ORISE 05-1711

HSS

Office of Health, Safety and Security

Beryllium Current Worker Health Surveillance Through 2005

Beryllium
Current Worker Health Surveillance
Through 2005

Office of Health, Safety and Security

Questions or comments about this report and suggestions for future reports may be directed to:

E-mail:

Paul Wambach, CIH at **paul.wambach@hq.doe.gov**
or Bonnie Richter, Ph.D. at **bonnie.richter@hq.doe.gov**

or direct letters to:

United States Department of Energy
Office of Illness and Injury Prevention Programs
Office of Health, Safety and Security
HS-13/270 Corporate Square Building
1000 Independence Avenue, SW
Washington, DC 20585-0270

Additional information about the Department of Energy Chronic Beryllium Disease Prevention Program can be found at:

www.hss.energy.gov/be/

The Oak Ridge Institute for Science and Education (ORISE) provided support to the development of this report. ORISE is a U.S. Department of Energy institute focusing on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists. ORISE is managed by Oak Ridge Associated Universities. This document was produced under contract number DE-AC05-06OR23100 between the U.S. Department of Energy and Oak Ridge Associated Universities.

TABLE OF CONTENTS

Acronyms and Units of Measurement

Acronyms

10 CFR 850	U.S. Code of Federal Regulations (CFR) Title 10, Part 850 *Chronic Beryllium Disease Prevention Program*
ANL	Argonne National Laboratory
BeLPT	Beryllium Lymphocyte Proliferation Test
CBD	Chronic Beryllium Disease
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissioning
DOE	U.S. Department of Energy
ETTP	East Tennessee Technology Park
EX	Estimate of Arithmetic Mean
Fermi	Fermi National Accelerator Laboratory
Hanford	Hanford Reservation
INL	Idaho National Laboratory
KAPL	Knolls Atomic Power Laboratory
KCP	Kansas City Plant
KM	Kaplan-Meier
LCL	Lower Confidence Limit
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LOD	Limit of Detection
NA	Not Applicable
NNSA	National Nuclear Security Administration
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
ORISE	Oak Ridge Institute for Science and Education
Pantex	Pantex Plant
PCB	Polychlorinated Biphenyl

PNNL	Pacific Northwest National Laboratory
Rocky Flats	Rocky Flats Environmental Technology Site
SNL	Sandia National Laboratories
SRS	Savannah River Site
TSCA	Toxic Substances Control Act
UCL	Upper Confidence Limit
UTL	Upper Tolerance Limit
Y-12	Y-12 National Security Complex

Units of Measurement

m^3	Cubic Meter
µg	Microgram

At a Glance

This report summarizes health data from medical examinations provided to over 16,000 current U.S. Department of Energy (DOE) workers who have had an association with beryllium work. These individuals received one or more DOE-provided screening examinations for chronic beryllium disease (CBD) between 1991 and the end of 2005.

Among the 16,267 participants, 95 (0.6%) are known to have been diagnosed with CBD and another 189 (1%) have been found to be sensitized to beryllium. These individuals have been offered government-provided insurance coverage for medical monitoring to determine if they are progressing to a lung-damaging stage of the disease and for medical care recommended to minimize lung damage and disability.

Differences in rates from site to site and among groups at the same site demonstrate that primary prevention through beryllium exposure control has the potential to reduce the incidence of sensitization and CBD.

Beryllium personal exposure monitoring data from 15 DOE sites are summarized in this report. The data were required to be reported to the Beryllium-Associated Worker Registry beginning in 2002. Monitoring data prior to 2002 were included for individuals in the Registry if available. The data indicate that controlling exposure to levels less than the DOE action level of 0.2 micrograms of beryllium per cubic meter of air ($\mu g/m^3$) has been feasible at most sites, but that additional effort is required at other sites.

The Registry is a secondary use of information generated for other purposes. The quality and completeness of reporting of any particular data element varies depending on its accessibility to the site staff members who report the information. Reporting has steadily improved since 2002 as deficiencies and inefficiencies are identified and corrected; however, significant room for further improvement remains. Progress depends on continuing collaboration between the reporting organization, the data center, line management, and Office of Health, Safety and Security staff members.

Data in this report suggest opportunities for further investigations that could more definitively characterize the working conditions associated with the development of CBD. The Rocky Flats Environmental Technology Site data suggest that a substantial subset of cleanup workers whose exposures were extensively monitored were protected by the low exposures achieved during this work. A study validating this has the potential to make a significant contribution to our understanding of CBD by quantifying a no observed adverse effects level. At other sites cases of CBD are occurring where personal exposure monitoring results have been low. These CBD cases could be due to exposures in the past; however, more extensive exposure monitoring is also indicated to rule out the chance that some unrecognized source of ongoing exposure exists.

Introduction

This report is the first in a series of periodic summaries of the U.S. Department of Energy (DOE) Beryllium-Associated Worker Registry. It summarizes cumulative data through the end of calendar year 2005. U.S. Code of Federal Regulations (CFR) Title 10, Part 850 *Chronic Beryllium Disease Prevention Program* (10 CFR 850) requires DOE sites to inventory and assess beryllium exposure hazards to determine whether employees are at risk for chronic beryllium disease (CBD). Sites that determine employees are at risk due to ongoing or past work must implement CBD prevention programs that include reporting health and exposure data to the DOE Beryllium-Associated Worker Registry. These sites are required to submit summary data in semi-annual progress reports. Health data are collected through the operation of medical surveillance programs for current workers at 20 DOE sites. Exposure data are collected through the operation of industrial hygiene programs at 15 sites that had continuing beryllium operations.

The category "current worker" describes individuals who were screened for CBD at a DOE occupational medicine clinic while they were employed. Current workers include both long-term employees who worked with beryllium years ago and workers exposed recently. Current workers who self-identify or are identified by supervisors as beryllium-associated workers are offered screening for CBD but are not required to participate. Individuals who have separated from employment at a DOE site are offered screening for CBD through programs operated by contract medical providers and cooperative agreement holders. The screening is performed at private clinics near the individual's current residence. These individuals are categorized as "former workers" and the results from these former worker programs are summarized in a separate report.

The primary purpose of the periodic summaries is to support planning and prioritization of future work. While the completeness and accuracy of data vary by site and medical provider, the available data are used as indicators of opportunities to prevent CBD or to better understand it. Reporting deficiencies are identified during each reporting cycle and discussed with the site so corrective actions can be taken or planned. The prevalence of CBD is a lagging indicator since it can be a long latency disease. Beryllium sensitization has less lag time and is a better indicator of risks associated with current working conditions. Exposure monitoring data provide indicators relevant to ongoing operations.

Beryllium is a silver-gray metallic element found in approximately 30 minerals. It is a lightweight but strong, hard metal that has many industrial applications. The primary commercial use of beryllium is for hardening other metals, especially copper. Copper-beryllium alloys have many applications in electronic industries and other fields where strength and the ability to be fabricated into complex shapes and conduct electricity are desirable. The light weight and ability to dissipate heat of beryllium oxide ceramics have led to applications in the electronic, nuclear, and aerospace industries. Both beryllium's transparency to x-rays and its ability to scatter and generate, but not absorb, neutrons when it is bombarded with protons have led to its use in nuclear weapons, experimental

reactors, and accelerators. Beryllium components have been manufactured and used at several DOE facilities since the 1940s.

Until the late 1940s, little was known about the delayed health effects possible from exposure to beryllium. The first occupational exposure limits were put in place in 1949 to prevent acute and chronic beryllium disease. These limits were 2 micrograms per cubic meter as a quarterly average and 25 micrograms per cubic meter as a 30-minute average. The adoption of exposure limits led to reduced exposure levels and prevention of acute beryllium disease, but also gave the perception that CBD was being controlled.

Increased CBD case reports in the mid-1980s led to development of a new medical screening test for CBD called the beryllium lymphocyte proliferation test (BeLPT). The BeLPT detects beryllium sensitization, an early step in the disease process that can progress to CBD. In the 1990s, DOE began using the BeLPT in medical surveillance programs to learn the extent of beryllium sensitization and CBD among employees. Findings from these projects led to establishing requirements for current worker medical surveillance programs that are published in 10 CFR 850.

