearce et al. 2003). Interferon alfa has been reported to cause destructive inflammatory thyroiditis, and the high concentrations of serum thyroid peroxidases in individuals treated with interferon alfa or interleukin-2 may be associated with Graves' disease (overt or subclinical hyperthyroidism) or hypothyroidism (Pearce et al. 2003). Once treatment with cytokines is discontinued, thyroid function usually returns to normal, but these individuals are at a higher risk for autoimmune thyroid dysfunction (Pearce et al. 2003).

2.4.7 Smoking

Several investigators have reported a link between smoking and autoimmune diseases of the thyroid, including Graves' disease (Prummel et al 2004; Vestergaard et al. 2002), goiter and thyroid nodules (Knudsen et al. 2002; Vestergaard et al. 2002). An interesting and fairly consistent finding has been an inverse association between hypothyroidism and smoking. In a cross-sectional study conducted on 4,649 subjects randomly selected from the Danish Civil Registration System, the prevalence of subclinical hypothyroidism was 50% lower in smokers than in non-smokers, and, consistent with increased hyperthyroidism, smokers had much lower serum TSH levels (Knudsen et al. 2002). Similarly, based on her study of NHANES III participants, Belin (2004) concluded that smokers who were not taking thyroid medications had a lower risk of having autoimmune thyroiditis and hypothyroidism, but had a higher risk for having TSH levels between 0.1 and 0.4 mIU/L (Belin et al. 2004). Knudsen and colleagues (2002) proposed that the inverse association between smoking and hypothyroidism may be attributable to thiocyanate, a degradation product of cyanide found in tobacco smoke. They point to the previous suggestion of Laurberg et al. (1998) that thiocyanate mediates a protective effect against the inhibitory effect of iodine on the thyroid through its competitive inhibition of iodine uptake. They proposed that the lower prevalence of subclinical hypothyroidism in their study subjects who smoked may have been a direct effect of iodine depletion in the thyroid gland (Knudsen et al. 2002).

2.5 Environmental Factors That Affect Thyroid Function

2.5.1 Iodine

Both a low iodine intake and a high iodine intake are associated with a high risk of thyroid disease, described by Laurberg et al. (2001) as a U-shaped relationship. Low iodine intake can lead to developmental brain damage and endemic goiter, while less severe iodine deficiencies are associated with an increase in thyroid growth and function that can lead to goiter and hyperthyroidism (more common in middle-aged and elderly populations) (Laurberg et al. 2001). Severely high levels of iodine intake are associated with thyroid hypofunction and goiter in children, while moderate and mild excess intakes of iodine are associated with an increased occurrence of hypothyroidism, most notably in the elderly (Laurberg et al. 2001).

Western countries have known about the importance of iodine intake and thyroid function for many decades. In the 20th century, goiters were endemic in the Midwestern United States and in Washington state. This deficiency of natural iodine was corrected by the addition of iodine to table salt in 1924 (Trowbridge et al. 1975). Other factors that increased iodine levels in the diet of Americans were the addition of iodate to bread as a stabilizer in the baking industry, and iodine supplements given to domestic animals that led to increased iodine in diary products and meats (Laurberg et al. 2001). In the United Kingdom, iodine was added to cow feed, thereby increasing the level of iodine in diary products (and iodine-based cleaning agents were also used in dairies) (Laurberg and Nehr 2002). An unplanned variation in dietary iodine intake can cause high levels of iodine and thyroid disease, most notably goiter. An example of unplanned variation in dietary iodine uptake was seen in a group of Peace Corps volunteers in Africa who developed goiters that were linked to the use of iodine resin filters to disinfect water (Backer and Hollowell 2000). A case study published in 1992 described a case of thyrotoxicosis in a 35-year-old beautician who worked with cosmetic creams containing iodine, thyroid hormones and thyroid extracts and who had heavy exposure to these creams through her skin (DelGuerra et al. 1992).

2.5.2 Perchlorate in Drinking Water

Most of the subjects in this study (91%) lived in New Mexico, where perchlorate is one of many contaminants identified in the regional groundwater and public water supplies – an occurrence thought to be the result of the wastewater discharge (McQuillan et al. 2003, www.nmenv.state.nm.us).

Perchlorate, which is used primarily as an oxidizer in solid propellants for rockets and missiles (Lamm et al. 1999), competitively inhibits the mechanism by which iodine is actively transported into the thyroid cell, and prevents thyroid hormone synthesis but not iodination (Greer et al. 2002; Wolff 1998). Animal studies to assess the thyroid effects of perchlorate have shown that the pituitary-thyroid axes in rats and humans have a similar physiology, but that the rat thyroid responds more rapidly to changes in iodine metabolism that will affect thyroid hormone production (Fukuda et al. 1975; Studer and Greer 1968). However, in a National Research Council (NRC) Report from the Committee to Assess Health Implications of Perchlorate Ingestion (2004), the committee concluded that it is impossible to extrapolate quantitatively from rodents to humans for human health risk assessments because rats are more sensitive than humans to agents that impede thyroid function. Thus, animal studies have not provided convincing evidence of toxicity data with regard to the effects of perchlorate on thyroid dysfunction.

With regard to studies of human health effects, two human volunteer studies detected a temporary drop in ^{123}I uptake that resolved two weeks after cessation of the study. In the first study, perchlorate was given in drinking water at various concentrations to 24 volunteers. The exposure group, whose dose of perchlorate was 0.5 mg/kg/day, had a slight downward trend during their 14-day exposure period in ^{123}I uptake; but, by 15 days post-exposure, their serum thyrotropin level had corrected itself (Greer et al. 2002). The second study of nine euthyroid males aged 22 to 30 years, also exposed experimentally to perchlorate in drinking water, found that low doses (10 mg/day for 14 days) did not affect thyroid hormone or TSH concentrations, urinary iodine excretion, CBC or blood chemistries. They found that thyroid ^{123}I uptake was decreased significantly in nine volunteers by a mean value of 38% from baseline, but this rebounded 14 days after perchlorate ingestion stopped (Lawrence et al. 2000). Most of the epidemiological studies done to assess thyroid dysfunction related to perchlorate exposure have found little evidence of an association. Two studies have examined thyroid outcomes in populations exposed to high levels of perchlorate in their drinking water. One, conducted in Nevada, used a Medicaid database to determine if the prevalence of any thyroid disorder (including congenital hypothyroidism) over a two-year period was associated with a level of perchlorate between 4 to 24 μg/L in drinking water (Li et al. 2001). The study found no evidence of increased hypothyroidism or thyroid abnormalities. Another study was done in Chile, where drinking water was contaminated by naturally occurring perchlorate from the Andes, to determine if newborns or school-age children had thyroid dysfunction. Compared to similar studies done in the western United States, the investigators found no evidence of thyroid suppression in Chilean newborns or school-age children who were exposed to drinking water with higher levels of perchlorate (Crump et al. 2000).

Two cross-sectional occupational studies looked at the thyroid health status of workers at ammonium perchlorate production facilities in Nevada and Utah (Gibbs et al. 1998; Lamm et al. 1999). Neither found effects on thyroid or bone marrow, and the Gibbs et al. study failed to identify effects on kidney or liver functions associated with perchlorate exposure.

Not surprisingly, the final report from the Committee to Assess Health Implications of Perchlorate Ingestion (2004) stated the following conclusions with respect to epidemiological studies in humans: 1) the ecological data were not consistent with a causal association between perchlorate exposure and congenital hypothyroidism; 2) based on studies of occupational exposures to ammonium perchlorate and ecological investigations in adults, the committee concluded that the epidemiological evidence was not consistent with a causal association between perchlorate exposure at the levels studied and thyroid dysfunction in adults; and 3) there was no evidence that individuals who had received long-term treatment for hyperthyroidism with moderately high doses of potassium perchlorate developed hypothyroidism, and there were no reports of new thyroid disorders, thyroid nodules, or thyroid cancer in individuals treated with potassium perchlorate for hyperthyroidism (NRC 2004). The committee noted that no studies have investigated the relationship between perchlorate and adverse health effects in vulnerable groups. The committee recommended that further research should include a series of interrelated clinical, mechanistic and epidemiological studies to clarify "safe" perchlorate exposures and to reduce the uncertainty in the understanding of human health effects associated with chronic exposures and the effects on sensitive populations (NRC 2004).

2.5.3 Organochlorine Compounds

A number of pesticides have been identified as affecting thyroid function (Brucker-Davis 1998; Pavuk et al 2003). One of these is DDT, which has been shown in animal studies to disrupt the metabolism of thyroid hormone (TH) and to compete with TH for protein-binding sites, thus inhibiting its transport (Brucker-Davis, 1998). Thiocarbamates, known for their fungicidal properties, are another group of pesticides with potential thyrotoxic effects. One group of thiocarbamates ethylenebisdithiocarbamates (EBDCs) are metabolized to ethylenethiourea (ETU), which causes goiter, decreased ^{131}I uptake and decreased TH in rats. Studies of workers exposed to EBDC and ETU have shown minimal thyroid effects – mild increases in T_4 and slight increases in TSH (Braverman et al 1978; Brucker-Davis 1998; Gordon et al. 1977); neither the effects of EBDC nor the effects of ETU have been seen as strong evidence of thyrotoxicity, but they have prompted a call for further investigation (Brucker-Davis 1998). The herbicide amitrole is associated with several mechanisms of thyroid dysfunction in rodents, but these have not been confirmed in humans (Alexander 1959; Jukes 1960). Identified effects are hyperplastic goiter, decreased ^{131}I uptake, hypothyroidism with low T_4 and elevated TSH (Brucker-Davis 1998). In a study of Vietnam veterans who participated in Operation Ranch Hand (the aerial spraying of herbicides, including TCDD-contaminated Agent Orange), the investigators reported an increased TSH mean for those in the high TCDD exposure category at two follow-up examinations, and an increasing trend in levels across the three Ranch Hand TCDD categories in 1982, 1985, 1987 and 1992 – suggesting that TCDD affects thyroid hormone metabolism and function (Pavuk et al. 2003).

Polychlorinated biphenyls (PCBs) – which are persistent in nature and are toxic to experimental animals, wildlife and humans – have been studied more frequently with regard to thyroid effects (Brouwer et al. 1999). The effects of various PCB congeners on endocrine systems include: 1) effects on the components of the endocrine system, such as hormones, metabolic enzymes, feedback regulatory systems, transport proteins and the endocrine gland itself; and 2) effects that change the endocrine system, such as immune effects, neurodevelopment, or induction of tumors (Brouwer et al. 1999). Additionally, it has been suggested that dioxin and dioxin-like PCBs may competitively bind to thyroid hormone receptors (Brouwer et al. 1999). PCBs may interfere with fetal brain development by means of their effects on the thyroid system (Zoeller et al. 2002). In a review of studies of neurological development in children, Ribas-Frito et al. (2001) reported that subtle adverse changes in neurodevelopment appear to be associated with prenatal PCB exposure.

Most studies of the effects of PCBs on thyroid function focus on the methods by which PCBs influence thyroid hormone levels through interference with signaling mechanisms and by reducing the levels of thyroid hormone available at the tissue level (Zoeller et al. 2002).

A community-based study in a Spanish city located near a former organochlorine compound facility assessed the association between hexachlorobenzene (HCB) and laboratory markers of thyroid and liver function. Findings included a decrease in total T_4 and an increase in GGT concentrations associated with serum concentrations of HCB (Sala et al. 2001).

Studies by Langer et al. looked at long-term occupational PCB exposures of adults, and community exposures of adults and adolescents (2003; 1998). However, the characterization of contaminant levels in the communities was not well explained. They reported increased thyroid volumes for those individuals who worked with PCBs for 21 to 35 years: 66% of these workers had thyroid disorders, compared to 54% in matched controls. Community exposures were associated with increased thyroid volume, thyroid nodules, anti-TPO antibodies and greater TSH levels in adult males (Langer et al. 2003; Langer et al. 1998).

In addition to PCBs, several pharmaceutical, environmental and naturally occurring chemicals can alter the synthesis, transport and metabolism of thyroid hormones (DeVito et al. 1999). These can also alter thyroid hormone signaling by direct binding to the TR, by indirectly altering phosphorylation of the TR, or by interacting with other accessory proteins (DeVito et al. 1999). Thyroid peroxidases (TPOs), key to the synthesis of thyroid hormones, are inhibited by a number of classes of synthetic chemicals, including thionamides, aromatic amines and polyhydric phenols (DeVito et al.

1999). Some plant products can also inhibit TPOs, including turnips and other cruciferous vegetables that contain goitrin and flavonoids (DeVito et al. 1999).

2.5.4 Organic Solvents

Organic solvents are used in cleaning, degreasing, painting, laboratory work and other operations, and thus comprise common occupational exposures (Browning 1965). The acute and chronic health effects of solvents have been the subject of numerous studies, some of which have focused on specific solvents, specific health outcomes, or combinations thereof. A large body of literature provides evidence that solvents affect the renal, liver, reproductive and nervous system (Schrier and Conger 1980; Stengel et al. 1996; Xiao and Levin 2000), but there has been almost no attention to potential adverse effects on the thyroid. The exception is a case-control study that was carried out using the Swedish cancer registry (Wingren and Axelson 1997). Cases of benign and malignant thyroid disease were matched to population-based controls to evaluate the etiologic role of occupational and environmental exposures. Exposures were assessed by questionnaires that queried diet, leisure activities, residence, and health and work histories. While some occupations, such as farming and bricklaying, were associated with thyroid cancer, several others known for heavy solvent use were related to benign thyroid disease. These included women chemists or laboratory workers (OR=9.4, CI 1.8-5.0) and male painters and lacquerers (OR=13.6, CI 2.8-6.7). Those who were classified as having unspecified solvent exposure were also at higher risk of benign thyroid disease; for women, the odds ratio was 2.8 (CI 0.9-9.0), and, for men, the odds ratio was 18.9 (CI 2.2-161). Despite this evidence linking organic solvents to thyroid dysfunction, no other studies of this relationship have been reported.

2.6 Radiation Exposure and Thyroid Function

2.6.1 Biological Effects of Radiation

Exposure to ionizing radiation can modify cells, leading to cell death, organ damage, or mortality, depending on the dose received. Biologic effects occur at the molecular, cellular and tissue levels. Of greatest concern is DNA damage through direct interaction of ionizing particles with DNA molecules or through the action of free radicals or other chemical intermediates produced when radiation interacts with adjacent cells (UNSCEAR 2000). While cell repair takes place, it may not be complete, thus passing on cellular modifications to future generations and possibly leading to neoplasms by means of initiation (UNSCEAR 2000). Most organ and tissue damage occurs above an exceeded threshold dose, but individual cellular damage can occur at lower doses of radiation (UNSCEAR 2000). Various dose-response models have been developed to demonstrate the relationship between radiation and biological effects, but they continue to be refined (UNSCEAR 2000).

As described below, most of our knowledge about the relationship between radiation exposure and health and, specifically, radiation and thyroid function, comes from studies of radiation treatment and exposure to atomic bombs or nuclear accidents. The majority of studies discussed here focus on thyroid outcomes.

2.6.2 Natural Background Radiation Levels

The amount of background radiation an individual experiences (i.e., radiation that is not generated from anthropogenic sources) comes primarily from cosmic rays and terrestrial radiation and can be modified by factors such as building construction and inhalation of radioactive contaminants in the environment. Thus, an individual's region of residence and living conditions are important factors in determining total exposure to ionization. Such sources are particularly relevant to the subjects of this study, who live in areas of high altitude (e.g. 7,000 feet above sea level) and in an area of the country (New Mexico) with unique geological formations.

Cosmic rays, which originate from space, are high-energy particles that interact with the nuclei of atmospheric constituents, producing radioactive nuclei called cosmogenic radionuclides. The intensity of cosmic radiation is altitude-dependent, and individuals who live at high altitudes may receive twice as large a dose of cosmic radiation as individuals at lower altitudes (Upton 1998). Airline crew and passengers also have notable potential for exposure to cosmic rays. Terrestrial radiation is naturally occurring and exists in different degrees in all media in the environment; exposures can be from internal or external sources of radionuclides (UNSCEAR Annex B 2000). Trace levels of terrestrial radionuclides are present in all soils, with levels varying by the type of rock from which the soils originate. The three main components of background levels of external radiation are the gamma-emitting radionuclides – ^{238}U, ^{232}Th and ^{40}K – each contributing equally to the incident external gamma radiation dose to humans in both indoor and outdoor situations (UNSCEAR Annex B 2000).

Indoor exposures to gamma rays depend on a building's construction materials and on the amount of time spent inside the building. In contrast to wooden materials, the use of earth materials generally does not increase indoor exposure (UNSCEAR Annex B 2000).

Internal exposures to terrestrial radiation occur through inhalation and ingestion. Although exposures through inhalation usually result from dust particles containing the decay chains of ^{238}U and ^{232}Th radionuclides, these sources are not considered to contribute significantly to internal exposure. The exception is exposure to radon and its short-lived decay products, which are the main source of inhalation exposure (UNSCEAR Annex B 2000).

2.6.3 Radiation Exposures from Industrial Activities

Radiation exposures from industrial activities are a concern when materials containing natural radionuclides are recovered, processed, or used such that humans can become exposed. Examples include mineral processing and combustion of fossil fuels in industries such as phosphate processing, metal ore mining and processing, electric power production, oil and gas extraction, and building material production. The raw materials used in these processes contain the natural radionuclides uranium and thorium, which are released to air, water and (sometimes) landfills, and can result in both internal and external human exposures. Internal irradiation can occur from inhalation of radionuclides, particularly near industrial plants (UNSCEAR Annex B 2000).

2.7 Sources and Human Health Effects of Radiation Exposure

2.7.1 Radiation Treatment and Thyroid Effects

Studies of patients who have received radiation treatment for medical conditions offer information about radiation effects from relatively intense, but not total body, exposures. Animal and human studies have shown that radiotherapy to the head and neck for tumors can lead to thyroid dysfunction, but findings are not consistent due to differences in radiotherapy volumes, doses, therapy techniques and inconsistent definitions of thyroid dysfunction. In an overview of the biologic effects of ionizing radiation, Jereczek-Fossa et al. (2004) point out that injury to thyroid tissue after radiotherapy includes vascular damage, parenchymal cell damage and autoimmune reactions. Primary hypothyroidism is the most common radiotherapy-induced thyroid abnormality following head and neck treatment, affecting approximately 20-30% of the patients treated, with rates depending on risk factors such as total treatment dose, prior thyroid resection and irradiated thyroid volume. Other thyroid conditions associated with radiotherapy include thyroiditis, Graves' disease and ophthalmopathy, benign adenomas and multinodular goiter. In addition, the relative risk of thyroid cancer is 15- to 53-fold higher than in the non-irradiated individuals.

2.7.2 Radiation Effects in Atomic Bomb Survivors

During the past 50 years, the Radiation Effects Research Foundation (RERF) has followed more than 200,000 atomic bomb survivors and their children. These studies have shown an increase in most types of cancer in proportion to radiation dose, and have demonstrated the latency of these excess cancers to be on the order of years or decades (National Academies 2003). As early as 1956, investigators found an increase of solid tumors, which was the most significant effect of the radiation exposure seen in the atomic bomb survivors. Excess risks for non-malignant thyroid disease and cardiovascular, digestive and respiratory diseases were identified around 30 years after exposure. While the exact mechanism for these non-cancer effects is in debate, current epidemiological research findings point to radiation effects as causal (National Academies 2003).

The research conducted to date by RERF has been relevant to the process of setting standards for protection against medical and occupational radiation exposures. Results indicate that most of the study participants had small radiation doses that are close to the ranges needed for protection in medical procedures, occupational exposures and other radiation sources (National Academies 2003). The Nagasaki Adult Health Study (n = 2,587) (Nagataki et al. 1994) demonstrated a dose-response relationship between radiation exposure and solid nodules (cancer, adenoma, goiter and non-diagnosed nodules) and a significant increase in autoimmune hypothyroidism.

2.7.3 Radiation Effects from Nuclear Accidents and Nuclear Weapons Testing

Studies of the aftermath of the Chernobyl, Ukraine nuclear power plant explosion in April 1986 have provided data on health effects associated with acute radiation exposure to a widespread population. Radionuclides, primarily ^{131}I and ^{137}Cs, were released at varying rates from the reactor over a 10-day period and were deposited in the greatest density over the western region of the former Soviet Union (UNSCEAR Annex J 2000). Every country in the northern hemisphere was found to have some level of radioactive ground contamination, with the greatest contamination in the Ukraine, Belarus and the Russian Federation (Moysich et al. 2002).

The health consequences from exposure to fallout from the Chernobyl accident included an increased incidence of thyroid cancers in the children of Belarus and Ukraine four years after the accident (Williams 2002). The incidence of thyroid cancer in children increased from 2 cases in 1986 to 583 cases in 1998 (Williams 2002). Although some have questioned these rates, the accuracy of diagnoses was felt by Williams (2002) to be verified. Furthermore, he asserted that higher rates of hypothyroidism in children from Belarus over the same time period may have been linked to the local milk and, therefore, were preventable (Williams 2002).

There have also been several studies of communities surrounding nuclear test sites. Since 1945, more than 500 atmospheric tests of nuclear weapons have been conducted around the world, resulting in radioactive debris or fallout that increased radiation doses to the world populations (National Academies of Science 2003). Zhumadilov et al. (2000) evaluated the possible relationship between thyroid abnormalities and radiation exposures in Kazakstan in a case review of 7,271 thyroid surgeries between 1966 through 1996; 67% of these individuals had goiters, 16% had an adenoma, 7% had thyroid cancer, 9.3% had Hashimoto's thyroiditis, and the remaining 1.3% had other less common forms of thyroiditis and other diagnoses (Zhumadilov et al. 2000). The most cases of Hashimoto's thyroiditis and cancer were found in the regions closest to the test site (Zhumadilov et al. 2000). Although not proving causality, the findings did suggest an increase in thyroid abnormalities, possibly related to the years of nuclear weapons testing done in this region (Zhumadilov et al. 2000).

Additional studies of nuclear test sites addressed the Pacific region and the Nevada Test Site (NTS), where atmospheric and above-ground nuclear tests were conducted between the 1940's and early 1960's (National Research Council 1999). Gilbert et al. (1998) examined thyroid cancer mortality data in the United States and incidence of thyroid cancer from selected areas for effects of exposures to ^{131}I from nuclear weapons testing at NTS. They found thyroid cancer deaths from 1957 through 1994 as well as incident cases of thyroid cancer from 1973 through 1994, analyzing excess relative risk of these by radiation dose, as estimated from 90 nuclear weapons tests at NTS. The findings were as follows: 1) no association was found for thyroid cancer deaths or incidence and cumulative ^{131}I dose, risk-weighted dose, or dose received after one year of age; 2) incidence and mortality rates were associated with ^{131}I

doses that were received under one year of age; and 3) there were increased mortality rates for the 1955 birth cohort and lifetime dose of ^{131}I (Gilbert et al. 1998). One major limitation was ascertainment of exposure due to uncertainties in dose estimation and population migration between 1940 and 1980 (Gilbert et al. 1998).

Additional population studies focused on consequences of plutonium production at the Hanford nuclear site in Washington state beginning in 1943. In the initial years of production, large amounts of gaseous and vaporized radionuclides, primarily ^{131}I, were released from the facility (Davis et al. 2004). The investigators conducted a retrospective cohort study from 1992 through 1997 of 3,440 individuals who were children in 1945 and 1946, the time of highest exposure to ^{131}I. Based on dose estimates by county of residence and health outcomes assessed through interviews, thyroid physical examinations and ultrasound examinations, and medical records, the investigators found no statistically significant association between estimated thyroid radiation dose and cumulative incidence of thyroid cancer, benign thyroid nodule, total neoplasia, any nodule, autoimmune thyroiditis, hypothyroidism, or autoimmune thyroiditis with hypothyroidism (Davis et al. 2004). A community-based health survey for the period between 1944 and 1995 looked at randomly selected individuals who lived downwind from the Hanford Site, and a control group from Portland, Oregon (Grossman et al. 2003). Although the study design and analyses limited the ability to draw inferences from these data, the investigators felt there was evidence for excess rates of cancer in the downwind population. For example, 37% percent of those downwind from Hanford reported cancer, versus 10% in the control group. Using self-reported data from the same community-based survey, Grossman et al. (2002) reported relatively high rates of thyrotoxicosis (hyperthyroidism, Graves' disease and toxic goiter). Almost one-half were manifested before age 30, and more than 75% were diagnosed before age 40; thus onset was much earlier than usually seen.

An extensive review considered studies of several populations with varied sources of radiation exposure – atomic bomb survivors, children who were irradiated from the Chernobyl accident, residents of the Marshall Islands (where the United States tested atomic weapons from 1945 to 1963) and studies of the Utah Cohort (where children were tested for health effects from atomic testing at NTS) (Eheman et al. 2003). The selected literature addressed the potential association between environmental sources of radiation and the presence of antithyroid antibodies and/or autoimmune thyroid disease. Perceiving evidence that the prevalence of antithyroid antibodies was higher than expected, the authors concluded that there may be an association between environmental radiation exposure and non-neoplastic thyroid diseases (Eheman et al. 2003).

2.7.4 Occupational Radiation Exposures and Health

Medical workers who face occupational exposure to radiation have frequently been the subject of study with regard to health effects. A Swedish case control study found that the odds of thyroid cancer in individuals who worked in the diagnostic radiation field were 2.9 (C.I. 1.1-8.3); and, for females only, the odds were 3.3 (C.I. 1.2-9.8) (Hallquist et al. 1993). Long-term, low-dose, occupational exposure to x-radiation may be a risk factor for thyroid nodules in medical workers, according to a study conducted in Pisa, Italy, of 50 workers exposed to radiation while working in orthopedic, hemodynamic, interventional radiology and radiotherapy units (Antonelli et al. 1995). When age and gender were controlled, the risk for developing thyroid nodules increased with longer duration of employment. When compared to controls who lived in an iodine-deficient area, the greatest risk existed for those employed greater than 20 years (Mantel-Haenszel relative risk 2.0 [CI 1.16-3.43]). An even greater risk was seen for the same exposure group (greater than 20 years) when compared to controls from the same area. This study suggests that long-term, low-dose exposure to x- radiation may be a risk for thyroid nodules.

Two Canadian studies have looked at the possible association between radiation exposure and cancer. In a case-control study, analysis of job histories of 1,272 thyroid cancer patients and 266 controls failed to demonstrate a relationship with radiation exposure, but had positive findings for increased thyroid cancer risk for those working in wood processing, pulp and papermaking (Fincham et al. 2000). A cohort study linked individuals and their dose records from the National Dose Registry of Canada with cancer incidence data from the Canadian Cancer Data Base (Sont et al. 2001). Findings were as follows: 1) there was a significant excess relative risk associated with radiation for all cancers in males; 2) the medical job category had the highest incident cases of cancer, but the collective cumulative dose and the mean cumulative dose for medical personnel was lower than in the industrial and nuclear power job categories; and 3) the only elevated standardized incidence ratios were for melanoma in males and thyroid cancer in females (Sont et al. 2001).

As mentioned above, the Chernobyl incident has led to a number of studies of radiation and health, including the health of workers involved in cleanup operations. A study of non-cancer thyroid disease in a large cohort of such workers showed a dose-dependent excess relative risk for those who entered the job at a time closest to the event (Ivanov et al. 2000). A second study of the same population of clean-up workers estimated standardized incidence rates (SIR) of thyroid cancer compared to the male population of Russia (Ivanov et al. 2002). Investigators found that the incidence of thyroid cancer increased in the early latency period (1986-1991) (SIR = 2.23, C.I. 1.02-4.22), but believed that the increase could have been related to the screening effect. In the second time period (1992-1998), the SIR was 5.24 (C.I. 3.88-6.93, $p < 0.05$), and the highest SIR was found in workers who were at Chernobyl immediately following the incident, from April through July 1986, when the thyroid was likely to incorporate available ^{131}I (SIR = 9.16, C.I. 5.33-14.67) (Ivanov et al. 2002). Therefore, the significant increase in thyroid cancer was not necessarily due to the external radiation doses that the workers received (Ivanov et al. 2002). In a follow-up study of this cohort, Ivanov et al. (2004) analyzed data from 8,654 clean-up workers who were 18-60 years old. The cancer incidence in this cohort did not exceed cancer incidence in the comparable age groups of the Russian population.

In 1994, two engineers who worked in a large parcel depot in northern England developed papillary cell thyroid cancer, causing suspicion that the only direct cause was ionizing radiation (MacCarthy 1999), possibly due to work tasks that included changing air filters after the Chernobyl nuclear accident. Of note, the plume of radioactivity from Chernobyl covered the United Kingdom by May 1986, and the north of England had 10 times more fallout deposited on the ground than in the south of England (MacCarthy 1999). Although a radiation survey done at the facility revealed no abnormal radioactivity, a screening program for thyroid cancer was carried out for 27 current and past engineering staff (MacCarthy 1999). There was no thyroid cancer among 18 men; 9 men had abnormal studies; 3 were found to have cases of multinodular goiter; 4 had small thyroid cysts; 1 had a borderline thyroxine level; and 1 had positive microsomal antibodies (MacCarthy 1999). The investigators could not conclude that the thyroid cancer seen in these relatively young workers was related to radiation from Chernobyl (MacCarthy 1999).

An additional study of Chernobyl workers was a longitudinal follow-up of a group sent from Latvia to clean up the area around the accident site and the surrounding area. This was a clinical study conducted in Latvia from 1998 to 1999, 12 to 13 years after the Chernobyl accident, that characterized the immune status of 385 male clean-up workers (age 33 to 63 years), and compared them to a control group of 47 healthy, age- and sex-matched blood donors with no history of radiation exposure (Kurjane et al. 2001). Fifty-nine clean-up workers (15%) were found to have thyroid pathology that included nodular goiter and diffuse goiter (Kurjane et al. 2001). Decreases in measures of cellular immunity (including CD16+ (NK), C4+, CD8+, CD3+ cells and complement activation) reflected an ongoing inflammatory process in all clean-up workers, and impairment of neutrophil phagocyte activity and levels of IgG and a significantly lower number of NK cells in the clean-up workers with thyroid pathology (Kurjane et al. 2001). Decreased NK cells were also reported in another study of adults and children who lived around the highly contaminated areas near Chernobyl (Koike et al. 1995). Chernobyl clean-up workers also had elevated blood and urine lead concentrations, which may have affected the immune system (Basaran et al. 2000; Undeger et al. 1996). Kurjane et al. (2001) concluded that the impairment of the immune system in these Chernobyl clean-up workers may have contributed to the development of their thyroid disorders.

2.7.5 Summary

Thyroid disease is common and has serious consequences, but most studies to date have focused on thyroid cancer. Although less studied with regard to risk factors, hyperthyroidism and hypothyroidism have been shown to be more prevalent in females and whites and are associated with increasing age. A number of exposures that are encountered in the environment and the workplace are also potential risk factors, but much of the literature addresses only populations with extraordinarily high doses of ionizing radiation. Further exploration of the role of workplace and environmental agents is warranted.

Chapter 3: Methodology

3.1 Overview

This chapter will discuss the study design, sample and instruments used for data collection. The study procedure will be outlined in detail, as well as human subject protection. Overall data handling, including data collection, management and analysis, will be presented. Because the manuscript option was selected for the dissertation format, Article 1 and Article 2, it must be noted that the study design and settings will remain the same for each manuscript; however, the sample, the dependent and independent variables and the analyses will differ. Before describing these studies, a brief discussion of the Parent Study – The Medical Exam Program for Former Workers from Los Alamos National Laboratory (LANL) – will be presented.

3.2 Design (Parent Study)

In the Defense Re-Authorization Act of 1993, Congress mandated that the Secretary of Energy and the Department of Energy (DOE) develop medical evaluation programs for former workers at risk for health problems from hazardous exposures they experienced while working at DOE sites. The Former Workers Medical Surveillance Program was developed in response to that mandate. The goal was development of medical evaluation programs for former workers at significant risk for health problems from hazardous exposures they experienced while working at DOE sites. In 1997, The Johns Hopkins School of Hygiene and Public Health (now called, and referred to hereafter, as the Johns Hopkins Bloomberg School of Public Health) entered into a cooperative agreement with the DOE to conduct a needs assessment at LANL. The purpose of the needs assessment was to determine if a medical screening program for former workers from LANL (called Phase I) was necessary. During Phase I, it was in fact determined that a screening program was necessary. The entire population of former workers at the LANL site who were still alive and could be located were offered a one-time free medical examination to identify adverse health effects that could potentially be related to past work at LANL and other DOE sites (Phase II). The findings from the LANL needs assessment and the development of the original medical exam program were discussed in detail in a previous publication (Breysse et al. 2001) and are described in Appendix B.

3.3 Study Recruitment (Parent Study)

3.3.1 Recruitment Letters

Two recruitment letters were developed for the Medical Exam Program for LANL Former Workers. The first letter was sent to former workers whose job title had a high probability of exposure to asbestos, beryllium, lead, noise, ionizing radiation, or solvents. Included in this recruitment packet was a three-page letter explaining the program, with an invitation to join the program, a consent form to complete an exposure and medical history questionnaire, and a self-addressed stamped envelope for return of the signed survey consent form.

The second letter was sent to former workers whose job title did not provide any information about their probable exposures at LANL. Examples of these job titles were "staff member" or "group leader." It was possible that a staff member worked in an administrative office and never had a need to enter areas where exposures could occur, or a staff member could have worked in areas that had a low or high probability of exposure to the agents of interest in this program. This letter explained the program, invited the former worker to complete a short exposure questionnaire, called Exposure Questionnaire #1 (EQ1) (see Appendix A), as well as a self-addressed stamped envelope in which the former worker was asked to return the questionnaire and a signed survey consent form.

3.3.2 Materials included with Recruitment Letters

The "Choice Form" gave the former worker the choice of how they wanted to participate in the program. The choices were an examination, a medical record review, or not to participate in the program. If former workers chose an examination, they were asked to choose where they wanted the examination completed: at the Los Alamos National Laboratory Occupational Medicine Clinic, by health care professionals from the Clinic; at the Española Program Office, by physicians from the Johns Hopkins Bloomberg School of Public Health and the University of New Mexico; or in Baltimore, Maryland, by physicians from the Johns Hopkins Bloomberg School of Public Health. Most former workers who resided on the east coast chose this option. (See Appendix A for a copy of the Choice Form.) Examinations were performed twice a month at the LANL Occupational Medicine Clinic in Los Alamos, New Mexico, once a month in Baltimore, Maryland at the Center for Occupational and Environmental Health, and four to five times a year at the LANL Former Workers Program Office in Española, New Mexico.

3.4 Sample (Parent Study)

As of December 31, 2002, the population of the Medical Exam Program for LANL Former Workers was 2, 315 former workers. They included: individuals who had worked at LANL any time from 1943 until the present; individuals who had worked for the University of California (UC) or any of the subcontractors at LANL; individuals who had worked with or around asbestos, beryllium, lead, noise, ionizing radiation, or solvents; and individuals who requested to be part of the Medical Exam Program even though they may had little or no exposures. Due to the nature of this program – that is, primarily a service oriented program – the program team allowed former workers to self-select into the program.

Once a former worker agreed to participate in the program, an exposure and medical history interview was conducted. The exposure and medical questionnaire is included in Appendix A. Those eligible individuals who chose an examination were then scheduled. This examination focused on the detection of possible health effects from exposure to the agents discussed previously. If a former worker self-reported ionizing radiation exposure, a chest x-ray, a complete blood count (CBC) and a thyroid stimulating hormone (TSH) level test were performed to determine if the former worker had any evidence of possible health effects from radiation exposure.

A medical record review was an alternative for inclusion in the overall program, and former workers from outside of New Mexico usually chose this option. A medical record review was conducted if a former worker was willing to mail the following documents to the program office at the Johns Hopkins Bloomberg School of Public Health: a history and physical examination record from their primary care provider that had been completed within the past two years; copies of CBC and TSH tests completed within the past two years; and a chest x-ray completed in the last two years (to be sent for a B-reading).

3.5 Study Instruments (Parent Study)

Exposure Questionnaire #1 (EQ1) was sent to former workers who had a job title that provided no information about their possible work-related exposures. The questionnaire was five pages long, and questions focused on work tasks that had a high probability of exposure to asbestos, beryllium, lead, noise, ionizing radiation and solvents. Once the questionnaire was returned to Baltimore, an algorithm was used to identify former workers who had any or all of the above exposures and who, therefore, should be invited to participate in the program. (A copy of EQ1 and the algorithm can be found in Appendix A.)

Exposure Questionnaire #2 (EQ2) was a 37-page interview that was completed via the telephone or in person after a survey consent form was obtained. A LANL former worker hired by the program conducted the interview with the program participant. The EQ2 collected demographic information, self-reported exposure and medical history, and information on smoking and alcohol use. Once the questionnaire was completed, an EQ2 algorithm was used to determine the examinations and testing that would be conducted at the former worker's examination, and which records the former workers would request from their health care provider for a medical record review. (A copy of EQ2 and the algorithm can be found in Appendix A).

3.6 Design (Studies 1 and 2)

This study was a cross-sectional study that resulted in two manuscripts for the purposes of this dissertation. The first manuscript ("Thyroid Dysfunction among Former Workers from a Nuclear Weapons Facility Compared to a National Population Sample" – Article 1) compares thyroid function in LANL former workers to the participants in the Third National Health and Nutrition Examination Study (NHANES III) (http://www.cdc.gov/nchs). The un-weighted NHANES III sample data (the comparison group) were used to determine if there were any differences in the thyroid function between these two groups, and whether there were trends by age, gender, or ethnicity. The second manuscript ("Thyroid Function and Workplace Exposures in Former Workers from a Nuclear Weapons Facility" – Article 2) analyzed the former associations between workplace exposures – particularly ionizing radiation and solvents – and thyroid function.

3.7 Sample (Article 1)

Eligibility requirements for Article 1 included the following:

- The program participant was employed at LANL for any period of time from 1943 until the present;
- The program participant had an exposure and medical history questionnaire interview (EQ2) completed on or before November 26, 2002;
- The program participant had an examination or a medical record review between April 12, 2000 and December 4, 2002; and
- The program participant had a TSH level drawn at their examination, or

they sent a copy of a recent TSH result to the program office for a medical record review.

Of the 2,315 former workers (FWs) who participated in the overall medical examination program, 1,712 met the criteria for inclusion in this study. Thirteen LANL FWs and one NHANES III participant reported past thyroid cancer and were eliminated from the study population. Their diagnosis and possible treatment methods would be likely to make them incomparable with the study populations with regard to the interpretation of their TSH levels. The development of thyroid cancer among LANL FWs will be treated in a separate analysis and reported elsewhere. The remaining LANL FW population was 1,699.

3.7.1 Comparison Group

The National Health and Nutrition Examination Survey (NHANES) is a periodic survey conducted by the National Center for Health Statistics. The survey was designed to gather information on the health and nutrition of adults and children in the U.S. civilian non-institutionalized population. The Third National Health and Nutrition Examination Survey (NHANES III) was based on a complex multistage probability sample design that was intended to provide national estimates of the health and nutritional status of the U.S. population. The data for NHANES III were collected from 1988 through 1994. Although sampling for the NHANES III surveys is designed to allow calculation of population estimates based on weighted results, this study used unweighted data to make comparisons to the LANL population.