Purpose of the Program

The Beryllium-Associated Worker Registry captures data created through the operation of the industrial hygiene and occupational medicine programs that support CBD prevention. Workers potentially exposed to beryllium are monitored periodically. Personal breathing zone results representative of workers' occupational exposure to beryllium are reported to the Registry. The BeLPT, symptoms questionnaires, and other tests recommended by the examining physician are used to screen for CBD. It is recommended that individuals with abnormal findings obtain a diagnostic evaluation to determine if they have CBD and whether treatment is indicated. In some cases, the disability caused by CBD can be minimized through early detection and treatment. Individuals who have abnormal BeLPT results are eligible for Department of Labor insurance coverage of recommended medical evaluations and care. Accessible results from screening and diagnostic evaluations are reported to the Registry. The routine collection and analysis of this information may be helpful to DOE in:

- Managing the DOE CBD prevention programs
- Identifying and offering screening to other workers who may be at risk for CBD
- Identifying working conditions associated with beryllium sensitization and CBD that provide an opportunity for intervention and prevention of future cases

Beryllium Exposure and CBD

Workers may have come into contact with beryllium in a number of jobs over the years. Machinists, welders, and operators may have been exposed through direct handling of beryllium and beryllium compounds. Performing quality assurance analyses on beryllium

materials, coming into contact with contaminated equipment, or working near a beryllium operation may have exposed other workers.

Exposure usually occurs when a person breathes in beryllium mists, dusts, or fumes that travel to the lungs. Exposure to very small amounts can cause some people to become sensitized to beryllium. CBD usually develops over several years or even decades and can be in a mild or severe form. Beryllium-related granulomas, i.e., non-cancerous tumors or growths due to inflammation, can make it difficult for the lungs to get oxygen to the bloodstream and body. Over time, scar tissue can develop causing permanent lung damage. Granulomas can also develop in other body tissues but do not normally result in a loss of function. Exposure to the skin, especially through cuts or punctures, can cause sensitization. However, the level of risk associated with skin exposure is not understood.

Symptoms of CBD include shortness of breath, cough, chest pain, fatigue, loss of appetite, and weight loss. Since these symptoms are also associated with other conditions, it is important to note that not all individuals who experience them have CBD. It is also possible to have CBD without having any of these symptoms. Workers who are sensitized or have signs or symptoms of lung disease should have a clinical evaluation by a knowledgeable physician (pulmonologist) to obtain a definitive diagnosis and recommended course of treatment.

In recent studies, less than 1% of current workers exposed to beryllium have developed the disease. CBD is not a fatal condition for most patients. For a few people, however, it can become serious enough to cause disability and contribute to a reduced life expectancy. Most people with the disease are able to control the symptoms with medication and regular medical evaluations. Early detection is thought to improve the chances for successful management of the disease.

The higher than expected prevalence of beryllium sensitization and CBD at several different DOE sites and among groups of workers with differing exposure potential supported a conclusion that the long-standing Occupational Safety and Health Administration (OSHA) permissible exposure limit for beryllium was not providing an adequate level of protection. DOE established an action level of 0.2 micrograms beryllium per cubic meter of air ($\mu g/m^3$) in 10 CFR 850 to constrain exposures to beryllium to a level one-tenth the OSHA permissible exposure limit. The rule requires routine exposure monitoring of beryllium workers to determine if the action level is being exceeded.

Beryllium is identified by the International Agency for Research on Cancer and the National Toxicology Program as a cancer-causing substance. The National Toxicology Program has identified beryllium as a known human carcinogen based on sufficient evidence of carcinogenicity in humans and data from animal studies.

Beryllium Lymphocyte Proliferation Test

The BeLPT is a blood test that examines how lymphocytes (white blood cells in the immune system that fight disease) react to beryllium. A BeLPT is considered abnormal if a person's lymphocytes react strongly to beryllium. An abnormal BeLPT may indicate that a person is more likely than others with similar exposure to develop CBD in the future or may be an early sign of CBD. An individual must have 2 abnormal blood tests to be considered beryllium sensitized.

A total of 16,267 current employees had been screened by site occupational medicine clinics by the end of 2005. Of these participants, 189 were found to be beryllium sensitized because of consistently abnormal BeLPT results, and another 95 were diagnosed as having CBD based on immunological evidence of sensitization to beryllium and pathology or other clinical findings consistent with CBD (Figure 1). The "Number Sensitized" and "Number with CBD" are mutually exclusive categories in the figures in this report. The "Rate Sensitized or CBD" is calculated by adding "Number Sensitized" and "Number CBD" and dividing by the "Number with BeLPT Results."

Figure 1. Current Worker Medical Surveillance Program Screening Results

Number with BeLPT Results	Number Sensitized[1]	Number with CBD
16,267	189 (1%)	95 (0.6%)

Selected Sites for Data Summaries

Site specific summaries are provided for 8 DOE sites where more than 500 workers had been screened by December 31, 2005. Summary data for the 12 sites where fewer than 500 workers were screened are included in figures summarizing data from all sites.

- Rocky Flats Environmental Technology Site 3,980 screened
- Hanford Reservation 3,359 screened
- Los Alamos National Laboratory 1,661 screened
- Y-12 National Security Complex 1,642 screened
- Pantex Plant 1,617 screened
- Kansas City Plant 1,011 screened
- East Tennessee Technology Park 695 screened
- Nevada Test Site 651 screened

[1] For all tables in this report "Number Sensitized" means the number of individuals found sensitized from two or more peripheral blood BeLPTs or from a bronchoalveolar lavage BeLPT. It does not include individuals who have been diagnosed as having CBD. "Individuals Sensitized" includes individuals who have been evaluated and found not to have CBD and individuals who have declined the offer of a diagnostic evaluation or are awaiting a scheduled evaluation.

This report should not be used to draw final conclusions regarding beryllium sensitization and CBD as the programs are ongoing and additional data are being collected.

Personal Exposure Monitoring Results

Sites with current beryllium operations report employee exposure monitoring data to the DOE Beryllium-Associated Worker Registry. The data are from analyses of air samples collected by personal samplers worn by a worker and thought to be representative of the worker's actual exposure. Sometimes a site will assign a result to co-workers performing the same work at the same time. In this report, a result associated with more than one worker is only used once to generate the site-wide exposure metrics shown in figures.

Data for 2005, or the most current analyzable data, are summarized for each site. The methods used to estimate summary statistics were chosen based on their utility in analyzing data that include results reported as non-detected. The majority of exposure monitoring results reported to the Registry are less than laboratory reporting limits for the sampling and analytical methods used. The metrics used to summarize exposures are the Kaplan-Meier estimate of mean and 90% confidence interval; the 95th percentile and order statistics estimate of 95% upper tolerance limit; and a product limit estimate of the percent of monitoring results exceeding the 0.2 µg/m^3 DOE action level and 90% confidence interval. Because relatively large numbers of monitoring results are required to produce confident estimates with these methods for data that include non-detects, data from more than one year were combined in some cases. For more information on the methods used, see Oak Ridge National Laboratory Technical Report ORNL/TM-2005/52, "Statistical Methods and Software for the Analysis of Occupational Exposure Data with Non-Detectable Values" available on the Web at:

www.csm.ornl.gov/esh/aoed/ORNLTM2005-52.pdf

The terms non-detect, non-detectable value, and non-detectable result are used to describe exposure monitoring results where the laboratory analysis of the air sample was reported as less than a value referred to as the reporting limit. The reporting limit is determined by the laboratory through a quality assurance process that specifies the level of precision and accuracy that a value must have to be reported to a customer. Reporting limits can vary depending on the analytical methods used, the matrix the air sample was collected on, and the presence of other contaminants in the air that can interfere with the analysis.

Rocky Flats Environmental Technology Site

Site Description

The DOE Rocky Flats Environmental Technology Site (Rocky Flats) is situated on a 6,262 acre reserve located 16 miles northwest of Denver, Colorado. The site's industrial complex included over 135 structures. The site was established in 1952 by the Atomic Energy Commission to serve as one of seven production plants in the national nuclear weapons complex. The main production and support activities were located near the center of the site and occupied approximately 385 acres. The remainder of the site served as a buffer zone. The northern half of the industrial complex was contained within a "protected area" and historically housed plutonium processing operations. The rest of the industrial area was involved with uranium, beryllium, and stainless steel operations. The site's operations also included the development of technology needed for the manufacture and assembly of nuclear weapons. In 2005, the mission was cleanup and closure of the site, which was achieved by the end of 2005.

Beryllium Operations

The primary beryllium operation at Rocky Flats was the production of beryllium metal nuclear weapons components. Beryllium research and development activities began at Rocky Flats in 1953 and continued until full-scale beryllium production work began in 1958. Beryllium metal was received from a commercial supplier, analyzed for purity, and machined to final tolerances using precision metal working tools. Beryllium production operations included:

- Machining (milling, drilling, turning, and polishing)
- Rolling and forming operations
- Component assembly (cleaning, machine welding and brazing, and hand welding)
- Disassembly of returned components for decommissioning
- Beryllium electrorefining
- Casting of beryllium ingots
- Development of pressed powder, heat-treated manufacturing technology
- Analytical analysis; research and development
- Quality control assurance testing (polishing and non-destructive testing including x-ray diffraction analysis)

Weapons production ended at Rocky Flats in 1989, and all beryllium production operations ceased in 1992. From 1992 through the end of 2005, beryllium work was primarily the decontamination and decommissioning (D&D) of contaminated equipment, utilities, and facilities.

Beryllium Workers

In 1984, the first case of CBD at Rocky Flats was diagnosed in a beryllium machinist worker. In 1986, the National Jewish Medical and Research Center, with funding from DOE, conducted a pilot program to determine the prevalence of beryllium sensitization and CBD in a group of 55 beryllium machinists. Based on the results of this program and with funding from the National Institutes of Health, the National Jewish Medical and Research Center expanded screening to include approximately 900 additional Rocky Flats employees who had a known opportunity for exposure to beryllium. In 1992, screening was offered to all Rocky Flats current and former workers. Health information for 3,980 and exposure information for 652 current employees have been reported to the Beryllium-Associated Worker Registry. In 2005, 53 workers were monitored for beryllium exposure while working at Rocky Flats.

Beryllium Sensitization and CBD Rates

The numbers and rates of beryllium sensitization and CBD among current workers at Rocky Flats are shown in Figure 2. Current employees have a low rate of beryllium sensitization (0.75%) suggesting success in controlling beryllium exposures during D&D operations.

Figure 2. Rocky Flats Current Worker Health Data

Number of Workers in Roster	3,998
Number with BeLPT Results	3,980
Number Sensitized	31
Number with Clinical Evaluations	7
Number with CBD	0
Rate Sensitized or CBD	0.8%

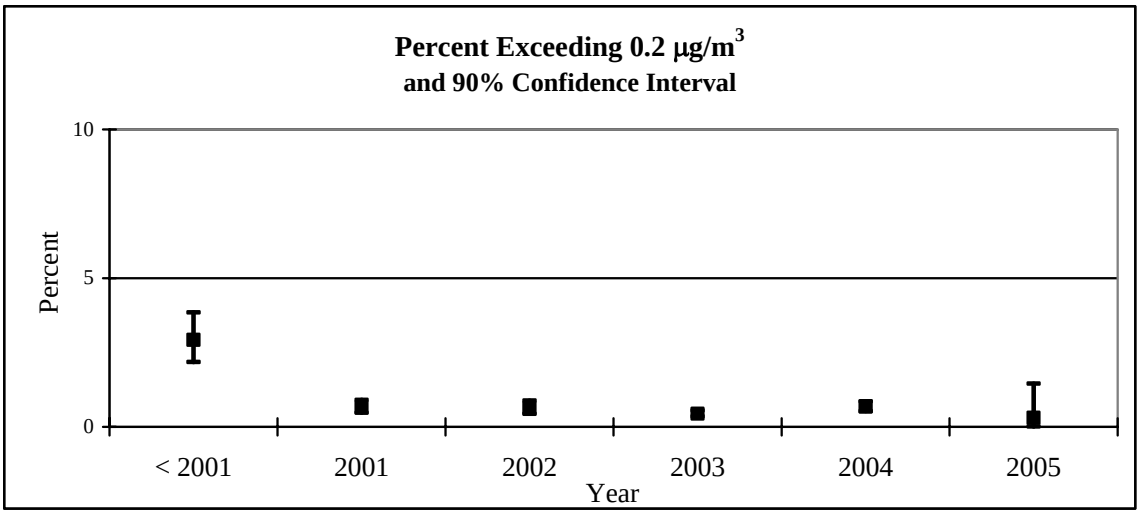
Beryllium Exposure Monitoring Results

The 2005 exposure monitoring results from Rocky Flats indicate a very high rate of compliance with the 0.2 $\mu g/m^3$ action level (Figure 3). The upper confidence limit of the percent exceeding the metric supports a conclusion that fewer than 5% of exposures exceed the action level. The low exposure levels are consistent with the low beryllium sensitization rates among current employees. The exposure monitoring results do not show any clear trend, which is a good indicator that exposures have been under control in recent years (Figure 4).

Figure 3. Rocky Flats Exposure Metrics for 2005

Kaplan-Meier (KM) Estimate of Arithmetic Mean (EX)	0.018	µg/m^3
KM 95% Lower Confidence Limit (LCL) for EX	0.013	µg/m^3
KM 95% Upper Confidence Limit (UCL) for EX	0.022	µg/m^3
Observed 95th Percentile of data	0.028	µg/m^3
Estimate of the 95th Percentile - 95% Upper Tolerance Limit	**0.061**	µg/m^3
Largest value in the data set	0.879	µg/m^3
Percent of results that are non-detects	92.3	%
Number of observations in the data set	324	
Number of detected results	25	
Number of individuals monitored	53	
Estimate of percent exceeding 0.2 µg/m^3 (F)	0.3	%
Estimate of the 95% LCL for F	0.02	%
Estimate of the 95% UCL for F	**1.5**	%

Figure 4. Rocky Flats Exposure Trend



Comments

Incomplete reporting from 2002 through 2004, combined with reductions in personnel associated with closure of the site, led to initiation of a special project to obtain Rocky Flats beryllium-related health and exposure data. Copies were made of all electronic medical and exposure records and provided to ORISE for use in adding missing data to the Registry. The low sensitization rates and low exposure levels among Rocky Flats cleanup workers provide an opportunity for further study of the levels that appear to have been protective.

Hanford Reservation

Site Description

The Hanford Site (Hanford) is located on 358,388 acres in southeastern Washington State, just north of Richland. It is bordered on the east by the Columbia River and on the south by the Yakima River and the city of Richland. The site was established in early 1943 to build the first full-size reactors to produce plutonium for nuclear warheads. A plutonium production complex with 9 nuclear reactors and associated processing facilities, Hanford played a pivotal role in the nation's defense for more than 40 years. Today, Hanford is engaged in the world's largest environmental cleanup project, involving more than 1,700 waste sites and about 500 contaminated facilities.

The Pacific Northwest National Laboratory (PNNL) operates laboratories on, and adjacent to, the Hanford site. PNNL began in 1965 when Battelle was awarded a contract to perform research and development for the Hanford Site. The Laboratory's first projects included fabricating reactor fuel and designing reactors, including the Fast Flux Test Facility at Hanford. PNNL is a multi-program laboratory that performs energy, environmental, and national security research.

Beryllium Operations

The cladding for reactor fuel included beryllium alloy components. Brazing operations in fuel fabrication areas used beryllium-containing base and filler materials. In addition, nuclear research and development activities led to fabrication of beryllium-containing components for experimental apparatus. Contaminated equipment and facilities are undergoing decontamination and decommissioning.

Beryllium Workers

Current workers have been given an opportunity to participate in medical surveillance programs. As of the end of 2005, a total of 3,359 current employees had participated. Accessible records show that 341 employees were monitored for beryllium exposure while working at Hanford. In 2005, 47 Hanford workers were monitored for beryllium exposure.

Beryllium Sensitization and CBD Rates

The numbers and rates of beryllium sensitization and CBD among current Hanford workers are shown in Figure 5. Among the 3,359 workers screened, 42 were reported to be sensitized and another 19 were diagnosed with CBD.

Figure 5. Hanford Current Worker Health Data

Number of Workers in Roster	3,438
Number with BeLPT Results	3,359
Number Sensitized	42
Number with Clinical Evaluations	19
Number with CBD	19
Rate Sensitized or CBD	1.8%

Beryllium Exposure Monitoring Results

Exposure monitoring results for 2005 indicate Hanford achieved a high rate of compliance with the 0.2 µg/m^3 action level. Only 2 of 74 monitoring results were detectable and none were above the action level (Figure 6). Similarly, in 2004, 164 samples were collected with only 3 detected results and none above the 0.2 µg/m^3 action level. From 2001 to 2003, there were too few workers monitored to draw confident conclusions about the degree of compliance with the action level.