NHANES III collected data from a sample of 33,225 individuals aged 12 and older, representing the geographic and ethnic distribution of the U.S. population. The participants selected from NHANES III were eligible for the comparison group in this study if the following were true: the participant was aged 20 years or older and had a valid TSH drawn during their NHANES III examination. All the participants under 20 years of age were eliminated, resulting in a total of 15,325 individuals eligible for inclusion in the study. Because there were only two African Americans in the LANL FW population, a decision was made to exclude this racial category from both samples. The final NHANES III sample included 11,204 individuals.

The following NHANES III data were included in this comparison study: age, gender, ethnicity, TSH levels, thyroid medical conditions (thyroid disease or goiter) and thyroid medication use. Because the only thyroid function blood sample collected for analysis in the Medical Exam Program for LANL FWs was the serum TSH, all other laboratory values from NHANES III were excluded.

The thyroid questions included in the NHANES III interview were questions about a physician diagnosis of a goiter or thyroid disease, and the age when they were informed of either of these conditions. The participants were also asked about prescription medication use. A more complete description of the data collected for NHANES III can be found on the Centers for Disease Control (CDC) Web site at: www.cdc.gov/nchs.

3.8 Dependent Variable (Article 1)

The TSH level was used as a screening test for thyroid dysfunction. The Medical Exam Program used three different laboratories to test blood samples for TSH levels, as well as the TSH levels that were received from FWs who requested a medical record review. Due to this variation, the reference range for normal TSH levels used in this study was adapted from three sources. Hollowell et al. (2002) provided an evaluation of thyroid function in the U.S. population using the population sampling data from NHANES III. In this article, the reference range for normal TSH values in the U.S. population was 0.4 to 4.5 mIU/L (Hollowell et al. 2002). The upper reference range of normal serum TSH concentration selected to define subclinical hypothyroidism was a TSH level greater than 4.5 mIU/L, as recommended by the Scientific Review and Consensus Panel representing the American Thyroid Association (ATA), the American Association of Clinical Endocrinologists (AACE) and the Endocrine Society (Surks et al. 2004). Subclinical hypothyroidism was defined as 4.5 to 10 mIU/L, and clinical hypothyroidism was defined as a TSH level >10 mIU/L (Col et al. 2004; Surks et al. 2004).

In Article 1, the TSH level was used as a continuous variable for univariate analyses, such as normal distribution plots or median TSH levels stratified by group (LANL FW versus NHANES III), gender, ethnicity, or age. The TSH level was logarithmically transformed due to the non-normal distribution of the data for use as a continuous variable. The TSH level was categorized for analysis of the prevalence of subclinical and clinical hypothyroidism using the following categories: subclinical hypothyroidism was a TSH level between 4.5 mIU/L < TSH ≤ 10.0 mIU/L, and clinical hypothyroidism was a TSH value >10.0 mIU/L (Col et al. 2004; Surks et al. 2004). The TSH level was also categorized for the calculations of the thyroid function status in the NHANES III and the LANL FW samples stratified by ethnic group and age groups. The TSH values used were based on the categories used by Hollowell et al (2002). The lower limit used to define hyperthyroidism was a TSH value <0.4 mIU/L. Normal thyroid function was a TSH value 0.4 mIU/L ≤ TSH value ≤ 4.5 mIU/L. The TSH value was also used as a parameter to define a case versus non-case (see Table 1).

The main thyroid information was collected during the exposure and medical history interview of FWs who participated in the Medical Exam Program for Former Workers at LANL. The thyroid questions included: (1) self-reported presence or absence of thyroid disease or a thyroid nodule, (2) the date of physician diagnosis of thyroid disease or a thyroid nodule, and (3) current thyroid medication and the name of the medication. Additionally, for those workers who did not have an exam but were eligible for the study, copies of records and blood tests were sent to the Medical Exam Program from a primary care provider for a medical record review.

Other factors that were measured in this study were: 1) the number of former workers who did not self-report thyroid disease or taking thyroid medication but who were found to have abnormal TSH levels; and 2) the number of former workers who reported using thyroid medication but who were found to have abnormal TSH levels.

Hollowell et al. (2002) reported thyroid function in the U.S. population by subgroups, including the total population, the disease-free population, the population reporting thyroid disease, goiter, or taking thyroid medication, and the reference population. The subgroups are described in Table 1. An additional subgroup was termed "case/non-case." The use of thyroid medication (yes/no) was combined with the TSH value to classify cases and non-cases (see Table 1).

Table 3.1: Definitions of the Sub Groups Used in this Study of LANL Former Workers (FW) and NHANES III Populations

<table>
<tr><th>Sub-Groups</th><th colspan="5">Description</th></tr>
<tr><td colspan="6">Total Population</td></tr>
<tr><td>LANL Former Workers</td><td colspan="2">All LANL former workers eligible for inclusion in this study (n = 1,699).</td><td>NHANES III</td><td colspan="2">All NHANES III participants who were 20 years of age and older, had a valid TSH level and were not African-American (n = 11, 204).</td></tr>
<tr><td colspan="6">Thyroid Disease Free Population</td></tr>
<tr><td>LANL Former Workers</td><td colspan="2">All LANL former workers eligible for inclusion in this study who did not report thyroid disease or thyroid medication use (n = 1467).</td><td>NHANES III</td><td colspan="2">All NHANES III participants who were 20 years of age and older, had a valid TSH level, and did not report thyroid disease, goiter, or thyroid medication use (n = 10,561).</td></tr>
<tr><td colspan="6">Population Reporting Thyroid Disease</td></tr>
<tr><td>LANL Former Workers</td><td colspan="2">All LANL former workers eligible for inclusion in this study who did report thyroid disease or thyroid medication use (n = 232).</td><td>NHANES III</td><td colspan="2">All NHANES III participants who were 20 years of age and older, had a valid TSH level, and did report thyroid disease, goiter, or thyroid medication use (n = 653).</td></tr>
<tr><td colspan="6">Thyroid Function</td></tr>
<tr><td>Hyperthyroidism</td><td>TSH value <0.4 mIU/L</td><td>Normal thyroid function</td><td>0.4 mIU/L ≤ TSH value ≤4.5 mIU/L</td><td>Hypothyroidism</td><td>TSH value >4.5 mIU/L</td></tr>
<tr><td colspan="6">Case/Non-Case</td></tr>
<tr><td>Case</td><td colspan="2">Any individual in either population 50 years of age or older with a TSH level > 4.5 mIU/L and /or reported thyroid medication use. (n = 912).</td><td>Non-case</td><td colspan="2">Any individual in either population 50 years of age or older who had a normal TSH level (0.4 ≤ TSH ≤ 4.5 mIU/L) and did not self-report thyroid medication use (n = 5,556).</td></tr>
</table>

3.9 Independent Variables (Article 1)

The main independent variable was "group," LANL former workers versus the NHANES III population. As discussed previously, eligible participants of the NHANES III included individuals 20 years of age and older who had a valid TSH level drawn at their examination. Both samples were then stratified by gender, age and ethnicity for analyses. In the final analysis, only individuals 50 years of age or older were included.

The median TSH level, the proportions of thyroid dysfunction and the proportions with clinical and subclinical hypothyroidism were stratified by gender and ethnic group and gender and age group for the total and thyroid disease-free populations and the population reporting disease. Both samples were then merged into the same database and every variable was merged (such as gender, age, and ethnicity). The merged database was then used for further analyses.

The other independent variables included in the analyses of the study data were:

1) Ethnicity, a categorical variable, included the three main classifications (white, Hispanic/Spanish, and "other").
2) Age was used as both a categorical and continuous variable. As a categorical variable, age was classified as the 20- to 49-year-olds, the 50- to 69-year-olds, and those who were 70 years and older.
3) Gender
4) Smoking History was a nominal variable (ever, never).

3.10 Statistical Analysis (Article 1)

The statistical analyses for Study I included:

- Frequency distributions of the demographic variables for each sample: distributions by age groups (20 to 49, 50 to 69, and 70+), gender (female, male), and ethnic group (white/Hispanic/other);
- Univariate analysis of the median TSH levels in the total, disease and disease-free populations by age groups, gender and ethnic groups;
- Proportions of hypothyroidism and hyperthyroidism in each population subgroup by age group and gender, and by ethnic group and gender;
- Proportions of clinical and subclinical hypothyroidism in each population subgroup by age group and gender, and by ethnic group and gender;
- Logistic regression with dependent variable case/non-case.

3.11 Sample (Article 2)

Of the 2,315 FWs who participated in the overall medical examination program, 1,712 FWs met the criteria for inclusion in this study. Once again, the 13 LANL FWs who reported past thyroid cancer were eliminated from the study population (as in Article 1). The remaining LANL FW population was 1,699. During the initial stages of data analysis, females (n = 204) and the ethnic group "others" (n = 56) were found to be low in number and, therefore, these two groups were eliminated from the study. As a result, the sample included only male LANL FWs who reported their ethnicity as white or Hispanic. The final number of FW included in this analysis was 1,439.

3.12 Dependent Variable (Article 2)

As stated previously, thyroid function (defined by serum TSH levels) was the dependent variable in this study. Thyroid dysfunction was classified as a case (hypothyroidism) defined as a TSH level >4.5 mIU/L and/or reporting thyroid medication use, or an individual having a normal TSH level (between 0.4-4.5 mIU/L) but who reported medication use. Median TSH levels and 25% to 75% quartiles were also used in the analyses.

Consistent with others who have evaluated thyroid function in the general population (Col et al. 2004; Surks et al. 2004), the upper serum TSH value of >4.5 mIU/L was used to define hypothyroidism, although this is not necessarily the level at which clinicians would initiate treatment. A reference range for TSH levels of 0.45 to 4.5 mIU/L was used by the members of the Consensus Development Conference, held in September 2002, and included members from the American Thyroid Association (ATA), the American Association of Clinical Endocrinologists (AACE) and the Endocrine Society to review clinical and research findings and to make recommendations to guide clinical practice (Surks et al. 2004).

The only subgroups described for the Article 1 analysis that were used in the Article 2 analysis were case/non-case (see Table 1). The TSH level was logarithmically transformed, due to the non-normal distribution of the data for use as a continuous variable. The use of thyroid medication (yes/no) was included with the TSH value to classify a case and a non-case (see Table 1).

3.13 Independent Variables (Article 2)

The main independent variable in this study was reported exposure to radiation. Radiation was used in the following manner. The exposure was measured by the reported frequency of exposure to radiation multiplied by the reported duration of exposure and summed for all job titles for each former worker. The intensity of exposure could not be estimated. This exposure value reflected the radiation cumulative exposure index (CEI) in days for each former worker in this study (see Table 3.2 and Figure 3.1).

Table 3.2: Values Assigned to Each Self-Reported Frequency and Duration of Use of Radiation, Lead, and Solvents in LANL Former Workers Population Study

Reported Frequency of Use of Radiation and the Other Agents	Value Assigned to the Frequency of Use	Reported Duration of Use for Radiation and the Other Agents	Value assigned to the Duration of Use
Never	0	Less than 1 year	0.5 year
Daily	5 days x 50 weeks = 250 days	1 to 5 years	3 years
Weekly	1 day x 50 weeks = 50 days	6 to 10 years	8 years
Monthly	12 days	Greater than 10 years	27 years (median)
Yearly	1 day	Don't know	Removed from the analysis
don't know	Removed from the analysis	Missing	0
Missing	0		

Figure 3.1: Self-reported Cumulative Exposure Index

$$\sum (\text{frequency} * \text{duration})_{\text{jobs1}-n} = \text{Cumulative Exposure Index}$$

Exposure to radiation was also analyzed as a continuous variable and was logarithmically transformed due to the non-normal distribution of the data for use as a continuous variable in linear and logistic regression models. The radiation exposure variable was also used as a categorical variable, compared to case status according to the following three definitions:

1) High radiation exposure = > median CEI (1,350 days)

   Low radiation exposure = ≤ median CEI (1,350 days)

2) High radiation exposure = a "yes" response to ever being removed from a job to prevent further radiation exposure and/or being decontaminated due to radiation exposure.

   Low radiation exposure = a "no" response to ever being removed from a job and/or being decontaminated.

3) High radiation exposure = a "yes" response to ever being removed from a job to prevent further exposure and/or being decontaminated due to radiation exposure, and/or having body counts due to radiation exposure.

   Low radiation exposure = a "no" response to ever being removed from a job to prevent further exposure and/or being decontaminated due to radiation exposure, and/or having body counts due to radiation exposure.

3.13.1 Job Title

Job title was used to determine which jobs had the higher mean serum TSH levels. LANL job titles were categorized into Common Occupation Classification System (COCS) codes for the Job Exposure Matrix (JEM). The COCS codes (described below) were then grouped together into the following categories of work: craft (building and construction trades) workers; engineers; general administrative workers; laborers and general service workers; general managers and first-line supervisors; professional and administrative workers; operators; scientists; technicians; and staff members. This information was used to understand which jobs may have been at a higher risk of exposure to radiation. During the Phase I Needs Assessment, a JEM was developed. The JEM was used to classify former workers by their job code into categories of probability of exposure to radiation, chemical and physical agents used over the past 50 years while working at LANL. Job titles from the rosters of former workers were assigned to a common occupational code based on an accepted classification scheme, namely the Common Occupation Classification System (COCS) (Stahlman and Lewis 1996). COCS codes were selected for use because they represented a common occupational taxonomy developed for the DOE and were used in other former worker programs.

Two possible categories were assigned to each job code. A one ("1") was assigned if there was a probability that a former worker was exposed to asbestos, beryllium, lead, noise, or radiation while they performed their usual job tasks. A zero ("0") was assigned to job codes if there was no probability that a former worker was exposed to the above mentioned agents while they performed their usual job tasks. Any job title with a probability of exposure to one or more of the agents chosen for this program were targeted for recruitment in the initial stages of the Medical Exam Program for LANL Former Workers. (The JEM is discussed in more detail in Appendix B and there is a copy in Appendix A.)

3.13.2 Lead and Solvents

The other agents of interest to this study included lead and solvents (chlorinated, aromatic, and others). These agents were analyzed to determine if they had independent effects on thyroid disease or if there were any interactions.

3.13.3 Other Chemicals that Affect Thyroid Function

It was generally known that perchlorate was a contaminant found in the drinking water in Los Alamos. Place of residence was defined as the current place that the former worker lived. This variable was used to identify how many former workers lived in proximity to Los Alamos National Laboratory and, therefore, may have been exposed to perchlorate-contaminated water.

3.13.4 Radiation Protection Practices

The following radiation work practices were specific to radiation exposure at LANL and included: removal from job or area due to exposure; decontamination due to exposure; working around plutonium; wearing of a radiation dosimetry badge; having nose swipes to determine radiation exposure; having body counts done for radiation exposure; and urine tests to determine body burden of radiation. These data were categorized as "yes" or "no" and were used in the Chi-square and logistic regression analyses.

3.13.5 Time Since Employment at LANL

Time since employment at LANL was used to determine the length of time since the former worker was exposed to radiation or other agents in the workplace at LANL. This variable was determined by using the reported date of leaving or retiring from work at

LANL and the date that the former workers completed their exposure and medical history interview for the parent study.

3.13.6 Time Worked at LANL

Time worked at LANL was used to determine the length of time that the former worker was employed at LANL. This variable was determined by using the reported date of beginning work at LANL and the reported date that the former workers ended their work at LANL.

3.13.7 Smoking History

Smoking history was a nominal variable (ever, never) that was used in the logistic regression analyses.

3.13.8 Ethnicity

Ethnicity was defined by a categorical variable (white or Hispanic/Spanish).

3.13.9 Age

Age was used as both a categorical variable (20-49 years; 50-69 years; and 70+ years) and as a continuous variable.

3.13.10 Education Level

Education level was defined as a categorical variable ($\leq$12 years and >12 years) and as a continuous variable.

3.13.11 Employer

Employer was categorized as: 1) the University of California, 2) Zia Company / Pan Am World Services/Johnson Controls International/ and Johnson Controls of Northern New Mexico (building and construction trades, laborers, janitors, etc.) or 3) other sub-contractors.

3.14 Statistical Analysis (Article 2)

The statistical analyses that were conducted for Article 2 included:

- Frequency distributions of the demographics of the LANL former worker population that included: age distributions by age groups (20-49, 50-69, and 70+ years of age), ethnic groups, education level, employers, and years worked at LANL;
- Median TSH levels and interquartile ranges (25% and 75%) for male LANL former workers by age groups and ethnicity, and by ethnicity and job codes;
- Median radiation cumulative exposure index (CEI) and interquartile ranges (25% and 75%) for male LANL former workers by age groups and ethnicity, and by ethnicity and job codes;
- Median solvent cumulative exposure index (CEI) (chlorinated, aromatic, and others) and interquartile ranges (25% and 75%) for male LANL former workers by age groups and ethnicity, and by ethnicity and job codes;

- Bivariate analysis TSH level (continuous variable) and predictor variables including radiation, solvents, age, education, years worked at LANL, and time since employed at LANL;
- Bivariate analysis with dependent variable thyroid case/non-case status and independent variables radiation (high/low), solvent exposure (low/medium/high), radiation protection measures, smoking history, and job codes;
- Logistic regression, adjusted for age, education, ethnicity, job type, time worked at LANL, with dependent variable thyroid case/non-case status and the independent variable radiation exposure (CEI); and
- Logistic regression, adjusted for age, education, ethnicity, job type, time worked at LANL, with dependent variable thyroid case/non-case status and independent variables solvent (chlorinated, aromatic, and others) exposure (CEI).

3.15 Data Management

The data used in this study were from the Medical Exam Program for Former Workers from LANL. Data were entered into a computer database designed for the larger program. Exposure and medical history data were originally entered into the databases from hard copies by Medical Exam Program team members. These data were randomly examined for quality control, and any discrepancies were corrected. Further data refinement occurred at the time of a former worker's examination, when physicians and health care providers validated the information in the Exposure and Medical History questionnaire. All test results were entered at the Baltimore Program office and were verified before the final results of the examination and testing were communicated to the former worker in a multiple-page letter that included copies of all tests. The data were checked for consistency and ranges and corrected when contradictory findings were observed or when there were missing variables.

3.16 Human Subject Protection

Data were maintained on password-protected servers, and the only individual with access to the complete databases was the program data manager. Other team members who required access to the data were given limited access; these individuals were only able to view a single record at a time and a unique identification number was needed to access results or personally identifiable information.

The Medical Exam Program for Former Workers from LANL was reviewed and approved each year by three Institutional Review Boards (IRBs): the Committee on Human Research at the Johns Hopkins Bloomberg School of Public Health; the Los Alamos National Laboratory Institutional Review Board for Human Subjects Research; and the Department of Energy Central Beryllium Institutional Review Board. All former workers participated in the Medical Exam Program for Former Workers from LANL on a voluntary basis, and withdrawal from the program was possible at any time. Former workers were informed that their data would only be analyzed in the aggregate, without identifiers. As the project coordinator, I was a co-investigator on the program and was included in the protocol as a student investigator. The studies reported here addressed one of the specific aims in the Medical Exam Program for Former Workers from LANL by determining the burden of disease due to possible workplace exposures in this former worker population.

Chapter 4: Thyroid Dysfunction Among Former Workers from a Nuclear Weapons Facility Compared to a National Population Sample

4.1 Abstract

Thyroid dysfunction is a common condition. Clinical hypothyroidism and hyperthyroidism have serious health consequences, and subclinical forms have a high probability of progressing to overt disease. Risk factors for thyroid dysfunction include high levels of ionizing radiation, certain medications, environmental chemicals and other metabolic disorders, but there is less certainty about the role of work-related exposures. This study examined thyroid function in former workers who had been employed at a nuclear weapons research and development facility where exposures included known thyrotoxic agents. Thyroid function was measured in these workers during a large medical screening program. Subclinical and clinical forms of dysfunction were classified based on serum thyroid stimulating hormone (TSH) levels and medical histories. These results were compared to those of individuals who were evaluated in the 1988-1994 National Health and Nutrition Examination Survey (NHANES III) cohort. Some of the identified associations between thyroid function and demographic factors were expected; for example, TSH levels increased with age. Additionally, rates of decreased thyroid activity (hypothyroidism) exceeded those of increased activity (hyperthyroidism). However,

overall rates of dysfunction were greater for the worker population, in contrast to the NHANES III findings and those described in the clinical literature, males in the worker group were more likely to have abnormal thyroid function measures when compared to females. Both men and women who had worked at this facility had higher rates of dysfunction than the NHANES III population. With regard to ethnicity, which has not been extensively addressed in other studies, higher rates of hypothyroidism were seen for Hispanics compared to whites. Based on the elevated rates and unexpected patterns of thyroid dysfunction, especially for male and for Hispanic workers, further research should consider the potential effects of specific exposures, including ionizing radiation and other substances recognized at this site.

4.2 Introduction

Thyroid dysfunction is a common condition, with an estimated prevalence in the United States of 1.3% for hyperthyroidism and an even higher rate of 4.6% for hypothyroidism.

Clinical hypothyroidism and hyperthyroidism have serious health consequences and subclinical forms have a high probability of progressing to overt disease. Therefore, estimates of the burden of thyroid disease, as well as screening recommendations, address both subclinical and overt cases.

A recently published report on U.S. population-based data from the Third National Health and Nutrition Examination Survey (NHANES III) (Hollowell et al. 2002) and a study of thyroid function of participants at a large health fair (Canaris et al. 2000) have reported demographic differences in thyroid function. Both studies indicated an association between thyroid dysfunction and increasing age and female gender, and the trend with age is believed to accelerate after age 60 (Surks et al. 2004; Sawin et al. 1979).

Some risk factors for thyroid dysfunction have been identified, including high levels of ionizing radiation, certain medications, environmental chemicals and other metabolic disorders (Birnbaum and Fenton 2003; Boice and Lubin 1997; Pearce et al. 2003; Van Raaij et al. 1993). However, there is less certainty about the role of work-related exposures or the risk of thyroid dysfunction in worker groups that might be expected to be affected by different exposures. Few studies have looked at specific worker populations.

A large screening program of former workers from a nuclear weapons facility assessed thyroid function in a group that worked with or around suspected thyrotoxic agents, including solvents and ionizing radiation. Medical screening examinations included measures of TSH and health histories that addressed thyroid disease and medication use. This offered the opportunity to assess thyroid function in an older group of former workers with relatively unique exposures. Thyroid measures for this group were then compared to those of the NHANES III sample to identify differences in prevalence of thyroid dysfunction and trends by age, gender and ethnicity.

4.3 Methods

4.3.1 Study Population

This study focused on a subgroup of former workers from Los Alamos National Laboratory (LANL) who participated in a larger medical examination program between April 2000 and December 2002. This program, the Medical Exam Program for Former

Workers from LANL, was part of a Department of Energy (DOE) funded response to a 1993 congressional mandate and offered medical screening to former workers who had worked with hazardous substances during their employment at DOE sites. At LANL, a physical examination and testing were offered to all former workers who worked there from 1943 until December 2002 and who were potentially exposed to asbestos, beryllium, lead, noise, ionizing radiation, or solvents.

The subgroup described in this study participated in the larger medical examination program and a TSH level was drawn as part of a targeted examination to those former workers who reported possible exposure to ionizing radiation in the exposure and medical history interview. The documented TSH levels used in the analyses were from the medical examination and from medical records. Of the 2,315 former workers who participated in the overall medical examination program, 1,712 former workers met the criteria for inclusion in this study. Non-white and non-Hispanic former workers were folded into the "other" ethnic group (n = 66).

NHANES III was used as the comparison group in this study. NHANES III is a periodic survey conducted by the National Center for Health Statistics. The survey was designed to evaluate the health and nutrition of adults and children in the U.S. civilian non-institutionalized population (Gunter et al. 1996). NHANES III is based on a complex multistage probability sample design that is intended to provide national estimates of several health and nutrition measures. This methodology employs sampling weights to arrive at population estimates, thus accounting for differential probability of selection and adjusting for non-coverage and non-response (Gunter et al. 1996). The current study did not apply sampling weights because the intent was not to extrapolate to the U.S. population. A more complete description of the NHANES III survey and data can be found at the CDC Web site: http://www.cdc.gov/nchs.

Data were collected in two parts: a home interview, and a health examination that included the blood drawn for TSH levels. African Americans in the NHANES III sample population were omitted from this study because there were only two African Americans in the LANL population and, therefore, no comparisons could be made with this group. Also, 13 LANL former workers and one NHANES III participant reported past thyroid cancer and were therefore eliminated from both study populations, as their diagnoses and possible treatment methods would be likely to make them incomparable with the study population with regard to the interpretation of their TSH levels. The remaining LANL former workers population was 1,699. The development of thyroid cancer among LANL former workers will be treated in a separate analysis and reported elsewhere.

4.3.2 Measures of Thyroid Function

For this study, thyroid dysfunction status was based only on serum TSH, the measure typically utilized in medical screening programs due to its high sensitivity for detection of thyroid dysfunction. While others have incorporated additional measures, such as T_4, T_3 and antithyroid antibodies in the formulation of thyroid disease classifications, these measures were not available for subjects who participated in the LANL FW medical screening program.

Thyroid dysfunction was classified as hyperthyroidism and hypothyroidism, with hypothyroidism further divided into subclinical and clinical disease. Consistent with others who have evaluated thyroid function in the general population (Col et al. 2004; Surks et al. 2004), the upper serum TSH value of >4.5 mIU/L was used to define hypothyroidism, although this is not necessarily the level at which clinicians would initiate treatment. To distinguish the group that some consider as clinically relevant, designated as "clinical hypothyroidism," the frequently cited serum TSH level of >10 mIU/L was used (Col et al. 2004; Surks et al. 2004). A reference range for TSH levels of 0.45 to 4.5 mIU/L was used by the members of the Consensus Development Conference (held in September 2002), at which members from the American Thyroid Association (ATA), the American Association of Clinical Endocrinologists (AACE) and the Endocrine Society met to review clinical and research findings and to make recommendations to guide clinical practice (Surks et al. 2004).

4.3.3 Analysis

All comparisons of thyroid function between LANL former workers and the NHANES III participants were conducted for the total samples, as well as for the subgroups considered to be the thyroid disease-free versus those with probable thyroid dysfunction. In the LANL former workers group, the population with probable thyroid disease was defined as those individuals who reported having thyroid disease or thyroid medication use, while the disease-free population was defined as those former workers who did not report thyroid disease or thyroid medication use. In the NHANES III group, the population with probable thyroid disease was defined as those individuals who reported a history of goiter, thyroid disease, or thyroid medication use, while the disease-free population was defined as those individuals who did not report a past history of goiter, thyroid disease, or thyroid medication use.

Group comparisons were made by ethnicity, gender and age to evaluate the differences in serum TSH levels. Prevalence of hyperthyroidism and hypothyroidism (total) were compared in the same demographic groups. Numbers in the LANL former workers group classified as hyperthyroid were small, therefore no further analysis of this group was done. Within those classified as having hypothyroidism, the study subjects defined as clinical and subclinical were compared by ethnicity, gender and age.

Finally, in those not considered to be hyperthyroid (TSH < 0.4 mIU/L) (Hollowell et al. 2002), logistic regression was used to determine predictors of hypothyroid dysfunction, and the study subjects were classified as a case if their TSH level was >4.5 mIU/L and/or they reported thyroid medication use. A non-case had a normal TSH level (0.4 mIU/L ≤ TSH ≤ 4.5 mIU/L) and did not report thyroid medication use. All statistical analyses were performed using SAS V 9.0.

4.4 Results

4.4.1 Demographics

Comparisons of LANL former workers and NHANES III populations are shown in Table 1. The LANL former worker population consisted of 88% males, in contrast to 48% in the NHANES III group. Within the total LANL population, the age range was 20 to 93 years, but 90% were over 50 years of age and the mean age was 65 years (SD ±11 years). The NHANES III population was noticeably younger, ranging in age from 20 to 90 years with a mean age of 49 years (SD ±20 years). Less than 50% were over 50 years of age. Forty-eight percent of the LANL population reported their ethnicity as white, and 46% reported that they were Hispanic or Spanish. The NHANES III population had a greater proportion (57%) of whites, while 38% were Hispanic. Twenty-six former workers did not disclose their ethnicity. As mentioned above, African Americans were not included in the samples.

As previously stated, comparisons of thyroid function were made between the two groups, as well as between the subgroups, who, based on their health history, were classified according to their thyroid disease status. In the LANL former workers group, 232 (14%) were considered to be "diseased" (i.e. they reported a history of thyroid disease or were taking thyroid medications). Within the NHANES III sample, 643 (6%) were thus classified based on reported thyroid disease, goiter, or thyroid medication use.

A summary of the median TSH levels for the total population, the disease and the disease-free subgroups is also presented in Table 2. In the total population as well as the disease-free subgroup, the TSH levels increased with age in both populations. For the same groups, TSH levels of male LANL former workers exceeded those of NHANES III males in all ethnic and age categories. Additionally, TSH levels of LANL males were greater than TSH levels of LANL females in most age and ethnic strata. The latter finding is not consistent with observations in other studies, which have found that TSH levels are higher in females.

In the diseased subgroups, the results do not conform to the patterns described above. However, there are fewer study subjects in this group and their TSH levels are more variable. Although individuals in this group, by definition, have recognized thyroid disease, their high TSH levels suggest that some may not be well controlled.

Table 3 compares thyroid dysfunction in the total population, the disease and the disease-free groups for LANL former workers and NHANES III populations. When thyroid status was defined as hypothyroidism and hyperthyroidism according to established parameters, hypothyroidism was more common than hyperthyroidism (8.3% and 2.8%, respectively) not shown. Proportions of male LANL former workers with hypothyroidism exceeded those of NHANES III males in all ethnic and age categories, except among those individuals 70 years of age and older in the total population and the disease-free group. This may be due to the older age distribution within the NHANES III over-70 group, compared to the LANL former worker over-70 group (mean age 78.0 and 75.4, respectively). When compared on gender, male LANL former workers had greater proportions of hypothyroidism than females in the two older age groups. For hyperthyroidism, the proportion with dysfunction does not show a trend with age. In general, the female LANL former workers had the highest proportions of hyperthyroidism.

The high TSH levels in the group classified as "diseased" accounted for the higher proportions of hyperthyroidism and hypothyroidism in both study populations. Unlike the disease-free group, for which the prevalence of hypothyroidism clearly exceeds that of hyperthyroidism, a varied pattern is seen for the diseased group. However, in several demographic subgroups, the prevalence of thyroid dysfunction exceeded 25%. This further suggests that diagnosis does not necessarily lead to normal TSH levels.

Table 4 addresses the prevalence of clinical and subclinical hypothyroidism. As expected, the proportion of subclinical hypothyroidism exceeds that of clinical hypothyroidism. Of note, however, is the fact that almost none of the female LANL former workers were classified as having clinical TSH levels, although the total number of women in the LANL group was small. As expected, most of those with no known disease were considered to have subclinical dysfunction. However, a greater proportion of individuals with recognized disease had TSH levels above 10 mIU/L, possibly indicating more severe diseases among those already diagnosed.

Table 5 presents the results of the logistic regression analysis that evaluated the odds of having an elevated TSH level and/or medication use among those not classified as hyperthyroid. The model controlled for group, age, gender, and ethnicity. The final model included an interaction term for age by gender. Those in the LANL former workers group were almost twice as likely to satisfy the case definition (OR 1.84, C.I. 1.53 - 2.22). Increasing age and female gender were positively associated with case status. Ethnicity was not predictive of thyroid dysfunction. Finally, the interaction term indicated that as males age, their risk of becoming a case increases at a greater rate than that of females. When stratified according to population, this relationship only existed within the NHANES III population.

4.5 Discussion

In contrast to previous studies of specific occupational groups, which have frequently looked at cancer (Gilbert et al. 1993; Iwasaki et al. 2003; Ritz et al. 1999; Wing et al. 2004; Zablotska et al. 2004), this study characterized thyroid function by serum TSH levels combined with self-reported thyroid diagnoses. Former workers from the LANL, whose thyroid function was compared to that of the 1988-1994 NHANES III cohort, were unique, in that most were males over the age of 50 who lived in the southwest United States, and a high proportion of these workers were of Hispanic or Spanish ethnicity. Their work in a nuclear weapons research and development facility was associated with radiation and other exposures suspected to have thyrotoxic properties (Ivanov et al. 2002; Nagataki et al. 1994; Pacini et al. 1999; Wingren and Axelson 1997; Yamada et al. 2004).

Many of the demographic trends for the LANL former workers were consistent with those noted in population-based studies, including one analysis of the same NHANES III cohort (Canaris et al. 2000; Hollowell et al. 2002; Sawin et al. 1979). For example, TSH levels increased with age in both groups, and rates suggestive of hypothyroidism exceeded those consistent with hyperthyroidism by two- to three-fold. Additionally, the majority of subjects with serum TSH levels above the upper limit that had been defined as normal for this study (4.5 mIU/L) fell within the parameters considered to be subclinical.

However, some differences by gender and age stood out in the comparison of these groups. While females have previously demonstrated a higher risk of thyroid dysfunction than males (Hollowell et al. 2002; Surks et al. 2004; Sawin et al. 1979), the highest rates in this study were seen for LANL males across all age and ethnic groups (Table 3). Higher rates in LANL males may be a reflection of increased risk associated with harmful workplace or environmental exposures, or the intensity of such exposures that were unique to the males. Further, because both males and females living in the Los Alamos area were likely to face similar environmental sources – possibly dietary – that might affect the thyroid (Dunn 2002; Fukuda et al. 1975; Galanti et al. 1997; Li et al. 2001; Studer and Greer 1968), these findings may point to occupational exposures that have occurred in jobs held primarily by men. Anecdotally, workers expressed their belief that men were more likely to work in jobs related to weapons development or production, and that women tended to hold clerical positions. Further, the rates of thyroid dysfunction for LANL males and females were greater than those in their respective gender groups in the NHANES III population, suggesting that all LANL workers may have experienced environmental or occupational risk factors.

Within the group considered to be "disease-free" (i.e. not reporting thyroid disease diagnoses or taking thyroid medication), one would expect most measures of TSH levels to fall within the normal range. As shown in Table 3, the proportion thus classified was small, with less than 3% below the TSH hyperthyroid cutoff level for both gender groups in each of the study populations; gender-specific groups exceeded the cutoff for hypothyroidism in slightly higher proportions, ranging from 4.6% to 7.3%. As expected, therefore, relatively few of those who reported no disease had abnormal TSH levels. Rates of undetected disease, therefore, appeared to be low. On the other hand, for those with known diagnoses of thyroid disease, in whom treatment would presumably normalize TSH levels, a substantial proportion were classified as having TSH above or below the TSH limits set for this study. This trend was more prominently seen for levels greater than 4.5 mIU/L, but also exceeded 10% within all gender-specific groups in the direction of hyperthyroidism. Of those with abnormal levels, a much larger proportion fell into the clinical range (TSH >10 mIU/L) within the group reporting disease (35% to 42% for LANL and NHANES III, respectively) compared to those with TSH >10 mIU/L in the disease-free group (10% and 18%). Hollowell (2002) also identified a greater proportion of the NHANES III population as having hypothyroidism, occurring more frequently within the group reporting disease.

Some of the observations for those of Hispanic and Spanish ethnicity in the LANL population (46%) raise concerns. While the proportions classified as hypothyroid were higher than those in the NHANES III group in all ethnic and age categories, the magnitude of this difference was greatest for Hispanics, at almost two-fold (9.1% vs. 4.1% for males, and 10.4% vs. 6.7% for females) (Table 3). Additionally, within the LANL group, higher proportions of hyperthyroid and hypothyroid TSH levels were identified for Hispanics when compared to whites; however, in the NHANES III group, rates were lower for Hispanics. This suggests that Hispanic LANL former workers, particularly the men, may be at greater risk for thyroid dysfunction. If occupational exposures were linked to thyroid dysfunction, it is possible that Hispanics were employed in jobs or areas where greater exposure occurred. Also of note is the fact that, among those with reported disease or medications, Hispanics in both the LANL and NHANES III populations were more likely to have TSH levels greater than 4.5 mIU/L. This group, despite a health care provider's recognition of their thyroid dysfunction, was less likely to demonstrate adequately controlled TSH levels. Such an outcome could be related to medical care factors, such as availability or access to providers. It is possible that Hispanics and whites differ in their care-seeking behavior, perhaps influenced by the availability of care providers who are attuned to cultural health issues.

The final model (Table 5) shows the expected relationship between age and gender in the prediction of thyroid dysfunction. With increasing age, the risk of becoming a case increased for males. The data also suggest that, compared to data from the U.S. population, LANL workers experience an almost two-fold risk of being a case as defined by recognized disease or TSH levels in excess of 4.5 mIU/L.

In summary, this study is one of the first to examine non-cancer morbidity in a population of former workers from a nuclear weapons facility. The inconsistent trends by demographic characteristics in the comparison of these two groups suggest that males may be at increased risk for developing thyroid dysfunction as they age. When controlling for age, group and ethnicity, females have a higher risk – a finding that is compatible with studies of the general population. Additionally, Hispanics at LANL had the highest rates of thyroid dysfunction. These differences may be related to environmental or occupational factors encountered in the geographic region of LANL or during employment at the nuclear weapons research and development facility. Because thyroid dysfunction is a common health-related condition and its risk factors are only partially understood, the possible etiologic role of workplace exposures should be pursued.

Table 4.1: Demographics for LANL Former Workers (FW) and NHANES III Total Populations* by Age, Gender, and Ethnicity

LANL FW (N = 1,699)										
	Whites N (%)		Hispanic N (%)		Other (%)		Unknown		Totals N (%)	
Gender ►	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
20 - 49 yrs	35 (5)	13 (17)	89 (13)	27 (24)	10 (18)	4 (40)	1	0	135 (9)	44 (22)
50 - 69 yrs	345 (46)	32 (42)	353 (52)	58 (50)	28 (50)	2 (20)	13	0	739 (49)	92 (45)
70+ yrs	364 (49)	31 (41)	230 (34)	30 (26)	18 (32)	4 (40)	9	3	621 (41)	68 (33)
Totals	744 (91)	76 (9)	672 (85)	115 (15)	56 (85)	10 (15)	23	3	1495	204

NHANES III (N = 11,204)										
	Whites N (%)		Hispanic N (%)		Other N (%)		Unknown		Totals N (%)	
Gender ►	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
20 - 49 yrs	1208 (41)	1482 (43)	1432 (68)	1467 (70)	165 (63)	212 (60)	0	0	2805 (53)	3160 (54)
50 - 69 yrs	883 (30)	914 (27)	493 (23)	483 (23)	71 (27)	98 (28)	0	0	1447 (27)	1495 (25)
70+ yrs	873 (29)	1019 (30)	178 (9)	157 (7)	27 (10)	42 (12)	0	0	1078 (20)	1219 (21)
Totals	2964 (47)	3415 (53)	2103 (50)	2107 (50)	263 (43)	352 (57)	0	0	5330	5874

*LANL FW = All LANL former workers with documented TSH level.
*NHANES III Population = respondents ≥20 years with a documented TSH level.