Figure 6. Hanford Exposure Metrics for 2005

Kaplan-Meier (KM) Estimate of Arithmetic Mean (EX)	0.0010	µg/m^3
KM 95% Lower Confidence Limit (LCL) for EX	0.000	µg/m^3
KM 95% Upper Confidence Limit (UCL) for EX	0.003	µg/m^3
Observed 95th Percentile of data	0.0010	µg/m^3
Estimate of the 95th Percentile - 95% Upper Tolerance Limit	**0.014**	µg/m^3
Largest value in the data set	0.014	µg/m^3
Percent of results that are non-detects	97.3	%
Number of observations in the data set	74	
Number of detected results	2	
Number of individuals monitored	47	
Estimate of percent exceeding 0.2 µg/m^3 (F)	0	%
Estimate of the 95% LCL for F	0	%
Estimate of the 95% UCL for F	**4.0**	%

Comments

In contrast with the experience at Rocky Flats, the low exposure levels from decontamination and decommissioning work at Hanford are not associated with low rates of sensitization and CBD. However, exposure monitoring has not been as extensive as it was at Rocky Flats, indicating the possibility that there were sources of unrecognized and uncontrolled exposure in the past. Investigations of the work histories of cases have not identified patterns suggestive of a possible source.

Los Alamos National Laboratory

Site Description

The Los Alamos National Laboratory (LANL) is one of three national laboratories that are part of the National Nuclear Security Administration (NNSA) within DOE. LANL covers approximately 28,000 acres in north central New Mexico. The Los Alamos Laboratory was established in 1943 as a weapons research and development site for the Manhattan Project. When LANL was first established, scientists worked to achieve the laboratory's original mission—developing atomic weapons. Following World War II, although scientists continued to focus on nuclear defense research and development, they also branched out into other nuclear energy and technology projects. Today, LANL's mission is divided into four focus areas: national security, energy resources, environmental quality, and fundamental science. Under the national security mission, LANL monitors the safety and reliability of nuclear weapons stockpiles, and tracks the international use and spread of nuclear weapons, materials, and technologies. The energy resources mission covers research and development of energy resources, including renewable, fossil, and nuclear fuels. The environmental quality mission focuses on the treatment, storage, and disposal of DOE wastes (both chemical and radiological), as well as research and development of remedial technologies. As part of the science mission, LANL conducts fundamental research in physics, materials science, chemistry, nuclear medicine, energy sciences, computational sciences, environmental sciences, and biological sciences.

Beryllium Operations

The primary beryllium operations at LANL support research and development, testing, and production activities. LANL fabricates beryllium metal nuclear weapon components to replace those consumed in the tests for stockpile stewardship. The processes include machining, welding, polishing, assembling, and testing of solid beryllium components. It is one of the metals studied in non-nuclear experiments using high explosives. Beryllium components have also been fabricated to support a wide range of energy and physics research and development unrelated to nuclear weapons.

Beryllium Workers

Current LANL employees were given an opportunity to participate in beryllium sensitization screening, and 1,661 had participated in medical screening by the end of 2005. A total of 254 current employees have been monitored for beryllium exposure since 1994. In 2005, 116 employees were monitored for beryllium exposure.

Beryllium Sensitization and CBD Rates

The numbers and rates of sensitization and CBD among current workers are shown in Figure 7 and indicate low rates.

Figure 7. LANL Current Worker Health Data

Number of Workers in Roster	2,828
Number with BeLPT Results	1,661
Number Sensitized	2
Number with Clinical Evaluations	51
Number with CBD	3
Rate Sensitized or CBD	0.3%

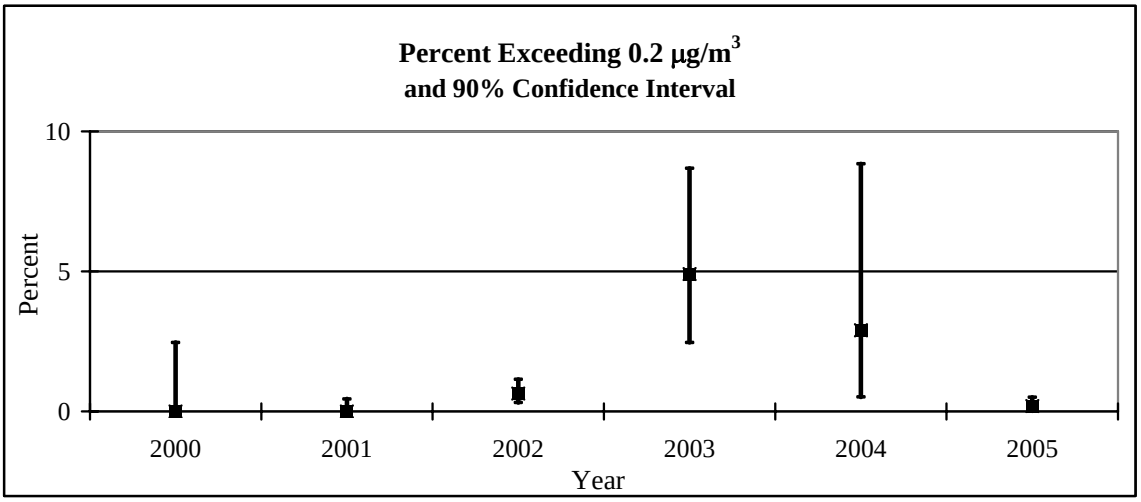
Beryllium Exposure Monitoring Results

The exposure monitoring results indicate that LANL achieved a high rate of compliance with the 0.2 µg/m^3 action level in 2005 (Figure 8). In 2003 and 2004, fewer samples were collected and the upper confidence limit of the percent exceeding the metric does not exclude the possibility that more than 5% of exposures were over the 0.2 µg/m^3 limit (Figure 9). The exposure monitoring results do not indicate any clear trend. The smaller confidence intervals occur in years with more frequent exposure monitoring.

Figure 8. LANL Exposure Metrics for 2005

Kaplan-Meier (KM) Estimate of Arithmetic Mean (EX)	0.016	µg/m^3
KM 95% Lower Confidence Limit (LCL) for EX	0.014	µg/m^3
KM 95% Upper Confidence Limit (UCL) for EX	0.017	µg/m^3
Observed 95th Percentile of data	0.013	µg/m^3
Estimate of the 95th Percentile - 95% Upper Tolerance Limit	**0.034**	µg/m^3
Largest value in the data set	1.222	µg/m^3
Percent of results that are non-detects	96.9	%
Number of observations in the data set	1527	
Number of detected results	48	
Number of individuals monitored	116	
Estimate of percent exceeding 0.2 µg/m^3 (F)	0.2	%
Estimate of the 95% LCL for F	0.05	%
Estimate of the 95% UCL for F	**0.5**	%

Figure 9. LANL Exposure Trend



Comments

Discussions with LANL staff members indicate that destructive testing of beryllium components and cleanup of facilities and areas used are a significant potential for beryllium exposure. Projects in 2003 and 2004 to characterize and cleanup contamination from past tests contributed to exceeding the action level at higher rates. Efforts to better control these exposures continue to be a focus of attention.

Y-12 National Security Complex

Site Description

The Y-12 National Security Complex (Y-12) is located in Oak Ridge, Tennessee on 811 acres within the Oak Ridge Reservation. The site was established in 1943 to produce highly enriched uranium as part of the Manhattan Project. Enriched uranium production started in November 1943. At its peak during World War II, the plant employed approximately 22,000 workers. After World War II, the plant's focus changed to manufacturing components for nuclear weapons. For more than 50 years, the complex has been one of the manufacturing facilities in the DOE weapons complex. Every weapon in the stockpile has some components manufactured at Y-12.

Beryllium Operations

The primary beryllium operation at Y-12 has been the production of weapons components from beryllium oxide ceramics. Beryllium oxide powder is received, mixed with other materials, pressed into a shape, and fired in a kiln. The blank work piece is machined using diamond grinding tools. The operations are supported by quality assurance testing of the materials when they are received, and at various fabrication steps and by dimensional inspection of the finished products. Beryllium oxide ceramic components from retired weapons are returned to Y-12 for declassification and recycling of the materials. Y-12 also performs engineering research and development of new beryllium oxide ceramic manufacturing methods.

In the past, Y-12 operations produced beryllium metal components for nuclear weapons. The unique fabrication capabilities at Y-12 are used today to support energy and defense projects that include the use of beryllium metal, ceramics, and alloys. Remodeling, maintenance, and D&D projects on the site have required work on beryllium-contaminated facilities, utilities, and equipment.

Beryllium Workers

Beginning in 1991, Y-12 employees likely to have been exposed to beryllium were identified and others were asked to self-identify whether they might have worked with beryllium. At Y-12, most participants either recall working with beryllium or are identified in records as having been assigned beryllium work. A total of 1,642 current Y-12 employees had been screened for CBD through the end of 2005; 425 workers in the Registry have been monitored for beryllium during their career; and 20 workers were monitored in 2005.

Beryllium Sensitization and CBD Rates

The numbers and rates of current employees with beryllium sensitization or CBD are shown in Figure 10. Figure 11 shows the numbers and rates by work activity (or job) categories, indicating similar rates for workers with a wide variety of job duties.

Figure 10. Y-12 Current Worker Health Data

Number of Workers in Roster	2,372
Number with BeLPT Results	1,642
Number Sensitized	44
Number with Clinical Evaluations	42
Number with CBD	42
Rate Sensitized or CBD	5.2%

Figure 11. Y-12 Current Worker Health Data by Work History Activity

Activity	Number with BeLPT Results	Number Sensitized	Number CBD	Rate Sensitized or CBD
Management	198	4	4	4.0%
Administrative Support	47	3	0	6.4%
In-House Professionals	178	3	4	3.9%
Field Professionals	193	8	1	4.7%
Technical Support	101	1	0	1.0%
Service	213	3	5	3.8%
Security and Fire	48	2	1	6.3%
Crafts	522	9	16	4.8%
Line Operators	97	3	4	7.2%
Unknown	45	8	7	33.3%
All Subjects	1,642	44	42	5.2%

Beryllium Exposure Monitoring Results

The exposure monitoring results from Y-12 indicate that compliance with the 0.2 µg/m^3 action level was uncertain in 2005 because more than 5% of measurements could have exceeded the action level (Figure 12). Exposure levels were significantly reduced from levels in prior years (Figure 13). The higher levels in 2004 were due in part to remodeling and retooling work that appears to have been successful in reducing exposures in 2005. Y-12 has been relying on the use of respiratory protective equipment to control exposures to levels below the action level (Figure 14). The estimates in Figure 14 were calculated by dividing each individual's 8-hour time weighted average exposure level by the assigned protection factor of the respirator being worn. The confidence level on estimates for 2005 is wider than for other years because of the smaller number of samples collected.

Figure 12. Y-12 Exposure Metrics for 2005

Kaplan-Meier (KM) Estimate of Arithmetic Mean (EX)	0.022	µg/m^3
KM 95% Lower Confidence Limit (LCL) for EX	0.009	µg/m^3
KM 95% Upper Confidence Limit (UCL) for EX	0.034	µg/m^3
Observed 95th Percentile of data	0.091	µg/m^3
Estimate of the 95th Percentile - 95% Upper Tolerance Limit	**0.415**	µg/m^3
Largest value in the data set	0.479	µg/m^3
Percent of results that are non-detects	83.9	%
Number of observations in the data set	93	
Number of detected results	15	
Number of individuals monitored	20	
Estimate of percent exceeding 0.2 µg/m^3 (F)	2.2	%
Estimate of the 95% LCL for F	0.4	%
Estimate of the 95% UCL for F	**6.6**	%

Figure 13. Y-12 Exposure Trend Without Considering Assigned Protection Factors for Respiratory Protective Equipment Worn

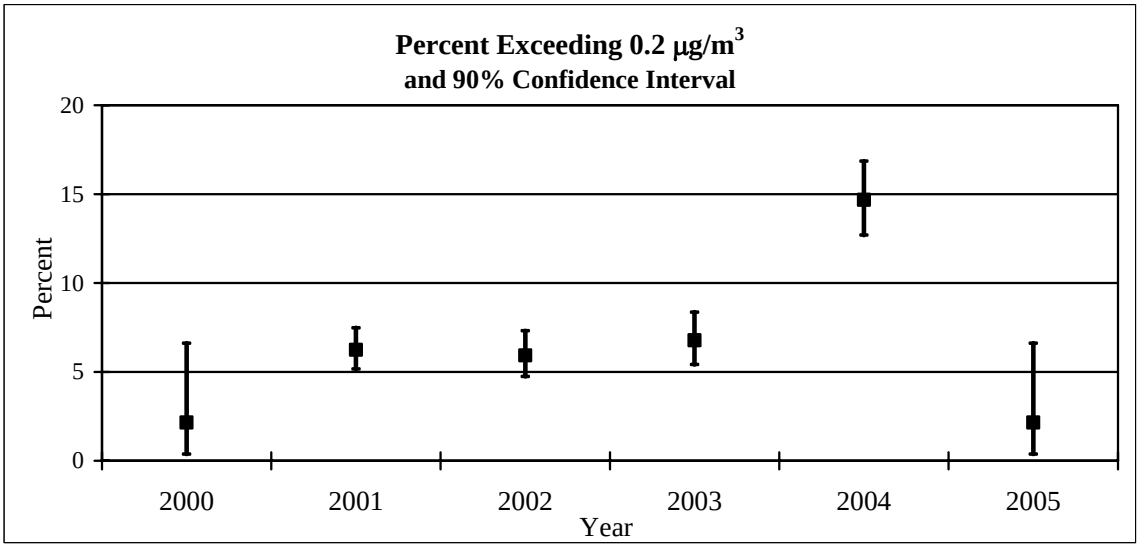
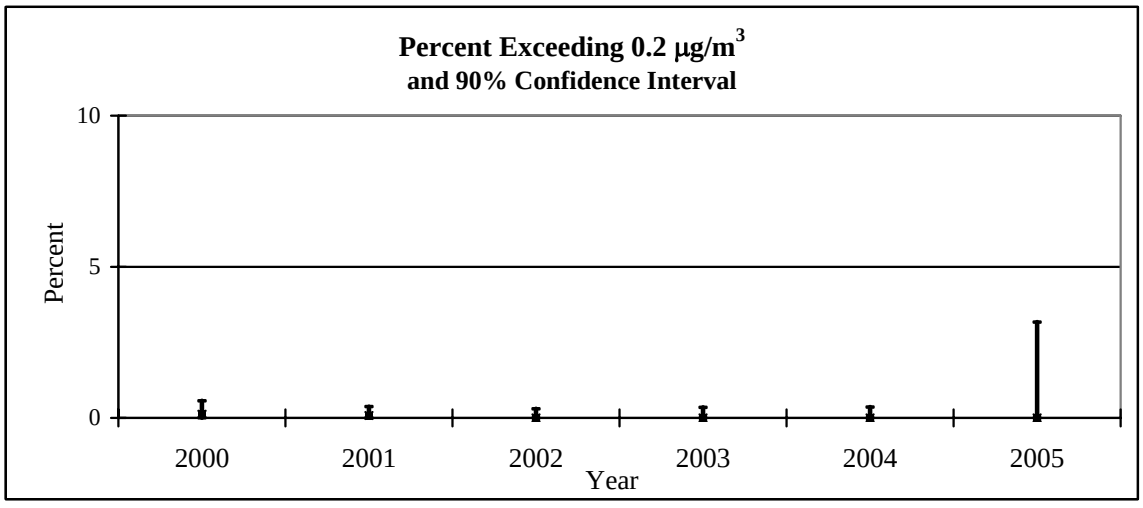


Figure 14. Y-12 Exposure Trend Considering Assigned Protection Factors for Respiratory Protective Equipment Worn



Comments

Both health and exposure data indicate that the risk for exposure to beryllium and developing CBD is higher at Y-12 than at other DOE sites. The data indicate a degree of risk that justifies continuing support of the ongoing efforts to improve working conditions at this plant.

Pantex Plant

Site Description

The Pantex Plant (Pantex), located on the Texas panhandle 17 miles northeast of Amarillo, was constructed in 1942 to serve as a conventional bomb plant for the U.S. Army. The plant was deactivated when World War II ended and remained vacant until 1949 when Texas Technological University purchased the site for experimental cattle-feeding operations. The land was sold subject to recall under the National Security Clause, and the Atomic Energy Commission requested the Army to reclaim and reopen the site in 1951 to expand nuclear weapons assembly facilities. In 1975, the Pantex Plant became the only nuclear weapons assembly and disassembly plant in the United States. Currently, the Pantex Plant has 5 primary operational missions: weapons assembly, weapons disassembly, evaluation of weapons, high explosive research and development, and interim plutonium pit storage.

Beryllium Operations

At Pantex, beryllium and beryllium-containing alloys were used in the fabrication of weapons components. Pantex also performed destructive testing involving explosives and beryllium weapons components. Conducting the tests and recovering data from the tests were considered highly hazardous activities, and workers were required to wear protective ensembles. Pit characterization, which was categorized as a special operation and is now inactive, sometimes involved minimal abrasion of the pit exterior with Scotchbrite or Brillo Pads. Currently, beryllium-containing components from weapons returned for dismantlement are demilitarized by crushing, shredding, or other means to make them unusable for military purposes and to ensure declassification. Firing Site operations require energetic demilitarization (firing to disable) of components that contain small amounts of beryllium.