Table 4.2: Median Thyroid-Stimulating Hormone (TSH) Levels (mIU/L) LANL Former Workers (FW) and NHANES III Populations by Gender, Ethnicity, and Age Groups

	LANL FW		NHANES III	
Total Population* (LANL FW = 1,699 NHANES III = 11,204)				
Ethnic Groups	Males N = 1,495 **Median**	Females N = 204 **Median**	Males N = 5,330 **Median**	Females N = 5,874 **Median**
All	2.00	1.84	1.58	1.60
White	2.04	1.81	1.60	1.70
Hispanic	1.91	1.84	1.50	1.50
Others	2.01	1.27	1.40	1.58
Age Groups	**Median**	**Median**	**Median**	**Median**
20 - 49 years	1.58	1.57	1.40	1.41
50 - 69 years	1.92	1.82	1.70	1.90
70+ years	2.24	2.00	1.99	2.00
Thyroid Disease Free Population ** (LANL FW = 1,467 NHANES III = 10,561)				
Ethnic Groups	Males N = 1,320 **Median**	Females N = 147 **Median**	Males N = 5,238 **Median**	Females N = 5,323 **Median**
All	1.97	1.79	1.58	1.60
White	2.03	1.81	1.60	1.70
Hispanic	1.87	1.76	1.50	1.50
Others	2.00	1.32	1.40	1.50
Age Groups	**Median**	**Median**	**Median**	**Median**
20 - 49 years	1.50	1.59	1.40	1.41
50 - 69 years	1.90	1.75	1.70	1.90
70+ years	2.25	2.05	2.00	2.08
Population Reporting Thyroid Disease ‡ (LANL FW = 232 NHANES III = 643)				
Ethnic Groups	Males N = 175 **Median**	Females N = 57 **Median**	Males N = 92 **Median**	Females N = 551 **Median**
All	2.27	1.92	1.59	1.50
White	2.15	1.66	1.40	1.50
Hispanic	2.73	2.15	1.91	1.30
Others	2.07	0.78	12.7	1.66
Age Groups	**Median**	**Median**	**Median**	**Median**
20 - 49 years	5.01	1.40	2.55	1.44
50 - 69 years	2.56	2.19	1.80	1.60
70+ years	2.17	1.79	1.10	1.50

*LANL FW = All LANL former workers with documented TSH level.
*NHANES III Population = respondents ≥ 20 years of age with a TSH level.
**Thyroid Disease Free Population LANL FW = LANL former workers with a TSH level not reporting thyroid disease or thyroid medication use.
**Thyroid Disease Free Population NHANES III = NHANES III participants ≥20 years of age with a TSH level and not reporting thyroid disease, goiter, or thyroid medication use.
‡ Population Reporting Thyroid Disease LANL FW = LANL former workers with a TSH level reporting thyroid disease or thyroid medication use.
‡ Population Reporting Thyroid Disease NHANES III = NHANES III participants ≥20 years of age with a TSH level reporting thyroid disease, goiter, or thyroid medication use.

Table 4.3: Proportion of Hypothyroidism and Hyperthyroidism in LANL Former Workers (FW) and NHANES III Populations by Ethnicity, Age and Gender

	Total Population* (LANL FW = 1,699 NHANES III = 11.204)											
	Hypothyroidism						Hyperthyroidism					
Ethnic Groups ▼	LANL FW			NHANES III			LANL FW			NHANES III		
Age Groups ▼	% Serum TSH > 4.5 mIU/L			% Serum TSH > 4.5 mIU/L			% Serum TSH < 0.4 mIU/L			% Serum TSH <0.4 mIU/L		
[LANL/NHANES III]	[Males/ Females]	Males (%)	Females (%)	[M/F]	Males (%)	Females (%)	[M/F]	Males (%)	Females (%)	[M/F]	Males (%)	Females (%)
All [1,699/11,204]	[1495/204]	8.6	7.8	[5330/5874]	4.8	8.3	[1495/204]	2.4	5.9	[5330/5874]	2.0	4.8
White [820/6379]	[744/76]	8.2	2.6	[2964/3415]	5.5	9.3	[744/76]	2.4	6.6	[2964/3415]	2.2	5.2
Hispanic [787/4210]	[672/115]	9.1	10.4	[2103/2107]	4.1	6.7	[672/115]	2.7	6.1	[2103/2107]	1.7	4.3
Others [92/615]	[79/13]	7.6	15.4	[263/ 352]	3.0	6.8	[79/13]	0	0	[263/ 352]	2.7	3.9
20 – 49 [179/5965]	[135/44]	3.7	9.1	[2805/3160]	2.6	4.4	[135/44]	2.9	4.5	[2805/3160]	1.8	3.7
50 – 69 [831/2942]	[739/ 92]	7.8	6.5	[1447/1495]	4.2	11.2	[739/ 92]	1.5	4.3	[1447/1495]	1.4	5.4
70+ [689/2297]	[621/ 68]	10.5	8.8	[1078/1219]	11.7	14.7	[621/ 68]	3.4	8.8	[1078/1219]	3.4	6.9
[LANL/NHANES III]	Thyroid Disease Free Population** (LANL FW = 1,467 NHANES III = 10,561)											
All [1,467/10,561]	[1320/147]	6.6	6.1	[5238/5323]	4.6	7.3	[1320/147]	1.3	2.7	[5238/5323]	1.7	2.4
White [686/5884]	[635/51]	6.1	0	[2896/2988]	5.3	8.4	[635/51]	0.8	3.9	[2896/2988]	1.6	2.1
Hispanic [699/4082]	[613/86]	7.2	9.3	[2082/2000]	3.9	5.9	[613/86]	1.9	1.4	[2082/2000]	1.6	2.7
Others [82/595]	[72/10]	5.6	10.0	[260/335]	2.3	5.9	[72/10]	0	0	[260/335]	2.7	3.6
20 – 49 [166/5799]	[129/37]	1.6	8.1	[2783/3016]	2.3	3.8	[129/37]	2.3	2.7	[2783/3016]	1.6	2.5
50 – 69 [729/2702]	[661/68]	5.7	4.4	[1408/1294]	3.8	10.1	[661/68]	0.9	0	[1408/1294]	0.9	1.7
70+ [572/2060]	[530/42]	8.9	7.1	[1047/1013]	11.7	14.1	[530/42]	1.5	7.1	[1047/1013]	2.7	3.1
[LANL/NHANES III]	Population Reporting Thyroid Disease‡ (LANL FW = 232 NHANES III = 643)											
All [232/643]	[175/57]	23.4	12.3	[92/551]	18.5	17.4	[175/57]	10.8	14.0	[92/551]	22.8	27.7
White [134/495]	[109/25]	20.2	8.0	[68/427]	16.2	15.9	[109/25]	11.9	12.0	[68/427]	27.9	26.9
Hispanic [88/128]	[59/29]	28.8	13.8	[21/107]	19.0	22.4	[59/29]	10.2	17.2	[21/107]	9.5	33.6
Others [10/20]	[7/3]	28.6	33.3	[3/17]	66.7	23.5	[7/3]	0	0	[3/17]	0	11.8
20 – 49 [13/166]	[6/7]	50.0	14.3	[22/144]	31.8	16.7	[6/7]	16.7	14.3	[22/144]	18.2	27.8
50 – 69 [102/240]	[78/24]	25.6	12.5	[39/201]	17.9	17.9	[78/24]	6.4	16.7	[39/201]	20.5	29.3
70+ [117/237]	[91/26]	19.8	11.5	[31/206]	9.7	17.5	[91/26]	14.3	11.5	[31/206]	29.0	26.2

*LANL FW = All LANL former workers with documented TSH level.
*NHANES III Population = respondents ≥20 years of age with a TSH level.
**Thyroid Disease Free Population LANL FW = LANL former workers with a TSH level not reporting thyroid disease or thyroid medication use.
**Thyroid Disease Free Population NHANES III = NHANES III participants ≥20 years of age with a TSH level and not reporting thyroid disease, goiter, or thyroid medication use.
‡Population Reporting Thyroid Disease LANL FW = LANL former workers with a TSH level reporting thyroid disease or thyroid medication use.
‡Population Reporting Thyroid Disease NHANES III = NHANES III participants ≥20 years of age with a TSH level reporting thyroid disease, goiter, or thyroid medication use

Table 4.4: Prevalence of Hypothyroidism Among LANL Former Workers (FW) and NHANES III Populations by Thyroid Status, Gender, Age and Ethnicity

Total Population*										
LANL Former Workers						NHANES III				
Ethnic and Age Groups ▼	Total N	Clinical N (%) (TSH > 10 mIU/L)		Subclinical N (%) (4.5 < TSH ≤ 10 mIU/L)		Total N	Clinical N (%) (TSH > 10 mIU/L)		Subclinical N (%) (4.5 < TSH ≤10 mIU/L)	
[LANL/ NHANES III] [1699/11,204]	Males/ Females	Male (%)	Female (%)	Male (%)	Female (%)	Males/ Females	Male (%)	Female (%)	Male (%)	Female (%)
All	1495/204	1.7	0.5	6.9	7.3	5330/5874	0.8	2.0	4.0	6.2
White	744/76	1.6	0	6.6	2.6	2805/3415	0.8	2.3	4.8	7.0
Hispanic	672/115	1.6	0	7.4	10.4	2103/2107	0.9	1.6	3.3	5.1
Other	79/13	2.5	1.5	5.1	7.7	263/352	0.8	1.7	2.3	5.1
20 – 49 yrs	135/44	1.5	0	2.2	9.1	2805/3160	0.3	0.9	2.3	3.4
50 – 69 yrs	739/92	1.6	0	6.2	6.5	1447/1495	0.8	3.3	3.4	7.9
70 + yrs	621/68	1.8	7.7	8.7	7.3	1078/1219	2.1	3.3	9.5	11.4
Thyroid Disease-free Population **										
Ethnic and Age Groups ▼	Total N	Clinical N (%) (TSH > 10 mIU/L)		Subclinical N (%) (4.5 < TSH ≤ 10 mIU/L)		Total N	Clinical N (%) (TSH > 10 mIU/L)		Subclinical N (%) (4.5 < TSH ≤ 10 mIU/L)	
[LANL/ NHANES III] [1467/10561]	Males/ Females	Male (%)	Female (%)	Male (%)	Female (%)	Males/ Females	Male (%)	Female (%)	Male (%)	Female (%)
All	1320/147	0.8	0	5.8	6.1	5238/5323	0.67	1.5	3.9	5.8
White	635/51	0.6	0	5.5	0	2896/2988	0.7	1.8	4.6	6.6
Hispanic	613/86	1.1	0	6.0	9.3	2082/2000	0.7	1.1	3.3	4.8
Other	72/10	0	0	5.6	10.0	260/335	0	1.5	2.3	4.5
20 – 49 yrs	129/37	0.8	0	0.8	8.1	2783/3016	0.2	0.7	2.1	3.1
50 – 69 yrs	661/68	0.8	0	4.9	4.4	1408/1294	0.6	2.5	3.3	7.6
70 + yrs	530/42	0.9	0	7.9	7.1	1047/1013	2.0	2.7	9.7	11.4
Population Reporting Thyroid Disease ‡										
Ethnic and Age Groups ▼	Total N	Clinical N (%) (TSH > 10 mIU/L)		Subclinical N (%) (4.5 < TSH ≤ 10 mIU/L)		Total N	Clinical N (%) (TSH > 10 mIU/L)		Subclinical N (%) (4.5 < TSH ≤ 10 mIU/L)	
[LANL/ NHANES III] [232/643]	Males/ Females	Male (%)	Female (%)	Male (%)	Female (%)	Males/ Females	Male (%)	Female (%)	Male (%)	Female (%)
All	175/57	8.0	6.7	15.4	10.5	92/551	8.7	6.9	9.8	10.5
White	109/25	7.3	0	12.8	8.0	68/427	2.9	5.8	13.2	10.1
Hispanic	59/29	6.8	0	22.0	13.8	21/107	0	11.2	0	11.2
Other	7/3	28.6	33.3	0	0	3/17	0	5.9	0	17.6
20 – 49 yrs	6/5	16.7	0	33.3	14.3	22/144	9.1	5.6	22.7	11.1
50 – 69 yrs	78/24	8.9	0	16.7	12.5	39/201	10.3	8.5	7.7	9.4
70 + yrs	91/26	6.6	3.8	13.2	7.7	31/206	6.4	6.3	3.2	11.2

*LANL FW = All LANL former workers with documented TSH level.
*NHANES III Population = respondents ≥20 years of age with a TSH level.
**Thyroid Disease-free Population LANL FW = former workers with a TSH level not reporting thyroid disease or thyroid medication use.
**Thyroid Disease-free Population NHANES III = NHANES III participants ≥20 years of age with a TSH level and not reporting thyroid disease, goiter, or thyroid medication use.
‡ Population Reporting Disease LANL FW = LANL former workers with a TSH level reporting thyroid disease or thyroid medication use.
‡ Population Reporting Disease NHANES III = NHANES III participants ≥20 years of age with a TSH level reporting thyroid disease, goiter, or thyroid medication use.

Table 4.5: Logistic Regression Model[‡] for the LANL Former Workers (N = 1,478) and the NHANES III (N = 5,015) Group Over 50 Years of Age and Interaction Term Age and Gender

	Base Model			Final Model*		
Independent Variables	**Maximum Likelihood Estimates**	**p-value**	**Odds Ratio (95% C.I.)**	**Maximum Likelihood Estimates**	**p- value**	**Odds Ratio (95% C.I.)**
Group						
(NHANES III)			1.00			1.00
LANL FW	0.6121	<0.0001	1.84 (1.53 – 2.23)	0.6114	<0.0001	1.84 (1.53 – 2.23)
Age	0.0284	<0.0001	1.03 (1.02 – 1.04)	0.0157	0.001	-
Ethnicity						
Whites			1.00			1.00
Hispanic	-0.057	0.49	0.94 (0.80 – 1.11)	-0.0532	0.53	0.95 (0.80 – 1.12)
Others	-0.392	0.06	0.67 (0.45 – 1.01)	-0.4045	0.05	0.67 (0.44 – 1.001)
Gender						
Females			1.00			1.00
Males	-0.7946	<0.0001	0.45 (0.38 – 0.53)	-2.8890	<0.0001	-
Smoking						
Never			1.00			1.00
Ever	0.0311	0.68	1.03 (0.89 – 1.19)	0.0577	0.4483	1.06 (0.91 – 1.23)
Age X Male Gender*		-	-	0.0300	<0.0001	-

[‡]Logistic Regression Model: odds of having an elevated TSH level and/or thyroid medication use
Case = TSH >4.5 mIU/L and/or reported thyroid medication use.
Non-Case = 0.4 ≤ TSH ≥ 4.5 mIU/L and no reported thyroid medication use.
*Interaction model

Chapter 5: Thyroid Function and Workplace Exposures in Former Workers from a Nuclear Weapons Facility

5.1 Abstract

Thyroid dysfunction, particularly hypothyroidism, is thought to be common in the U.S. population (prevalence 4.6%) and can be associated with other serious medical conditions. Subclinical and overt hypothyroidism have been associated with cardiovascular disease, hyperlipidemia, psychiatric and cognitive abnormalities, and there is increasing concern about thyroid function during pregnancy and the possible effect on childhood development. Given its potentially large public health impact, there are surprisingly few population studies of thyroid dysfunction, and the studies that have been done have not discussed any possible association between thyroid dysfunction and workplace exposures.

Based on findings from a previous study of a cohort of former workers from a nuclear weapons facility, this study examined a possible relationship between thyroid function (TSH levels and hypothyroidism) and potential occupational risk factors, including exposures to radiation and solvents. No association was found between thyroid dysfunction and radiation exposure, but a modest association was found that suggests an effect in this worker population that may be related to chlorinated solvents. Causal

relationships between thyroid dysfunction and human exposures should be further investigated to inform approaches for preventing adverse thyroid outcomes.

5.2 Introduction

Thyroid dysfunction, particularly hypothyroidism, is thought to be common in the U.S. population (prevalence 4.6%) and can be associated with serious medical conditions. Vanderpump and Tunbridge (2002) described hypothyroidism as an insidious health problem with significant morbidity and subtle, nonspecific symptoms. Subclinical and overt hypothyroidism have been negatively associated with cardiovascular dysfunction, higher lipid levels and psychiatric and cognitive abnormalities (Biondi et. al 2002; Canaris et al. 2000; Cooper 2001; Klein and Ojamaa 2001; Larisch et al. 2004). In addition, there is increasing concern about thyroid function during pregnancy, and about the effect on childhood development (Howdeshell 2002; Schettler 2001).

Many environmental agents have been associated with thyroid disease or dysfunction. Recent studies have suggested that low levels of endocrine disrupting chemicals (organochlorine compounds and certain metals) can interfere with thyroid status during pregnancy, leading to a potentially significant impact on fetal neuro-development (Colborn 2004; Ribas-Frito et al. 2001; Takser et al. 2005). Radiation exposure has also been reported as a risk factor for thyroid disease (Boice 1998; Ivanov et al. 2000; Jereczek-Fossa et al. 2004; Nagataki et al. 1994). The literature implicates occupational external radiation exposure, including that associated with clean-up after the Chernobyl nuclear accident, as well as therapeutic radiation exposure. Other environmental agents of concern include perchlorates and organic solvents (Greer et al 2002; Wingren and Axelson 1996; Xiao 2000).

Given its potentially large public health impact, there are surprisingly few population studies of thyroid dysfunction. Only two cross-sectional and one cohort follow-up study have been done to determine the prevalence and incidence of thyroid dysfunction in the general population (Canaris et al. 2000; Hollowell 2002; Vanderpump et al. 1995). In addition, two European studies of thyroid dysfunction on working populations have been reported (Pirich et al. 2000; Schaaf et al. 1993). Interestingly, these studies did not discuss any possible relationship between thyroid dysfunction and workplace exposures.

As a part of a medical examination program at the Los Alamos National Laboratory (LANL), we screened a large number of former workers with self-reported ionizing radiation and chemical exposure for thyroid function (measured by thyroid stimulating hormone [TSH] levels and health histories). We have previously compared the TSH levels among the LANL cohort to other population-based estimates of TSH and found, after controlling for age and ethnicity, that males in the LANL former worker population had significantly higher TSH levels. This analysis suggests that a possible occupational risk factor may be associated with thyroid function, particularly among the males in this cohort. The purpose of this study is to examine the relationship between thyroid function (TSH levels and hypothyroidism) and potential occupational risk factors in this cohort. Radiation exposure is of primary concern in this analysis. The ability to evaluate radiation exposure as a risk factor for hypothyroidism is limited by the fact that having reported radiation exposure is a prerequisite for having TSH screening. As a result, there is no non-exposed group. However, we should still be able to compare and contrast those workers who had long duration, high frequency exposure to those who had short duration, low frequency exposure.

5.3 Methods

5.3.1 Study Population

The group of LANL former workers in this study participated in a larger medical examination program conducted between April 2000 and December 2002. This larger program, the Medical Exam Program for Former Workers from LANL, which was part of a Department of Energy (DOE) funded response to a 1993 Congressional mandate, offered medical screening to former workers who had worked with hazardous substances during their employment at DOE sites. At LANL, a physical examination and testing were offered to all former workers who worked there from 1943 until December 2002 and who were potentially exposed to asbestos, beryllium, lead, noise, ionizing radiation, or solvents. This program is described in more detail elsewhere (Breysse et al. 2001).

As part of a targeted examination protocol, an exposure and medical history interview was completed with every former worker who agreed to participate in the parent program, and a TSH level was drawn from those former workers who reported possible exposure to ionizing radiation. During the job history interview, participants listed every job they held while employed at the laboratory; for each job, they estimated the frequency and duration of exposure to radiation, solvents (chlorinated, aromatic and others), lead and other agents of concern. In addition, workers were asked if they were ever subjected to radiation-specific exposure protection measures, such as wearing a radiation badge, participating in a urine monitoring program, or being decontaminated after accidental radiation exposure. Any interview response that indicated historical workplace radiation exposure resulted in the participant receiving a radiation screening examination that included blood TSH measurement.

Thirteen LANL former workers who reported past thyroid cancer were eliminated from the study population for the analysis presented in this paper, as their diagnosis and possible treatment methods would be likely to make them incomparable to this study population with regard to the interpretation of their TSH levels. (The development of thyroid cancer among LANL former workers will be treated separately and reported elsewhere.) Another group that was dropped for the purpose of these analyses were those whose TSH was <0.4 mIU/L (n = 36), thus suggesting hyperthyroidism. Since the research question focused on the predictors of hypothyroidism, this was not a suitable comparison population.

The questionnaire that assessed solvent exposure was not administered to all participants in the screening program. Unlike radiation exposure, which was reported by almost all workers, a relatively large number stated that they did not know whether they had been exposed to solvents. These individuals were dropped from selected analyses dealing with the effect of solvent exposure, but the numbers differed according to solvent category.

In the initial stages of data analysis, females (n = 204) and the ethnic group "others" (non-white, non-Hispanic; n = 56) were found to be relatively few in number and, therefore, were not included in the study group. Individuals under the age of 50 were also excluded because they were relatively few in number (n=121), most had a relatively short work history at the laboratory, and their inclusion resulted in a skewed age distribution. As a result, 1,282 male former workers aged 50 or older, who were either white or Hispanic, were included in the analyses of radiation exposure. For analyses of chlorinated, aromatic, and other solvents, 829, 888, and 884 former workers were included, respectively.

5.3.2 Measures of Thyroid Function

Thyroid dysfunction status was based on serum TSH, the measure typically utilized in medical screening programs due to its high sensitivity for detection of thyroid dysfunction. Additional measures, such as T_4, T_3, and antithyroid antibodies, which are sometimes used to classify thyroid disease, were not assessed in LANL former workers for the medical screening program. TSH values >4.5 mIU/L were used to define hypothyroidism in the current study. This is consistent with the normal reference range for TSH levels of 0.45 to 4.5 mIU/L, which was defined at a 2002 consensus development conference by representatives of the American Thyroid Association (ATA), the American Association of Clinical Endocrinologists (AACE) and the Endocrine Society, who met to discuss the basis for making clinical decisions regarding treatment of subclinical thyroid disease (Surks et al. 2004). Although levels of TSH >10 mIU/L are indicative of "clinical" or "overt" hypothyroidism, values between 4.5 mIU/L and 10 mIU/L are considered by most to be "subclinical." For TSH levels within this range, initiation of treatment depends on additional evidence of thyroid disease. In the absence of other indices of thyroid function, those with levels greater than 4.5 mIU/L were included in the hypothyroid group and thereby designated as "cases." Because thyroid medications are known to affect TSH levels, such medication use was an alternate criterion for meeting the case definition. Cases were therefore those who had a TSH level >4.5 mIU/L or who reported taking thyroid medication (almost exclusively levothyroxine).

5.3.3 Measures of Exposure

During the parent program, a Job Exposure Matrix (JEM) was developed. Job titles from the rosters of former workers were assigned to a common code based on an accepted classification scheme to all job titles. There were a number of such schemes available.

However, this investigation chose to use the Common Occupation Classification System (COCS) (Stahlman and Lewis 1996). COCS codes were selected for use in this study because they represent a common occupational taxonomy developed for the DOE and used by other former worker programs. (See Appendix A for copy of JEM.)

Exposure assignment is based solely on self-reports of frequency and duration of working with or around agents of concern (radiation and or solvents). Table 1 presents the values assigned to the self-reported frequencies and duration of workplace exposures. Figure 1 shows the formula used to compute, across all jobs, the Cumulative Exposure Index (CEI), which is a weighted estimate of working-lifetime exposure. The CEI, used as an independent exposure variable, was calculated for each agent for each person in the cohort. This index was later logarithmically transformed to better approximate the normal distribution. The radiation CEIs were divided at the median value to classify exposures into "high" and "low" levels. Additionally, reports of radiation protective measures were used to develop two indices of possible radiation exposure intensity. In the first index, workers were classified as having experienced "high" peak doses if they were ever removed from a job or decontaminated due to radiation exposure. The second index added the condition of having ever been subject to total body radiation counts as another potential marker of intense radiation exposure. For each of these two indices, workers who reported experiences of any of the protective actions listed above were compared to all others.

In the case of solvent exposure, many reported no exposure for one or more of the solvent classes. These individuals were retained in a "low" exposure group that served as the reference group in some analyses. Those who fell at or below the median of the remaining solvent CEI values were considered to have "medium" exposure, and those above the median were coded as "high."

5.3.4 Statistical Analysis

As mentioned above, skewed distributions of TSH levels, radiation exposure CEI and solvent CEI necessitated log transformations of these variables. Thyroid function, as measured by both TSH levels as a continuous variable and case status (TSH >4.5 mIU/L and/or thyroid medication use) was assessed by age, job title and CEI. In addition, all analyses were stratified on ethnicity. Bivariate analyses evaluated correlations between TSH levels and all continuous independent variables. Chi-square analyses were used to examine associations between case status and independent variables of interest, including job title and each individual type of radiation protection practice. Further analyses evaluated the relationship between thyroid function, case status and the two forms of dichotomized levels of radiation protection practices. Finally, separate logistic regression models were used to evaluate the influence of the two exposures of interest – radiation and solvents – on thyroid case status. In addition to the respective CEIs for each exposure, components of the logistic models included variables that were significantly associated with case status in bivariate analyses – age, education level, ethnic group, years worked at LANL, years since last worked at LANL and job type. All statistical analyses were performed using SAS V 9.0.

5.4 Results

Table 2 presents the demographic information for male LANL former workers included in this study (n = 1,439). The numbers of whites and Hispanics were similar in this cohort. This was an older population; as former workers, many had already retired. The median ages of the white and Hispanic males were 69 years and 64 years, respectively. The biggest difference between white and Hispanic participants is in the education level.

Only 9% of the white participants had <12 years of education, compared to 32% of the Hispanics. An analysis of employers and employment duration shows that most of the white workers were employed by the University of California, holding many scientific and technical positions, while the greatest proportion of Hispanics worked for support subcontractors. In addition, a greater proportion of Hispanics than whites had worked at LANL for 10 years or less. There were also disparities in the type of jobs held according to ethnic group. Hispanics were more concentrated in two categories of jobs: laborers and general service workers (41%) and building crafts (34%). Among whites, the proportion in the building crafts also equaled 34%, but 17% occupied positions related to the scientific mission of LANL. Thirteen percent of both groups were technicians.

Table 3 summarizes the median and interquartile range TSH levels by age and ethnic group. As expected, TSH levels increased in the higher age groups, but were fairly equivalent between the ethnic groups. The highest median TSH levels, 2.26 mIU/L, were for ≥70-year-old Hispanics. None of the 75% values exceeded the threshold case definition of TSH >4.5 mIU/L.

Table 4 presents a summary of median and interquartile range TSH levels by job category and ethnic group. When compared by job category, operators had the highest median TSH levels for both Hispanics and whites (2.9 mIU/L and 2.5 mIU/L, respectively). The lowest TSH levels were for professional and administrative workers for both Hispanics and whites (1.6 mIU/L and 1.9 mIU/L, respectively).

Distributions by demographic characteristics and CEI for the exposures of interest, radiation and solvents, are shown in Table 5. Among male workers over 50 years old, CEIs for radiation were comparable across age and ethnic groups. The inter-quartile ranges were also identical. This is not entirely surprising, given that having reported some radiation exposure was a prerequisite for entering the study. When similar comparisons by age and ethnic group were made for solvents, Hispanic workers demonstrated CEIs that were generally equal to or higher than those of whites. Higher values were particularly evident in the case of aromatic solvents. Additionally, the upper quartile ranges tended to be higher for Hispanics for all solvent types.

The distribution of CEIs by job title and age for radiation and solvents are presented in Tables 6 and 7, respectively. The highest median radiation CEIs, 18.5, were seen among Hispanic technicians and white scientists (range 2.0 to approximately 18.6). For all other job categories, the median CEIs for radiation were <10. The median CEIs for solvents ranged from 0.1 to 7.9, with the highest CEI values occurring for scientists, technicians and operators. The group with the highest CEI for chlorinated solvents was Hispanic technicians (4.9). White professionals had the highest CEI value for aromatic solvents (4.6). The highest overall value by job type was 7.9, reported for Hispanic scientists (n = 12).

Bivariate comparisons of TSH levels and CEIs, age, education, years worked at LANL, years since last exposure and ethnic group are summarized in Table 8. Only age and highest level of education were correlated with log TSH levels. CEI for radiation was not correlated, nor were any of the solvent type CEIs. Similarly, the means of TSH values did not differ significantly by ethnic group.

In addition to evaluating TSH as a continuous variable, Table 9 reports on the association between thyroid case status by all levels of demographic variables, protective work practices and categories of job. Again, age is positively associated with being a case, as defined above (consistent with hypothyroidism) (X^2 = 19.2, p <.0001). In addition, those who had experienced radiation whole body counts to detect excessive exposure (typically done after an accidental exposure) and those who were staff members were more likely to be defined as cases. Case status was also compared using other combinations of the protective practices believed to indicate the highest concern for radiation exposure. Those who experienced removal from the job or decontamination were not more likely to be considered cases. Similarly, if one of the above conditions *or* radiation detection counts were experienced, no association was seen. (This table is included in Appendix C.)

Tables 10 and 11 present the final logistic regression models that assessed, for this former worker population, the relationship between the exposures to radiation and solvents and thyroid status (case versus non-case), controlling for age, education, ethnicity, years worked at LANL and job categories. Regression diagnostic testing was performed, and Hosmer-Lemeshow statistics were found to be acceptable for each model. Radiation CEI was entered into the model as a log transformed continuous variable, but was not found to be associated with increased risk of becoming a case. However, as previously found in bivariate analyses, increasing age was a predictor of thyroid status (OR = 1.04, CI = 1.02-1.07). While the results suggested that the risk of becoming a case increased with education level and duration of employment at LANL, the confidence limits for their respective odds ratios included unity.

Each type of solvent CEI was evaluated separately, controlling for the same variables described above (Table 10). CEIs for each solvent were ordered from low (no reported exposure) to high (levels higher than the median of all CEIs). Controlling for individual and job variables, there was an increasing trend in risk for being a case with increasing levels of exposure for each type of solvent. However, the confidence interval only exceeded the value of one for the highest level of chlorinated solvents (OR 1.71, C.I. 1.01-2.90). Age was also a predictor of case status across all solvent exposure models, but with only slightly elevated odds ratios, from 1.03 to 1.04.

5.5 Discussion

A previous study that characterized thyroid function of former LANL workers (Article 1) provided evidence that thyroid function was worse than found in studies of the U.S. population (Canaris et al. 2000; Hollowell et al. 2002, and Sawin et al. 1985). For example, the age-adjusted prevalence of thyroid dysfunction in the LANL cohort was found to be higher in males relative to females, whereas rates among females have exceeded those of males in other reports (Canaris et al. 2000; Hollowell et al. 2002; Sawin et al. 1985, and Vanderpump and Tunbridge 2002). In addition, males of all age groups (20-49, 50-69 and 70+) in the LANL cohort were found to have significant higher TSH levels when compared to the NHANES III population. Such findings suggested that environmental or occupational exposures might be impacting the thyroid function in LANL workers.

Because the job histories of the former LANL workers included known exposure to agents believed to be linked to thyroid dysfunction – notably radiation and several types of solvents – further study of this group was warranted

In addition, the workers participating in the LANL screening program are an interesting group to study because most of this study population had worked at LANL for many years and because all were over age 50, therefore allowing time for the potential manifestation of thyroid disease. (Because the incidence of hypothyroidism increases with age, an older population is appropriate for study.) Finally, the index of exposure – a measure of overall time spent working with an agent – ranged widely, thereby allowing an evaluation of exposure-response relationships.

The present study was limited to males, as TSH levels are known to differ by gender and because males in this cohort were found to have higher age-adjusted TSH levels than females. In addition, there were more males in the screened group, making stratification more statistically powerful. Finally, men were believed to have held jobs with the greatest likelihood of relevant exposures (radiation and solvents), compared to women.

After controlling for other demographic and work-related variables, age was consistently associated with thyroid function in each of the models. The incidence of hypothyroidism is known to increase with age, particularly after age 60 (Vanderpump et al., 1995). Thus, the trend seen for this group was expected, and suggests that the case definition used to define thyroid disease is valid.

Interest focused on radiation exposure in this study, because of observed associations that linked thyroid dysfunction and medical treatment, environmental contamination around test sites and accident clean-up operations (Ivanov et al. 2000; Jereczek-Fossa et al. 2004; Zhumadilov et al. 2000). Health care workers comprise another occupational group in whom thyroid effects of radiation have been established (Hallquist et al. 1993). The current study, however, failed to identify such a relationship in a logistic model that assessed radiation exposure expressed as a cumulative index. Exposures of those in the LANL former worker population may have been less than those experienced by subjects in the above investigations. In addition, as previously mentioned, there were no non-radiation exposed workers in this population, so the best that can be concluded is that the higher exposed workers (based on CEI) did not have worse thyroid function than those with lower-radiation exposure.

Alternatively, the cumulative index used in this study may have been too crude to adequately quantify exposures to either radiation or solvents. Because the data were based on self-reported information that was collected as part of a health screening study, the assessment of frequency and duration of work with regard to each agent was very general. Worker self-reports of exposure are notably problematic for retrospective exposure assessments (Blanc et al. 2005; Heinrich et al. 2004). However, radiation is a unique agent in many regards, and LANL took many special precautions to educate and protect workers. At a general level, it is not unreasonable to expect workers to accurately self-report having been a radiation worker. The use of mid-point CEI estimates for each frequency and duration response also may have led to poorly refined exposure estimates. Values may not have adequately discriminated between individuals with differing levels of actual radiation exposure. Furthermore, since we did not have access to LANL monitoring records for this study, it was not possible to validate occupational histories or CEIs using monitoring data. As a result, the probability of misclassification is difficult to estimate in this study. It is likely, however, that any misclassification is non-differential, biasing the results to the null.

In addition to the CEI, personal protective actions were also considered as being indicative of intermittent high level exposures. While the experience of having had whole body radiation detection counts was positively related to thyroid health status in bivariate analyses, neither this single indicator nor combinations that collapsed other protective actions were predictive of thyroid case status in a multivariate model. Protective practices undoubtedly targeted workers in jobs that had potential for contact with radiation sources; however, their use may not have signified actual exposure. In fact, such practices may have reduced exposure or led to greater caution in handling radioactive materials.

Although exposure estimates may have been crude, the results did suggest an association between hypothyroidism and working with solvents – chlorinated solvents, in particular. The odds ratio indicated that individuals who reported exposure to chlorinated solvents were 1.7 times more likely to be classified as a hypothyroidism case. There is a single literature report of an association between benign thyroid disease and solvents at work (based among chemists, painters, lacquerers and laboratory workers) (Wingren and Axelson 1997); however, specific solvent types were not defined in this study, nor were amounts of solvent exposure quantified.

There are many accounts of a relationship between other chlorinated compounds and thyroid dysfunction. For example, there is evidence of an effect of persistent organochlorine compounds on maternal hormone levels in pregnant women (Takser et al. 2005). In particular, polychlorinated biphenyls (PCBs) have been shown to affect neurological development in children (Ribas-Frito et al. 2001). Brouwer et al. (1999) have documented effects of PCB congeners on metabolic systems, and others have shown that PCBs interfere with signaling mechanisms, thereby reducing the levels of thyroid hormone available at the tissue level (Zoeller et al. 2002). A relationship between chlorinated solvents and thyroid dysfunction, as suggested by the current study, is therefore thought to be plausible.

Studies of the relationship between thyroid disease and environmental and occupational exposures have tended to focus on thyroid cancer, often neglecting the important health consequences that can arise from the hormonal dysfunction associated with hypothyroidism and hyperthyroidism. These consequences include potential effects on the developing fetus and chronic and debilitating conditions in adults. There is little known about environmental causes of thyroid dysfunction. This study, although not designed for this purpose, is one of the few such reports investigating potential occupational risk factors for thyroid disease. Although the evidence is modest, the results suggest an effect in this worker population that may be related to chlorinated solvents. An association with radiation exposure was not supported by the data that were available from a health screening program, but such an association should not be ruled out. Causal relationships between thyroid dysfunction and human exposures should be further investigated to inform approaches for preventing adverse thyroid outcomes.