Beryllium Workers

Current workers have been given an opportunity to participate in medical surveillance programs. As of the end of 2005, over 1,600 current employees had participated and 462 current workers had been monitored for beryllium exposure at some point in their career. In 2005, 40 workers were monitored for beryllium exposure while working at Pantex.

Beryllium Sensitization and CBD Rates

The numbers and rates of beryllium sensitization and CBD among current workers are shown in Figure 15. Among the 1,617 workers screened, 34 were referred for clinical evaluations because of symptoms or sensitization, 2 had no sensitization or CBD, 17 were found to be sensitized, and 15 were diagnosed with CBD. Roster data with demographic information, vital status, and year hired were missing for 7 of the individuals screened for CBD. The numbers and rates for workers in different work activity (or job) categories indicate risks exist for workers with a wide range of different job duties (Figure 16).

Figure 15. Pantex Current Worker Health Data

Number of Workers in Roster	1,610
Number with BeLPT Results	1,617
Number Sensitized	17
Number with Clinical Evaluations	34
Number with CBD	15
Rate Sensitized or CBD	2.0%

Figure 16. Pantex Current Worker Health Data by Work History Activity

Activity	Number with BeLPT Results	Number Sensitized	Number CBD	Rate Sensitized or CBD
Management	126	0	1	0.8%
Administrative Support	171	2	2	2.3%
In-House Professionals	85	0	0	0.0%
Field Professionals	121	1	1	1.7%
Technical Support	137	3	1	2.9%
Service	87	1	2	3.4%
Security and Fire	370	7	1	2.2%
Crafts	147	2	1	2.0%
Line Operators	301	1	6	2.3%
Unknown	72	0	0	0.0%
All Subjects	1,617	17	15	2.0%

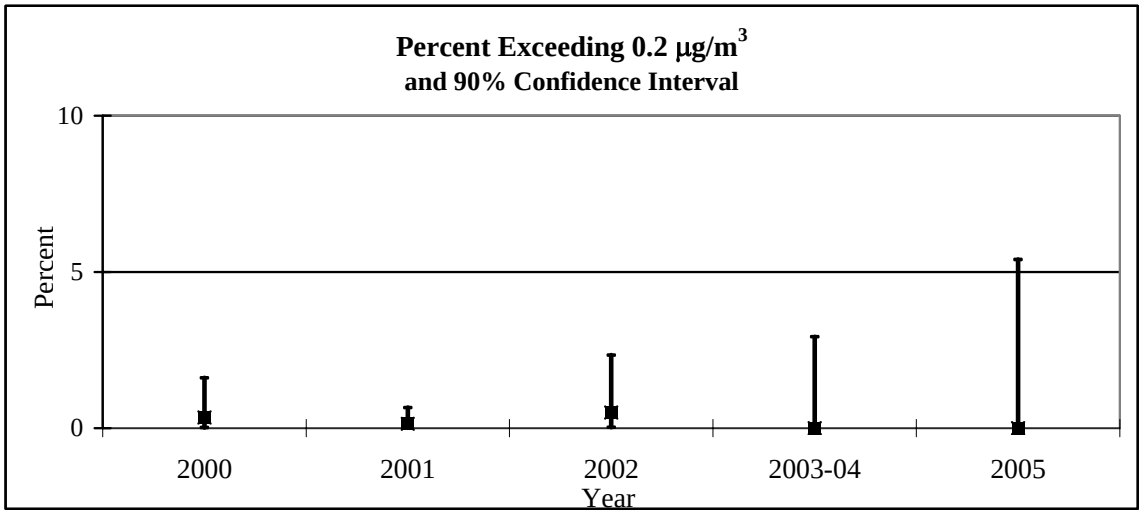
Beryllium Exposure Monitoring Results

Exposure monitoring results from Pantex indicate a high rate of compliance with the 0.2 µg/m^3 action level, although some uncertainty exists in results for 2005 because of the smaller number of samples collected (Figures 17 and 18).

Figure 17. Pantex Exposure Metrics for 2005

Kaplan-Meier (KM) Estimate of Arithmetic Mean (EX)	0.001	µg/m^3
KM 95% Lower Confidence Limit (LCL) for EX	-0.001	µg/m^3
KM 95% Upper Confidence Limit (UCL) for EX	0.004	µg/m^3
Observed 95th Percentile of data	0.001	µg/m^3
Estimate of the 95th Percentile - 95% Upper Tolerance Limit	**NA**	µg/m^3
Largest value in the data set	0.023	µg/m^3
Percent of results that are non-detects	96.3	%
Number of observations in the data set	54	
Number of detected results	2	
Number of individuals monitored	40	
Estimate of percent exceeding 0.2 µg/m^3 (F)	0	%
Estimate of the 95% LCL for F	0	%
Estimate of the 95% UCL for F	**5.4**	%

Figure 18. Pantex Exposure Trend



Comments

The work histories of current Pantex employees with beryllium sensitization and CBD have been investigated, but researchers have been unable to identify characteristics the cases have in common that point to likely sources of exposure. Therefore, the discrepancy between health data indicating significant risk and monitoring data that show low exposure levels remains unexplained.

Kansas City Plant

Site Description

The Kansas City Plant (KCP) is situated on approximately 141 acres of the Bannister Federal Complex located 12 miles south of downtown Kansas City, Missouri. The facility was built by the Navy during World War II to assemble engines for U.S. Navy fighter planes. In 1949, the Atomic Energy Commission asked the Bendix Corporation to manage the facility and build non-nuclear components for nuclear weapons. Over the past 50 years, the products manufactured at the KCP have become smaller and much more complex. The facility has evolved into a research production facility that specializes in science-based manufacturing. The KCP operates 3 major factories involved in the development and production of non-nuclear weapons components, and produces more than 40 product lines for the nation's defense system.

Beryllium Operations

Small quantities of copper beryllium alloys are used for fabrication of electronic components. Exposure monitoring of these operations indicated very low potential for exposures that might exceed exposure limits, and no routine exposure monitoring programs were implemented. Subsequent to finding beryllium sensitization among KCP workers, the pattern of contamination detected by surface sampling indicated that beryllium oxide ceramic process equipment used in the production of engineered materials may have been a source of beryllium exposure. The work area where this equipment was used to produce materials and the work area where the material was used for subsequent parts fabrication operations were found to be contaminated with beryllium. Decontamination work has been ongoing; therefore, there is a continuing potential for beryllium exposure.

Beryllium Workers

The potential for significant beryllium exposure was not recognized at KCP initially, and no records have been found that could be used to identify potentially exposed workers. The manufacturing operations at KCP have been highly flexible to produce small numbers of a wide variety of components and materials. Historically, a significant proportion of KCP workers performed the facility and equipment remodeling (retooling) needed to achieve manufacturing flexibility. The 1,011 participants in the Beryllium Worker Medical Surveillance Program have self-identified that they worked with beryllium or believe their work may have exposed them to beryllium. Of these, 118 have been monitored for beryllium exposure at some time in their career, and 13 employees were monitored in 2005.

Beryllium Sensitization and CBD Rates

A total of 1,011 current KCP employees have been screened for CBD. Beryllium sensitization and CBD results among current workers are shown in Figure 19. Twenty-one of the current employees were reported to be sensitized and 11 were reported diagnosed with CBD. Figure 20 shows the numbers and rates by work activity (or job) categories, indicating similar rates for workers with a wide variety of job duties.

Figure 19. KCP Current Worker Health Data

Number of Workers in Roster	1,089
Number with BeLPT Results	1,011
Number Sensitized	21
Number with Clinical Evaluations	31
Number with CBD	11
Rate Sensitized or CBD	3.2%

Figure 20. KCP Current Worker Health Data by Work History Activity

Activity	Number with BeLPT Results	Number Sensitized	Number CBD	Rate Sensitized or CBD
Management	64	0	0	0.0%
Administrative Support	120	4	0	3.3%
In-House Professionals	2	0	0	0.0%
Field Professionals	110	2	1	2.7%
Technical Support	162	4	3	4.3%
Biohazard	12	1	0	8.3%
Service	82	1	1	2.4%
Security and Fire	71	0	2	2.8%
Crafts	236	5	0	2.1%
Line Operators	152	4	4	5.3%
All Subjects	1,011	21	11	3.2%

Beryllium Exposure Monitoring Results

In 2005, a total of 398 personal exposure monitoring samples were collected among 13 current KCP workers. All of the results were non-detects, indicating a high rate of compliance with the 0.2 µg/m^3 action level. All 209 exposure monitoring samples collected among 24 workers in 2003 and 2004 were non-detected results. However, these results are difficult to interpret because the laboratory reporting limits for some samples were higher than the DOE action level of 0.2 µg/m^3. In 2001 and 2002, a total of 103 samples were collected from 45 KCP workers; all results were non-detected and laboratory reporting limits were lower than the action level. This was also true for the 106 samples collected among 45 workers in 2000.