Table 5.1: Values Assigned to Each Reported Frequency and Duration of Use of Radiation, Lead, and Solvents in Former Workers (FW) from Los Alamos National Laboratory (LANL)

Frequency of Use of Radiation and the Other Agents	Value Assigned to the Frequency of Use of Radiation and the Other Agents	Duration of Use for Radiation and the Other Agents	Value assigned to the Duration of Use for Radiation and the Other Agents
never	0	less than 1 year	0.5 year
daily	5 days x 50 weeks = 250 days	1 to 5 years	3 years
weekly	1 day x 50 weeks = 50 days	6 to 10 years	8 years
monthly	12 days	greater than 10 years	27 years (median)
yearly	1 day	don't know	removed
don't know	Removed	missing	0
missing	0		

Figure 5.1: Computation of the Cumulative Exposure Index (CEI)

$$\sum (\text{frequency} * \text{duration})_{\text{jobs1} - n} = \text{Cumulative Exposure Index}$$

Table 5.2: Demographics Male LANL Former Workers (N= 1,439) by Age and Ethnicity and Work History by Age and Ethnicity

Variables	Gender		
Age Groups	**White Males N (%)**	**Hispanic Males N (%)**	**Totals N (%)**
20 – 49 years	35 (5)	89 (13)	124 (9)
50 – 69 years	345 (46)	353 (51)	698 (48)
≥ 70 years	364 (49)	230 (33)	594 (41)
Missing	-	23 (3)	23 (2)
Totals	744 (52)	695 (48)	1439 (100)
Median Age (Years)	69 (36 – 93)	64 (29 – 91)	67 (29 – 93)
Education Level	**White Males N (%)**	**Hispanic Males N (%)**	**Totals N (%)**
< 12 years	64 (9)	221 (32)	285 (20)
12 years	246 (33)	275 (40)	521 (36)
13 – 16 years	228 (30)	160 (23)	388 (27)
> 16 years	206 (28)	16 (2)	222 (15)
Missing	-	23 (3)	23 (2)
Totals	744 (52)	695 (47)	1439 (100)
Median (Years)	14 (0 – 41)	12 (0 – 22)	12 (0 – 41)

Employers	**White Males N (%)**	**Hispanic Males N (%)**	**Totals N (%)**
UC*	587 (79)	255 (37)	842 (58)
Zia** (Building & Trades Unions)	140 (19)	380 (55)	520 (36)
Subcontractors***	17 (2)	37 (5)	54 (4)
Missing	-	23 (3)	23 (2)
Totals	744 (52)	695 (48)	1439 (100)
Years of Employment at LANL	**White Males N (%)**	**Hispanic Males N (%)**	**Totals N (%)**
< 1 year	23 (3)	18 (3)	41 (3)
1 – 10 years	97 (13)	143 (21)	240 (17)
11 – 20 years	141 (19)	165 (24)	306 (21)
> 20 years	483 (65)	346 (51)	829 (58)
Missing	-	23 (3)	23 (1)
Totals	744 (52)	695 (48)	1439 (100)
Median Years Employed at LANL	26 (0 – 53)	21 (0 – 52)	24 (0 - 53)

*University of California
**Main Subcontractor = Zia, Pan Am World Services, Johnson Controls Incorporated, Johnson Controls of Northern New Mexico
***other subcontractors

Table 5.3: Median TSH Levels Interquartile Ranges (Quartiles 25% - 75%) by Age Groups and Ethnicity in Male LANL Former Workers

Median TSH levels (mIU/L) (25% - 75% Quartiles)						
	White Males			Hispanic Males		
Age Groups	N (%)	Median (mIU/L)	Quartiles (25% - 75%)	N (%)	Median (mIU/L)	Quartiles (25% - 75%)
20 – 49 years	35 (5)	1.78	(1.30 - 2.60)	89 (13)	1.48	(1.01 – 2.29)
50 – 69 years	345 (46)	1.95	(1.39 – 2.84)	353 (53)	1.81	(1.29 – 2.67)
70 + years	364 (49)	2.21	(1.59 – 3.28)	230 (34)	2.26	(1.49 – 3.64)
Totals	**744 (100)**	**2.16**	**(1.45 – 3.04)**	**672 (100)**	**1.91**	**(1.3 – 3.0)**

Table 5.4: Median TSH Levels (mIU/L) Interquartile Ranges (25% - 75% Quartiles) by Ethnicity and Job Codes Males LANL Former Workers

White Males			Hispanic Males		
Description	**N**	**Median TSH (25% - 75% Quartiles)**	**Description**	**N**	**Median TSH (25% - 75% Quartiles)**
Operators	15	2.5 (1.6 – 3.1)	Operators	34	2.9 (1.7 – 3.7)
Scientists	122	2.3 (1.5 – 3.1)	Technicians	77	2.0 (1.3 – 3.0)
Laborers, General Service, Workers, Security	49	2.3 (1.6 – 3.4)	Laborers, General Service Workers. Security	245	1.9 (1.4 – 2.8)
Engineers	63	2.1 (1.5 – 3.9)	Staff Members	4	1.9 (1.4 – 2.2)
Staff Members	79	2.0 (1.3 – 3.1)	Crafts (Building and Trades)	195	1.9 (1.3 – 3.0)
Technicians	88	1.9 (1.4 – 2.7)	Scientists	25	1.8 (1.2 – 3.0)
Professional, Administrative	30	1.9 (1.5 – 3.3)	Professional, Administrative	6	1.6 (1.1 – 2.2)
General Managers, First Line Supervisors	14	1.9 (1.5 – 3.3)			
Crafts (Building and Trades)	230	1.9 (1.4 – 2.9)			
Totals	**690**	**2.16 (1.4 – 3.0)**	**Totals**	**586**	**1.9 (1.3 – 3.0)**

Table 5.5: Median Cumulative Exposure Indices with Interquartile Ranges (Quartiles 25% - 75%) by Age Groups and Ethnicity Male LANL Former Workers

Median Radiation Cumulative Exposure Index (CEI) in Years

	White Males			Hispanic Males		
Age Groups	N (%)	Median (CEI)	Quartiles (25% - 75%)	N (%)	Median (CEI)	Quartiles (25% - 75%)
20 – 49 years	32 (5)	1.1	(0.3 – 2.9)	79 (13)	2.0	(0.4 - 5.5)
50 – 69 years	324 (47)	3.7	(0.9 – 18.5)	309 (53)	3.7	(0.9 – 18.5)
70 + years	335 (48)	3.7	(0.9 – 18.5)	200 (34)	3.1	(1.1 - 18.5)
Totals	691	3.7	(0.9 – 18.5)	588	3.7	(0.9 – 18.5)

Median Chlorinated Solvents Cumulative Exposure Index (CEI) in Years

Age Groups	N (%)	Median (CEI)	Quartiles (25% - 75%)	N (%)	Median (CEI)	Quartiles (25% - 75%)
20 – 49 years	13 (3)	0.3	(0.2 – 0.6)	24 (12)	1.3	(0.3 – 12.3)
50 – 69 years	181 (48)	1.7	(0.3 – 3.6)	110 (55)	2.5	(0.6 – 6.2)
70 + years	183 (49)	2.5	(0.6 – 5.1)	66 (33)	2.5	(1.0 – 12.3)
Totals	377	2.0	(0.3 – 4.9)	200	2.5	(0.6 – 12.3)

Median Aromatic Solvents Cumulative Exposure Index (CEI) in Years

Age Groups	N (%)	Median (CEI)	Quartiles (25% - 75%)	N (%)	Median (CEI)	Quartiles (25% - 75%)
20 – 49 years	8	0.3	(0.2 – 1.3)	23	1.7	(0.3 – 7.2)
50 – 69 years	119	0.7	(0.1 – 2.5)	88	1.7	(0.6 – 5.1)
70 + years	117	1.7	(0.6 – 5.1)	53	2.5	(0.6 – 5.1
Totals	244	1.1	(0.3 – 2.8)	164	2.5	(0.6 – 5.1)

Median Other Solvents Cumulative Exposure Index (CEI) in Years

Age Groups	N (%)	Median (CEI)	Quartiles (25% - 75%)	N (%)	Median (CEI)	Quartiles (25% - 75%)
20 – 49 years	18 (4)	0.5	(0.2 – 1.7)	34 (12)	2.5	(0.3 – 10.3)
50 – 69 years	210 (50)	2.5	(0.6 – 12.3)	166 (58)	2.5	(0.6 – 12.3)
70 + years	192 (46)	2.5	(0.6 – 5.1)	84 (30)	2.5	(0.6 – 12.3)
Totals	420	2.5	(0.6 – 7.5)	284	2.5	(0.6 – 12.3)

Table 5.6: Median Cumulative Exposure Indices (in years) with Interquartile Ranges (25%-75% Quartiles) in Male LANL Former Workers by Job Codes

Median Radiation Cumulative Exposure Index					
White Males			Hispanic Males		
Description	N	Median CEI (25% - 75% Quartiles)	Description	N	Median CEI (25% - 75% Quartiles)
Scientists	122	18.5 (2.0 – 18.5)	Technicians	77	18.5 (2.0 – 18.6)
Operators	15	6.5 (2.0 – 18.5)	Scientists	25	9.6 (3.7 -18.5)
Technicians	88	5.5 (2.0 – 18.5)	Laborers, General Service, Security	245	3.7 (0.9 – 18.5)
Staff Members	79	3.7 (0.9 – 18.5)	Operators	34	3.7 (0.4 – 18.5)
Professional, Administrative	30	3.7 (0.9 – 5.5)	Crafts (Building and Trades)	195	3.7 (0.9 – 5.7)
General and First Line Managers	14	2.4 (0.9 – 18.5)	Professional, Administrative	6	3.7 (0.3 – 20.5)
Laborers, Gen. Service, Security	49	2.0 (0.3 – 11.6)	Staff Members	4	2.0 (0.6 – 8.3)
Crafts (Building and Trades)	230	2.0 (0.4 – 7.8)			
Engineers	63	1.1 (0.3 – 8.9)			
Totals	**690**	**3.7 (0.9 – 18.5)**	**Totals**	**586**	**3.7 (0.9 – 9.7)**

Table 5.7: Median Solvent Cumulative Exposure Indices (in years) with Interquartile Ranges (25% - 75% Quartiles) in Male LANL Former Workers (FW) by Job Codes

Median Solvent Cumulative Exposure Index													
White Males							Hispanic Males						
	Chlorinated		Aromatic		Others			Chlorinated		Aromatic		Others	
Description	Median CEI (25% - 75% Quartiles)		Median CEI (25% - 75% Quartiles)		Median CEI (25% - 75% Quartiles)		Description	Median CEI (25% - 75% Quartiles)		Median CEI (25% - 75% Quartiles)		Median CEI (25% - 75% Quartiles)	
Laborers	11	2.5 (0.3 – 12.3)	10	1.0 (0.3 – 12.3)	14	2.0 (0.3 – 12.3)	Technicians	38	4.9 (1.7 – 12.3)	37	2.5 (0.6 -12.3)	49	4.9 (1.7 – 12.3)
Technicians	53	2.5 (0.6 – 10.3)	42	2.2 (0.6 – 5.1)	59	3.5 (1.0 – 12.3)	Engineers	70	2.5 (1.0 – 12.3)	62	2.5 (1.0 -10.3)	129	2.4 (1.0 – 12.3)
Scientists	88	2.5 (0.6 – 4.5)	72	0.6 (0.6 – 2.5)	95	2.5 (0.6 – 12.3)	Scientists	10	2.5 (0.7 - 12.3)	9	2.5 (0.9 – 2.5)	12	7.9 (2.5 – 12.3)
Engineers	158	2.0 (0.3 – 3.4)	80	1.0 (0.2 – 2.5)	174	1.8 (0.3 – 5.1)	Operators	7	1.9 (0.6 – 12.3)	8	3.5 (0.6 -9.4)	9	3.7 (0.6 – 12.3)
Managers, First Line Super.	7	2.0 (1.7 – 2.5)	4	1.7 (1.0 – 4.6)	7	2.5 (2.0 – 12.3)	Laborers	44	1.2 (0.1 – 2.5)	46	1.0 (0.6 – 2.5)	83	1.7 (0.6 – 5.1)
Professional, Admin.	14	1.6 (0.1 – 12.3)	8	4.6 (0.2 – 12.3)	20	2.5 (0.3 – 8.7)	Crafts (Building and Trades)	0	-	0	-	-	-
Operators	7	0.7 (0.3 – 12.3)	4	1.0 (0.5 – 6.7)	8	1.4 (0.6 – 2.5)	Professional, Admin.	2	0.15 (0.1 – 0.3)	0	-	-	-
Staff Members	39	0.6 (0.3 – 2.5)	24	1.7 (0.1 – 2.5)	43	1.4 (0.3 – 2.5)	Managers, First Line Super.	-	-	2	0.1 (0.01 -0.3)	2	0.15 (0.1 – 0.3)
Totals	**377**	**2.0 (0.3 – 4.9)**	**244**	**1.1 (0.3 – 2.8)**	**420**	**2.5 (0.6 – 7.5)**	**Totals**	**200**	**2.5 (0.6 – 12.3)**	**164**	**2.5 (0.6 – 5.1)**	**284**	**2.5 (0.6 - 12.3)**

Table 5.8: Crude Associations of TSH with Selected Predictor Variables Among Male LANL Former Workers ≥50 Years of Age

Independent Variables		N	Mean (SD)	R^2	p-value
Radiation Cumulative Exposure Index*		1138	2.54 (0.01)	-0.006	0.85
Chlorinated Solvent Cumulative Exposure Index		948	4.02 (8.2)	0.04	0.22
Aromatic Solvent Cumulative Exposure Index		887	2.52 (6.4)	0.078	0.02
Other Solvent Cumulative Exposure Index		887	5.2 (8.9)	0.057	0.09
Age		1265	68.2 (8.3)	0.082	0.003
Education		1250	13.3 (13.3)	-0.079	0.005
Years Worked at LANL		1265	24.1 (11.4)	0.035	0.21
Years since Last Worked at LANL		1265	14.2 (11)	0.020	0.46
t - Test	**Ethnicity**			**t - value**	**p-value**
	White	627	0.71 (0.6)	0.60	0.55
	Hispanic	543	0.68 (0.7)		

*TSH levels and Radiation Cumulative Exposure Index logarithmically transformed

Table 5.9: Crude Associations of Thyroid Case Status with Selected Predictor Variables in Male LANL FW Age ≥ 50 Years (N = 1,403)

Independent Variables	X^2	p-value
Radiation (High > 1350 days/ Low ≤1350 days)	0.3	0.61
Chlorinated Solvents (High > 1000 days; Med ≤ 1000 days; Low = 0)	4.1	0.12
Aromatic Solvents (High > 625 days; Med ≤ 625 days; Low = 0)	1.2	0.56
Other Solvents (High > 1350 days; Med ≤ 1350 days; Low = 0)	1.5	0.47
Age all categories (20 – 49, 50 – 69, 70+)	19.2	<0.0001
Ethnicity (Hispanic)	1.3	0.25
Education Level	0.3	0.59
Employers (all)	1.2	0.54
Years Worked at LANL	1.9	0.2
Smoking History	0.006	0.94
Radiation Protection Practices		
Removed from Job	1.9	0.16
Decontaminated	0.04	0.83
Worked with or around Plutonium	0.3	0.57
Wore a radiation dosimeter	0.02	0.87
Had nose swipes taken	0.09	0.76
Had radiation detection counts	4.6	0.03
Had urine tests	0.2	0.62
Jobs		
Crafts (Building and Trades)	1.5	0.22
Engineers	1.5	0.22
Laborers, General Service Workers	2.2	0.14
General Managers, First Line Supervisors	0.1	0.75
Professional, Administrative	0.01	0.91
Operators	0.3	0.59
Scientists	0.03	0.85
Technicians	0.2	0.66
Staff Members	3.0	0.08

*Case TSH level was > 4.5 mIU/L and/or reporting thyroid medication use.
*Non-case had a normal TSH level (0.4 mIU/L ≤ TSH ≤ 4.5 mIU/L) and not reporting thyroid medication use.

Table 5.10: Logistic Regression Model for Radiation Cumulative Exposure Index and Thyroid Status* Controlling for Demographics, Years Worked at LANL, and Job Category Former Workers ≥ 50 Years of Age (N = 1,237)

Independent Variables	Maximum Likelihood Estimate	S.E.	p- value	Point Estimate (95% C.I.)
Radiation Cumulative Exposure Index**	-0.046	0.03	0.18	0.95 (0.89 – 1.02)
Age	0.039	0.01	0.0001	1.04 (1.02 – 1.06)
Education Level	0.013	0.03	0.66	1.01 (0.96 – 1.07)
Ethnic Group				
Whites				1.0
Hispanics	-0.117	0.21	0.57	0.89 (0.59 – 1.34)
Years Worked at LANL	0.007	0.008	0.38	1.01 (0.99 – 1.02)
Job Categories				
Crafts/Building/Construction	0.535	0.63	0.39	1.71 (0.49 – 5.92)
Engineers	1.010	0.68	0.14	2.75 (0.72 – 10.48)
Managers	1.182	0.89	0.19	3.26 (0.56 – 19.02)
Laborers	1.099	0.65	0.09	3.00 (0.84 – 10.73)
Professionals				1.0
Operators	0.746	0.76	0.33	2.11 (0.47 – 9.38)
Scientists	0.659	0.66	0.31	1.93 (0.53 – 7.00)
Technicians	0.906	0.65	0.16	2.47 (0.69 – 8.83)
Staff Members	-0.027	0.008	0.38	0.97 (0.96 – 0.99)

*Case TSH level was > 4.5 mIU/L and/or reporting thyroid medication use.
**Non-case had a normal TSH level (0.4 mIU/L ≤ TSH ≤ 4.5 mIU/L) and not reporting thyroid medication use.
**Radiation Cumulative Exposure Index logarithmically transformed

Table 5.11: Logistic Regression Model for All Solvents Cumulative Exposure Index and Thyroid Status* Controlling for Demographics, Years Worked at LANL, and Job Category Male Former Workers ≥ 50 Years of Age

Independent Variables	Maximum Likelihood Estimate	S.E.	p- value	Point Estimate (95% C.I.)
Chlorinated Solvent Cumulative Exposure Index (Low) ‡				1.0
Chlorinated Solvent Cumulative Exposure Index (Med) ‡	0.173	0.24	0.46	1.19 (0.75 - 1.89)
Chlorinated Solvent Cumulative Exposure Index (High) ‡	0.536	0.27	0.05	1.71 (1.01 - 2.90)
Age	0.029	0.01	0.02	1.03 (1.004 - 1.06)
Education Level	0.014	0.03	0.66	1.01 (0.95 - 1.08)
Ethnicity (whites)				1.0
Hispanics	0.001	0.24	0.99	1.001 (0.62 - 1.60)
Years Worked at LANL	-0.005	0.01	0.59	0.99 (0.98 - 1.01)
Aromatic Solvents				
Aromatic Solvent Cumulative Exposure Index (Low) †				1.0
Aromatic Solvent Cumulative Exposure Index (Med) †	0.285	0.24	0.23	1.33 (0.83 - 2.12)
Aromatic Solvent Cumulative Exposure Index (High) †	0.303	0.25	0.23	1.35 (0.83 - 2.22)
Age	0.036	0.01	0.01	1.04 (1.01 - 1.06)
Education Level	0.029	0.03	0.38	1.03 (0.96 - 1.10)
Ethnicity (whites)				1.0
Hispanics	-0.064	0.24	0.79	0.94 (0.58 - 1.51)
Years Worked at LANL	-0.004	0.01	0.66	0.99 (0.98 - 1.01)
Other Solvents				
Other Solvents Cumulative Exposure Index (Low) •				1.0
Other Solvents Cumulative Exposure Index (Med) •	0.062	0.25	0.80	1.06 (0.65 - 1.74)
Other Solvent Cumulative Exposure Index (High) •	0.338	0.27	0.21	1.40 (0.83 - 2.37)
Age	0.033	0.01	0.01	1.04 (1.01 - 1.06)
Education Level	0.017	0.03	0.59	1.02 (0.95 - 1.08)
Ethnicity (whites)				1.0
Hispanics	0.023	0.23	0.92	1.02 (0.65 - 1.62)
Years Worked at LANL	-0.0004	0.009	0.97	1.00 (0.98 - 1.02)

*Case TSH level was > 4.5 mIU/L and/or reporting thyroid medication use.
**Non-case had a normal TSH level (0.4 mIU/L ≤ TSH ≤ 4.5 mIU/L) and not reporting thyroid medication use.
‡ (High > 900 days/Med ≤ 900 days versus 0 days N = 829)
† (High > 650 days/Med ≤ 650 days versus 0 days N = 888)
• (High > 900 days/Med ≤ 900 days versus 0 days N = 884)
Job categories were included in the model but are not shown (Crafts/Building/Construction, Engineers, Managers, Laborers, Professionals, Operators, Scientists, Technicians, Staff Members).

Chapter 6: Conclusions

6.1 Overview

This chapter will discuss the major findings of the analyses and the implications for the specific aims and the research questions. The strengths and limitations of this study will also be addressed, followed by suggested public health implications and recommendations for future research.

6.2 Goals of Study

The goal of this research project was to investigate the impact of working at a Department of Energy National Laboratory, Los Alamos National Laboratory (LANL), on thyroid function in a group of former workers. Specifically, the thyroid function in this group was compared to a population-based sample that had been collected as a part of the Third National Health and Nutrition Examination Survey (NHANES III). Potential occupational risk factors as predictors of abnormal thyroid function were investigated in this cohort.

6.21 Specific Aims

The LANL former worker data were examined in two phases: in phase one, descriptive findings that suggested an elevated level of thyroid dysfunction in this worker group supported the need for further consideration of potential work-related risk factors in phase two. The two phases were conducted according to the two specific aims discussed below.

Specific Aim One: to examine thyroid function in LANL Former Workers compared to the NHANES III population-based sample.

In the study discussed in Article 1, titled "Thyroid Dysfunction among Former Workers in a Nuclear Weapons Facility Compared to a National Population Sample," we compared the thyroid function of a group of former workers who were employed for various periods of time at a nuclear weapons research and development facility in Los Alamos, New Mexico (n = 1699) to the population-based NHANES III sample (n = 11,204). The LANL former workers cohort in this study was a sub-sample of former workers who participated in a larger medical screening program conducted in Los Alamos and Española, New Mexico, from April 2000 through August 2004. The NHANES III sample included participants in a periodic survey conducted by the National Center for Health Statistics (NCHS). This survey was designed to gather information on the health and nutrition of adults and children in the U.S. civilian non-institutionalized population.

Thyroid dysfunction was evaluated by means of two approaches: 1) levels of Thyroid Stimulating Hormone (TSH); and 2) a dichotomous variable based on TSH level and thyroid medication use. Comparisons were made by age, gender and ethnicity using these two approaches. The presence or absence of thyroid disease and the use of thyroid medication was available for both the LANL and the NHANES III groups, and these conditions were incorporated into the classifications of the sub-groups used in the analyses.

LANL males had higher median TSH levels in all ethnic and age groups as compared to NHANES III males, and male LANL former workers had higher median TSH levels as compared to female LANL former workers in the older age groups (50-69 years and 70+ years). Hispanic males and females had higher median TSH levels than the Hispanics in the NHANES III population. In further analyses, male LANL former workers had the highest proportions of TSH levels greater than 4.5 mIU/L (the case definition for hypothyroidism) in all ethnic groups and in the 50-69-year age group compared to NHANES III males.

These are important findings for several reasons. The major prevalence studies of thyroid function in the United States have found higher TSH levels in females, especially those in the 50- to 69-year age group. This is consistent with studies conducted in the United Kingdom (Canaris et al. 2000; Hollowell et al. 2002; Vanderpump et al. 1995). In the two prevalence studies mentioned above, one study did not consider ethnicity in the analyses and the other study found TSH levels in Hispanics to be lower than or equal to those levels found in whites.

Possible explanations for these findings include environmental exposures unique to this sample, or the risk associated with the occupational exposures of LANL former workers, such as radiation and solvents that were known to be present in the LANL work environment.

Specific Aim 2: To examine whether reported exposures to radiation or to chlorinated, aromatic and other solvents are associated with thyroid function in this population of former workers.

Article 2, titled "Thyroid Function and Workplace Exposures in Former Workers from a Nuclear Weapons Facility," addresses Specific Aim Two. Reported frequency and duration of exposures to radiation and to chlorinated, aromatic and other solvents were analyzed to assess the relationship between these workplace exposures and thyroid case status (TSH >4.5 mIU/L and/or taking thyroid medication). The sample in this study was white and Hispanic males (n = 1439). Females (n = 204), the ethnic group "others" (n = 56) and males less than 50 years of age (n = 121) were not included in the final analysis due to their relatively small numbers. Radiation exposure was not associated with thyroid case status in bivariate or in multiple logistic regression analyses. Exposure to solvents did show a modest increase in the risk of thyroid case status for each group of solvents, but only chlorinated solvents demonstrated a statistically significant odds ratio. There was some evidence of a trend of increased risk with increasing levels of exposure for each type of solvent. This trend was identified by means of logistic regression analyses that controlled for age, education, ethnicity, years working at LANL and job category. This trend was most evident for chlorinated solvents and for other solvents.

6.3 Implications of Findings

The findings of the first phase are important for several reasons. First, these results suggest that thyroid function in the former worker group is worse than expected compared to the NHANES III sample, which suggests that an occupational or environmental risk factor may be impacting thyroid function in this group. This conclusion is supported by the fact that males have higher TSH levels than females in the LANL cohort. The major prevalence studies of thyroid function in the United States and elsewhere have uniformly found higher TSH levels in females especially in the 50- to 69-year age group (Hollowell et al. 2002; Vanderpump et al. 1995). Furthermore, we found that, as a group, Hispanics had higher TSH levels than the Hispanics from the NHANES III sample, again suggesting that environmental or occupational exposures may play a role in these differences. As discussed previously, a large proportion of Hispanic LANL former workers reported working as laborers, janitors and in the building crafts. These jobs may have presented an opportunity for exposure to radiation or solvents to the workers while performing their job duties. Radiation has been identified as a risk factor for thyroid pathology in Chernobyl clean-up workers (Kurjane et al. 2001), and organic solvents have been associated with benign thyroid disease (Wingren and Axelson 1997).

Although the literature on environmental determinants of thyroid disease is limited, radiation, persistent organochlorine compounds and solvents have been associated with thyroid disease. Radiation and solvent exposures were historically commonplace at LANL.

To conduct the analyses reported in Article 2 ("Thyroid Function and Workplace Exposures in Former Workers from a Nuclear Weapons Facility"), exposures to radiation and chlorinated, aromatic and other solvents were characterized by a Cumulative Exposure Index (CEI). We then assessed the relationship between this index of workplace exposures and thyroid levels, and hypothyroidism case status (TSH >4.5 mIU/L and/or thyroid medication use). The population in this study was limited to white and Hispanic males (n = 1439).

The radiation CEI was used as a continuous variable initially and then it was categorized in three different ways: 1) "high" = > median CEI, and "low" = ≤ median CEI; 2) "high" = "yes" to ever decontaminated or removed from a job due to radiation exposure, versus "low" = "never"; and 3) "high" = "yes" to ever decontaminated or removed from a job or had body counts for radiation detection, versus "low" = "never". No association was found with radiation for any of these approaches. As discussed in Article 2, the CEI and the categories used to classify radiation into high and low groups were crude and based on self-reports

Exposure to radiation was not associated with abnormal thyroid function in bivariate or in multiple logistic regression analysis. This result was initially surprising, since radiation exposure has been clearly linked to thyroid dysfunction in the literature (Boice 1998; Ivanov et al. 2000; Jereczek-Fossa et al. 2004; Nagataki et al. 1994). However, all the LANL former workers in the cohort had experienced some radiation exposure and thus did not represent non-exposed individuals. Only dose-response relationships could be evaluated. Additionally, due to the crude nature of the exposure assessment, non-differential exposure misclassification may have occurred. This may have biased the results to the null. Future studies should evaluate radiation exposure more objectively and should include a sample of non-radiation exposed workers.

In contrast to radiation, exposure to solvents did show a modest increase in the risk of hypothyroidism. This increase was found for all solvent classes, but only chlorinated solvents had a statistically significant odds ratio (OR = 1.71, CI 1.01-2.90). There was some evidence of a dose response relationship for solvents, with an increasing trend in risk for hypothyroidism with increasing levels of exposure (controlling for age, education, ethnicity, years working at LANL and job category). This trend was most evident for chlorinated solvents and for other solvents.

These results are consistent with the only other study of solvent exposure and thyroid status found in the published literature, which found an association between benign thyroid disease and solvent exposure among chemists, painters, lacquerers and laboratory workers (Wingren and Axelson 1997); however, specific solvent types were not defined in this study, nor were amounts of solvent exposure quantified.

6.4 Strengths and Limitations

6.41 Strengths

A strength of this study was its focus on a possible work-related health outcome in a group of elderly former workers. There is growing concern about the health consequences of occupational exposures that may become manifest within our aging population after long latency periods. This is especially important considering the growing number of older workers and their increasing lifespan. The parent program funded by the Department of Energy (DOE) offered a rare opportunity to examine the data from the screening program to assess chronic health outcomes related to previous work at a nuclear weapons facility.

Another strength of this work was that it focused on a non-cancer health outcome. Extensive research has been done on radiation workers in the nuclear weapons and power generating industries in the United States and Europe. However, most of these studies have reported mortality or morbidity from cancer or all-cause health outcomes, and few have reported health effects related to the non-cancer outcome of thyroid dysfunction (Gilbert et al. 1993; Iwasaki et al. 2003; Ritz et al. 1999; Wing et al. 2004; Zablotska et al. 2004).

In addition, this study is one of only very few studies investigating occupational risk factors for hypothyroidism. This is a highly significant area of research, since hypothyroidism is known to increase with age and has important health consequences. Furthermore, sample sizes were fairly large (more than 1,200 workers in most analyses).

The large proportion of Hispanics allowed the evaluation of demographic trends in thyroid dysfunction and workplace exposures in this important ethnic group. The proportions of high TSH levels and subclinical and clinical thyroid disease in Hispanics suggest the need for future studies of minority populations and thyroid status, and the need to identify environmental or workplace exposure related to the dysfunction.

While self-reported thyroid disease and thyroid medication use were more subjective measures of diagnosis, the TSH laboratory studies did offer an objective, reliable measure of thyroid function. This allowed comparisons to national data and definitions of thyroid status according to the approaches used in several other studies.

6.4.2 Limitations

Limitations arose from the fact that data were generated from a medical screening program as opposed to a specifically designated research study. For example, the study population had taken part in a screening program for radiation-exposed workers, thereby eliminating the ability to include a non-exposed group. Additionally, given the voluntary nature of enrollment in the screening program, it was not clear whether selection bias affected the degree to which radiation exposed LANL workers were represented by the sample. This may have threatened the external validity of the study. The data collection instruments had been designed for a medical screening program, and detailed exposure and work history information was, therefore, not collected. For example, we knew little about non-LANL work history or leisure time activity. Radiation dosimetry records and industrial hygiene sampling records were not accessible but would have allowed more accurate exposure assessments and might have been useful for the validation of the self-reported exposure histories. Also, because many of these former workers were elderly and many years had passed since their employment at LANL, recall bias may have been a significant factor in influencing self-reports of exposure and health histories.

The exposure metrics used in this research likely resulted in non-differential exposure misclassification, but it is not possible to estimate the magnitude of such misclassification.

While TSH is a valuable screening tool for the general population, other measures of thyroid function – such as T_4, T_3 and antithyroid antibodies – may have enhanced our ability to define thyroid dysfunction according to the more refined classification used by others, including the determination of autoimmune dysfunction. These additional measures will be considered for futures studies of this population.

6.5 Public Health Implications

Thyroid dysfunction is a highly prevalent and often under-recognized condition, as demonstrated by our findings and by the estimates of others. Hollowell et al. (2002) reported a prevalence of hypothyroidism (clinical and subclinical disease) of 4.6% and a prevalence of hyperthyroidism (clinical and subclinical disease) of 1.3% for the U.S. population aged 12 years and older. Other estimates of the prevalence of thyroid dysfunction in adult populations range from 2% for hypothyroidism and from 5 to 17% for subclinical hypothyroidism, and from 0.2% for hyperthyroidism and from 0.1 to 6.0% for subclinical hyperthyroidism (Ladenson et al. 2000). Of note is the report of the American Association of Clinical Endocrinologists (AACE 2002), which indicated that the prevalence of subclinical hypothyroidism rises to 20% in individuals over 60 years of age. We can therefore project that the rising costs of managing thyroid dysfunction and its associated medical conditions will further increase the burden of disease and the already high costs of health care for the elderly.

Beyond the burden of disease associated with thyroid conditions alone, thyroid dysfunction is associated with several serious medical conditions. Although the causal pathways are not clearly understood, subclinical and overt hypothyroidism have been associated with cardiovascular dysfunction, higher lipid levels and psychiatric and cognitive abnormalities (Biondi et. al 2002; Canaris et al. 2000; Cooper 2001; Klein and Ojamaa 2001; Larisch et al. 2004). Acceleration of the rate of bone loss presents an additional problem for postmenopausal women (AACE 2002). In addition, there is increasing concern about thyroid function during pregnancy and the effect that thyroid dysfunction may have on childhood development and the related consequences in adult life (Howdeshell 2002; Schettler 2001). The suggestion that occupational and environmental exposures may play an etiological role in thyroid dysfunction is therefore important.

In considering etiological agents for non-malignant thyroid dysfunction, this work pointed to a potential role of organic solvents, particularly chlorinated solvents. This would imply widespread exposures, as organic solvents are common agents in the workplace and are used by many individuals in the home for hobbies and home repair. Wingren and Axelson (1997) found solvent exposure as a potential cause of benign thyroid disease in individuals who were employed in occupations where solvents are routinely used, such as chemists, laboratory workers or painters. Although the evidence remains fairly weak for organic solvents, it is consistent with findings of studies of chlorinated compounds that have provided evidence of an effect of persistent organochlorine compounds on maternal hormone levels in pregnant women (Takser et al. 2005), on neurological development in children and on metabolic systems (Brouwer et al. 1999; Kilby et al. 1998; LaFranchi et al. 2005; Oki et al. 2004; Ribas-Frito et al. 2001; Zoeller et al. 2002). Identification of a causal relationship between thyroid dysfunction and use of organic solvents, therefore, has implications for the size of the population at risk.

The results of the analyses have some implications for screening in the general and worker populations. Medical organizations, such as the American Thyroid Association (ATA), AACE and the American Academy of Family Physicians, have made recommendations regarding screening of asymptomatic adults for thyroid dysfunction (Cooper 2001). Most of these groups recommend screening for thyroid dysfunction after the age of 50 to 60 years, but the ATA recommends screening men and women after the age of 35 years (Cooper 2001). In light of the previous discussion regarding the health effects of chlorinated solvents as well as their wide spread use, there may be reason to reconsider the age recommendations for screening. If the association between solvent exposure and thyroid dysfunction is confirmed in future studies, workplace screening for thyroid dysfunction may be warranted.

6.6 Future Research

An hypothesis driven population-based epidemiologic study of the LANL workforce is needed to further investigate the relationships reported here. The study population should include current and former workers as well as members of the community, who are exposed to several identical or related compounds. A sample of LANL workers and community members may help to differentiate between exposures to thyrotoxicants in the workplace or outside of the workplace. Such a design would benefit from more detailed exposure and medical histories and, where possible, objective measures in lieu of or in addition to self-reports. More complete thyroid function measures should also be incorporated into the study design to reduce misclassification of thyroid dysfunction and to allow better differentiation of clinical versus subclinical thyroid disease and autoimmune thyroid disease.

Other occupational cohorts with similar exposures to radiation, solvents and other worker place exposures should be conducted to further explore the etiologic agents associated with thyroid dysfunction. Workers with known solvent exposure, a common workplace chemical, comprise a particularly important target population for future studies.

There is also a need for mechanistic studies of thyroid dysfunction in humans to determine the causes of thyroid disorders. Research has attempted to identify the factors that influence thyroid dysfunction and its relationship to exposure to organochlorine compounds. However, most have relied on animal studies, which have a questionable relevance to human endocrine systems (Greer et al. 2002; Wolff 1998).

Another area of research that should be considered is the management of thyroid dysfunction in the community. As reported elsewhere (Hollowell et al. 2002; Canaris et al. 2000), we found that the management of thyroid dysfunction in the LANL former worker sample was inconsistent. Despite diagnosis of thyroid dysfunction by a health care provider, some individuals demonstrated inadequately controlled TSH levels. Potential explanations for this may include: under-medication or non-adherence to medication regimens, and lack of insurance or the financial means to pay for the prescribed medications. These issues should be further explored.

In conclusion, this study identified a difference in thyroid function between former workers from LANL and the NHANES III population-based samples, and suggested that workplace exposures might influence these differences. These findings suggest the need for further occupational and community population-based studies investigating a range of potential etiologic agents as well as mechanistic research. Additionally, it is important to identify preventive strategies for reducing risk and the health effects associated with thyroid dysfunction.

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Appendix A

Common Occupational Classification System (COCS) Used for the Development of the Job Exposure Matrix During the Phase I Needs Assessment at Los Alamos National Laboratory

Code	Definition
A000	**Unknown Job Title**
C000	**Crafts/Skilled Operators**
C010	Carpenters/Construction Workers
C020	Electricians/Electrical Workers
C040	Machinists
C050	Masons/Bricklayers/Cement Workers
C070	Painters
C080	Plumbers and Pipefitters
C090	Structural/Metal/Foundry Workers/Blacksmiths
C100	Vehicle and Mobile Equipment Mechanics/Other Mechanics
C110	Welders/Cutters/Braziers/Solderers/Burners
C120	Other Crafts
C130	Asbestos/Insulation Workers
C140	Explosive/Detonation Workers
C150	Maintenance/Salvage Workers/Facilities
C160	Printers
E000	**Engineers**
E010	Chemical Engineers
E020	Civil Engineers
E040	Electrical Engineers
E050	Environmental Engineers/Sanitary Engineers
E060	Industrial Engineers
E070	Mechanical Engineers
E080	Nuclear Engineers
E120	Safety Engineers
E130	Other Engineers
E140	Construction Engineers
G000	**General Administrative, Secretarial, Clerical Support Staff**
G003	Student, support staff
L000	**Laborers and General Services Workers**
L010	Firefighters
L020	Food Service Workers
L030	Janitors and Cleaners
L040	Laundry Workers
L050	Handlers helpers, and Laborers (general)
L060	Handlers Helpers, and Laborers (specialized)
L070	Light Vehicle Drivers
L080	Security Guards
L090	Other Laborers and General Security Guardservice Workers
L100	Warehouse Workers, Partsman

Common Occupational Classification System (COCS) Used for the Development of the Job Exposure Matrix During the Phase I Needs Assessment at Los Alamos National Laboratory

Code	Definition
M000	**General managers, Executives, First Line Supervisors, and Program/Project Managers**
N000	**Nevada Test Site Workers, Field Party**
P000	**Professional Administrative and Related Occupations**
P010	Accountants and Auditors
P020	Architects/Draftsman
P030	Buyers, Procurement and Contracting Specialists
P050	Compliance Inspectors
P070	Cost Estimators and Planners and Schedulers
P080	Health Physicists
P090	Industrial Hygienists/Safety
P100	Lawyers
P120	Physicians
P130	Physicians Assistants, Nurses, Other Medical Support Occ.
P150	Trainers
P180	Military Personnel
R000	**Operators**
R010	Chemical System Operators
R012	Chemical Systems Technicians
R030	Material Moving Equipment Operators
R040	Nuclear Plant Operators
R042	Nuclear Plant Technicians
R070	Utilities Operators
R072	Utilities Technicians
R080	Other Operators
R090	Furnace/Boiler Operators
R092	Furnace/Boiler Technicians
R100	Explosives Operators
R110	Accelerator, Particle Beam, LAMPF Operator
R112	Accelerator, Particle Beam, LAMPF Technician
R120	Compressed Gas Facility Operator
R122	Compressed Gas Facility Technician

Common Occupational Classification System (COCS) Used for the Development of the Job Exposure Matrix During the Phase I Needs Assessment at Los Alamos National Laboratory

Code	Definition
S000	**Scientists**
S010	Chemists
S012	Chemical Technician
S013	Chem Tech, Student
S020	Environmental Scientist
S030	Geologists
S032	Geology Technician
S040	Life Scientists
S042	Life Science Technicians
S050	Materials/Metallurgy Scientists
S052	Materials/Metallurgy Technicians
S060	Mathematicians
S070	Physicists
S072	Physics Technician
S090	Other Scientists
S100	Computer Scientists
T000	**Technicians**
T010	Computer Operator/Coders
T013	Computer Technician, Student
T020	Drafters/ Draftsman (Tech)
T030	Engineering Technicians
T040	Environmental Sciences Technicians
T040.4	Water Treatment and Management Activities/Solid Waste
T040.6	Transportation Activities
T050	Health Physics Technicians
T060	Industrial Safety and Health Technicians
T070	Instrument and Control Technicians
T080	Laboratory Technicians
T090	Media Technicians includes Photography, Video, Radio
T100	Surveying and Mapping Technicians
T110	Other Technicians
T113	Technician, Student
T120	Mechanical Technician (Mech Tech)
T123	Mech Tech, Summer/Student
Y000	**Staff Member**
Y003	Research Assistant, Associate, Grad. Research Assoc., Student
Z000	**Employees, Students, Faculty, Visitors**
Z000	Employees (unspecified, part-time, short-term, unclassified)
Z003	Students, unspecified
Z004	Faculty, unspecified
Z005	Guest, Visitor

Agents	JOB CODES: G000, G003 (Support Staff)						M000 (Management)						Z000, Z003, Z004, Z005 (Employees, faculty, students, visitors)					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	Y000, Y003 (Staff Member)						N000 (Nevada Test Site)						E000 (Engineers)					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0
Manganese	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Plutonium	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0
Polonium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0
Physical Agents																		
Lasers	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Noise	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ Microwaves	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Ultraviolet Radiation	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0
Vibration	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/Silica	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0
Vinyl Chloride	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0

Agents	JOB CODES																	
	E010, E050, E060, E070						E020, E140						E040					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/Silica	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	E080						E120, E130						S000, S060, S090, S100, (Scientists)					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	S010, S012, S013						S030, S032						S040, S042					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Other Aromatic Solvents	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Glycol Ethers	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Radioactive materials																		
Americium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
External Radiation	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Plutonium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Polonium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Uranium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Other Isotopes	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Physical Agents																		
Lasers	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1
Noise	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	S050, S052						S070, S072						P000, P010, P020, P030 P070, P100, P150					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Manganese	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Nickel	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Carbon Tetrachloride	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Radioactive materials																		
Americium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Plutonium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Polonium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Uranium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Noise	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ Microwaves	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Ultraviolet Radiation	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	P050						P080						P090					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Noise	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1

Agents	JOB CODES																	
	P120, P130						P180						T000, T110, T113 (Technicians)					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Carbon Tetrachloride	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Radioactive materials																		
Americium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	0	0
Degreasers	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
PBB/PCB	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Pesticides/Herbicides	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1

Agents	JOB CODES																	
	T010, T013, T020, T090, T100						T030						T040					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	T040.4, T040.6						T050						T060					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
External Radiation	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Plutonium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Polonium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Other Isotopes	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Noise	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
PBB/PCB	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Rock Dust/ Silica	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1

Agents	JOB CODES																	
	T070						T080						T120, T123					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Cadmium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Solvents																		
Chlorinated Solvents	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carbon Tetrachloride	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Benzene	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Other Aromatic Solvents	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Glycol Ethers	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Other Solvents	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Radioactive materials																		
Americium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
External Radiation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plutonium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Polonium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Other Isotopes	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Physical Agents																		
Lasers	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
PBB/PCB	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1

Agents	JOB CODES																	
	C000, C120 (Crafts/Skilled Operator)						C010**						C020**					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Ultraviolet Radiation	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust / Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

** Mobile Code, however in the opinion of those familiar with operations by these craft workers, external ionizing radiation exposure was unlikely. As a result, external ionizing radiation was not universally assigned to this job code.