Comments

The KCP health data indicate beryllium sensitization and CBD rates similar to those at sites with beryllium fabrication operations. However, KCP lacks a history of extensive fabrication operations or exposure monitoring data that identify a significant source of exposures. Also, investigation of the work histories of cases has not identified a common characteristic of work associated with beryllium sensitization and CBD at KCP.

East Tennessee Technology Park

Site Description

The East Tennessee Technology Park (ETTP), formerly known as the K-25 Plant, is located on 4,689 acres in Roane County, Tennessee, 13 miles west of downtown Oak Ridge. The current site configuration is the product of past missions and programs, the most significant of which was the Oak Ridge Gaseous Diffusion Plant, which operated from the end of World War II until 1985. Most of the buildings are 30 years or older. The primary mission of ETTP is decontamination and decommissioning of facilities and equipment, and environmental restoration of the site. ETTP also operates a Toxic Substances Control Act (TSCA) incinerator, which handles radioactive, hazardous, and uranium-contaminated polychlorinated biphenyl (PCB) wastes. The long-term goal for ETTP is to convert the site into a private industrial park. The reuse of key site facilities through title transfer is part of the closure plan for the site.

Beryllium Operations

In addition to operation of the gaseous diffusion plant, shop areas at ETTP supported a variety of defense and energy research and development missions. Work for Others projects included fabrication of beryllium components. As a result, contaminated equipment and facilities are undergoing decontamination and decommissioning.

Beryllium Workers

Current workers have been given an opportunity to participate in medical surveillance programs. By the end of 2005, 695 current employees had participated in the programs. From 2002 to 2005, 97 workers were monitored for beryllium exposure while working at ETTP.

Beryllium Sensitization and CBD Rates

The numbers and rates of beryllium sensitization and CBD among current workers are shown in Figure 21. Among the 695 workers screened, 9 were found to be sensitized to beryllium and 5 were diagnosed with CBD.

Figure 21. ETTP Current Worker Health Data

Number of Workers in Roster	913
Number with BeLPT Results	695
Number Sensitized	9
Number with Clinical Evaluations	5
Number with CBD	5
Rate Sensitized or CBD	2.0%

Beryllium Exposure Monitoring Results

Results from 2002 through 2005 are difficult to interpret due to non-detected values with laboratory reporting limits above the 0.2 µg/m^3 action level (Figure 22). As a result, compliance with the action level is uncertain, and estimates do not support a conclusion that fewer than 5% of exposures exceeded the action level in those years.

Figure 22. ETTP Exposure Metrics for June 2002 – July 2005

Kaplan-Meier (KM) Estimate of Arithmetic Mean (EX)	0.003	µg/m^3
KM 95% Lower Confidence Limit (LCL) for EX	0.002	µg/m^3
KM 95% Upper Confidence Limit (UCL) for EX	0.004	µg/m^3
Observed 95th Percentile of data	0.006	µg/m^3
Estimate of the 95th Percentile - 95% Upper Tolerance Limit	**0.207**	µg/m^3
Largest value in the data set	0.412	µg/m^3
Percent of results that are non-detects	98.0	%
Number of observations in the data set	298	
Number of detected results	6	
Number of individuals monitored	97	
Estimate of percent exceeding 0.2 µg/m^3 (F)	5.7	%
Estimate of the 95% LCL for F	3.7	%
Estimate of the 95% UCL for F	**8.4**	%

Comments

Sensitization and CBD rates among current employees screened at ETTP are higher than at other DOE sites except for Y-12, KCP, and Pantex. These results suggest a need to investigate beryllium sensitization and CBD cases among current ETTP employees to identify possible causes of exposure that have not been recognized. ETTP should establish data quality objectives for exposure monitoring that include use of sampling and analytical methods with reporting limits less than the DOE action level of 0.2 $\mu g/m^3$.

Nevada Test Site

Site Description

The Nevada Test Site (NTS) is located on 864,000 acres with the southern entrance to the site approximately 65 miles north of Las Vegas. It is one of the largest secured areas in the United States. The NTS has seen more than four decades of nuclear weapons testing. Since the nuclear weapons testing moratorium in 1992, the NTS has diversified into many program areas, such as subcritical experiments, hazardous chemical spill tests, emergency response training, conventional weapons testing, waste management, and environmental technology studies. The NTS conducts both non-destructive and destructive tests of nuclear weapons components in support of the nuclear weapons stockpile stewardship program.

The NTS is supported by laboratories and facilities in and near Las Vegas that develop specialized sensors and sensor systems, instrumentation and high-speed recording systems, and data analysis and data communication equipment. Employees in California, Maryland, Nevada, and New Mexico perform aerial radiation and environmental surveys of government sites, industrial nuclear power plants, and mining sites around the world to measure the levels of background and man-made radiation. They are part of the DOE nuclear emergency response program.

Beryllium Operations

The NTS has a legacy of beryllium use associated with nuclear weapons tests and tests of experimental reactors. Beryllium-containing materials were used in instruments fabricated and assembled to support the nuclear weapons testing mission. Beryllium components in experimental reactors were disassembled, inspected, declassified, and disposed of.

Beryllium Workers

Current workers have been given an opportunity to participate in medical surveillance programs. By the end of 2003, 651 current employees had participated. In 2002 and 2003, there were 34 workers monitored for beryllium exposure while working at NTS.

Beryllium Sensitization and CBD Rates

The numbers and rates of beryllium sensitization and CBD among current workers are shown in Figure 23. Among the 651 workers screened, 10 were reported to be sensitized to beryllium and none were reported to be diagnosed with CBD.

Figure 23. NTS Current Worker Health Data

Number of Workers in Roster	794
Number with BeLPT Results	651
Number Sensitized	10
Number with Clinical Evaluations	NA
Number with CBD	0
Rate Sensitized or CBD	1.5%

Beryllium Exposure Monitoring Results

Results from 2002 through 2003 indicate a very high rate of compliance with the 0.2 µg/m^3 action level (Figure 24). The upper confidence limit of the percent exceeding metric supports a conclusion that fewer than 5% of exposures exceeded the action level in those years.

Figure 24. NTS Exposure Metrics for 2002 – 2003

Kaplan-Meier (KM) Estimate of Arithmetic Mean (EX)	0.006	µg/m^3
KM 95% Lower Confidence Limit (LCL) for EX	0.005	µg/m^3
KM 95% Upper Confidence Limit (UCL) for EX	0.007	µg/m^3
Observed 95th Percentile of data	0.020	µg/m^3
Estimate of the 95th Percentile - 95% Upper Tolerance Limit	**0.025**	µg/m^3
Largest value in the data set	9.635	µg/m^3
Percent of results that are non-detects	57.7	%
Number of observations in the data set	477	
Number of detected results	202	
Number of individuals monitored	34	
Estimate of percent exceeding 0.2 µg/m^3 (F)	0.2	%
Estimate of the 95% LCL for F	0.01	%
Estimate of the 95% UCL for F	**1.0**	%

Comments

The NTS has not reported any health or exposure data to the Registry since 2003. Plans are in place and work is progressing to correct this by February 2007.

Summary of All Reported Data

Health Data for All Current Employees

Figure 25 provides summary health data from the 20 organizations providing information on current employees to the Beryllium-Associated Worker Registry.

Figure 25. Summary Data for All Current Employees

Site	Number Tested	Number Sensitized	Number CBD	Rate Sensitized or CBD
Rocky Flats Environmental Technology Site	3,980	31	0	0.8%
Hanford Reservation	3,359	42	19	1.8%
Los Alamos National Laboratory	1,661	2	3	0.3%
Y-12 National Security Complex	1,642	44	42	5.2%
Pantex Plant	1,617	17	15	2.0%
Kansas City Plant	1,011	21	11	3.2%
East Tennessee Technology Park	695	9	5	2.0%
Nevada Test Site	651	10	0	1.5%
Savannah River Site	428	8	0	1.9%
Sandia National Laboratories	396	0	0	0%
Lawrence Livermore National Laboratory	281	0	0	0%
Oak Ridge National Laboratory	222	1	0	0.5%
Argonne National Laboratory	90	3	0	3.3%
DOE Oak Ridge Operations	82	1	0	1.2%
Idaho National Laboratory	51	0	0	0%
Wackenhut Security Services Inc.	51	0	0	0%
Knolls Atomic Power Laboatory	22	0	0	0%
Fermi National Accelerator Laboratory	18	0	0	0%
Brookhaven National Laboratory	9	0	0	0%
Southwest Power Administration	1	0	0	0%
All Sites Combined	16,267	189	95	1.7%

Summary of Personal Exposure Monitoring Results

Figures 26, 27, and 28 provide summary exposure monitoring results for 14 of the 15 sites reporting exposure data to the Beryllium-Associated Worker Registry. As described earlier, data from the Kansas City Plant are not included because they did not support the calculation of statistical metrics. Figure 26 shows the time periods over which the monitoring results apply.