Agents	JOB CODES																	
	C040						C050						C070					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Chromium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Cobalt	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Nickel	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1
Carbon Tetrachloride	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1
Glycol Ethers	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1
Radioactive materials																		
Americium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Plutonium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Vibration	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Degreasers	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Metal Working Fluids	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust / Silica	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	C080**						C090						C100					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Beryllium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Lead	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Other Aromatic Solvents	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Radioactive materials																		
Americium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Fiberglass	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1

** Mobile Code, however in the opinion of those familiar with operations by these craft workers, external ionizing radiation exposure was unlikely. As a result, external ionizing radiation was not universally assigned to this job code.

Agents	JOB CODES																	
	C110*						C120						C130*					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Cadmium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Radioactive materials																		
Americium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
External Radiation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plutonium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Polonium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Uranium	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Other Isotopes	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radiofrequency/ microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Degreasers	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0

* Mobile Craft – These workers were given exposure to asbestos and all radioactive materials listed in the JEM.

Agents	JOB CODES																	
	C140						C150*						C160					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	19.90	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Carbon Tetrachloride	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Radioactive materials																		
Americium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Uranium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
MOCA	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Mobile Craft – These workers were given exposure to asbestos and all radioactive materials listed in the JEM.

Agents	JOB CODES																	
	R000 (Operators)						R010, R012						R030					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	R070						R080						R090, R092					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	R040, R042						R100						R110, R112					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plutonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ microwaves	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Ultraviolet Radiation	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Agents	JOB CODES																	
	R120, R122						L000 (Laborers, General Service)						L010					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plutonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uranium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Isotopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

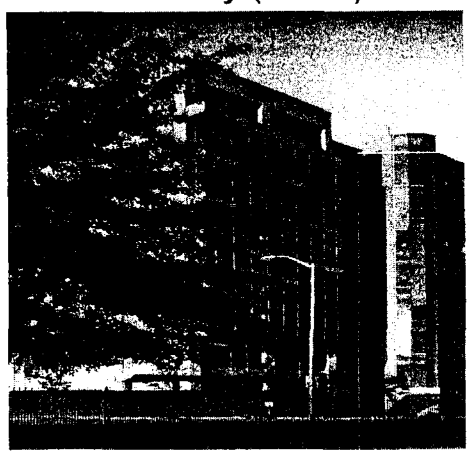
Agents	JOB CODES																	
	L020, L070						L030*						L040					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
External Radiation	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Plutonium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Polonium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Uranium	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Other Isotopes	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Mobile Craft – These workers were given exposure to asbestos and all radioactive materials listed in the JEM.

Agents	JOB CODES																	
	L050, L060*						L080, L090						L100					
METALS	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990	1940	1950	1960	1970	1980	1990
Arsenic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvents																		
Chlorinated Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Aromatic Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycol Ethers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Solvents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radioactive materials																		
Americium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
External Radiation	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Plutonium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Polonium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Uranium	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Other Isotopes	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Physical Agents																		
Lasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Radiofrequency/ Microwaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet Radiation	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vibration	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Agents																		
Acrylonitrile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asbestos	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Degreasers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fiberglass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isocyanates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Working Fluids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBB/PCB	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Pesticides/Herbicides	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dust/ Silica	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Vinyl Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Welding Fumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Mobile Craft – These workers were given exposure to asbestos and all radioactive materials listed in the JEM.

Former Workers Medical Exam Program for Los Alamos National Laboratory (LANL)



Conducted by

Johns Hopkins University Bloomberg School of Public Health

Los Alamos National Laboratory

Laborers' Health & Safety Fund of North America

National Jewish Medical and Research Center

The University of New Mexico

Funded by

The United States Department of Energy

What is the Former Worker Medical Exam Program at LANL?

The program offers a free exam **or** a review of medical records to former workers whose past work may have affected their health. The program will focus on former workers who are eligible based on exposures to the following hazards:

Table 1: Agents/Exposures	
• Asbestos	• Noise
• Beryllium	• Radiation
• Lead	• Solvents

Who will be examined?

All eligible former workers who were employed by:

- University of California
- Zia
- Pan Am World Services
- Johnson Controls International
- Johnson Controls of Northern New Mexico
- Other subcontractors

... and worked at LANL anytime between 1943 and the present.

How do eligible former workers take part in the exam program?

Former workers will be invited to take part if they were significantly exposed to any or all of the agents in Table 1.

If they are eligible, we will ask former workers to:

- complete a **confidential** interview
- decide if they want a free medical exam **or** record review
- decide **where** they want the free exam **or**
- choose **not to take part in** the exam program

Who will do the medical exams?

If **a free exam is decided on**, the choices are:

- in Española, NM, by physicians from Johns Hopkins and the University of New Mexico, **or**
- in Los Alamos, NM, by physicians and health professionals from the LANL Occupational Medicine Group (EH-2), **or**
- in Baltimore, MD, by physicians from Johns Hopkins

What happens during the exams?

The exams will take **from 1 to 2 hours** and include tests based on specific exposures. The types of tests that may be done are:

Components of the Health Exam
• Physical Examination
• Spirometry (breathing test)
• Audiogram (hearing test)
• Blood tests
• Chest X-ray

How will this program benefit you or other former workers?

The program has several benefits:

- the chance to be checked by doctors trained in illnesses caused by work
- the chance to find out more about your health
- the chance to ask questions about past exposures at LANL, and
- the chance to learn what steps can be taken if a health problem is found

What if an eligible person wants both an exam and a medical records review or a repeat exam?

Because of limits to our budget, we are able to offer either one free exam **or** one medical record review per eligible former worker, but not both.

Who will get the results of the exams and medical records reviews? How private are these results?

Former workers will get their results in the mail **within 2 to 3 months** after the exam. If there are any abnormal results, we will tell you what to do next. This may include additional tests or exams. Your personal health care provider can do the follow-up or we can help you find a doctor. Due to limits in our budget, we can't pay for follow-up testing.

The results are private to the extent possible by law. No one's name will ever be used in published reports about this program.

What about secrecy or classified information?

No one will be asked to give any **classified information**. Former workers should not answer any questions that they are concerned about. If a former worker has information that may be classified and needs to clarify this further, please contact the LANL Classifications Office at 505-667-5011.

Where can more information be found about the program or to schedule a free exam?

For more information about this program, contact:

NEW MEXICO PROGRAM OFFICE:
Española Medical Arts Building
1010 Spruce Street, Suite B
Española, New Mexico, 87532
Toll-free telephone: (877) 500- 8615
Local telephone number: (505) 753-0193

COORDINATING OFFICE:
Johns Hopkins University
Bloomberg School of Public Health
615 N. Wolfe Street, Room 7503B
Baltimore, MD 21205
email: lanlfwms@jhsph.edu
Telephone: (410) 955-4130

VISIT OUR INTERNET SITE AT:
http://www.jhsph.edu/~lanlfw

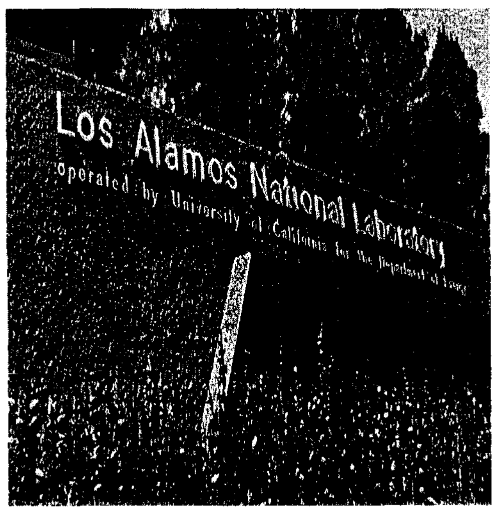
Who funds this program and why?

This program is funded by the Department of Energy (DOE) to examine former workers for health problems that might be due to hazardous exposures they had during the time they worked at DOE sites. The program at LANL is one of ten programs at DOE workplaces. In the future, what is learned from these programs might make it possible for former workers to have routine health and safety exams similar to those provided to current workers.

More Information about the agents in the exam program:

Agent/Other Names	Some examples of who used the agent or where it was found at LANL
Asbestos	sheet metal workers, insulation workers, asbestos removal workers, pipefitters, electricians, metallurgist
Beryllium	machining, weapons testing
Lead	foundry, lead bricks, solder, shielding, explosives, plumbing, pipefitting
Noise	machine shops, test firing, drilling, grinding operations, injection molding, construction work, compressed gas facility
Radiation	weapons production, testing, research
Solvents	scientists, machinists, technicians, crafts, machine shops, widespread use throughout the lab

Thank You for Your Help with this Program!



Above: Entrance, Los Alamos National Laboratory

Cover Photo: The Johns Hopkins University
Bloomberg School of Public Health

FORMER WORKERS WITH KNOWN EXPOSURES

Date

Dear ,

We are writing to invite you to take part in a program that looks at the health of former Los Alamos National Laboratory (LANL) workers. The program will include people who worked for the University of California, Zia, Pan Am and Johnson Controls.

The Department of Energy has funded Johns Hopkins University School of Hygiene and Public Health to do this program. During the years 2000 to 2003, we will perform **free health exams or medical record reviews** on about 3,000 former workers. The program is trying to find out if the health of former workers has been affected as a result of their past work with or around **asbestos, beryllium, lead, noise or radiation.**

A Steering Committee of former workers, union representatives, community members and health professionals helps to guide the program team. The team includes faculty and staff from:

- Johns Hopkins University School of Hygiene and Public Health;
- Health and Safety Fund of the Laborers' International Union of North America;
- Environmental Health and Safety Division of Los Alamos National Laboratory;
- National Jewish Medical and Research Center; and
- University of New Mexico.

You are eligible to take part in the program because of the type of work that you did at LANL. The health exam program will offer former workers **their choice** of a **one-time free health exam and tests or a medical record review.** These are explained below. You may also choose **not to participate in the exam program.**

THE PROGRAM HAS 3 STEPS

STEP 1: SCHEDULE an INTERVIEW

Please **schedule a visit at our office to be interviewed** (1-877-500-8615). You can also **complete the interview by phone,** if you don't live nearby. This interview will help us decide **what medical tests** you should have during your free health exam. These tests could be hearing tests, a chest x-ray, blood tests or breathing tests. Not all former workers will receive **all** tests. The exact tests you receive **depend** on what type of work you did in the past.

You will need to do the interview even if you choose a **medical record review**.

STEP 2: CHOOSE an EXAM OR RECORD REVIEW

The second step is to choose a free health exam **or** record review.

If you **would like an exam**, you can choose to have it done at the LANL Occupational Medicine Group / Clinic (EH-2) by LANL personnel, **or** done at the program office in Española, New Mexico (separate from LANL) by doctors from Johns Hopkins University and the University of New Mexico.

OR

If you would like a **medical record review**, we will ask you to sign a medical record release. This release will go to your doctor and request him / her to send selected reports, x-rays and records to the program at Johns Hopkins University for review. One of the occupational medicine doctors from Johns Hopkins will review these records. **We will send you a letter with an opinion about what was found or not found in your records.** You can choose this option if you have had selected tests and x-rays within the past two years. If not, we recommend that you come in for the free exam.

STEP 3: RESULTS

We will notify you in a letter of the results of your exam or medical record review. We will include a number for you to call if you have questions about your results. There will also be opportunities to talk with doctors about your results at other exam sessions. We will tell you in this letter if a follow-up exam is needed. If there are any abnormal results, we will tell you what to do next. This may include additional tests or exams. The follow-up care can be done by your personal health care provider or we will help you get a doctor for this follow-up if you don't already have a doctor.

WHAT IS IN THIS PACKET?

1. CHOICE FORM

Please read over this form and make your choices. Please send this back to us by 4/14/2000 and provide us with your **correct mailing address and phone number**.

You may choose:

- a one-time free health exam **<u>or</u>** medical record review,
- to have your free health exam at LANL, at the program office by doctors from Johns Hopkins University and the University of New Mexico, **<u>or</u>** at the Center for Occupational and Environmental Health in Baltimore, Maryland by doctors from Johns Hopkins University,
- **not to take part** in the program.

2. CONSENT FORMS

If you wish to take part in this exam program, please read and sign the consent form and send it back to us. This form will give permission for the in-person or telephone interview. This interview will help us to decide what type of exam and tests you should have - if you choose that option. It will also help us to decide which medical records to request for your medical record review - if you choose that option. There are two consent forms, **please keep one copy for yourself.**

3. POSTCARD

Send this postcard back if you want this letter and consent form in **Spanish.**

4. ENVELOPE

Please mail back your **choice form** and a **signed consent form** in this envelope.

5. MAP

Enclosed is a map to the **Former Workers' Program Office**. Please call to schedule your interview (1-877-500-8615).

6. BROCHURE THAT DESCRIBES THE HEALTH EXAM PROGRAM

If you have any questions about the program, please contact us. The address and telephone number are listed on the front page of this letter. Thank you very much for taking the time to help us with this program.

Sincerely yours,

Brian S. Schwartz, M.D., M.S.
Co-Principal Investigator

Patrick Breysse, PhD.
Co-Principal Investigator

Choice Form

Name: ____

Address: ____

____

Telephone: ____

WHICH DO YOU CHOOSE?

□ 1) A free health examination

OR

□ 2) A free medical record review

OR

□ 3) I am not interested in joining this program. Please do not contact me again.

If you picked #1 or #2, please call the office to schedule a time to complete the confidential interview (1-877-500-8615)

IF YOU PREFER A FREE HEALTH EXAM, WHERE WOULD YOU LIKE TO HAVE IT DONE?

□ 1) The LANL Occupational Medicine Clinic, in Los Alamos by LANL personnel.

OR

□ 2) At the program office in Española, New Mexico by doctors from Johns Hopkins University and the University of New Mexico.

OR

□ 3) Either is OK. Please schedule me for the first available date.

Please send this form back in the enclosed envelope.

Form sent to former workers that asks them to choose an examination, a medical record review, or not to participate in the program. They also choose where to have their examination done

Choice Form

Name: ______________________________

Address: ______________________________

____

Telephone: ______________________________

WHICH DO YOU CHOOSE?

☐ 1) A free health examination

OR

☐ 2) A free medical record review

OR

☐ 3) I am not interested in joining this program. Please do not contact me again.

If you picked #1 or #2, please call the office to schedule a time to complete the confidential interview (1-877-500-8615)

IF YOU PREFER A FREE HEALTH EXAM, WHERE WOULD YOU LIKE TO HAVE IT DONE?

☐ 1) The LANL Occupational Medicine Clinic, in Los Alamos by LANL personnel.

OR

☐ 2) At the program office in Española, New Mexico by doctors from Johns Hopkins University and the University of New Mexico.

OR

☐ 3) Either place in New Mexico is OK. Please schedule me for the first available date.

OR

☐ 4) At the Center for Occupational and Environmental Health (COEH) in Baltimore, Maryland by doctors from Johns Hopkins University.

Please send this form back in the enclosed envelope.

Name (Nombre): ______________________________

Address: ____
(Dirección)

Telephone (Telefono): ______________________________

☐ Please send this letter and consent form in Spanish
(Favor de enviarme esta carta y forma de consentimiento en español).

For completion of the surveys, please have:

☐ a Spanish-speaking interviewer contact me
(que me llame un entrevistador que hable español).

☐ An English-speaking interviewer (if, for example, you have poor vision) contact me.

☐ I am not interested in taking part in the program.
(No estoy interesado(a) en participar en el programa).

Please send this card back in the enclosed envelope
(Favor de mandar esta tarjeta en el sobre que se adjunta).

Name(Nombre): ______________________________

Address: ____
(Direccion)

Telephone (Telefono): ______________________________

☐ Please send this letter and consent form in Spanish
(Favor de enviarme esta carta y forma de consentimiento en español).

For completion of the surveys, please have:

☐ a Spanish-speaking interviewer contact me
(que me llame un entrevistador que hable español).

☐ An English-speaking interviewer (if, for example, you have poor vision) contact me.

☐ I am not interested in taking part in the program (No estoy interesado(a) en participar en el programa).

Please send this card back in the enclosed envelope
(Favor de mandar esta tarjeta en el sobre que se adjunta).

Invitation Letter to Former Workers with Unknown Exposures

Date

Name
Address
Address

Dear ,

We are writing to invite you to take part in a program that looks at the health of former Los Alamos National Laboratory (LANL) workers. The program will include people who worked for the University of California, Zia, Pan Am, and Johnson Controls.

The Department of Energy has funded Johns Hopkins University School of Hygiene and Public Health to do this program. During the years 2000 to 2003, we will perform **free health exams <u>or</u> medical record reviews** on about 3,000 former workers. The program is trying to find out if the health of former workers has been affected as a result of their past work with or around **asbestos, beryllium, lead, noise or radiation.**

A Steering Committee of former workers, union representatives, community members, and health professionals helps to guide the program team. The program team includes faculty and staff from:

- Johns Hopkins University School of Hygiene and Public Health;
- Health and Safety Fund of the Laborers' International Union of North America;
- Environmental, Health, and Safety Division of Los Alamos National Laboratory;
- National Jewish Medical and Research Center; and
- University of New Mexico.

THE PROGRAM HAS THREE STEPS

<u>STEP 1</u>: READ and SIGN the CONSENT FORM, COMPLETE the SURVEY.

You will first be asked to read and sign the enclosed consent form, complete the survey and mail both of them back to us. This survey will be used to decide if you are **eligible** for a free health exam **<u>or</u>** medical record review. This decision is based on the work you did and where you worked at Los Alamos.

<u>STEP 2</u>: REVIEW of the SURVEY.

We will **review** your survey and then send you a letter that tells whether or not you are eligible for the program. If you are **eligible**, the letter will ask you to **schedule**

a visit at our office in Española, New Mexico to be interviewed (1-877-500-8615). You can also complete the **interview by phone,** if you don't live nearby. We will also ask you if you would like a health exam **or** medical record review. You will need to do the interview even if you choose a **medical record review**.

The **interview will help us decide** what type of health exam and tests you should have **or** what tests and x-rays we will need for reviewing your medical records. These tests could be hearing tests, a chest x-ray, blood tests, or breathing tests. **Not all former workers will receive all tests**. The exact tests you receive depend on what type of work you did in the past.

STEP 3: SCHEDULE.

Once the interview is complete, we will ask you to ***choose*** *the free health* exam **or** the medical record review.

If you **eligible** for the program and choose an exam, you can choose to have it done at the LANL Occupational Medicine Group/Clinic by LANL personnel, **or** done at the program office in Española, New Mexico (separate from LANL) by doctors from Johns Hopkins University and the University of New Mexico.

OR

If you **eligible** for the program and choose a **medical record review**, we will ask your family doctor to send to us selected medical records or reports. You can choose this option **if** you have had these selected tests and x-rays within the past two years. If not, you should come in for the free exam. One of the Hopkins doctors will review these records or reports, and send you an opinion about the findings.

WHAT IS IN THIS PACKET?

1. CONSENT FORMS

Please read the consent form carefully. If you are interested in taking part in the program, sign it and return it to us in the enclosed envelope. There are two copies, **please keep one copy for yourself**.

2. POSTCARD

Please send this postcard back to us within the **next two weeks.** Please provide your **correct mailing address and phone number**.

Check if you want:

- the survey and consent form in Spanish;
- a Spanish-speaking interviewer;
- an English-speaking interviewer (if, for example, you have poor vision);
- to tell us you are **not interested** in taking part in the program.

3. SURVEY

This survey will be used to decide if you are **eligible** for a free health exam **<u>or</u>** medical record review. Please fill it out carefully, and return it in the enclosed envelope within the next **two weeks**. All of the information you give us will be kept in confidence. All the program records will be kept at Johns Hopkins University in Baltimore, Maryland.

4. ENVELOPE

Please mail back your **survey**, a **signed consent form** or the postcard in this envelope.

5. A BROCHURE THAT DESCRIBES THE HEALTH EXAM PROGRAM

If you have any questions about the program, please contact us at the address on the top of this letter. Thank you very much for taking the time to help us with this program.

Sincerely yours,

Brian S. Schwartz, M.D., M.S.
Co-Principal Investigator

Patrick Breysse, Ph.D.
Co-Principal Investigator

Date__________

RE: Medical Exam Program for Former Workers at Los Alamos National Laboratory

Dear

You have selected a medical record review as part of this program. Our goal with the medical record review is to enable former workers who live at a distance from New Mexico or are not able to come to the clinic to participate in the program. Therefore, we want to review physical examinations and test results done with your own doctor within the last 2 years that are similar to those we would do if you came to be evaluated in our clinic. Based on your questionnaire, you should receive an examination and tests for the specific exposures noted below:

□ asbestos □ beryllium □ lead □ noise □ radiation

In order to get the results of these tests that you may have had recently, **please take the enclosed forms to your doctor**. The program **does not have** resources to pay for the tests or the medical records that are requested in this letter. The forms that are in this packet include:

- A letter for your doctor explaining the program and the **medical record review.**
- A form that indicates what tests we will need to review for this program.
- Two medical release forms - **please sign both forms.** One form is **for your doctor** and one is **for our records**. Please **return one signed copy** in the self-addressed stamped envelope.
- Two consent forms - **please sign one form** and **return it in the** self-addressed stamped envelope. Please keep one copy for your records.
- Two consent forms for Beryllium Testing - **please sign one form** and **return it in the** self-addressed stamped envelope. Please keep one copy for your records.

If your exposure questionnaire indicates that you were exposed to beryllium, you will need **a lymphocyte proliferation test for beryllium sensitization (LPT). The LPT must be obtained through the program.** We will arrange to have the blood test done through the Oak Ridge Institute for Science and Education (ORISE). ORISE manages the beryllium program for the DOE and the blood test will be paid for through this program. **We will provide instructions on how this will be done.** We will use a unique identification number on the blood sample and request so that the test will be done anonymously. Please call the Española office (1-877-500-8615) so that we can arrange this test.

We look forward to receiving information from you. If you have any additional questions, please contact us at the New Mexico Office or: e-mail: lanlfwms@jhsph.edu
website: http://www.jhsph.edu/~lanlfw

Sincerely,

____

- ☐ Brian S. Schwartz, MD, MS, Co-Principal Investigator
- ☐ Virginia M. Weaver, MD, MPH, Co-investigator

Date__________

RE: Medical Exam Program for Former Workers at Los Alamos National Laboratory

Dear Doctor

Your patient, ____________________________, would like to participate in the Johns Hopkins University Medical Exam Program for Los Alamos National Laboratory (LANL) Former Workers. This program is a four-year project that started in August 1999 and is funded by the Department of Energy (DOE). The purpose is to perform medical exams on former LANL workers whose past work may have affected their health. Former workers who had significant exposure to asbestos, beryllium, lead, noise, and/or ionizing radiation are invited to join the program. These former LANL workers are offered the choice of a one-time free health examination with selected tests or a medical record review. Your patient has chosen a medical record review.

In this program, the general approach is to test workers for specific health effects based on their exposure histories. We have already obtained an exposure history from your patient. The results of the exposure questionnaire suggest that your patient was exposed to the agents listed in table 1 on the next page. Each exposure requires a specific physical exam and test(s).

As requested by your patient, we will review the results of these tests and exams in light of their occupational exposure. Further exposure-specific tests, such as blood lead, may be useful later, for example, in former workers with abnormal kidney function and a history of lead exposure. However, many tests that are routinely used to monitor currently exposed workers are not useful in former workers.

If your patient has had the exams or tests in the table in the past two years, please provide us with the results. In the case of the chest X-ray, please send it to our Hopkins address so we can obtain a B-reading. **The lymphocyte proliferation test for beryllium sensitization (LPT) must be obtained through the program.** We will arrange to have the blood test done through the Oak Ridge Institute for Science and Education (ORISE). ORISE manages the beryllium program for the DOE and the blood test will be paid for through this program. **We will provide instructions on how this will be done.** We will use a unique identification number for your patient so that the test will be done anonymously. The program **does not have** resources to pay for the tests or the medical records that are requested in this letter with the exception of the LPT.

We look forward to receiving information from you. If you have any additional questions, please contact number listed on the bottom of this page.

Sincerely,

____

- ☐ Brian S. Schwartz, MD, MS, Co-Principal Investigator
- ☐ Virginia M. Weaver, MD, MPH, Co-investigator

Name: ______________________________ Date:____________________

Former LANL Workers - Medical Record Review

Table 1 - Agents and Testing Components

* A check indicates that your patient's exposure history revealed significant past exposure to the checked agents.

PLEASE NOTE: We need the most recent reports, preferably within the past two years. The program **does not have** resources to pay for the tests or the medical records that are requested in this letter with the exception of the LPT.

✓	Agent	Testing	Date Done
□	All agents	□ please send a copy of most recent physical examination report to Hopkins office for review	
□	Asbestos	□ chest X-ray - please send a copy of the original film to Hopkins office for B-reading for asbestos	
		□ spirometry - please send a copy to Hopkins office for review	
□	Beryllium	□ chest X-ray - please send a copy of the original film to Hopkins office for B-reading for beryllium	
		□ lymphocyte proliferation test ** **(patient should call the Española office to arrange testing 1-877-500-8615)**	
□	Lead	□ BUN, creatinine - please send a copy to Hopkins office for review	
□	Noise	□ audiogram - please send a copy to Hopkins office for review	
□	Radiation	□ chest X-ray - please send a copy of the original film to Hopkins office for B-reading for fibrosis	
		□ CBC with differential, TSH - please send a copy to Hopkins office for review	

Name: ______________________ Date: ______________________

Former LANL Workers - Medical Record Review

Medical Release to Obtain Copies of Records from Personal Physician or Others

I, ____,

give the staff at the Johns Hopkins University School of Hygiene and Public Health permission for the activities checked below, as part of the Department of Energy Former Workers Medical Exam Program at the Los Alamos National Laboratory (LANL).

CHECK:

❒ **Obtain copies of my medical records, blood tests, and chest x-rays (as needed) from my private doctor and/or from the health care facility where they are stored.**

Chest X-rays ________ Blood Tests ______________

Spirometry ________ Audiometry ______________

Personal physician

Name ______________________________
Address ______________________________
Address ______________________________
City/State/Zipcode ______________________________
Telephone number ______________________________
Fax number ______________________________

Other Health Care Facility

Name ______________________________
Address ______________________________
Address ______________________________
City/State/Zipcode ______________________________
Telephone number ______________________________
Fax number ______________________________

CHECK:

❒ **Obtain copies of my medical records, blood tests, spirometry, audiometry and/or chest x-rays from the LANL Occupational Medicine Clinic. (If we find certain abnormalities on your screening tests in this program, we may need to get copies of your previous screening tests from the LANL Occupational Medicine Clinic for comparison).**

______________________ ______________________

Signature **Printed Name** **DOB**

______________________ ______________________

Witness to signature **Date**

This release form is valid for one year from the date signed. The former worker may withdraw their permission for this release at any time.

Name: ______________________________ Date: ____________________

Former LANL Workers - Medical Record Review

Medical Release to Obtain Copies of Records from Personal Physician or Others

I, ____,

give the staff at the Johns Hopkins University School of Hygiene and Public Health permission for the activities checked below, as part of the Department of Energy Former Workers Medical Exam Program at the Los Alamos National Laboratory (LANL).

CHECK:

❒ **Obtain copies of my medical records, blood tests, and chest x-rays (as needed) from my private doctor and/or from the health care facility where they are stored.**

Chest X-rays _________ Blood Tests _______________

Spirometry _________ Audiometry _______________

Personal physician

Name ______________________________
Address ______________________________
Address ______________________________
City/State/Zipcode ______________________________
Telephone number ______________________________
Fax number ______________________________

Other Health Care Facility

Name ______________________________
Address ______________________________
Address ______________________________
City/State/Zipcode ______________________________
Telephone number ______________________________
Fax number ______________________________

CHECK:

❒ **Obtain copies of my medical records, blood tests, spirometry, audiometry and/or chest x-rays from the LANL Occupational Medicine Clinic. (If we find certain abnormalities on your screening tests in this program, we may need to get copies of your previous screening tests from the LANL Occupational Medicine Clinic for comparison).**

______________________________ ______________________________
Signature **Printed Name** **DOB**

______________________________ ______________________________
Witness to signature **Date**

This release form is valid for one year from the date signed. The former worker may withdraw their permission for this release at any time.

Name: ______________________________ Date: ____________________

Former LANL Workers - Medical Record Review

Medical Release of Program Records to Personal or Referral Physician

I, ____, give the staff at the Johns Hopkins University School of Hygiene and Public Health permission for the activities checked below, as part of the Department of Energy Former Workers Medical Exam Program at the Los Alamos National Laboratory (LANL).

CHECK:

❐ **Send copies of all program records to my personal physician.**

Personal physician

Name ______________________________
Address ______________________________
Address ______________________________
City/State/Zipcode ______________________________
Telephone number ______________________________
Fax number ______________________________

CHECK:

❐ **Send copies of all program records to other physicians that may be involved in my care, such as any physicians involved in the diagnosis or treatment of diseases that may be due to my former work at Los Alamos National Laboratory. This may also include LANL for Workers' Compensation issues.**

Other physician

Name ______________________________
Address ______________________________
Address ______________________________
City/State/Zipcode ______________________________
Telephone number ______________________________
Fax number ______________________________

______________________________ ______________________________
Signature Printed Name

______________________________ ______________________________
Witness to signature Date

This release form is valid for one year from the date signed. The former worker may withdraw their permission for this release at any time.

Form C (Revised 01/2001) (WORD)

SURVEY CONSENT FORM

The Johns Hopkins Medical Institutions
(The Johns Hopkins Bloomberg School of Public Health)
Date/Revision: 9/18/01 Application No: 96-04-23-01
Title of Program: Medical Screening of Former Workers at
Los Alamos National Laboratory (LANL)

Date: ____________________

ID: ____________________

Explanation of Program to Subject

PURPOSE OF PROGRAM:

We invite you to join a health examination program. This program offers you a one-time free health exam and some medical testing. The purpose of the program is to see if you have any health problems that may be related to exposures that you had at Los Alamos National Laboratory (LANL). This program is looking for health problems due to exposures to asbestos, beryllium, lead, noise, and radiation. You may also choose a medical record review in place of the free health exam.

This program is offered to former LANL workers because Congress told the Department of Energy (DOE) to develop medical evaluation programs for former DOE workers who may have significant risk of health problems due to their work with hazardous or radioactive substances during their employment at DOE facilities. We invited you to take part because you had a job at LANL where you probably worked with one or more of the agents listed above or you contacted the program and asked to take part. We also invited you to take part in the program because you worked for one or more of the following employers at LANL:

- Los Alamos National Laboratory (LANL),
- Los Alamos Scientific Laboratory,
- the Manhattan Engineering District,
- Project "Y,"
- Zia,
- Pan Am World Services,
- Johnson Controls Incorporated,
- Johnson Controls of Northern New Mexico.

PROCEDURES:

If you agree to take part in the program, you may be asked to complete one or more surveys.

- Some former workers will receive a letter, a survey, and this consent form. The first survey [Exposure Questionnaire #1 (EQ1)] will help to decide who is eligible for the health exam **or** medical record review. Not all workers will get the first survey. If you received the first survey, please read and sign this consent form, and complete the survey in this packet. Return the signed consent form and the survey in the stamped, self-addressed envelope.
- Some former workers will receive a letter and this consent form, but no survey. If you do not get a survey in this packet, please read and sign this consent form. Return the signed consent form in the stamped, self-addressed envelope. You will be asked to complete one or more different surveys in the future, either in-person, over the telephone or through the mail.

RISKS AND DISCOMFORTS:

There are no physical risks or discomforts to you from completing the surveys. You do not have to answer any questions that you do not want to answer.

(THIS CONSENT FORM CONTINUES ON THE OTHER SIDE)

BENEFITS:

Your answers will help to find out more about the work and health of former LANL workers.

ALTERNATIVES TO PARTICIPATION:

You do not have to take part in this program. If you do take part, and later change your mind, you may quit at any time. If you decide not to take part, none of your union, health, or retirement benefits will be affected. You may withdraw at any time.

QUESTIONS YOU MAY HAVE ABOUT THE PROGRAM:

This consent form explains the program. Please read it carefully. Ask questions about anything you do not understand. If you do not have questions now, you may ask later. During the program, you will be told any new facts that could affect whether you want to stay in the program. If the program relates to a health problem you have, we will explain what other treatment could be given outside the program. You should understand those options before you sign this form. If you have questions you should call the principal investigator, Brian Schwartz, MD at 410-955-4587.

PRIVACY INFORMATION:

We will keep the program information private to the extent possible by law. However, state law requires us to report certain contagious diseases or if we find information about child abuse. Also, under certain conditions, people responsible for making sure that the research is done properly may review your program records. This might include people from Johns Hopkins, the National Institutes of Health, the Food and Drug Administration, or the sponsoring company (if any). All of these people are also required to keep your identity confidential. Otherwise, the information that identifies you will not be given out to people who are not working on the program, unless you give permission.

All program information is kept in locked file cabinets at Johns Hopkins Bloomberg School of Public Health in Baltimore. Program data is stored in a computer at Johns Hopkins Bloomberg School of Public Health in Baltimore. The data is stored with unique identifiers and access to the data is restricted to the Principal Investigator and the data manager. All reports sent to DOE contain group data. No individual is identified in these reports.

IN CASE OF INJURY:

If you are injured as a result of being in the program, or think you have not been treated fairly, please contact Dr. Schwartz, MD at 410-955-4130. The services at the Johns Hopkins Hospital or the Johns Hopkins Bayview Medical Center will be open to you in case of any such injury. However, the Johns Hopkins University, the Johns Hopkins Hospital, the Johns Hopkins Bayview Medical Center, the Johns Hopkins Bloomberg School of Public Health, the Los Alamos National Laboratory, and the Federal Government do not have a program to pay you if you are hurt or have other bad results which are not the fault of the program doctors.

You and your insurance company will be responsible for payment of any treatment or hospitalization you require if you are injured as a result of being in the program. It is up to you to check with your insurance company before you start this program to find out what your insurance company would pay for.

(THIS CONSENT FORM CONTINUES ON THE NEXT PAGE)

QUESTIONS ABOUT YOUR RIGHTS AS A PROGRAM SUBJECT:

If you have any questions about your rights as a subject in this program, you should call the Joint Committee on Clinical Investigation at (410) 955-3008, or the Johns Hopkins Bayview Medical Center Institutional Review Board for Human Research (410) 550-1853 to receive help or advice.

JOINING OF YOUR OWN FREE WILL (Volunteering for the program):

You do not have to join this or any program. If you do join, and later change your mind, you may quit at any time. If you refuse to join the program, you will not be penalized or lose any benefits to which you are otherwise entitled.

WHAT YOUR SIGNATURE MEANS:

Your signature below means that you understand the information given to you about the program and in this consent form. If you sign the form it means that you agree to join the program.

WE WILL GIVE YOU A COPY OF THIS CONSENT FORM.

(THIS CONSENT FORM CONTINUES ON THE OTHER SIDE)

PROGRAM APPROVED FOR ENROLLMENT OF: X Adults Only

NOT VALID WITHOUT THE COMMITTEE OR IRB STAMP OF CERTIFICATION

VOID ONE YEAR FROM ABOVE DATE
RPN NO____________________
Form C (Revised 01/2001)

____
Subject's signature (including children, when applicable) Date

____
Surrogate Signature for Subjects not Competent to Give Consent Date

Relationship of Surrogate to Subject: ____________________

____
Signature of Investigator or IRB/JCCI Approved Designee Date

____
Witness to Consent Procedures (Optional unless subject is illiterate, or unable to sign) Date

NOTE: A COPY OF THE SIGNED CONSENT FORM MUST BE KEPT BY THE PRINCIPAL INVESTIGATOR AND A COPY OF THE CONSENT FORM MUST BE PLACED IN THE PATIENT'S RECORD.

Form C (Revised 01/2001) (WORD)

MEDICAL SCREENING CONSENT FORM

The Johns Hopkins Medical Institutions
(The Johns Hopkins Bloomberg School of Public Health)
Date/Revision: 9/18/01 Application No: 96-94-23-01
Title of Program: Medical Screening Program for Former Workers at Los Alamos National Laboratory (LANL)

Date: ____________________

ID: ____________________

Former LANL Workers Medical Screening Program

PURPOSE OF PROGRAM:

We invite you to join a health examination program. This program offers you a one-time free health exam and some medical testing. The purpose of the program is to see if you have any health problems that may be related to exposures that you had at Los Alamos National Laboratory (LANL). This program is looking for health problems due to exposures to asbestos, beryllium, lead, noise, and radiation. You may also choose a medical record review in place of the free health exam.

This program is offered to former LANL workers because Congress told the Department of Energy (DOE) to develop medical evaluation programs for former DOE workers who may have significant risk of health problems due to their work with hazardous or radioactive substances during their employment at DOE facilities. We invited you to take part because you had a job at LANL where you probably worked with one or more of the agents listed above or you contacted the program and asked to take part. We also invited you to take part in the program because you worked for one or more of the following employers at LANL:

- Los Alamos National Laboratory (LANL),
- Los Alamos Scientific Laboratory,
- the Manhattan Engineering District,
- Project "Y,"
- Zia,
- Pan Am World Services,
- Johnson Controls Incorporated,
- Johnson Controls of Northern New Mexico.

PROCEDURES:

Health Examination:

If you choose the health exam, we will ask you if you want it by health care providers from either:

- the Los Alamos National Laboratory Occupational Medicine Group/Clinic,

or

- the Johns Hopkins Bloomberg School of Public Health and the University of New Mexico.

The type of exam will vary by the type of exposures that you had at work. You will also get some medical tests. These tests also depend on the exposures you had at work. The tests we will do for each agent are listed in the table below. The specific and exam and tests that you will receive are on the Intake Form.

(Please continue on the other side)

Agent/Exposure	Chest X-ray	Breathing Test	Hearing Test	Blood Test	Stool for Blood
Asbestos	**yes**	**yes**	no	no	**yes**
Beryllium	**yes**	no	no	**yes**	no
Lead	no	no	no	**yes**	no
Noise	no	no	**yes**	no	no
Radiation	**yes**	no	no	**yes**	**yes**

Medical Record Review:

If you would like a **medical record review**, we will ask you to sign consent forms and medical record releases. We will request that **you take the release to your doctor** and request him/her to send selected reports, x-rays, and records to the program at Johns Hopkins University for review. One of the occupational medicine doctors from Johns Hopkins will review these records. After the review, we will send you a letter with an opinion about what was found or not found in your records. You can choose this option if you have had appropriate tests and x-rays within the past two years. If not, we recommend that you have the health exam.