Summaries of the exposure monitoring results in Figures 26 and 27 do not consider the use of respiratory protective equipment. Exposure monitoring that demonstrates 95% confidence that fewer than 5% of exposure levels exceed limits is considered to be proof of compliance with the 10 CFR 850 action level. Sites in Figure 27 for which the upper confidence level is less than 5% meet this criterion. Sites in which the lower confidence level is above 5% are out of compliance. When the span of the confidence interval includes 5%, compliance is considered to be uncertain. Figure 28 provides a reanalysis of exposure data adjusted for use of respiratory protective equipment from five sites whose unadjusted data indicated they were out of compliance or that compliance was uncertain. The reanalysis indicates that compliance at Argonne National Laboratory and Fermi National Accelerator Laboratory remains uncertain. These two laboratories have had relatively few monitored beryllium operations in recent years, and these metrics are more representative of working conditions that existed in the past than of ongoing work. They do indicate that future beryllium work will require detailed attention to minimize exposures.

Figure 26. Summary Exposure Monitoring Statistics

Metrics	ANL	Fermi	Hanford	INL	KAPL	LANL	LLNL	NTS	ORNL	Pantex	RFETS	SNL	SRS	Y-12	Units
Arithmetic Mean	0.07	0.28	0.0010	0.00	0.02	0.02	0.07	0.01	0.02	0.00	0.02	0.13	0.01	0.02	$\mu g/m^3$
LCL for Mean	0.00	-0.10	0.0000	0.00	-0.04	0.01	0.03	0.01	-0.04	0.00	0.01	-0.08	0.01	0.01	$\mu g/m^3$
UCL for Mean	0.13	0.67	0.0030	0.01	0.07	0.02	0.11	0.01	0.07	0.00	0.02	0.34	0.02	0.03	$\mu g/m^3$
Observed 95th%	0.29	0.36	0.0010	0.01	0.03	0.01	0.13	0.01	0.01	0.00	0.03	0.02	0.05	0.09	$\mu g/m^3$
95/95 UTL	**NA**	**NA**	**0.01**	**0.06**	**0.23**	**0.03**	**0.50**	**0.02**	**0.16**	**NA**	**0.06**	**0.10**	**0.10**	**0.42**	$\mu g/m^3$
Maximum	1.29	4.80	0.01	0.07	0.24	1.22	5.13	6.21	0.67	0.02	0.88	19.00	0.10	0.48	$\mu g/m^3$
% Non-Detect	85.2	62.5	97.3	94.3	98.2	96.9	86.5	17.5	98.1	96.3	92.3	56.6	87.9	83.9	%
Number of Results	54	24	74	122	111	1527	266	223	105	54	324	152	107	93	
Number > LOD	8	9	2	7	2	48	36	184	2	2	25	66	13	15	
% > 0.2 $\mu g/m^3$ (F)	7.4	20.8	0.0	0.0	2.7	0.2	4.9	0.4	1.0	0.0	0.3	0.7	0.0	2.2	%
LCL for F	2.6	8.6	0.0	0.0	0.7	0.1	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.4	%
UCL for F	**16.2**	**38.9**	**4.0**	**2.4**	**6.8**	**0.5**	**7.7**	**2.1**	**4.4**	**5.4**	**1.5**	**3.1**	**2.8**	**6.6**	%
Minimum Date	Apr-02	Nov-86	Jan-05	Jan-05	Feb-95	Jan-05	Jan-05	Jan-03	Jan-02	Feb-05	Jan-05	Jan-04	Jan-02	Jan-05	
Maximum Date	Nov-02	May-04	Dec-05	Dec-05	Jan-05	Dec-05	Dec-05	Sep-03	Nov-04	Dec-05	Jun-05	Dec-04	Dec-04	Dec-05	

LCL: Lower Confidence Limit
UCL: Upper Confidence Limit
UTL: Upper Tolerance Limit
LOD: Limit of Detection

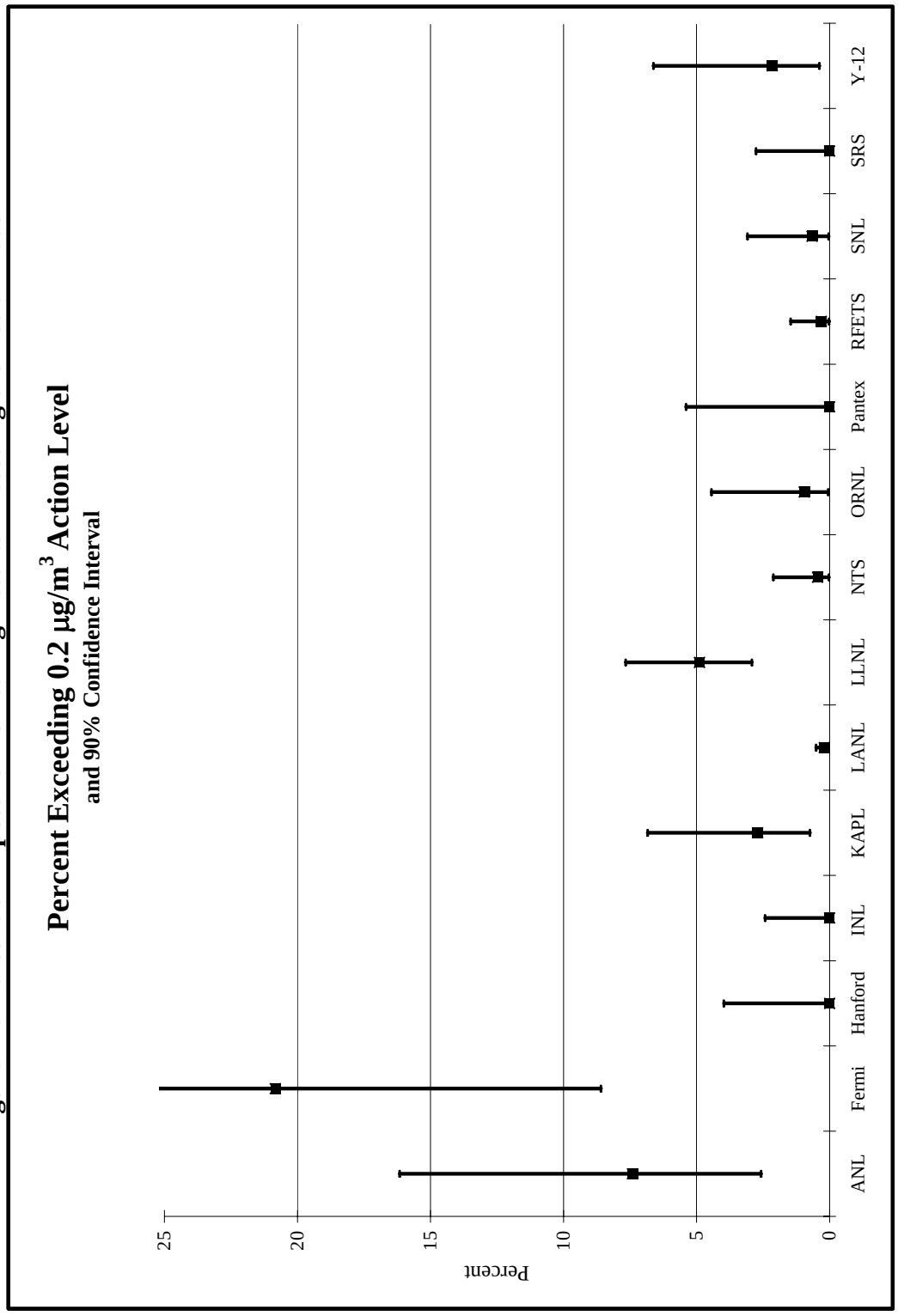


Figure 27. Percent of Exposure Monitoring Results Exceeding the Action Level

Figure 28. Exposure Levels Considering Respirator Assigned Protection Factors