RESULTS:

We will send you a letter with the results from the health exam and testing within **8 to 10 weeks**. We will notify you in a letter of the findings from the medical record review. If there are any abnormal results, we will tell you what to do next. The next steps could include additional medical testing done by a doctor of your choice or by a doctor recommended by the program, if you do not have a doctor. We will not provide you with medical care, treatment, or pay for these, after the free health exam unless your abnormal results are related to beryllium exposure. (This is explained in more detail in the beryllium consent form). If we think you have a disease caused by past work at LANL, we will assist you in obtaining treatment and benefits by offering recommendations to you and to your health care provider. We will not provide that treatment or those benefits ourselves.

RISKS/DISCOMFORTS:

Whether or not you have any of these tests, will depend on the exposures you had at work. Not all workers will get all of these tests.

Radiation: The chest x-ray is the same as any other medical chest x-ray. There is a small amount of radiation exposure from it. The radiation exposure you will receive from participating in this program is equivalent to an exposure of 0.002 rem to your whole body. Naturally occurring radiation (cosmic radiation, radon, etc.) produces whole body radiation exposures of about 0.3 rem per year. Occupationally exposed individuals are permitted to receive whole body exposures of 5 rem per year.

Physical exam: Your exam will focus on the part of the body that may have been affected by the types of exposures that you told us about in your interview. We will also check your blood pressure, and listen to your heart and lungs.

Breathing Test: This is a test to check for effects from exposure to **asbestos.** You will be asked to breathe out into a small tube while a technician takes measurements. There are no physical risks from this test for a healthy person. You should let the technician know if you have or had any of the following:

(Please continue on the next page)

- high blood pressure,
- recent surgery to your head, neck, mouth, chest or abdomen,
- a cold, the flu, or an ear infection within the past 3 weeks,
- a recent nose bleed, bruising of your eyes, or bruising anywhere on your body, and
- if you used a bronchodilator, eaten a meal, or smoked within the past hour.

If you have any of these conditions, the technician may need to change the way the breathing test is done or not do it today.

Hearing Test: This is a test to check for effects from exposure to **noise.** You will sit in a soundproof booth. A technician will ask you to listen to different sounds and say if you hear them. There are no physical risks from this test.

Blood Tests: There are minimal risks from having blood drawn although many individuals experience anxiety from blood sticks. It is possible to have some pain or discomfort, bruising, and swelling at the needle stick site. In order to reduce the risks, a trained phlebotomist (a person who draws blood) will take 1 to 3 tubes of blood for some or all of the following tests:

1) Lymphocyte Proliferation Test (LPT): This is a blood test to check for sensitization to **beryllium**. The test will tell the doctors if your exposure to beryllium caused you to be sensitized to beryllium. If the test is positive, we will ask you to return for another sample. If you have two positive samples, you will need further tests and we will tell you what to do next. This is explained in more detail in the beryllium consent form. Please read the next consent form for beryllium testing. If your Intake Form indicates beryllium exposure, you will need to read and sign another consent.

2) Complete Blood Count: This test counts the number of red cells, white cells, and platelets in your blood. This test will look for possible blood system effects from exposure to **radiation**.

3) Thyroid-stimulating Hormone: This test will measure the amount of thyroid hormone in your blood. This test will look for possible effects from **radiation** to the thyroid.

4) Serum creatinine and blood urea nitrogen (BUN): These tests will look for effects of **lead** on the kidneys.

Anxiety: Many of the exams and tests that are done through this program are similar to those done at your Primary Care Provider's office but it is not unusual to experience anxiety or stress when you are asked to have these tests and exams done.

BENEFITS/LIMITATIONS:

You will have the chance to talk to doctors and medical personnel who are trained in occupational health. You can ask questions. By joining the program, you will be able to find out about your health.

You will help us to learn if workers have health problems that may have been caused by work at LANL. You will help us to find health problems from past LANL work.

(Please continue on the other side)

ALTERNATIVES TO PARTICIPATION:

Your decision to have the health exam **or** medical record review is voluntary. You do not have to take part in this program. If you do take part, and later change your mind, you may quit at any time. If you decide not to take part, your union, health, or retirement benefits will not be affected.

During the program, you will be told any new facts that could affect whether you want to stay in the program.

QUESTIONS YOU MAY HAVE ABOUT THE PROGRAM:

This consent form explains the program. Please read it carefully. Ask questions about anything you do not understand. If you do not have questions now, you may ask later. During the program, you will be told any new facts that could affect whether you want to stay in the program. If the program relates to a health problem you have, we will explain what other treatment could be given outside the program. You should understand those options before you sign this form. If you have questions you should call the principal investigator, Brian Schwartz, MD, at 410-955-4587.

PRIVACY INFORMATION:

We will keep the program information private to the extent possible by law. However, state law requires us to report certain contagious diseases or if we find information about child abuse. Also, under certain conditions, people responsible for making sure that the research is done properly may review your program records. This might include people from Johns Hopkins, the National Institutes of Health, the Food and Drug Administration, or the sponsoring company (if any). All of these people are also required to keep your identity confidential. Otherwise, the information that identifies you will not be given out to people who are not working on the program, unless you give permission.

All program information is kept in locked file cabinets at Johns Hopkins Bloomberg School of Public Health in Baltimore. Program data is stored in a computer at Johns Hopkins Bloomberg School of Public Health in Baltimore. The data is stored with unique identifiers and access to the data is restricted to the Principal Investigator and the data manager. All reports sent to DOE contain group data. No individual is identified in these reports.

IN CASE OF INJURY:

If you are injured as a result of being in the program, or think you have not been treated fairly, please contact Dr. Schwartz, MD at 410-955-4130. The services at the Johns Hopkins Hospital or the Johns Hopkins Bayview Medical Center will be open to you in case of any such injury. However, the Johns Hopkins University, the Johns Hopkins Hospital, the Johns Hopkins Bayview Medical Center, Johns Hopkins Bloomberg School of Public Health, the Los Alamos National Laboratory, and the Federal Government do not have a program to pay you if you are hurt or have other bad results which are not the fault of the program doctors.

(Please continue on the next page)

You and your insurance company will be responsible for payment of any treatment or hospitalization you require if you are injured as a result of being in the program. It is up to you to check with your insurance company before you start this program to find out what your insurance company would pay for.

QUESTIONS ABOUT YOUR RIGHTS AS A PROGRAM SUBJECT:

If you have any questions about your rights as subject in this program, you should call the Joint Committee on Clinical Investigation at (410) 955-3008, or the Johns Hopkins Bayview Medical Center Institutional Review Board for Human Research (410) 550-1853 to receive help or advice.

JOINING OF YOUR OWN FREE WILL (Volunteering for the program):

You do not have to join this or any program. If you do join, and later change your mind, you may quit at any time. If you refuse to join the program, you will not be penalized or lose any benefits to which you are otherwise entitled.

WHAT YOUR SIGNATURE MEANS:

Your signature below means that you understand the information given to you about the program and in this consent form. If you sign the form it means that you agree to join the program.

WE WILL GIVE YOU A COPY OF THIS CONSENT FORM.
PROGRAM APPROVED FOR ENROLLMENT OF: X Adults Only

NOT VALID WITHOUT THE COMMITTEE
OR IRB STAMP OF CERTIFICATION

VOID ONE YEAR FROM ABOVE DATE
RPN NO________________________
Form C (Revised 01/2001)

Subject's signature (including children, when applicable) Date

Surrogate Signature for Subjects not Competent to Give Consent Date

Relationship of Surrogate to Subject: ____________________

Signature of Investigator or IRB/JCCI Approved Designee Date

Witness to Consent Procedures (Optional unless subject is illiterate, or unable to sign) Date

NOTE: A COPY OF THE SIGNED CONSENT FORM MUST BE KEPT BY THE PRINCIPAL INVESTIGATOR AND A COPY OF THE CONSENT FORM MUST BE PLACED IN THE PATIENT'S RECORD

Health Examination Program for Former Los Alamos National Laboratory Workers
Exposure Questionnaire #1 (EQ1)

Please fill in your name, address, and job title information on this page and then answer the questions on the following pages. These questions ask about your work at the Los Alamos site. Anyone who is a former employee of one of the employers listed below should complete this questionnaire.

- Los Alamos National Laboratory (LANL)
- Los Alamos Scientific Laboratory (LASL)
- University of California (UC)
- Johnson Controls, Inc. (JCI)
- Johnson Controls of Northern New Mexico (JCNNM)
- Zia Company
- Pan-Am Company
- Any other contractor or subcontractor at the Los Alamos site

Today's Date: ____________________
Month Day Year

Name: Dr. Mr. or Ms.____________________
First Name Middle Initial Last Name

Home Street: ____________________
Street

____
City State Zip Code

Home Telephone Number: (________)____________________

What is your Social Security Number? ____________________

While working at LANL, what was your usual job title (the one you worked at the longest)?

____

Describe your usual job title (the one you worked at the longest)?:

____

How many years did you work at that job? ____ ____ Yrs.

Who was your employer at LANL? (Check all that apply) ☐ U. California

☐ Pan Am ☐ ZIA ☐ JCI ☐ JCNNM ☐ Other:____________________

Health Examination Program for Former Los Alamos National Laboratory Workers
Exposure Questionnaire #1 (EQ1)

Please answer all of the following questions regarding your work at LANL.

Box 1 - Beryllium		
1.1) Did you ever work with beryllium (including metal, alloys, ceramics, or any other beryllium compound)?	☐ Yes	☐ No
1.2) Did you ever work close to someone while they worked with beryllium (including metal, alloys, ceramics, or any other beryllium compound)?	☐ Yes	☐ No
1.3) Did you regularly walk through an area where beryllium was used? For example, V-shop, sm-39, Sigma building, CMR building, or others.	☐ Yes	☐ No

Box 2 - Noise		
2.1) Did you regularly work in an area where you had to speak loudly to talk with other people nearby?	☐ Yes	☐ No
2.2) Were you ever required to use earplugs or ear muffs?	☐ Yes	☐ No
2.3) Did you ever have annual hearing tests done while at LANL because you worked in a noisy area?	☐ Yes	☐ No

Box 3 - Asbestos		
3.1) Did you regularly work with asbestos?	☐ Yes	☐ No
Have you ever installed or removed, or worked close to someone who was installing or removing :		
3.2.1) building insulation	☐ Yes	☐ No
3.2.2) pipe insulation	☐ Yes	☐ No
3.2.3) floor tiles	☐ Yes	☐ No

Health Examination Program for Former Los Alamos National Laboratory Workers
Exposure Questionnaire #1 (EQ1)

Please answer all of the following questions regarding your work at LANL.

Box 4 - Lead		
4.1) Did you ever work making lead shielding or bricks or use lead for any other work?	☐ Yes	☐ No
4.2) Did you regularly work prepping surfaces for painting. For example, scraping, chipping, or grinding.	☐ Yes	☐ No
4.3) Did you ever work on a construction site where lead was present?	☐ Yes	☐ No
4.4) Did you ever have a blood lead test?	☐ Yes	☐ No

Box 5 - Radiation		
5.1) Did you ever work directly with ionizing radiation (for example, tritium, uranium, plutonium, polonium, external ionizing radiation, gamma, alpha, or beta, or other types)?	☐ Yes	☐ No
5.2) Did you ever have urine tests done for radiation exposure?	☐ Yes	☐ No
5.3) Did you regularly work in an area where radioactive materials or sources were used?	☐ Yes	☐ No
5.4) Did you ever wear a radiation monitoring badge to determine exposure?	☐ Yes	☐ No

Box 6 - Protective Equipment			
6.1) Did you ever wear or use a respirator?		☐ Yes	☐ No
If Yes, did you use a respirator because you worked with or around:			
6.2.1) asbestos	☐ Don't know	☐ Yes	☐ No
6.2.2) beryllium	☐ Don't know	☐ Yes	☐ No
6.2.3) lead	☐ Don't know	☐ Yes	☐ No
6.2.4) radiation	☐ Don't know	☐ Yes	☐ No

Health Examination Program for Former Los Alamos National Laboratory Workers
Exposure Questionnaire #1 (EQ1)

Please answer all of the following questions regarding your work at LANL.

Box 7 - Symptoms			
7.1) Do you usually have a cough?		□ Yes	□ No
7.2) Are you troubled by shortness of breath when hurrying on a level surface or walking up a slight hill?		□ Yes	□ No
7.3) Did you ever have a breathing test (you were told to blow as hard as you could into a machine) requested by LANL?		□ Yes	□ No
If Yes, check if you had a breathing test because you worked with or around:			
7.3.1) asbestos	□ Don't know	□ Yes	□ No
7.3.2) beryllium	□ Don't know	□ Yes	□ No
7.4) Did you ever have a chest X-ray requested by LANL?		□ Yes	□ No
If Yes, check if you had a chest x-ray because you worked with or around:			
7.4.1) asbestos	□ Don't know	□ Yes	□ No
7.4.2) beryllium	□ Don't know	□ Yes	□ No
7.4.3) radiation	□ Don't know	□ Yes	□ No

Health Examination Program for Former Los Alamos National Laboratory Workers
Exposure Questionnaire #1 (EQ1)

Box 8 - Other Remarks

Please use this space to tell us anything else that you want us to know (such as, health or exposure concerns).

Please answer all of the following questions regarding your work at LANL.

Box 9 - Participation

The program has a number of examination slots available for former workers who request examinations even if their past exposures were not of great concern.

9.1) Would you still like to have an examination even if we review your answers to the questions above and don't have concerns about your exposures?

☐ Yes ☐ No

9.2) If you answered "Yes", please indicate which exposures you are most concerned about (*Check all that apply*) :

- ☐ Asbestos
- ☐ Beryllium
- ☐ Lead
- ☐ Noise
- ☐ Radiation

Thank you for taking the time to complete this questionnaire.

Health Examination Program for Former Los Alamos National Laboratory Workers
Exposure Questionnaire #1 (EQ1)

Date:______ **Name:________________________** **Reviewer's Initials:____________**

Agent	Algorithm	FW	Result	Eligible?
Beryllium (Box 1)	If 1.1 = Yes		INVITE	
	If 1.2 = Yes		INVITE	
	If 1.3 = Yes		INVITE	
Noise (Box 2)	If 2.1 = Yes		INVITE	
	If 2.2 = Yes		Maybe	
	If 2.3 = Yes		Maybe	
	If 2.2 **and** 2.3 = Yes		INVITE	
Asbestos (Box 3)	If 3.1 = Yes		INVITE	
	If 3.2.1 = Yes		INVITE	
	If 3.2.2 = Yes		INVITE	
	If 3.2.3 = Yes		INVITE	
Lead (Box 4)	If 4.1 = Yes		INVITE	
	If 4.2 = Yes		INVITE	
	If 4.3 = Yes		Maybe	
	If 4.4 = Yes		**INVITE**	
	If 4.3 **and** 4.4 = Yes		INVITE	
Radiation (Box 5)	If 5.1 = Yes		INVITE	
	If 5.2 = Yes		INVITE	
	If 5.3 = Yes		Maybe	
	If 5.4 = Yes		Maybe	
	If 5.2 **and** 5.3 = Yes		INVITE	
	If 5.2 **and** 5.4 = Yes		INVITE	
	If 5.3 **and** 5.4 = Yes		INVITE	
PPE (Box 6)	If 6.1 = Yes		Maybe	
	If 6.2.1 = Yes		INVITE	
	If 6.2.2 = Yes		INVITE	
	If 6.2.3 = Yes		INVITE	
	If 6.2.4 = Yes		INVITE	

Health Examination Program for Former Los Alamos National Laboratory Workers
Exposure Questionnaire #1 (EQ1)

Agent	Algorithm	FW	Result	Eligible?
Symptoms (Box 7)	If 7.1 = Yes		Sample	
	If 7.2 = Yes		Sample	
	If 7.3.1 = Yes		INVITE	
	If 7.3.2 = Yes		INVITE	
	If 7.4.1 = Yes		INVITE	
	If 7.4.2 = Yes		INVITE	
	If 7.4.3 = Yes		INVITE	
Participation (Box 9)	If interested in exam = Yes		INVITE	
Concern:	Asbestos			
	Beryllium			
	Lead			
	Noise			
	Radiation			
	Solvents			
Comments (Box 8)				

Exposure Questionnaire # 2

CHECK THAT THE SURVEY CONSENT FORM WAS COMPLETED BEFORE BEGINNING THE INTERVIEW.

SURVEY CONSENT SIGNED: YES ☐ NO ☐

INTERVIEWER READ:

Hello, I am ___________ . Thank you for agreeing to take part in the medical exam program for former workers at Los Alamos National Laboratory (LANL).

- I am a former worker from LANL, too. I used to work at ___________ and am now working part-time on this project. My job is to talk to other former workers about their medical and work history at LANL.
- I just want to remind you that the answers you give today will be kept confidential.

INTERVIEWER READ- IF THERE IS NO CONSENT FORM:

- **IN-PERSON**: I see that we do not have a copy of the consent form that was sent to you. Would you please **READ AND SIGN THE SURVEY CONSENT FORM BEFORE WE BEGIN.** After the consent is signed - **WE WILL BEGIN THE INTERVIEW**
- **BY TELEPHONE:** If the survey consent is not signed, we cannot do the interview now. If you do not have a consent form, we will mail one to you. We will call you once we receive a signed consent form and complete the interview at that time.
- Do you have any questions before we get started?

  If NO - we will begin the interview

  If YES - see list of Frequently Asked Questions

Question asked by former worker: ________________________________

____

Date received at JHU:______________________

Date entered: ______________________

Entered by:______________________

Interviewer: ______________________ Interviewer's Initials ________

NOTE: THIS IS A TWO-SIDED SURVEY

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: _____ **ID Number**: ___________ **Interviewer's Initials**: ________

Part A– Personal Information

INTERVIEWER READ:
I would like to make sure that we have your correct personal information. You do not have to answer any questions that you do not want to answer. We can still do the health exam or record review even if you do not answer all the questions. However, please try to answer as many questions as possible.

I would like to verify your name and Social Security Number:

1.1 What is your name? ______________________________
Last First Middle Initial

1.2 What is your social security number: ________ - ______ - __________

1.3 What was your Z-number? ____________________

I would like to verify your home address and telephone number:

1.4 What is your home address: ______________________________
Street

____
City State Zip Code

1.5 What is your home phone #: ______________________________
Area code

1.6 How old were you on your last birthday? _____ _____ Yrs.

1.7 What is your date of birth? Date: _____/_____/_____
month day year

INTERVIEWER INSTRUCTION: Don't read question 1.8 unless absolutely necessary

1.8 Are you male or female? 1. __ Male 2. __ Female

1.9 Which of the following racial or ethnic groups do you identify with? Check all that apply:

1. _White 2. _ Black 3. _ Native American 4. _ Hispanic 5. _ Asian 6. _ Spanish 7. _ Other

1.10 What is the highest grade you finished in school? _____ _____Yrs.
(12 years = finished high school. Include any college years)

1.11 Do you have a regular family doctor or primary care provider? ☐ YES ☐ NO

If yes, please provide the following: Provider name______________________________

Address: ______________________________

____

Phone #: ______________________________

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: _____ **ID Number**: ______________ **Interviewer's Initials**: ________

Part B – Work History

INTERVIEWER READ:
I would like to ask you some questions about your past work at Los Alamos National Laboratory (LANL). These questions will help us learn about anything you may have been exposed to while working there.
I will also ask you questions about your health and your past medical history.
This information will be used to decide what type of exam and tests that you should have.
We also want to locate your fellow workers and to learn about where beryllium, lead, noise, asbestos and radiation were found and used throughout LANL in the past.
Please do not tell me any classified information.

2.1 When did you first <u>start</u> working at LANL? __ __ /__ __ __ __ (Month / year)

2.2 When did you <u>last</u> work at LANL? __ __ /__ __ __ __ (Month / year)

Interviewer Instruction: Part-time consulting does not count as employment. **Workers temporarily off work on worker's compensation are not eligible for this Program.**

2.3 While working at LANL, what was your usual job title (the one you worked at the longest) ?

____

2.4 How many years did you work at that job? _____ _____ Yrs.

2.5 Who was your employer at LANL?

☐ U. California ☐ Pan Am ☐ ZIA ☐ JCI ☐ JCNNM

2.6 Have you ever worked for any other sub-contractors while working at LANL?

☐ YES ☐ NO

If yes, please name that company: ______________________
Other subcontractor

2.7 While working at LANL during this time, did you work for any other employer?

☐ YES ☐ NO ☐ Don't remember

If yes, which employer:

____

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ______________ **Interviewer's Initials**: ________

Part C – Exposure History (Question 3)

INTERVIEWER READ:
I am going to ask you about all the jobs you held at LANL for at least 6 months. Start with the first job you had at LANL and work forward. If you know, include where and when you worked, and the type of work that you did.
For each job title that you held, I will ask you questions about certain exposures you may have had, dates, and the buildings and TA's (technical areas) where you worked.

For the purpose of completing this form, the term **beryllium** means beryllium metals, alloys, ceramics, or other beryllium compounds.
Radiation includes internal and external radiation, plutonium, neutron, tritium, americium, polonium, uranium, alpha, beta, or gamma radiation.

3.0 - List of All Jobs Held at LANL.

INTERVIEWER INSTRUCTION:
If the former worker had more than 5 jobs while working at Los Alamos National Laboratory, please use the additional forms. Consider two jobs with similar job titles to be different if they have very different job tasks and exposures. In general try to group similar jobs together.

For example: an apprentice plumber, plumber-first class, etc. would all be grouped under the job title "plumber".

If you are not sure whether multiple jobs should be listed under the same job title, fill out separate job title sheets (one job title sheet for each of the jobs in question).

3.1. What was your first Job Title? : ______________________________

3.1.1 What was your Start Date? : ________/________
month year

3.1.2 What was your End Date? : ________/________
month year

3.1.3 What was the Tech Area-Building that you worked at the longest?

____

3.1.4 Job Specific Information for Job # 1

INTERVIEWER INSTRUCTIONS – hand the former worker the answer key for the "Agents and Exposures" answer grid on the following page.

For Questions 4 and 5, ask what type of protective equipment they used and how often they used them.

Choices for general PE and noise-specific PE are provided on the answer key. Space is provided for the former worker to briefly comment on or clarify an answer.

INTERVIEWER READ: Please answer questions 1-5 in order. Look at the corresponding answer choices on your answer key to choose your answer.

In this part of the interview, I will ask you questions about five agents that you may have been exposed to while working at LANL: (1) beryllium, (2) lead, (3) noise, (4) asbestos, (5) radiation. I would like to know if you were exposed to any of these agents while you worked as a ______________________________.
(Interviewer fill in Job Title #1 from above)

I will also ask you to tell me what kind of protective equipment you used. If you know, please tell me how often you used this equipment. Examples of protective equipment include, but are not limited to, respirators, dust masks, glove boxes, fume hoods, coveralls and booties or other protective clothing.

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

AGENTS and EXPOSURES for Job Title #1

AGENTS	1. How often did you work with or use each agent?						2. How long did you work with or use each agent?					3. Comments
	A	B	C	D	E	X	A	B	C	D	X	
a) Asbestos												
b) Beryllium												
c) Lead												
d) Noise												
e) Radation												
f) Chlorinated Solvents (i.e. carbon tetrachloride, chloroform, some degreasers-i.e. trichloroethylene)												
g) Aromatic Solvents (i.e., toluene, benzene, xylene)												
h) Other Solvents (i.e. acetone, hexane, alcohols)												

ANSWER KEY

QUESTION 1

Key	How Often Used?
A	Never
B	Daily
C	Weekly
D	Monthly
E	Yearly
X	Don't know

QUESTION 2

Key	How Long Used?
A	Less than 1 year
B	1 to 5 years
C	6 to 10 years
D	Greater than 10 years
X	Don't know

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ________________ **Interviewer's Initials**: _________

3.2 What was your second Job Title? : ____________________

3.2.1 What was your Start Date? : ________/________ (month / year)

3.2.2 What was your End Date? : ________/________ (month / year)

3.2.3 What was the Tech Area-Building that you worked at the longest?____________

3.2.4 Job Specific Information Job # 2

INTERVIEWER INSTRUCTIONS – hand the former worker the answer key for the "Agents and Exposures" answer grid on the following page.

For Questions 4 and 5, ask what type of protective equipment they used and how often they used them.

Choices for general PE and noise-specific PE are provided on the answer key.
Space is provided for the former worker to briefly comment on or clarify an answer.

INTERVIEWER READ: Please answer questions 1-5 in order. Look at the corresponding answer choices on the answer key to choose your answer.

In this part of the interview, I will ask you questions about five agents that you may have been exposed to while working at LANL: (1) beryllium, (2) lead, (3) noise, (4) asbestos, (5) radiation. I would like to know if you were exposed to any of these agents while you worked as a ____________________________.
(Interviewer fill in Job Title #2 from above)

I will also ask you to tell me what kind of protective equipment you used. If you know, please tell me how often you used this equipment. Examples of protective equipment include, but are not limited to, respirators, dust masks, glove boxes, fume hoods, coveralls and booties or other protective clothing.

AGENTS and EXPOSURES for Job Title #2

AGENTS	1. How often did you work with or use each agent?						2. How long did you work with or use each agent?					3. Comments
	A	B	C	D	E	X	A	B	C	D	X	
a) Asbestos												
b) Beryllium												
c) Lead												
d) Noise												
e) Radiation												
f) Chlorinated Solvents (i.e. carbon tetrachloride, chloroform, some degreasers i.e. trichloroethlyene)												
g) Aromatic Solvents (i.e., toluene, benzene, xylene)												
h) Other Solvents (i.e. acetone, hexane, alcohols)												

ANSWER KEY

QUESTION 1

Key	How Often Used?
A	Never
B	Daily
C	Weekly
D	Monthly
E	Yearly
X	Don't know

QUESTION 2

Key	How Long Used?
A	Less than 1 year
B	1 to 5 years
C	6 to 10 years
D	Greater than 10 years
X	Don't know

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ________________ **Interviewer's Initials**: _________

3.3 What was your 3rd Job Title? : ______________________________

3.3.1 What was your Start Date? : __________/__________
month year

3.3.2 What was your End Date? : __________/__________
month year

3.3.3 What was the Tech Area-Building that you worked at the longest? :

____

3.3.4 Job Specific Information Job # 3

INTERVIEWER INSTRUCTIONS – hand the former worker the answer key for the "Agents and Exposures" answer grid on the following page.

For Questions 4 and 5, ask what type of PE they used and how often they used them.

Choices for general PE and noise-specific PE are provided on the answer key.
Space is provided for the former worker to briefly comment on or clarify an answer.

INTERVIEWER READ: Please answer questions 1-5 in order. Look at the corresponding answer choices on the answer key to choose your answer.

In this part of the interview, I will ask you questions about five agents that you may have been exposed to while working at LANL: (1) beryllium, (2) lead, (3) noise, (4) asbestos, (5) radiation. I would like to know if you were exposed to any of these agents while you worked as a ______________________________.
(Interviewer fill in Job Title #3 from above)

I will also ask you to tell me what kind of protective equipment you used. If you know, please tell me how often you used this equipment. Examples of protective equipment include, but are not limited to, respirators, dust masks, glove boxes, fume hoods, coveralls and booties or other protective clothing.

AGENTS and EXPOSURES for Job Title #3

AGENTS	1. How often did you work with or use each agent?						2. How long did you work with or use each agent?					3. Comments
	A	B	C	D	E	X	A	B	C	D	X	
a) Asbestos												
b) Beryllium												
c) Lead												
d) Noise												
e) Radiation												
f) Chlorinated Solvents (i.e. carbon tetrachloride, chloroform, some degreasers i.e. trichloroethlyene)												
g) Aromatic Solvents (i.e., toluene, benzene, xylene)												
h) Other Solvents (i.e, acetone, hexane, alcohols)												

ANSWER KEY

QUESTION 1

Key	How Often Used?
A	Never
B	Daily
C	Weekly
D	Monthly
E	Yearly
X	Don't know

QUESTION 2

Key	How Long Used?
A	Less than 1 year
B	1 to 5 years
C	6 to 10 years
D	Greater than 10 years
X	Don't know

Date: ______ **ID Number**: ________________ **Interviewer's Initials**: _________

3.4 What was your 4th Job Title? ______________________

3.4.1 What was your Start Date? : __________/________
month year

3.4.2 What was your End Date?: __________/________
month year

3.4.3 What was the Tech Area-Building that you worked at the longest? :

____

3.4.4 *Job Specific Information Job # 4*

INTERVIEWER INSTRUCTIONS – hand the former worker the answer key for the "Agents and Exposures" answer grid on the following page.

For Questions 4 and 5, ask what type of PE they used and how often they used them.

Choices for general PE and noise-specific PE are provided on the answer key.
Space is provided for the former worker to briefly comment on or clarify an answer.

INTERVIEWER READ: Please answer questions 1-5 in order. Look at the corresponding answer choices on answer key card to choose your answer.

In this part of the interview, I will ask you questions about five agents that you may have been exposed to while working at LANL: (1) beryllium, (2) lead, (3) noise, (4) asbestos, (5) radiation. I would like to know if you were exposed to any of these agents while you worked as a ______________________.
(Interviewer fill in Job Title #4 from above)

I will also ask you to tell me what kind of protective equipment you used. If you know, please tell me how often you used this equipment. Examples of protective equipment include, but are not limited to, respirators, dust masks, glove boxes, fume hoods, coveralls and booties or other protective clothing.

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ______________ **Interviewer's Initials**: ________

AGENTS and EXPOSURES for Job Title #4

AGENTS	1. How often did you work with or use each agent?						2. How long did you work with or use each agent?					3. Comments
	A	B	C	D	E	X	A	B	C	D	X	
a) Asbestos												
b) Beryllium												
c) Lead												
d) Noise												
e) Radiation												
f) Chlorinated Solvents (i.e. carbon tetrachloride, chloroform, some degreasers i.e. trichloroethlyene)												
g) Aromatic Solvents (i.e., toluene, benzene, xylene)												
h) Other Solvents (i.e. acetone, hexane, alcohols)												

ANSWER KEY

QUESTION 1

Key	How Often Used?
A	Never
B	Daily
C	Weekly
D	Monthly
E	Yearly
X	Don't know

QUESTION 2

Key	How Long Used?
A	Less than 1 year
B	1 to 5 years
C	6 to 10 years
D	Greater than 10 years
X	Don't know

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ________________ **Interviewer's Initials**: _________

3.5 What was your 5th Job Title?: ______________________________

3.5.1 What was your Start Date?: ________/________
month year

3.5.2 What was your End Date?: ________/________

month year

3.5.3 What was the Tech Area-Building that you worked at the longest?:____________

3.5.4 Job Specific Information Job # 5

INTERVIEWER INSTRUCTIONS – hand the former worker the answer key for the "Agents and Exposures" answer grid on the following page.

For Questions 4 and 5, ask what type of PE they used and how often they used them.

Choices for general PE and noise-specific PE are provided on the answer key.
Space is provided for the former worker to briefly comment on or clarify an answer.

INTERVIEWER READ: Please answer questions 1-5 in order. Look at the corresponding answer choices on answer key card to choose your answer.

In this part of the interview, I will ask you questions about five agents that you may have been exposed to while working at LANL: (1) beryllium, (2) lead, (3) noise, (4) asbestos, (5) radiation. I would like to know if you were exposed to any of these agents while you worked as a ______________________________.
(Interviewer fill in Job Title #5 from above)

I will also ask you to tell me what kind of protective equipment you used. If you know, please tell me how often you used this equipment. Examples of protective equipment include, but are not limited to, respirators, dust masks, glove boxes, fume hoods, coveralls and booties or other protective clothing.

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

AGENTS and EXPOSURES for Job Title #5

AGENTS	1. How often did you work with or use each agent?						2. How long did you work with or use each agent?					3. Comments
	A	B	C	D	E	X	A	B	C	D	X	
a) Asbestos												
b) Beryllium												
c) Lead												
d) Noise												
e) Radiation												
f) Chlorinated Solvents (i.e. carbon tetrachloride, chloroform, some degreasers i.e. trichloroethlyene)												
g) Aromatic Solvents (i.e., toluene, benzene, xylene)												
h) Other Solvents (i.e. acetone, hexane, alcohols)												

ANSWER KEY

QUESTION 1

Key	How Often Used?
A	Never
B	Daily
C	Weekly
D	Monthly
E	Yearly
X	Don't know

QUESTION 2

Key	How Long Used?
A	Less than 1 year
B	1 to 5 years
C	6 to 10 years
D	Greater than 10 years
X	Don't know

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** _________

Part D: SPECIFIC EXPOSURES (Questions 4-10)

INTERVIEWER READ:
We have found that certain job tasks may be associated with exposure to beryllium, lead, noise, asbestos and radiation. I will ask you to tell me if you performed any of these job tasks while working at LANL.

Beryllium

INTERVIEWER INSTRUCTION:
Please read each of the beryllium-specific job tasks. Ask the former worker if they have ever performed these tasks, and place a check mark in the column that responds to their answer.

NOTE: Make sure that former worker knows these job tasks are only related to **beryllium**. For example, "grinding/machining" means grinding or machining **with beryllium**, and not on other substances. Space is provided if the former worker wishes to briefly comment on or clarify an answer.

Job Task		1) Ever Performed? Y, N, or DK	2) For which job title? Place a √ in job title box					3) Comments
			1st	2nd	3rd	4th	5th	
4.1.1	Ingot casting or other foundry work							
4.1.2	Billet preparation							
4.1.3	Sawing/Band sawing							
4.1.4	Powder processing							
4.1.5	Coating							
4.1.6	Welding (soldering, brazing, arc melting)							
4.1.7	Grinding/Machining							
4.1.8	Decontaminating tools/ equipment							
4.1.9	Heat treating							
4.1.10	Sanding or polishing							
4.1.11	Ventilation maintenance							
4.1.12	Launder clothing							
4.1.13	Extrusion work							
4.1.14	Flame plating on substrates							
4.1.15	Vaporizing							
4.1.16	Die Casting							
4.1.17	Purification							
4.1.18	Etching							
4.1.19	Detonation of test shots							
4.1.20	Other job tasks							
4.1.21	Other job tasks							

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

Beryllium Buildings

INTERVIEWER INSTRUCTIONS: Please read the list of each of the buildings at LANL where beryllium was used. Ask if they have ever spent at least 8 hours working in any of these buildings. Place a check mark in the column that corresponds to their answer.

Space is provided for the former worker to briefly comment on or clarify an answer.

4.2 Did you ever spend at least 8 hours working in any of the following building areas.

☐ YES ☐ NO ☐ Don't know (DK)

If No or DK, go to Question 4.3

List of LANL Buildings where beryllium was used

Buildings		1) Ever worked? Y, N, or DK	2) For Which Job Title?					Comments
			1st	2ND	3RD	4TH	5TH	
4.2.1	Delta Building (TA-1)							
4.2.2	Gamma Building (TA-1)							
4.2.3	I Building (TA-1)							
4.2.4	M Building (TA-1)							
4.2.5	Sigma Building (TA-1)							
4.2.6	V-Shop (TA-1)							
4.2.7	SM-39 (TA-3)							
4.2.8	SM-66 (TA-3)							
4.2.9	SM-102 (TA-3)							
4.2.10	SM-141 (TA-3)							
4.2.11	CMR (Chemistry & Metallurgy Research, SM-29 TA-3)							
4.2.12	TA-21 (DP SITE)							
4.2.13	TA-53 (Los Alamos Meson Physics Facility, LAMPF)							

4.2.13 Were there any other job tasks, TA's, or buildings that you worked in where beryllium was used?

____

____

4.3 Were you ever in a beryllium monitoring program?

☐ YES ☐ NO ☐ Don't know

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: _____ **ID Number**: _______________ **Interviewer's Initials**: ________

Lead Job Tasks

INTERVIEWER INSTRUCTION:
Please read each of the lead-specific job tasks, and ask the former worker if they have ever performed these tasks.

NOTE: Make sure that former worker knows these job tasks are only related to **lead**. For example, "band-sawing" means band-sawing **on lead**, and not on other substances. Space is provided for the former worker to briefly comment on or clarify an answer.

Job Task		1) Ever Performed? Y, N, or DK	2) For which job title? Place a √ in job title box					3) Comments
			1st	2ND	3RD	4TH	5TH	
5.1.1	Grinding/ scraping of paints							
5.1.2	Band sawing							
5.1.3	Welding/ Soldering							
5.1.4	Machining							
5.1.5	Decontaminating tools and equipment							
5.1.6	Hot cutting lead shielding							
5.1.7	Working with powders							
5.1.8	Ventilation maintenance							
5.1.9	Laundering clothing							
5.1.10	Extrusion work							
5.1.11	Die casting							
5.1.12	Pipe fitting, plumbing e.g., pouring lead joints							
5.1.13	Making and detonating shots							
5.1.14	Melting lead for brick/ingot or shield production							
5.1.15	Other job tasks where lead was heated or melted							
5.1.16	Handling large amounts of lead bricks or shielding without gloves							
5.1.17	Other job tasks							

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

Lead Buildings

INTERVIEWER INSTRUCTION:
Please read the list of each of the buildings at LANL where lead was used. Ask if they have ever spent at least 20 hours working in any of these buildings. Place a check mark in the column that corresponds to their answer.

5.2 Did you ever spend at least 20 hours in any of these building areas?

☐ YES ☐ NO ☐ Don't know (DK)

If No or Don't Know (DK), skip to p.20 Question 6.0

Building Area		Ever worked? Y, N, or DK	2) For Which Job Title?				
			1st	2nd	3rd	4th	5th
5.2.1	Lead Furnace (TA-3)						
5.2.2	Lead Foundry (SM-66 TA-3)						
5.2.3	Los Alamos Meson Physics Facility						

5.2.4 Were there any other job tasks, buildings, or TA's that you worked in where lead levels were high?

____

____

5.3 Have you ever been in a lead monitoring program?

☐ YES ☐ NO ☐ Don't know (DK)

5.4 Have you ever had a blood lead test done?

☐ YES ☐ NO ☐ Don't know (DK)

QUESTION 6.0: NOISE

INTERVIEWER INSTRUCTION:
Please read each of the noise-specific job tasks, and ask the former worker if they have ever performed these tasks. Make sure that the former worker understands that these job tasks are only related to exposure to **loud noise**.

Space is provided for the former worker to briefly comment on or clarify an answer.

Job Task		1) Ever Performed? Y, N, or DK	2) For which job title?					3) Comments
			1st	2nd	3rd	4th	5th	
6.1.1	Construction Work							
6.1.2	Drilling							
6.1.3	Grinding							
6.1.4	Machine or shop work							
6.1.5	Injection molding							
6.1.6	Test firing							
6.1.7	Compressed Gas Facility work							
6.1.8	Work in an equipment room							
6.1.9	Other job tasks ________							
6.1.10	Other job tasks ________							

5.2.5 Were there any other job tasks, buildings, or TA's that you worked in where noise levels were high?

____

____

6.2 Have you ever been in a noise monitoring program?

☐ YES ☐ NO ☐ Don't know (DK)

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

7.0: ASBESTOS

INTERVIEWER INSTRUCTION:
Please read each of the asbestos-specific job tasks. Ask the former worker if they have ever performed these tasks, and place a check mark in the column that corresponds to their answer.

NOTE: Make sure that former worker knows these job tasks are only related to **asbestos.** For example, "plumbing and pipe fitting work" means plumbing and pipe fitting work done with or around **asbestos.** Space is provided for the former worker to briefly comment on or clarify an answer.

Asbestos oven and/or apron use should only be noted if asbestos was crumbling and in poor condition. This should be noted in the comments section of question 7.1.5.

Job Task		**1) Ever Performed ?** **Y, N, or DK**	**2) For which job title?** **Place a √ in job title box**					**3) Comments**
			1st	**2nd**	**3rd**	**4th**	**5th**	
7.1.1	Install and remove pipe, boiler/hot water heater insulation							
7.1.2	Spray on insulation							
7.1.3	Grind brakes/ transmission parts							
7.1.4	Make asbestos ovens							
7.1.5	Make asbestos aprons							
7.1.6	Install/ remove soundproof materials, floor tiles, or transite wall board.							
7.1.7	Plumbing and pipe fitting work							
7.1.8	Work with asbestos gaskets							
7.1. 9	Other asbestos removal tasks ________________							
7.1.10	Other job tasks ________________							

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

7.1.11 Were there any other job tasks, TA's or buildings that you worked in where asbestos was used?

____

____

7.2 Have you ever been in an asbestos monitoring program?

☐ YES ☐ NO ☐ Don't know (DK)

QUESTION 8.0: RADIATION

INTERVIEWER INSTRUCTION:
Please read each of the radiation-specific job tasks. Ask the former worker if they have ever performed these tasks and place a check in the column that corresponds to their answer.

Space is provided for the former worker to briefly comment on or clarify an answer.

1) What job tasks did you perform around radiation that required you to use Protective Equipment?		**2) For which job title?** **Place a √ in job title box**					**3) Comments**
		1st	2nd	3rd	4th	5th	
8.1.1							
8.1.2							
8.1.3							
8.1.4							
8.1.5							

8.2 Were you ever removed from a job or work location to prevent further radiation exposure?

☐ YES ☐ No ☐ Don't know (DK)

If yes, please provide the following information:

For Which Job Title?	**Year**	**TA/Building that you were working in**

8.3 Were you ever decontaminated because of radiation exposure?

☐ YES ☐ No ☐ Don't know (DK)

8.3.1 If yes, please provide the following information:

	Date (Yr)	For which job title?					How many times?						TA/Building where you worked
		1st	2nd	3rd	4th	5th	1	2	3	4	>4	DK	
8.3.1.1													
8.3.1.2													
8.3.1.3													
8.3.1.4													
8.3.1.5													

8.4 Did you ever work with or around plutonium?

☐ Yes ☐ No ☐ Don't Know (DK)

8.5 Did you ever wear a film badge to check for radiation exposure?

☐ YES ☐ No ☐ Don't know (DK)

INTERVIEWER INSTRUCTION: For **Questions 8.6 – 8.8**, hand the former worker the Answer Key for Radiation Exposure (shown below).

Interviewer: Answer Key for Radiation Exposure

KEY	How Often?	KEY	Why?
A	ONCE	A	ROUTINE MONITORING
B	SELDOM	B	ACCIDENT
C	OFTEN	X	DON'T KNOW
D	ALWAYS		
X	DON'T KNOW		

8.6 Did you ever have nose swipes taken to check for radiation exposure?

☐ Yes ☐ No ☐ Don't Know (DK)

8.6.1 If yes, when, for which job title, and how many times?

	Time Period	Job title					How often?					Why?		
		1st	2nd	3rd	4th	5th	A	B	C	D	X	A	B	X
8.6.1.1														
8.6.1.2														
8.6.1.3														
8.6.1.4														
8.6.1.5														

8.7 Did you ever have body counts taken to check for radiation exposure?

☐ Yes ☐ No ☐ Don't Know (DK)

8.7.1 If yes, when, for which job title, and how many times?

	Time Period	Job title					How often?					Why?		
		1st	2nd	3rd	4th	5th	A	B	C	D	X	A	B	X
8.7.1.1														
8.7.1.2														
8.7.1.3														
8.7.1.4														
8.7.1.5														

8.8 Did you ever have urine tests taken to check for radiation exposure?

☐ Yes ☐ No ☐ Don't Know (DK)

8.8.1 If yes, when, for which job title, and how many times?

	Time Period	Job title					How often?					Why?		
		1st	2nd	3rd	4th	5th	A	B	C	D	X	A	B	X
8.8.1.1														
8.8.1.2														
8.8.1.3														
8.8.1.4														
8.8.1.5														

Date: ______ **ID Number**: ________________ **Interviewer's Initials**: ________

QUESTION 9.0: SOLVENTS

INTERVIEWER INSTRUCTION: Please ask the former worker whether they performed any of the following tasks involving solvents. Indicate for which job title they performed these tasks.

Job Task		1) Ever Performed? Y, N, or DK	Job Title				
			1	2	3	4	5
9.1.1	Machining						
9.1.2	Degreasing						
9.1.3	Parts/tools cleaning						
9.1.4	Laboratory Chemist						
9.1.5	Other:						
9.1.6	Other:						

INTERVIEWER INSTRUCTION: Please use the key below to answer questions 9.2.1-9.2.3.

		A	B	C	D	E	X
9.2.1	In your work with solvents did you get solvents on your skin?						
9.2.1a	If yes, did your skin get dry and cracked?						
9.2.2	In your work with solvents did you feel "high" at work?						
9.2.3	In your work with solvents, did you to feel tired at work?						

Key	How Often Did This Happen?
A	Never
B	Daily
C	Weekly
D	Monthly
E	Less than monthly
X	Don't know

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** _________

9.3 Did a doctor ever tell you that you had abnormal liver tests?

☐ YES ☐ NO ☐ DON'T KNOW (DK)

When? ____ ____/ ____ _____
Month Year

9.4 Is there anything else that you would like to tell us about the solvents or chemicals that you used during your work at LANL?

____

____

____

____

10.0: OTHER DOE SITES

10.1 Did you ever work at any other DOE sites?

☐ Yes ☐ No ☐ Don't Know (DK)

If No or Don't Know, skip to Question 10

If Yes, please tell me the DOE site and year/years that you were there:

	DOE SITE	YEAR
10.1.1		
10.1.2		
10.1.3		
10.1.4		
10.1.5		

Part E: MEDICAL HISTORY (Questions 11-20)

INTERVIEWER READ:
The next questions are about any illnesses you have or had in the past. Please give approximate dates where needed.

INTERVIEWER INSTRUCTION: If the answer to Part A is NO, skip to the next question.

	Condition	A. Have you ever had or do you still have?	B. When did the doctor first tell you this?	C. Are you taking medications for this?	D. What is the name of the medication(s)?
		No Yes DK	Year	No Yes DK	
11.1	Asthma	1 2 8	|__|__|__|__|	1 2 8	
11.2	Sarcoidosis	1 2 8	|__|__|__|__|	1 2 8	
11.3	Pneumoconiosis (lung scarring from silica, coal, asbestos)	1 2 8	|__|__|__|__|	1 2 8	
11.4	Tuberculosis	1 2 8	|__|__|__|__|	1 2 8	
11.5	Allergies	1 2 8	|__|__|__|__|	1 2 8	
11.6	COPD or emphysema	1 2 8	|__|__|__|__|	1 2 8	
11.7	Pneumonia	1 2 8	|__|__|__|__|	1 2 8	
11.8	Chronic beryllium disease	1 2 8	|__|__|__|__|	1 2 8	
11.9	Bronchitis	1 2 8	|__|__|__|__|	1 2 8	
11.10	Frequent sinus Infections	1 2 8	|__|__|__|__|	1 2 8	
11.11	Heart attack/angina	1 2 8	|__|__|__|__|	1 2 8	
11.12	Arrhythmia (irregular heart beat)	1 2 8	|__|__|__|__|	1 2 8	

	Condition	A. Have you ever had or do you still have?			B. When did the doctor first tell you this?	C. Are you taking medications for this?			D. What is the name of the medication(s)?
		No	Yes	DK	Year	No	Yes	DK	
11.14	High blood pressure	1	2	8	|__|__|__|__|	1	2	8	
11.15	Blood disorders	1	2	8	|__|__|__|__|	1	2	8	
11.16	Epilepsy/seizure	1	2	8	|__|__|__|__|	1	2	8	
11.18	Head injury	1	2	8	|__|__|__|__|	1	2	8	
11.19	Parkinson's disease	1	2	8	|__|__|__|__|	1	2	8	
11.20	Stroke	1	2	8	|__|__|__|__|	1	2	8	
11.22	Nerve damage in Arms or legs	1	2	8	|__|__|__|__|	1	2	8	
11.23	Multiple sclerosis	1	2	8	|__|__|__|__|	1	2	8	
11.25	Hepatitis (yellow Jaundice)	1	2	8	|__|__|__|__|	1	2	8	
11.26	Alcoholism	1	2	8	|__|__|__|__|	1	2	8	
11.29	Rheumatoid arthritis	1	2	8	|__|__|__|__|	1	2	8	
11.30	Lupus	1	2	8	|__|__|__|__|	1	2	8	
11.32	Gout	1	2	8	|__|__|__|__|	1	2	8	
11.33	Diabetes (high blood sugar)	1	2	8	|__|__|__|__|	1	2	8	
11.34	Thyroid disease or nodule (lump)	1	2	8	|__|__|__|__|	1	2	8	
11.35	Kidney disease	1	2	8	|__|__|__|__|	1	2	8	
11.36	Other illness List:	1	2	8	|__|__|__|__|	1	2	8	
		1	2	8	|__|__|__|__|	1	2	8	

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ________________ **Interviewer's Initials**: ________

QUESTION 12.0 : CANCER HISTORY

Interviewer Read: Now I would like to ask you about cancer. Has a doctor ever told you that you have any of the following cancers?

INTERVIEWER INSTRUCTION: If answer to Part A is No, skip to the next question

Cancer		A. Ever had it?		B. When did the doctor first tell you?
		No	Yes	Year
12.1	Leukemia	1	2	|__|__|__|__|
12.2	Thyroid cancer	1	2	|__|__|__|__|
12.3	Lung cancer	1	2	|__|__|__|__|
12.4	Skin cancer	1	2	|__|__|__|__|
12.5	Breast cancer	1	2	|__|__|__|__|
12.6	Esophageal (feeding tube) cancer	1	2	|__|__|__|__|
12.7	Stomach cancer	1	2	|__|__|__|__|
12.8	Osteosarcoma (bone cancer)	1	2	|__|__|__|__|
12.9	Colon Cancer	1	2	|__|__|__|__|
12.10	Other cancer List:	1	2	|__|__|__|__|

QUESTION 13.0: PRESCRIPTION MEDICINE

13.0 Do you take any other prescription medicine not listed elsewhere?

☐ Yes ☐ No ☐ DON'T KNOW

If yes, please list them in the table on the following page:

A. Medicine		B. Why are you taking it?
13.1		
13.2		
13.3		
13.4		

QUESTION 14.0: ABNORMAL TEST RESULTS

INTERVIEWER READ: Now, I want to ask you about abnormal test results. Has a doctor ever told you that you had any of the problems listed below?

INTERVIEWER INSTRUCTION: If the answer to Part A is No, skip to next question

Problem		A. Ever had it?	B. When did the doctor first tell you?
		No Yes	Year
14.1	Abnormal chest X ray	1 2	|__|__|__|__|
14.2	Abnormal breathing tests	1 2	|__|__|__|__|
14.3	Increased lead in your blood	1 2	|__|__|__|__|
14.4	Abnormal hearing test	1 2	|__|__|__|__|
14.5	Abnormal lymphocyte test for beryllium	1 2	|__|__|__|__|

QUESTION 15.0: HOSPITALIZATIONS

15.1 Have you ever been a patient in the hospital (except for surgery or childbirth)?

☐ YES ☐ NO ☐ Don't Know (DK)

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

15.2 How many times were you hospitalized for 2 or more nights? _______

15.3 If yes, please fill out the table below, starting with your most recent hospitalizations.

	A. Reason	B. Year
15.3.1		
15.3.2		
15.3.3		

QUESTION 16: ACCIDENTAL EXPOSURES

16.1 Have you ever had a work-related incident involving exposure to radiation or a chemical that required immediate medical attention?

☐ YES ☐ NO ☐ Don't Know (DK)

If Yes, please tell me the type of exposure, effect (inhaled, radiation wound to hand) and year. See first line as an example.

	A. Exposure	B. Effect	C. Year
	Example – plutonium	Right hand wound treated with surgery	1952
16.2			
16.3			

QUESTION 17.0: Lung symptoms

INTERVIEWER READ: The next questions are about **lung symptoms** you could have from the **workplace exposures** we are looking at in this program.

	Symptoms (DK = Don't Know)	**Response**
17.1	Do you usually have a cough?	NO .... 1 YES .... 2 DK 3
17.1.1	If yes, for how many years have you had this cough?	/___/___/ (years)
17.2.	Does your chest ever sound wheezy or whistling at times other than when you have a cold?	NO .... 1 YES .... 2 DK 3
17.2.1	If yes, for how many years has this been present?	/___/___/ (years)

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** _________________ **Interviewer's Initials:** _________

17.3	Are you troubled by shortness of breath when hurrying on a level surface or walking up a slight hill?	NO .... 1 YES .... 2 DK 3
17.4	Do you have to walk slower than people of your age because of shortness of breath?	NO .... 1 YES .... 2 DK 3
17.5	Do you ever have to stop for breath when walking at your own pace on the level?	NO .... 1 YES .... 2 DK 3

INTERVIEWER: If the participant can't answer the shortness of breath questions because he/she cannot walk for some other reason, please check here. 17.6 ☐

QUESTION 18.0: REVIEW OF SYSTEMS

INTERVIEWER READ: Now I'm going to ask you about some symptoms or problems.

INTERVIEWER INSTRUCTION:
If the answer to Part A is Yes, ask when the former worker had these symptoms:
Note: PAST = you had symptom or problem in the past, but no longer have it.
If the answer to Part A is No, skip to the next question.

	Symptom	**A) Have you ever had?** **Circle the correct answer**			**B) When did you have it?** **Put a √ in the correct box**		
		No	**Yes**	**DK**	**NOW**	**PAST**	**DK**
18.1	Trouble hearing	1	2	8			
18.2	Ringing in ears	1	2	8			
18.3	Wear a hearing aid	1	2	8			
18.4	Trouble swallowing	1	2	8			
18.6	Stomach pain	1	2	8			
18.9	Blood in your stool	1	2	8			
18.10	Black or tarry stools	1	2	8			
18.14	Problems with coordination	1	2	8			
18.15	Slurred words	1	2	8			
18.16	Numbness in arms or legs	1	2	8			
18.17	Tingling in arms or legs	1	2	8			
18.18	Weakness in arms or legs	1	2	8			
18.21	Tremors (shaking in arms or legs)	1	2	8			

18.23	Chest pain or pressure with activity	1	2	8			
18.24	Chest pain or pressure when resting	1	2	8			
18.25	Chest tightness	1	2	8			
18.26	Swelling of your feet	1	2	8			
18.29	Weight loss	1	2	8			
18.32	Changes in any spots on skin	1	2	8			
18.33	Breast lumps or discharge	1	2	8			
18.34	Bleed or bruise easily	1	2	8			
18.35	Blood in urine	1	2	8			

QUESTION 19.0 – SMOKING HISTORY

INTERVIEWER READ: *I would like to ask you some questions about smoking.*

Note: DK = Don't Know

	Cigarette Use	Response
19.1	Have you smoked at least 100 cigarettes in your entire life?	NO **(skip to Q. 20.0)** ....1 YES 2
19.2	How old were you when you started smoking cigarettes?	/___ ___/ age in yrs. DK 8
19.3	Do you smoke cigarettes now (as of one month ago)?	NO **(skip to Q. 19.5)** ....1 YES 2
19.4	On average, how many cigarettes have you smoked per day for the whole time you Smoked?	/___/___/ Cigarettes a day DK... 8
INTERVIEWER INSTRUCTION: SKIP TO QUESTION 20.0 IF SUBJECT IS A CURRENT SMOKER. IF SUBJECT IS A FORMER SMOKER COMPLETE QUESTIONS BELOW.		
19.5	On average, when you smoked, how many cigarettes did you smoke a day?	/___/___/ Cigarettes a day DK 8
19.6	What was the date when you stopped smoking cigarettes?	/______/ year DK 8

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** _________

QUESTION 20.0: ALCOHOL USE

INTERVIEWER READ:
Now I have some questions about your alcohol use, included are beer, wine and liquor such as whiskey or gin, and any other type of alcoholic beverage.

INTERVIEWER INSTRUCTION:
IF SUBJECT IS A CURRENT DRINKER – **COMPLETE QUESTIONS 20.0-20.5**
IF SUBJECT IS A FORMER DRINKER – **COMPLETE QUESTIONS 20.6 TO 20.8**

	Alcohol Use (Current Drinker)	**Response** (circle correct choice)
20.1	Have you had at least one drink of beer, wine, or liquor in your entire life?	NO **(skip to Q. 21.0)**................ 1 YES 2
20.2	How old were you when you first started drinking alcohol?	/___/___/ age in years DK 8
20.3	Do you drink beer, wine, or liquor now? (1 drink = 1 beer, 1 shot, or 5oz of wine)	NO **(skip to Q. 20.6)**.............. 1 YES .... 2 DK 8
20.4	About how often do you drink beer, wine, or liquor on average?	Everyday.............................. 2 5 – 6 days/wk .... 3 3 – 4 days/wk .... 4 1 – 2 days/wk .... 5 less than 4 days per month .... 6 DK 8
20.5	About how many drinks per week do you drink? (1 drink = I beer, 5 oz wine, 1 shot)	___/___/___/ # of drinks per week DK 8

	Alcohol Use (Former Drinker)	**Response** (circle the correct choice)
20.6	When you used to drink, about how often did you drink on average?	Everyday ....2 5 – 6 days/wk ....3 3 – 4 days/wk ....4 1 – 2 days/wk ....5 less than 4 days per month ....6 DK 8
20.7	On the days that you drank beer, wine, or liquor, about how many drinks per week did you drink? (1 drink = 1 beer, 5 oz wine, 1 shot)	/___/___/ # of drinks per week DK 8
20.8	How long ago did you stop drinking alcohol?	/___/___/___/___/___/ year DK.......................................8

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

LOCATING OTHER FORMER WORKERS

INTERVIEWER READ:

We need your help to identify other former LANL workers who may have worked at jobs similar to yours. Please provide their name, address, phone number, and the building where they worked, if you know.

Name	address	phone	building
Name	address	phone	building
Name	address	phone	building
Name	address	phone	building
Name	address	phone	building

INTERVIEWER INSTRUCTION: Separate sheets are provided if the former worker to complete this question at home, if necessary.

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ________________ **Interviewer's Initials**: _________

QUESTION 21 : CONTACTS

INTERVIEWER READ: I would like to get the names of **2 people** who you think would always know where you are living or would know how to get in touch with you.

21.0 Person #1

21.1 NAME: ______________________________

21.2 What is (name's) relationship to you?

Spouse	1
Sibling	2
Cousin	3
Uncle/Aunt	4
Friend	5
Daughter/Son	6
Parent	7
Other	8

21.3 What is their address?

____
street

____
city state zip code

21.4 What is their phone number?

____
area code

21.5 How long has (name) been living there? /___/___/ Yrs.

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number**: ______________ **Interviewer's Initials**: ________

22.0 Person #2

22.1 NAME: ______________________________

22.2 What is (name's) relationship to you?

Spouse	1
Sibling	2
Cousin	3
Uncle/Aunt	4
Friend	5
Daughter/Son	6
Parent	7
Other	8

22.3 What is their address?

____
street

____
city state zip code

22.4 What is their phone number?

____
area code

22.5 How long has (name) been living there?/___/___/ Yrs.

Is there anything else that you would like to share with us about your work, what you worked with, or any health concerns that you may have?

____

____

____

____

Johns Hopkins University School of Hygiene and Public Health EQ2

Date: ______ **ID Number:** ________________ **Interviewer's Initials:** ________

Date:	ID Number:	Reviewer's initials:		
Agent/Exposure	Algorithm: Page	Algorithm: Question #	√ If Yes	Priority (If yes)
Asbestos	6, 8, 10, 12, 14 or added jobs	Does 2a) = C or D?		3
Score: _______	21	7.2 Asbestos monitoring program = YES?		
Notes:	26	11.3 = YES?		
	6, 8, 10, 12, 14 or added jobs	Does 2a) = A, B, or X and 1a) = B or C?		2
	6, 8, 10, 12, 14 or added jobs	Does 2a) = A, B, or X and 1a) = D, E, or X?		1
	30, 31	17.1 = yes AND either 17.3, 17.4 or 17.5 = YES AND 19.1 = NO		M
	29	14.1 or 14.2 = YES?		
	20	Sum of the responses for the asbestos tasks (#7.1.1 – 7.1.10, "Ever performed") where YES = 1, No = 0, DK = 0.		SUM ______
Beryllium	6, 8, 10, 12, 14 or added jobs	Does 2b) = C or D?		3
Score: _______	16	4.3 Be Monitoring Program = YES?		
Notes:	16	4.2.1 – 4.2.14 Buildings = YES?		
	26	Does 11.2 or 11.8 = YES?		
	29	Does 14.5 = YES?		
	30	Does 16.1 or 16.2 or 16.3 = YES for BE?		
	6, 8, 10, 12, 14 or added jobs	Does 2b) = A, B, or X and 1b) = B or C?		2
	6, 8, 10, 12, 14 or added jobs	Does 2b) = A, B, or X and 1b) = D, E, or X?		1
	29	14.1 or 14.2 = YES?		M
	30, 31	17.1 = yes AND either 17.3, 17.4 or 17.5 = YES AND 19.1 = NO		
	15	Sum of the responses for the beryllium tasks (#4.1.1 – 4.1.21, "Ever performed") where YES = 1, No = 0, DK = 0.		SUM ______
Lead	6, 8, 10, 12, 14 or added jobs	Does 2c) = C or D?		3
Score: _______	18	Does 5.3 OR 5.4 = YES?		
Notes:	29	Does 14.3 = YES?		
	6, 8, 10, 12, 14 or added jobs	Does 2c) = A, B, or X and 1c) = B or C?		2
	6, 8, 10, 12, 14 or added jobs	Does 2c) = A, B, or X and 1c) = D, E, or X?		1
	18	5.2.1 – 5.2.3 Buildings = YES?		1
	27	Does 11.35 = YES?		M
	17	Sum of the responses for the lead tasks (#5.1.1 – 5.1.17, "Ever performed") where YES = 1, No = 0, DK = 0.		SUM ______
Noise	6, 8, 10, 12, 14 or added jobs	Does 2d) = C or D?		3
Score: _______	19	6.2 Noise Monitoring Program = YES?		
Notes:	6, 8, 10, 12, 14 or added jobs	Does 2d) = A, B, or X and 1d) = B or C?		2
	6, 8, 10, 12, 14 or added jobs	Does 2d) = A, B, or X and 1d) = D, E, or X?		1
	19	Sum of the responses for the noise tasks (#6.1.1 – 6.1.10, "Ever performed") where YES = 1, No = 0, DK = 0.		SUM ______
Radiation	6, 8, 10, 12, 14 or added jobs	Does 2e) = C or D?		3
Score: _______	21	8.2= YES?		
Notes:	21, 22, 23	8.3, 8.4, 8.6, 8.7, or 8.8 = YES?		
	30	16.1 or 16.2 or 16.3 = YES for radiation		
	6, 8, 10, 12, 14 or added jobs	Does 2e) = A, B, or X and 1e) = B or C?		2
	6, 8, 10, 12, 14 or added jobs	Does 2e) = A, B, or X and 1e) = D, E, or X?		1
	22	8.5= YES?		
	27	11.34 = YES?		M
	28	Does 12.1, 12.2, 12.6, 12.7 or 12.8 = YES?		

OVER - See page 2

Date:	ID Number:	Interviewer's initials:		
Agent/Exposure	**Algorithm**		**√ If Yes**	**Priority (If yes)**
	Page	**Question #**		
Solvents **Score:** ______ **Notes:**	6, 8, 10, 12, 14 or added jobs	Does 2 f, g, h) = C or D?		3
	24	Does 9.2.1a or 9.2.2 or 9.2.3 = B or C		
	6, 8, 10, 12, 14 or added jobs	Does 2 f, g, h) = A, B, or X and 1f, g, h) = B or C?		2
	6, 8, 10, 12, 14 or added jobs	Does 2 f, g, h) = A, B, or X and 1f, g, h) = D, E, or X?		1
	24	9.3 = YES?		M
	27	11.22, 11.25, 11.35 = YES?		
	28	12.1 = YES?		
	31	18.16, 18.17, 18.18, 18.21 = YES		
	24	Sum of the responses for the solvent tasks (#9.1.1 – 9.1.6, "Ever performed") where YES = 1, No = 0, DK = 0.		SUM ______

Johns Hopkins University Former LANL Workers Program
Espanola Exam

Frequently asked questions and answers on what you need to do to prepare for your examination.

Do I need to come in fasting for any blood work that may be done during my examination? You **do not** need to fast for your examination. You may eat breakfast or lunch before you come in.

Should I come in early to fill out any paper work? We have found it beneficial to have you come in at least 15 minutes early to fill out any needed paperwork ahead of your actual exam. This also allows you more time with the physician.

Do I need to bring a list of all the medications I am currently taking? If you have already answered these questions during the medical history of your Exposure Questionnaire you don't need to bring any additional information. If you feel that the information you gave the interviewer was incomplete please bring a list of medications with you when you come in for your exam.

We have also found it helpful if you bring in an address and phone number for your Primary Care Provider. If you have any abnormalities that need attention we would like to call or fax this information to your Doctor with your written consent.

Will the complete exam be done on the same day? On the day of your examination you will be told what testing will be done before you see the Doctor. You should plan on spending at least 2 hours with us. If you need a chest x-ray or hearing test we will be sending you to the Espanola hospital to have these done. The wait in x-ray is dependent on how busy they are. The hearing test is scheduled ahead of time and you are usually able to get in and out quickly.

If I am unable to come in for my scheduled appointment how much notice do I need to give you? If you are able to let us know at least one week in advance we are able to schedule someone else. We know that emergencies do come up and you may not be able to let us know till the day of your appointment. We sincerely appreciate any advance notice that you can give us as we can usually get someone else in if we have enough notice. **WE DO MAKE EVERY EFFORT TO CALL YOU THE DAY BEFORE YOUR EXAM TO REMIND YOU OF YOUR APPOINTMENT.**

Your scheduled appointment is ______________________________

If you have any additional questions please don't hesitate to call our office at 753-0193 or toll free 1-877-500-8615

Physician Evaluation Form

ID number___________ Today's date (mo/da/yr)____/____/____

Summary of medical history (review of Exposure and Medical History Questionnaire [EQ2])

Physician instruction: review pages ______ to ______ in EQ2 and note important issues here.

Current medications ____

Current symptoms ____

____

Significant current medical diagnoses ____

____

Physical examination (an X indicates the examination must be performed for the exposure)

Examination	Asb	Be	Pb	Noise	Rad	NL	NOT Normal (describe)
BP ___/___	X	X	X	X	X		
Skin					X		
Ears				X			
Thyroid					X		
Lymph nodes					X		
Lungs	X	X	X	X	X		
Heart	X	X	X	X	X		
Abdomen	X				X		
Rectal for heme	X				X		
Prostate					X		
Extremities	X	X					
Neurologic			X				
Mental status			X				
Cranial nerves			X				
Motor			X				
Sensory			X				
Reflexes			X				

☐ CHECK HERE IF MEDICAL ISSUE NEEDS IMMEDIATE ATTENTION.
Describe:____

____

Physician name______________________________ Date__________________

Physician signature______________________________

JHU Former LANL Worker Program 11/7/02

Name: ______________________________

Summary of Findings from the Medical Exam and Testing

Agent(s) that you were evaluated for:				
□ Asbestos	□ Beryllium	□ Lead	□ Noise	□ Radiation

Part 1 Overall Results

□ normal				
□ not normal	□ found problems that you already know about - continue regular follow-up as planned			
□ not normal	□ additional testing or new follow-up may be needed - see below			
For Office Use Only	□ OFFICE1	□ OFFICE2	□ Pb	□ NIHL
	□ FDN	□ FP Filing	Asb □ IF □ INT □ PP	

Part 2 Physical Exam

EXAM		DESCRIPTION	RECOMMENDATIONS
BLOOD PRESSURE	□ normal		
	□ not normal	______/______ (Syst) (Dias)	□ follow-up with your doctor and take these forms

EXAM		DESCRIPTION	RECOMMENDATIONS
LUNGS	□ normal		
	□ not normal	crackles in your lower lungs □ right □ left □ both	□ follow-up with your doctor and take these forms
SKIN	□ normal		
	□ not normal	□ skin lesions: ____________	□ follow-up with your doctor and take these forms
	□ not done		
PROSTATE	□ normal		
	□ not normal	□ enlarged	□ follow-up with your doctor and take these forms
	□ not normal	□ nodule	□ follow-up with your doctor and take these forms
	□ not done		
OTHER EXAM FINDING	□ not normal: ______________________		□ follow-up with your doctor and take these forms

Name: ______________________________

EXAM	RECOMMENDATIONS	
STOOL HEMOCCULT	□ normal	
	□ not normal	□ follow-up with your doctor and take these forms
	□ not done	

Part 3 Testing

TEST		DESCRIPTION	RECOMMENDATIONS
CHEST X-RAY	□ normal		
	□ not normal		
	□ not normal	□ scarring of the pleura (lining around lungs) □ right □ left □ both	□ follow-up with your doctor and take these forms
	□ not normal	□ scarring of the lungs □ right □ left □ both	□ follow-up with your doctor and take these forms
	□ not tested		
	If you have had a Chest X-ray report in the past that is different from our reading (for example, it showed changes from asbestos and ours doesn't) and you would like us to review it - please send us a copy of that report or contact the NM Program Office at 1-877-500-8615 or 505-753-0193.		

TEST		DESCRIPTION	RECOMMENDATIONS
AUDIOGRAM (Hearing Test) □ audio letter sent	□ normal		
	□ not normal	□ hearing loss present (average at 0.5, 1,2 and 3,000 Hz > 25 dB)	□ If you have problems hearing - you should talk to your doctor to see if a hearing aid will help (if you haven't already).
	□ not normal	□ hearing in human speech range is OK (loss > 3,000 Hz)	□ use hearing protection when exposed to noise.
	□ not normal	□ asymmetric (worse in one ear) hearing loss, no history of rifle use.	□ follow-up with your doctor - take these forms to your doctor
	□ not tested		

Name: ______________________________

TEST		DESCRIPTION	RECOMMENDATIONS
SPIROMETRY (Breathing Test)	□ normal		
	□ not normal	□ restriction (not able to breathe **in** as big a breath as normal)	□ follow-up with your doctor and take these forms
	□ not normal	□ obstruction (not able to breathe **out** as fast as normal)	□ follow-up with your doctor and take these forms
	□ not tested		

TEST		RECOMMENDATIONS
TSH (Thyroid test)	□ normal	
	□ increased	□ follow-up with your doctor and take these forms
	□ decreased	□ follow-up with your doctor and take these forms
	□ not done	

TEST		RECOMMENDATIONS	
LPT (Lymphocyte Proliferation Test for beryllium sensitivity)	□ normal		
	□ not normal	□ test was abnormal	□ You should file a claim with the Department of Labor (DOL) (see enclosed information).
	□ not normal	□ borderline elevated (1 of the results was increased)	□ you need a repeat test. Please call 1-877-500-8615 and we will discuss a repeat test.
	□ uninterpretable	□ must be repeated due to difficulties with the test	□ you need a repeat test. Please call 1-877-500-8615 and we will discuss a repeat test.
	□ not tested		
BUN (kidney test)	□ normal		
	□ elevated (slightly)		□ just give your doctor a copy at your next scheduled visit.
	□ elevated		□ follow-up with your doctor and take these forms
	□ not done		
CREATININE (kidney test)	□ normal		
	□ elevated (slightly)		□ just give your doctor a copy at your next scheduled visit
	□ elevated		□ follow-up with your doctor and take these forms
	□ not done		

Name: ______________________________

TEST		RECOMMENDATIONS
CBC (Blood count)	□ normal	
	□ some results are listed as abnormal but these are of no concern	□ just give your doctor a copy at your next scheduled visit
	□ anemia (low red blood cells - cells that carry oxygen)	□ follow-up with your doctor and take these forms
	□ decreased platelets (responsible for blood clotting)	□ follow-up with your doctor and take these forms
	□ other : ________________ ______________________	□ just give your doctor a copy at your next scheduled visit □ follow-up with your doctor and take these forms
	□ not done	

Additional comments

□ We think that you need an additional evaluation to address your specific concern.

Your concern is a complex one that is beyond the scope of this program. If you would like your concern addressed, call Dr. Karen Mulloy at the University of New Mexico in Albuquerque to arrange an appointment an evaluation (505-272-2900). The project cannot pay for this visit. You will need a referral from your primary care provider to have this evaluation. Please let us know if you have difficulty with this process.

□ You should consider filing a workers' compensation claim with the Sate of New Mexico for :

(see enclosed information)

□ You should consider filing a claim with the Department of Labor and the Energy Employees Occupational Illness Compensation Act for: ______________________________

(see enclosed information

□ Virginia M. Weaver, MD, MPH
□ Brian M. Schwartz, MD, MS

Appendix B

Background: The Department of Energy (DOE) Former Los Alamos National Laboratory (LANL) Workers Medical Examination Program

Needs Assessment

In the Defense Re-Authorization Act of 1993, Congress mandated that the Secretary of Energy and the Department of Energy (DOE) develop medical evaluation programs for former workers at risk for health problems from hazardous exposures they experienced while working at DOE sites. The Former Workers Medical Surveillance Program was developed in response to that mandate. The goal was development of medical evaluation programs for former workers at significant risk for health problems from hazardous exposures they experienced while working at DOE sites. In December 1997, a cooperative agreement was awarded by DOE to the Johns Hopkins School of Hygiene and Public Health, now called (and referred to hereafter as) the Johns Hopkins Bloomberg School of Public Health (JHBSPH), to perform a Medical Surveillance Program Needs Assessment for former workers at Los Alamos National Laboratory. The program was developed as a broad collaborative project that included occupational health specialists from: the Health and Safety Fund of the Laborers' International Union of North America (LIUNA); the LANL Environment, Safety and Health Division; and the National Jewish Medical and Research Center (NJMRC).

The overall objectives of the Phase I Needs Assessment were:

- To determine if a medical screening program was needed for former workers employed at the LANL site;
- If needed, to begin preparations for such a program, and
- To assist the DOE in meeting its legislative mandate.

Phase I focused on the identification of former employees at the LANL site who may have been at significant risk for occupational disease.

If needed, the overall goals of Phase II were to:

- Notify the former workers at the LANL site who were at risk for occupational disease;
- Offer them medical screening that could lead to medical intervention; and
- Integrate this program with existing LANL health and safety programs for current workers so that when these current workers retire they will have a system to automatically enroll them in the appropriate surveillance program.

LANL was selected as the focus site for this project for several reasons, including:

- The LANL site is a large research facility that has a long history of industrial hygiene monitoring and medical surveillance for workers;
- The site has been active since 1943;
- The LANL site will remain in operation as the DOE downsizes the nuclear weapons complex;
- The workforce represents several different cultures, including Mexican Americans, Spanish Americans and Native Americans;
- We located more than 35,000 former workers who worked at the LANL site for varying amounts of time since 1943 and who were potential participants in the medical examination program;
- There are extensive exposure data showing the types and levels of hazards that existed over the 60 years that LANL has been in operation; and
- Past work activities have caused health concerns among different former worker groups.

The initial focus of the project was on two groups – beryllium-exposed former workers and machinists. Beryllium-exposed workers were chosen for the following reasons:

- Other DOE sites have a significant number of current and former beryllium workers with beryllium sensitivity and Chronic Beryllium Disease (CBD);
- The lymphocyte proliferation test is a screening test used to detect possible beryllium sensitivity and early disease; and
- There is a specific treatment available if CBD is detected.

Machinists were chosen for the following reasons:

- They had a wide range of past exposures to metals, radiation, solvents and other chemicals; and
- There were also reports of possible adverse health effects due to past exposures to these agents.

The program investigators met with former workers, industrial hygienists and occupational medicine physicians during the course of the Needs Assessment. After these meetings, the program investigators made the decision to broaden the focus of the Needs Assessment and to offer medical examinations to other former workers with a range of exposures to many hazards.

The DOE directed the Former Workers Medical Surveillance Programs to document that there was a need for a medical evaluation program. The four specific issues that the Needs Assessment was to address for the final report included:

- Documentation of the nature of the specific hazards, to include:
    a) Chemical, physical, or radiological properties of the hazards;
    b) The duration and degree of potential exposure to these hazards; and
    c) The extent of the documentation of the presence and use of these hazards at the LANL site;
- Documentation of the nature and extent of the health impacts that may be found by answering these questions:
    a) How well are the health impacts understood; and
    b) Are these health impacts appropriately characterized?
- Documentation of the size of the target former workers' population; and
- Documentation of the concerns and recommendations of former workers concerning these hazards.

The final determination of need included judgments about:

- The extent of the exposure to an agent;
- The potential health impact of that exposure;
- The number of people exposed;
- The assessment of former worker concerns;
- The availability of medical screening tests to detect the health effects associated with the targeted hazards or conditions; and
- The availability of medical interventions that can decrease morbidity or mortality.

The final determination of need used an algorithm that integrated information on each hazard, including the assessment of exposure, the health impacts of the hazards, the size of populations exposed to the hazards, and the concerns and recommendations of former LANL workers about each hazard. The severity of a health outcome was documented through the occupational health literature. The five factors were scored from 1 to 3 and added. The summary score was multiplied by a binary (1 or 0) intervention suitability factor (I.S.F.) that was 1 if both of the following were available:

- A screening test with acceptable sensitivity and specificity for the health outcome of concern; and
- An intervention that decreases morbidity or mortality.

This process resulted in an Intervention Needs Factor (I.N.F.) score. If the score was 11, these hazards were selected for the first year of the medical screening program called Phase II.

The program team reviewed extensive data sources as part of the Needs Assessment. Several of these data sources were the Industrial Hygiene databases, including the sampling and radiation databases, and exposure monitoring information. A job exposure matrix (JEM) was developed to document exposure to these hazards by job title. The final determination of the Needs Assessment concluded the need for a medical screening program for former LANL workers with past exposure to: asbestos, beryllium, lead, noise, ionizing radiation and chlorinated solvents.

The Department of Energy reviewed the Needs Assessment and approved a Phase II Medical Screening Program for Former workers at Los Alamos National Laboratory. Phase II was funded in 1999 and examinations started in April 2000. The Phase II program is discussed in the next section.

Phase II Medical Examination Program

Phase II of the program involved the development and implementation of a medical screening program for former workers from LANL. This phase of the program began in 1999. The name of the program was changed to the "Former Workers from LANL Medical Exam Program" in our recruitment materials, since former workers had a one-time examination and testing and not the repeat examinations and testing found in a routine medical screening program. The initial recruitment efforts were focused on former workers whose job title suggested a high probability of exposure to one or more of the following agents: asbestos, beryllium, lead, noise and radiation. If a former worker had a job title that provided no information about their possible work-related exposures (e.g. staff member or group leader), an initial questionnaire was sent with the recruitment letter in order to determine if the job involved exposures to the above agents. The exposure questionnaire and the recruitment letters are included in Appendix A.

Rosters of LANL former workers who were potential participants in this program were developed during the Phase I Needs Assessment. The two main rosters included former workers from the University of California (UC), the contractor that managed LANL for the DOE, and former workers from the main subcontractors that provided building and trade services to LANL. There were other subcontractors who worked at the laboratory, but unavailability of records for this group of former workers precluded their participation in the recruitment process. Additionally, many of these former workers joined the program once they heard about it from other former workers. By the beginning of Phase II of this program, the rosters contained more than 37 thousand (37,000) former workers from both employers. Vital status was determined on all the individuals in the rosters up to 1997, and those who were deceased were removed from the rosters. This left a former worker population of approximately 27 thousand (27,000) former workers.

Development of Recruitment Materials

A) Risk Communication Panel (RCP)
Risk communication was a major part of the design of Phase I and II. During Phase I, a group of former workers were recruited as members of a Risk Communication Panel (RCP). The former worker members of the RCP worked for employers at LANL, UC and the building and trades unions. The main duties of the RCP were to review program materials and to offer advice to the risk communication team. The RCP was able to provide information about the culture of LANL and the beliefs and attitudes of the local population. The RCP remained part of the program team for the first three years of Phase II.

The first six months of the medical exam program involved developing recruitment and program materials. The materials described below were developed by the program team. Once the materials were drafted, the RCP reviewed the initial drafts of these materials. Changes were made to the materials based on input from the RCP. In the next step, former workers from UC and the building and trades unions were invited to participate in focus groups. During these focus groups, former workers reviewed final drafts of the recruitment and program materials and offered suggestions for changes to these documents. The recruitment materials that were developed are described below.

B) Consent Forms
Four (4) different consent forms were developed for this program. The Focus Group Consent Form was used for focus group participants. Focus groups were used in the Phase I Needs Assessment and during the first two years of Phase II. The consent form explained the purpose of the focus group and informed the former worker that the session would be tape recorded. The focus groups were conducted to assess workers' concerns and to obtain their input on the materials that were designed for use in the program. Two copies of the consent form were used with the focus groups; One copy was for the program records and the other copy was given to the former workers for their records.

A Survey Consent Form was developed that explained the program, the risks and benefits of participation, and confidentiality issues. The Survey Consent Form had two purposes: (1) to obtain the former worker's consent for Exposure Questionnaire #1, and (2) to obtain the former worker's consent for Exposure Questionnaire #2. The survey consent form also emphasized the voluntary nature of participation in the program and the choice to leave the program at any time. Two survey consent forms were sent with recruitment letters. The former worker was asked to sign one and return it in the self-addressed stamped envelope that was in the recruitment packet. As explained above, the second copy was for the former workers records.

The Medical Screening Consent Form was developed to inform the program participants of the purpose of the program, the tests that were to be completed during the examination, a description of all the tests along with any adverse reactions to the tests, the risks and benefits of participation in the program, and how the participant's confidentiality would be protected. The medical screening consent form was usually signed at the time of the examination.

The Beryllium Lymphocyte Proliferation Test (BeLPT) Consent Form was used for individuals who were potentially exposed to beryllium during their employment at LANL. This consent was developed even though the medical screening consent form did explain the BeLPT test. A separate consent form was developed for the BeLPT blood test for the following reasons: (1) if an abnormal test required further blood testing and possibly an evaluation for chronic beryllium disease; (2) if the BeLPT was a test that was not routinely done at health care providers offices; or (3) in the event that there was an abnormal test result, the former worker was usually advised to not work with beryllium again. (Of note, many of the former workers who participated in this program were retired and did not have to worry about working with beryllium in the future.) There were some younger former workers who did not currently work at LANL but still worked in their specific trade. These workers could be rehired at LANL in the future and therefore had the potential for further beryllium exposure. The BeLPT consent form explained why the test was done, what a false positive and a false negative result meant, what an abnormal test meant to the individual, the risks and benefits of having the test, and how the participant's confidentiality would be protected. After the examination session, the samples were sent overnight to one of four DOE-approved laboratories for processing.

At the examination session, each participant was encouraged to read and ask questions about the consent forms. Copies of all the consent forms were given to each participant at the end of the examination session. Two copies of the Medical Screening Consent Form and the Beryllium Lymphocyte Proliferation Test Consent Form were sent to former workers who requested a medical record review in place of the examination. The medical record review (MRR) was offered to former workers who lived outside of New Mexico or who were unable to travel to Española, N.M., Los Alamos, N.M, or Baltimore, Md. for an examination.

C) Recruitment Letters

Two reruitment letters were developed for this program. The first letter was sent to former workers whose job title had a high probability of exposure to asbestos, beryllium, lead, noise, or radiation. The exposure status was based on the Job Exposure Matrix (JEM) developed during the Phase I Needs Assessment. It is discussed briefly below. A copy of the JEM is included in Appendix A. Examples of job titles of interest were plumbers/pipefitters, laborers and janitors. Included in this recruitment packet was a three-page letter explaining the program and inviting the former worker to join the program, a program pamphlet (see Appendix A), two Survey Consent Forms, a Choice Form (see Appendix A), a map to the New Mexico Program Office in Española, N.M., and a self-addressed stamped envelope in which the former worker was asked to return the choice form and a signed survey consent form.

The second letter was sent to former workers whose job title did not provide any information about their probable exposures at LANL. Examples of these job titles were staff member or group leader. A staff member could have worked in an administrative office and never had a need to enter areas where exposures could occur, or a staff member could have worked in areas that had a high probability for exposures to the agents of interest in this program. Included in this recruitment packet was a three-page letter explaining the program and inviting the former worker to complete a short exposure questionnaire, called Exposure Questionnaire #1 (EQ1) (see Appendix A) Survey Consent Forms, a program pamphlet, and a self-addressed stamped envelope in which the former worker was asked to return the questionnaire and a signed survey consent form.

D) Program Pamphlet

The program pamphlet was developed by the program team and the RCP. The RCP was asked to review and edit the pamphlet. The pamphlet discussed the program using a series of questions and answers (see Appendix A). An example of one of the questions in the pamphlet was "Who funds the LANL Former Worker Program?" A concise answer was given to the question. The former worker was given the addresses and telephone numbers of the program offices in Baltimore, Maryland, and Española, New Mexico. The New Mexico Program Office also had a toll-free number.

E) Choice Form

This form was developed to give the former worker the choice of how they wanted to participate in the program. The choices were: an examination, a medical record review, or the choice not to participate in the program. If a former worker chose an examination, they were asked to choose where they wanted the examination done: at the Los Alamos National Laboratory Occupational Medicine Clinic, by health care professionals from the Clinic; or at the Española Program Office, by physicians from the Johns Hopkins Bloomberg School of Public Health and the University of New Mexico. In 2001, a third choice was added to the choice form: an examination in Baltimore by physicians from the Johns Hopkins Bloomberg School of Public Health. Former workers who resided on the east coast chose this option (see Appendix A).

F) Exposure and Medical History Questionnaire #1 (EQ1)

Exposure Questionnaire #1 (EQ1) was designed to be short and to ask questions that the program team used to determine exposure history and eligibility for participation in the program. The questionnaire was five pages long and included a section for the former worker to express exposure or health concerns that were not included in the questionnaire. This questionnaire was sent to potential participants who had a job title that provided no information about their possible work-related exposures. The questions included in the questionnaire were focused on work tasks that had a high probability of exposure to asbestos, beryllium, lead, noise, or radiation. Once the questionnaire was returned to Baltimore, an algorithm was used to identify former workers who had exposures and who should be invited to participate in the program. A copy of EQ1 and the algorithm can be found in Appendix A.

Development of Materials for Examinations

A) Exposure and Medical History Questionnaire #2 (EQ2)
Exposure Questionnaire #2 (EQ2) was computerized and designed for use after a former worker agreed to participate in the program. The 37-page questionnaire was completed via the telephone or in person. A LANL former worker who was employed by the Former Workers Program conducted the interview with the program participant. It was felt that using a former worker to conduct the interview would accomplish several things: (1) the interviewee may have felt more relaxed having another former worker as the interviewer; (2) the interviewer had knowledge of the physical environment around LANL and recognized and knew where a "Technical Area" (called a TA by the former workers) was located and what work was done there; and (3) one of the former worker interviewers spoke the local dialect of Spanish and was able to translate the questionnaires and the consent forms to former workers with limited command of English. The questionnaire collected demographic information, exposure and medical history, and information on smoking. At the end of the interview, the former worker was asked if they had any concerns that were not covered in the interview. These concerns were documented on the questionnaire. Once the questionnaire was completed, another algorithm was used to determine the examinations and testing required at the examination session. This algorithm was also used to determine which medical records were requested from a health care provider for the former worker's medical record review. A copy of the questionnaire (EQ2) and the algorithm can be found in Appendix B.

B) Examination and Medical Record Review (MRR) Materials
Materials were designed specifically for these two parts of the program and included history and physical forms, laboratory requests, progress notes, a non-occupational incident form, a form for spirometry, a hearing testing form, and a checklist for the cover of charts. Several letters were developed for the medical record review. These materials included a letter to the former worker explaining the MRR process, a letter to the former worker's health care provider that explained the program, and a table that specified which reports were needed for the MRR. Medical record release forms were also developed for use with the examination and MRR. One medical record release form gave the program permission to obtain old tests or chest x-rays that were needed to complete the evaluation. The second medical record release form gave the program permission to send records to the former worker's health care provider or to

another physician who was needed to complete the evaluation. Former workers could refuse to sign either or both of the medical record release forms.

C) Materials for Communication of Results from the Examination or Medical Record Review (MRR)

Letters were developed to inform the program participants of the results of the examination and medical record review. A normal examination and testing letter was developed, as well as an abnormal examination and testing letter. The normal letter was used if the examination and testing were normal or if they found conditions that the former worker was already aware of, such as hypertension. The letter outlined the tests completed and encouraged the former worker to continue regular follow-up with their health care provider. A letter was developed for the former worker's health care provider that explained the LANL Former Workers Program and informed the health care provider that the examination and testing was within normal limits. The abnormal letter specified the abnormality or abnormalities that were found, and a letter to the former worker's health care provider was developed that offered recommendations for the former worker's health care provider if the abnormality was potentially work-related.

A reference titled "Information for Clinicians" was developed and sent to each health care provider in the former worker's results packet. This document discussed the occupationally related diseases or conditions that can develop due to exposure to the agents of interest in this program. The reference included a list of signs and symptoms and recommendations for intervention.

Letters were developed to inform former workers of the results of a repeat BeLPT test along with recommendations for follow-up. Letters were developed to inform former workers who may have been eligible for workers' compensation due to possible work-related diseases. These letters explained the process that was in place for filing a workers' compensation claim in the state of New Mexico.

D) Other Phase II Activities

Other activities that were completed during the first six months included the location of office space for the New Mexico (NM) Program Office, and hiring a NM Program Coordinator, who spent several months finding equipment and furniture for the NM Program Office. The NM Program Coordinator also hired office personnel and LANL former workers who conducted the EQ2 interviews. The NM Program office was used for the EQ2 interviews that were done daily and for the examination sessions that were done four to five times per year by physicians from Johns Hopkins Bloomberg School of Public Health and the University of New Mexico. The medical exam program began in April 2000. Thirty former workers were recruited for the first examination session.

D) Risk Communication Handbook

A 215-page book was developed titled "Handbook for Medical Exam Program for Former Workers from Los Alamos National Laboratory." This handbook included sections that explained or contained information on the following:

- The purpose of the program;
- The program team;
- The Risk Communication Panel;
- The Steering Committee that included local stakeholders and community members;
- The Scientific Advisory Board that included specialists from the fields of occupational medicine, industrial hygiene, and labor;
- The program agents of interest, signs and symptoms of adverse health effects of these agents, and treatment options;
- Frequently asked questions;
- Compensation programs;
- Web sites for further information; and
- A glossary of terms used in the Handbook.

The purpose of this handbook was to explain the program and its purposes to a former worker. Another objective was to provide future reference materials to the former worker once the program was completed. A draft of this handbook was reviewed by former workers in focus groups, by the Risk Communication Panel, by the Steering Committee, and by the program team. Suggestions made by these reviewers were incorporated into the handbook. This handbook was given to former workers at the time of the examination or it was mailed to former workers who completed the program with an examination or a medical record review.

Selection of Job Titles for Inclusion in the LANL Former Workers Program

During the Phase I Needs Assessment, a Job Exposure Matrix (JEM) was developed. The JEM was used to classify a former worker by their job code into categories of exposure to radiation, chemicals, and physical agents. Job titles from the rosters of former workers developed during the Needs Assessment were assigned to a common code based on an accepted classification scheme to all job titles. There were a number of such schemes available; However, this investigation chose to use the Common Occupation Classification System (COCS) (Stahlman EJ, RE Lewis 1996). COCS codes were selected for use in this study because they represent a common occupational taxonomy developed for the DOE and used by other former worker programs.

Two possible categories were assigned to each job code. A "1" was assigned if there was a probability that a former worker was exposed to the above mentioned agents while they performed their usual job tasks, and a "0" was assigned to job codes if there was no probability that a former worker was exposed to the above mentioned agents while they performed their usual job tasks.

Eligibility for Inclusion in the LANL Former Workers Program

As of December 31, 2002, the population of the LANL Former Workers Program was 2,315 former workers. This number reflected all the former workers who agreed to participate in the program after they were recruited by letter or at a local health fair, or were identified by other program participants.

Eligibility requirements for the LANL Former Workers Program included:

- The potential participant worked at LANL any time from 1943 until the present and worked for the University of California or any of the subcontractors at LANL;
- The potential participant worked with or around asbestos, beryllium, lead, noise, or radiation;
- The potential participant retired from work at LANL for the University of California (UC) (some retirees worked short periods at LANL as consultants);
- The potential participant retired from work for one of the subcontractors or no longer worked at the LANL site; or
- A potential participant requested to be part of the program even though they may have had little or no exposures. Due to the nature of this program – that is, primarily a service oriented program – the program team decided to allow former workers to self-select to the program.

The Medical Examination

For former workers who chose a medical exam, the exam and testing addressed the possible health issues identified by Exposure Questionnaire #2 (EQ2), which was completed during the confidential interview. Not all participants received all of the tests.

The type of exam varied by the type of exposures that the former worker had at work. Each former worker received some medical tests. These tests also depended on the exposures the worker had at LANL. The tests that were done for each exposure were listed in Table 1, the Intake Form (on the next page). On this form, which was used at the time of the medical exams, the specific exam and tests that each former worker received were indicated. The form was explained to the former worker at the time of the exam, and a copy of the form was given to the former worker for his or her records.

Table 1 – Intake form

Agent	Type of Physical Exam	Testing
☐ **Asbestos**	blood pressure	exam only
	Heart	exam only
	Lungs	1) chest x-ray 2) spirometry - breathing test
	Abdomen	exam only
	Extremities	exam only
	rectal exam	rectal exam to test for blood
☐ **Beryllium**	blood pressure	exam only
	heart	exam only
	lungs	1) blood test – beryllium lymphocyte proliferation test (BeLPT) 2) chest x-ray
	extremities	exam only
☐ **Lead**	blood pressure	exam only
	heart/lungs	exam only
	nervous system	exam only
	blood test only	blood test to check for kidney function (BUN, creatinine)
☐ **Noise**	blood pressure	exam only
	ears	audiogram - hearing test
	heart/lungs	exam only
☐ **Radiation**	blood pressure	exam only
	heart	exam only
	lungs	chest x-ray - if you had plutonium exposure
	abdomen	exam only
	skin	CBC - complete blood count - to check the numbers of blood cells
	thyroid	TSH - test for thyroid gland function
	rectal exam	to check the size of the prostate gland
		stool specimen to test for blood
☐ **Health Counseling**		mammogram recommended for women over 40 years of age
		prostate specific antigen (PSA) recommended for men over 50 years of age

- *Column 1* – a list of the five agents that were screened for in this program. A check mark is placed next to the agents that were the focus of the exams and testing.
- *Column 2* – indicates the type of physical exam that was done for each agent.
- *Column 3* - indicates the type of tests that was done for each agent.

Description of Exams and Tests:

Chest X-ray – The chest x-ray, which was the same as any other medical chest x-ray, included only one view. It was done to look for lung changes that may be caused by exposure to asbestos, beryllium, or radiation. There was a small amount of radiation exposure from this x-ray.

Physical exam – Each former worker's exam focused on the parts of the body that may have been affected by the types of exposures that were discussed in the exposure and medical history interview (EQ2). All workers had their blood pressure checked, and a physician or health care provider listened to their heart and lungs.

Breathing Test – This was a test to check for effects from exposure to asbestos. Spirometry was not done if the former worker had any of the following:

a. High blood pressure;
b. Recent surgery to the head, neck, mouth, chest, or abdomen;
c. A cold, bronchitis, pneumonia, the flu, or an ear infection within the past three weeks;
d. A recent nose bleed, bruising of the eyes, or bruising anywhere on the body;
e. If a bronchodilator (medication that opens breathing passages) was used, a meal was eaten, or a cigarette was smoked within an hour of the test

If a former worker had any of these conditions, the technician needed to change the way the breathing test was done on the day of the exam, or the physician may have decided not to do the test at all.

Hearing Test – This was a test to check for effects from exposure to noise. Former workers sat in a soundproof booth. There were no physical risks from this test.

Blood Tests – Whether or not a former worker had any of these tests depended on the work exposures. Not all workers received all of these tests. There were minimal risks from having blood drawn. The tests included the following:

a. Beryllium Lymphocyte Proliferation Test (BeLPT) – This is a blood test to check for beryllium sensitization. The test told the doctors if the workers' exposure to beryllium caused them to be sensitized to beryllium. If the test was abnormal, the worker returned for another test. If the former worker had two abnormal samples, he or she needed further testing and was referred for a Chronic Beryllium Disease evaluation.

b. Complete Blood Count (CBC) – This test looked for possible blood system effects from exposure to radiation.
c. Thyroid-stimulating Hormone (TSH) – This test, which measured the amount of thyroid hormone in the blood, looked for possible effects from radiation to the thyroid gland.
d. Serum creatinine and blood urea nitrogen (BUN) – These tests looked for the possible effects of lead on the kidneys.

What is a Beryllium Lymphocyte Proliferation Test (BeLPT)?

There are blood cells in the body called lymphocytes that fight disease. At the laboratory, the lymphocytes are removed from the blood sample, then beryllium and other test agents are added to the cells. The test is "abnormal" if the lymphocytes react to the beryllium in a specific way.

Experts believe that a BeLPT is abnormal in people who have become sensitized to beryllium. It is not clear what "sensitized" really means, but studies have shown that some people with an abnormal BeLPT have or will develop chronic beryllium disease (CBD). In some people, "sensitized" might mean that the person was exposed to beryllium and the body reacted to it. It is possible that a sensitized individual is more likely than others to get CBD. This test was offered because doctors believe that the BeLPT is useful in detecting cases of CBD early, or because cases might be missed or diagnosed as another type of lung problem. If CBD was found, doctors would then decide what treatment was needed to minimize the lung damage caused by it.

If the test was abnormal, the worker would have a repeat test. If there were two abnormal tests, the worker was considered sensitized and further testing was recommended.

At least six tubes of blood were taken at the time of the repeat BeLPT test. These tubes of blood were identified with an identification number only. No former workers' names were used on the blood samples or request forms for this test. These tubes of blood were shipped overnight to one of three laboratories in the United States that performed the BeLPT test for the Former Workers Medical Exam Programs. These laboratories are:

- The National Jewish Medical and Research Center in Denver, Colorado;
- The Oak Ridge Institute for Science and Education in Oak Ridge, Tennessee; and
- Specialty Laboratories in Santa Monica, California.

The Medical Record Review

For those who chose a medical record review, a program doctor reviewed selected medical records and sent an opinion about them to the former worker. Opinions could be based on tests, x-rays, or reports that were been done in the past two years. It is possible that either a limited opinion or no opinion could be given. If the x-rays and blood tests were more than two years old, it was necessary for the former worker to come in for an exam.

In order to do the medical record review, participants were asked to sign several medical release forms and consent forms. The former worker presented the following to their health care provider:

- A letter from the program doctors;
- A form that indicated which tests, x-rays and records were needed for the review; and
- A copy of the medical release.

These records were then sent to the Johns Hopkins University Bloomberg School of Public Health, where the medical record review was done. If a BeLPT was needed, the program arranged to have a BeLPT done at a laboratory near the former worker's home and sent to one of the DOE-approved BeLPT labs.

Ten to twelve weeks after the exam or the medical record review, the former worker received a results letter that outlined the findings from the exam or review. The packet included the following (which are described in greater detail further below):

- A letter to the former worker;
- A four-page table that reviewed each part of the examination – the overall results, the exam, and the tests. This table is described below, and there is also a copy of the table following this description;
- A letter for the former worker's primary care provider; and
- A change of address card that the former worker could use to notify the program if they chose to do so.

A. Results Letter

This letter, which was from the program physicians at Johns Hopkins, told the former worker whether everything from the medical exam was normal or not normal. Former workers who had questions about the results letter called the Espanola Program Office and spoke with the New Mexico Program Coordinator. If there were further questions, the former worker met with one of the program physicians during the examination periods.

B. Results Table

The exposures that were identified in the exposure and medical history questionnaire (EQ2) were checked in this box.

How To Read The Results Table:

Agents – The very top box of the form is called "Agents." Each agent tested for had a check in the box by its name. For example, "☑ Asbestos" meant that you were tested for the health effects associated with Asbestos.

Agent(s) that you were evaluated for:				
☐ Asbestos	☐ Beryllium	☐ Lead	☐ Noise	☐ Radiation

Part 1; Overall Results – The second big box gave the overall results of the exam. The occupational medicine physician who reviewed the results from the examination or medical record review would give the findings. One of the overall ratings, as shown below, would be checked. The ratings were the following:

☐	**normal**	The examination and tests were all normal at the time the former worker was seen by the examiner.
☐	**not normal**	**Found a problem you already know about**. If this box is checked there was a problem identified during the examination or tests but this problem is one that the former worker already knows about and is currently receiving treatment or medication for.
☐	**not normal**	**Additional testing**. If this box is checked, it means there was a problem identified that needs more testing or treatment. The letter to the former worker's primary care provider will include recommendations for further testing if the problem is possibly work related.

Part 2; Physical Exam – In this section, results were given for each part of the exam. The occupational medicine physician would rate each part of the exam as one of the following:

☐	**normal**	If this box is checked, it means the examination and tests were all normal at the time the former worker was seen by the health care provider.
☐	**not normal**	If this box is checked, it means there was a problem identified during the examination and the former worker should follow up with his or her doctor.
☐	**not tested**	If this box is checked, it means this part of the examination was not done for the former worker.

The different parts of the examination were:

1. Blood pressure;
2. Lung examination;

3. Skin examination;
4. Prostate examination;
5. Stool specimen for occult blood; and
6. Other exam findings.

Part 3; Testing – The third section of the results table listed findings from the occupational medicine physician who reviewed the results from the **blood tests**, the **audiometry** (hearing test), and the **spirometry** (breathing test). The doctor indicated whether each test was the following:

☐	**normal**	If this box is checked, it means the test was normal at the time the former worker had the examination.
☐	**not normal**	If this box is checked, it means the test was not normal at the time the former worker had the examination and the former worker should follow-up with their doctor.
☐	**not tested**	If this box is checked, it means the test was not done during the examination.

The possible tests included:

1. Chest x-ray;
2. Spirometry (breathing test);
3. Audiogram (hearing test); and
4. Blood tests ...
   - Thyroid Stimulating Hormone Level;
   - Lymphocyte Proliferation;
   - BUN;
   - Creatinine; and
   - CBC.

Additional Comments Box – In this box, the program physician would address any specific concerns that the former worker had. The former worker was asked about any specific concerns during the EQ2 interview or during the physical examination.

C. Letter for Primary Care Provider (PCP)

Also in the packet was a letter for the worker's primary care provider (PCP). This letter described the Former LANL Workers Program and let the PCP know whether the examination and testing were normal or abnormal. If abnormal results were found, the letter recommended additional testing.

D. Change of Address Card

Finally, the packet included a change of address card. This card was included so that former workers could let us know if they moved.

Summary of Findings from the Medical Exam and Testing

Agent(s) that you were evaluated for:				
☐ Asbestos	☐ Beryllium	☐ Lead	☐ Noise	☐ Radiation

Part 1 **Overall Results** ☐ **EXAM** ☐ **Medical Records Review (MRR)**

☐ normal	
☐ not normal	☐ found problems that already know about – continue regular follow-up as planned
☐ not normal	☐ additional testing or new follow-up may be needed – see below

Part 2 **Physical Exam**

EXAM		DESCRIPTION	RECOMMENDATIONS
BLOOD PRESSURE	☐ normal		
	☐ not normal	______/______ (Syst) (Dias)	☐ follow-up with your doctor and take these forms
LUNGS	☐ normal		
	☐ not normal	crackles in your lower lungs ☐ right ☐ left ☐ both	☐ follow-up with your doctor and take these forms
SKIN	☐ normal		
	☐ not normal	☐ skin lesions: ____________	☐ follow-up with your doctor and take these forms
	☐ not done		
PROSTATE	☐ normal		
	☐ not normal	☐ enlarged	☐ follow-up with your doctor and take these forms
	☐ not normal	☐ nodule	☐ follow-up with your doctor and take these forms
	☐ not done		
OTHER EXAM FINDING	☐ not normal:____________ ____________ ____________		☐ follow-up with your doctor and take these forms
STOOL HEMOCCULT	☐ normal		
	☐ not normal	☐ follow-up with your doctor and take these forms	
	☐ not done		

PART 3 TESTING

TEST		DESCRIPTION	RECOMMENDATIONS
CHEST X-RAY	☐ normal		
	☐ not normal		
	☐ not normal	☐ scarring of the pleura (lining around lungs) ☐ right ☐ left ☐ both	☐ follow-up with your doctor and take these forms
	☐ not normal	☐ scarring of the lungs ☐ right ☐ left ☐ both	☐ follow-up with your doctor and take these forms
	☐ not tested		
	If you have had a Chest X-ray report in the past that is different from our reading (for example, it showed changes from asbestos and ours doesn't) and you would like us to review it - please send us a copy of that report or contact the NM Program Office at 1-877-500-8615 or 505-753-0193.		
SPIROMETRY (Breathing Test)	☐ normal		
	☐ not normal	☐ restriction (not able to breathe **in** as big a breath as normal)	☐ follow-up with your doctor and take these forms
	☐ not normal	☐ obstruction (not able to breathe **out** as fast as normal)	☐ follow-up with your doctor and take these forms
	☐ not tested		
AUDIOGRAM (Hearing Test) ☐ audio letter sent	☐ normal		
	☐ not normal	☐ hearing loss present (average at 0.5, 1,2 and 3,000 Hz > 25 dB)	☐ If you have problems hearing - you should talk to your doctor to see if a hearing aid will help (if you have not already).
	☐ not normal	☐ hearing in human speech range is OK (loss > 3,000 Hz)	☐ none.
	☐ not normal	☐ asymmetric (worse in one ear) hearing loss, no history of rifle use.	☐ follow-up with your doctor - take these forms to your doctor
	☐ not tested		
TEST		**DESCRIPTION**	**RECOMMENDATIONS**

TEST	DESCRIPTION		RECOMMENDATIONS
TSH (thyroid test)	☐ normal		
	☐ increased		☐ follow-up with your doctor and take these forms
	☐ decreased		☐ follow-up with your doctor and take these forms
	☐ not done		
BeLPT (Beryllium Lymphocyte Proliferation Test for beryllium sensitivity)	☐ normal		
	☐ not normal	☐ test was abnormal	☐ you need a repeat test. Please call our office to schedule the test – 505-753-0193 or 1-877-500-8615 (toll-free). You should file a claim with the Department of Labor (DOL) (see enclosed information).
	☐ not normal	☐ borderline elevated (1 of the results was increased)	☐ please call our office to schedule a repeat blood test - 505-753-0193 1-877-500-8615 (toll-free)
	☐ uninterpretable	☐ must be repeated due to difficulties with the test	☐ please call our office to schedule a repeat blood test - 505-753-0193 1-877-500-8615 (toll-free)
	☐ not tested		
BUN (kidney test)	☐ normal		
	☐ elevated (slightly)		☐ just give your doctor a copy at your next scheduled visit.
	☐ elevated		☐ follow-up with your doctor and take these forms
	☐ not done		
CREATININE (kidney test)	☐ normal		
	☐ elevated (slightly)		☐ just give your doctor a copy at your next scheduled visit
	☐ elevated		☐ follow-up with your doctor and take these forms
	☐ not done		

CBC (blood count)	☐ normal	
	☐ some results are listed as abnormal but these are of no concern	☐ just give your doctor a copy at your next scheduled visit
	☐ anemia (low red blood cells - cells that carry oxygen)	☐ follow-up with your doctor and take these forms
	☐ decreased platelets (responsible for blood clotting)	☐ follow-up with your doctor and take these forms
	☐ other : ______________ ______________ ______________	☐ just give your doctor a copy at your next scheduled visit ☐ follow-up with your doctor and take these forms
	☐ not Jone	

Additional Comments

- ☐ We think that you need additional evaluation to address your specific concern:

  ____
  ____
  ____

- ☐ Your concern is a complex one that is beyond the scope of this program. If you would like your concern addressed, call Dr. Karen Mulloy at the University of New Mexico in Albuquerque to arrange an appointment for an evaluation (505-272-2900). The project cannot pay for this. **You will need a referral from your primary care provider to have this evaluation. Please let us know if you have difficulty with this process.**

- ☐ We have the following comments about your specific concern(s):

  ____
  ____
  ____

- ☐ You should consider filing a workers' compensation claim with the state of New Mexico for:

  ______________________________.

  (see enclosed information)

- ☐ You should consider filing a claim with the Department of Labor and the Energy Employees Occupational Illness Compensation Act for:

  ____

  (see enclosed information).

Signature

☐

☐

Appendix C

Table Job Codes by Ethnicity LANL Former Workers

	White Males		Hispanic Males	
COCS	**Description**	**N (%)**	**Description**	**N (%)**
G000	General Administrative	1 (0.13)	General Administrative	0
C000	Crafts (Building and Trades)	252 (34)	Crafts (Building and Trades)	231 (34)
E000	Engineers	67(9)	Engineers	2 (0.3)
M000	General Managers, First Line Supervisors	15 (2)	General Managers, First Line Supervisors	2 (0.3)
L000	Laborers, General Service Workers, Security	57 (8)	Laborers, General Service Workers, Security	277 (41)
P000	Professional, Administrative	34 (5)	Professional, Administrative	9 (1)
R000	Operators	15 (2)	Operators	36 (5)
S000	Scientists	130 (17)	Scientists	26 (4)
T000	Technicians	92 (12)	Technicians	85 (13)
Y000	Staff Members	81 (11)	Staff Members	4 (0.6)
Totals		744 (100)		672 (100)

*COCS = Common Occupational Classification System

Table 10 Comparison of TSH Status Bivariate Analysis White and Hispanic Male LANL Former Workers Radiation (High/Low) and TSH as Case/Non-Case* (N = 1403)

Radiation Exposure		(%) Cases	(%) Non-Case	X^2	p-value	OR (95% C.I.)
Ever removed or decontaminated						
	Low	15.7%	84.3%	1.1	0.29	0.85 (0.62 – 1.1)
	High	13.6%	86.3%			
Total		15%	85%			
Ever removed or decontaminated or had body counts						
	Low	16.9 %	83.1%	2.8	0.09	0.77 (0.58 – 1.04)
	High	13.6%	86.4%			
Total		15%	85%			

*Case TSH level was > 4.5 mIU/L and/or reporting thyroid medication use.
**Non-case had a normal TSH level (0.4 mIU/L ≤ TSH ≤ 4.5 mIU/L) and not reporting thyroid medication use.

Curriculum Vita

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EDUCATION AND TRAINING

PhD	9/2005	Department of Environmental Health Sciences Division of Occupational and Environmental Health Johns Hopkins Bloomberg School of Public Health Baltimore, Maryland
MPH	1994	Johns Hopkins University School of Hygiene and Public Health Baltimore, Maryland
BSN	1992	Thomas Jefferson University College of Allied Health Sciences Philadelphia, Pennsylvania
Diploma in Nursing	1972	Fitzgerald-Mercy Hospital School of Nursing Darby, Pennsylvania
Nursing Licenses	1999 to Present 1999 to Present 1972 to Present	State of Maryland State of New Mexico State of Pennsylvania

PROFESSIONAL EXPERIENCE

2000 to Present	Research Associate Department of Environmental Health Sciences Division of Occupational and Environmental Health Johns Hopkins Bloomberg School of Public Health
1998 to Present	Project Coordinator Department of Energy *Former Los Alamos National Laboratory Medical Exam Program* Pilot Program funded by the Department of Energy
1983 to 1993	Office Nurse Eastern Orthopedic Institute Media, Pennsylvania

1991 to 1992	Staff Nurse Orthopedic Unit, Riddle Memorial Hospital Media, Pennsylvania
1981 to 1983	Staff Nurse Special Care Unit (ICCU) Riddle Memorial Hospital Media, Pennsylvania
1980 to 1981	Staff Nurse Intensive-Cardiac Care Units Mercy Catholic Medical Center, Fitzgerald-Mercy Division Darby, Pennsylvania
1974 to 1980	Office Nurse Orthopedic Department The Media Clinic Media, Pennsylvania
1972 to 1974	Staff Nurse Surgical Unit Mercy Catholic Medical Center, Fitzgerald-Mercy Division Darby, Pennsylvania

PROFESSIONAL ACTIVITIES

2001 to Present	Certified Occupational Hearing Conservationist
1994 to Present	American Public Health Association
1994 to 1995	American Association of Occupational Health Nurses
1992 to 1995	Orthopedic Nurse Certified
1992 to 1993	National Association of Orthopedic Nurses

HONORS AND AWARDS

1992	Sigma Theta Tau International
1992	Adaline Potter Wear Memorial Prize Outstanding Achievement
1989	The Gateway Award for Outstanding Academic Achievement Pennsylvania State University

1972	Outstanding Nurse Class of 1972 Fitzgerald-Mercy Hospital School of Nursing

PUBLICATIONS

Stefaniak AB, Weaver VM, **Cadorette M,** Guthrie-Pucket LS, Schwartz BS, Wiggs LD, Jankowski MD, Breysse PN (2003). Summary of historical beryllium use and airborne concentration levels at Los Alamos National Laboratory. *Applied Occup. Env. Hyg.*, 18(9):708-715.

Patrick N. Breysse, Virginia Weaver, **Maureen Cadorette**, Laurie Wiggs, Barbara Curbow, Aleksandr Stefaniak, Jim Melius, Lee Newman, Hugh Smith, Brian Schwartz (2002). Development of a medical examination program for former workers at a Department of Energy national laboratory. *American Journal of Industrial Medicine,* 42 (5):443-454.

Sithisarankul, P., **Cadorette, M.**, Davoli, C., Serwint, J., Chisholm, J., Strickland, P. (1999) Plasma 5-aminolevulinic acid: a potential biomarker for effect of inorganic lead in children. *Environmental Research*, 80: 41-49.

Fitzgerald, S., Dienemann, J. **Cadorette, M.** (1998). Domestic violence in the workplace. *AAOHN Journal*, 46 (7): 345-355.

TEACHING

10/22/1998	Speaker: Occupational Health Nursing Seminar, Johns Hopkins University *The Global Information System: Implications for Occupational and Environmental Health*
3/30/1997	Advanced Topics in Occupational Health Nursing, Johns Hopkins University Speaker: *Community Populations and Environmental Exposures*
3/1998	Advanced Topics in Occupational Health Nursing, Johns Hopkins University Speaker: *Environmental Justice and Environmental Legislation*
10/10/1996	Speaker: Occupational Health Nursing Seminar, Johns Hopkins University *Air Pollution, Environmental Justice, and Use of GIS for Exposure Assessment*
1/31/1995	Occupational and Environmental Health Nursing, Johns Hopkins University Speaker: *Environmental Health Nursing*

RESEARCH GRANT PARTICIPATION

1998 to Present

Development of a Medical Surveillance Program for Former Workers at Los Alamos National Laboratory
Funding Agency: Department of Energy
Principal Investigators: Brian Schwartz, MD, MS; Patrick Breysse, PhD, CIH
Funding level: 80%
Main Grant Objective: To locate former LANL workers and offer them a free medical examination and tests in order to detect occupational illness related to past work-related exposures to asbestos, beryllium, lead, noise and radiation.

2002 to 2004

National Occupational Research Agenda (NORA)
Funding Agency: National Institute for Occupational Safety and Health (NIOSH)
Principal Investigator: Jacqueline Agnew, PhD
Funding level: 20%
Main Grant Objective: To foster the development of interdisciplinary research skills that are needed to effectively address the NORA priority areas.

PRESENTATIONS

8/19/2005

Cadorette, M. Thyroid Dysfunction in a Group of Former Workers from a Nuclear Weapons Facility. Thesis Defense Seminar, Johns Hopkins Bloomberg School of Public Health, Division of Occupational and Environmental Health

2/15/2005

Cadorette, M. Thyroid Dysfunction in Former Workers from a Nuclear Weapons Facility. Research in Progress Seminar, Johns Hopkins Bloomberg School of Public Health, Division of Occupational and Environmental Health

3/8/2004

Cadorette, M. Thyroid Disease and Radiation Exposure Study. Research in Progress Seminar, Johns Hopkins Bloomberg School of Public Health, Division of Occupational and Environmental Health

10/28/2002

Cadorette, M. An Integrated Approach to Health Risk Communication with Workers and Community at Best Practices in Occupational Safety and Health, Education, Training and Communication: Ideas that Sizzle, 6th International Conference Scientific Committee on Education and Training in Occupational Health, ICOH

10/3/2002	Cadorette, M. Risk Communication in the Former Los Alamos National Laboratory Workers Medical Exam Program, Johns Hopkins Bloomberg School of Public Health, Occupational Health Nursing Seminar
10/21-25/2001	Mulloy, K., Cadorette, M., Breysse, P., Curbow, B., Weaver, V., Smith, H., Wiggs, L., Melius, J., Newman, L., Schwartz, B. Medical Screening Program for Former Workers at Los Alamos National Laboratory (LANL). American Public Health Association 129th Annual Meeting & Exposition, Atlanta Georgia
10/8/1999	Poster Presentation: *Development of a Risk Communication Program for Former Los Alamos National Laboratory Workers* at the Chesapeake Section Meeting of the American Conference of Government Industrial Hygienists (ACGIH)
7/19-22/1999	Poster Presentation: *Development of a Risk Communication Program for Former Los Alamos National Laboratory Workers* at the Department of Energy Occupational Medicine Meeting in Albuquerque, New Mexico
11/12/1998	Presentation: *Geographical Information Systems: Applications to Occupational and Environmental Research* at the International Occupational Health and Environmental Health Nursing Conference Devonshire Park Centre, Eastbourne, East Sussex, United Kingdom
10/16/1998	Poster Presentation: *Development of a Medical Surveillance Program for Former Workers at Los Alamos National Laboratory* at the Chesapeake Section Meeting of the ACGIH
4/22/1998	Poster Presentation: *Development of a Medical Surveillance Program for Former Workers at Los Alamos National Laboratory* at Los Alamos National Laboratory for the Division of Environment, Safety and Health External Review Committee

ADDITIONAL INFORMATION

My areas of research interest include the environment, adverse health effects related to air pollution, and the health of former workers from the nuclear defense industry. I am currently coordinating a project that offers former workers from a nuclear defense facility a free medical examination to determine if they have occupational illnesses related to past exposures to asbestos, beryllium, lead, noise and radiation.