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Beryllium Contamination Inside Vehicles of Machine Shop Workers

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Inhalation of beryllium particles causes a chronic, debilitating lung disease—chronic beryllium disease (CBD)—in immunologically sensitized workers. Evidence that very low concentrations of beryllium may initiate this chronic disease is provided by incidences of the illness in family members exposed to beryllium dust from workers' clothes and residents in neighborhoods surrounding beryllium refineries. This article describes the results of a cross-sectional survey to evaluate potential take-home beryllium exposures by measuring surface concentrations on the hands and in vehicles of workers at a precision machine shop where cases of CBD had recently been diagnosed. Many workers did not change out of their work clothes and shoes at the end of their shift, increasing the risk of taking beryllium home to their families. Wipe samples collected from workers' hands and vehicle surfaces were analyzed for beryllium content by inductively coupled argon plasma-atomic emission spectroscopy (ICP-AES). The results ranged widely, from nondetectable to 40 $\mu g/ft^2$ on workers' hands and up to 714 $\mu g/ft^2$ inside their vehicles, demonstrating that many workers carried residual beryllium on their hands and contaminated the inside of their vehicles when leaving work. The highest beryllium concentrations inside the workers' vehicles were found on the drivers' floor (GM = 19 $\mu g/ft^2$, GSD = 4.9), indicating that workers were carrying beryllium on their shoes into their vehicles. A safe level of beryllium contamination on surfaces is not known, but it is prudent to reduce the potential for workers to carry beryllium away from the work site.

Keywords Beryllium, Machinists, Surface Beryllium Contamination, Take-Home Exposure

INTRODUCTION

Inhalation of beryllium compounds is associated with a chronic debilitating lung disease, chronic beryllium disease (CBD), characterized by granulomas in the lungs and mediastinal lymph nodes.[1] CBD is the result of a beryllium-specific T lymphocyte-mediated hypersensitivity.[2,3]

First described by Hardy and Tabershaw in 1946, most of the early CBD cases were workers exposed to high concentrations of beryllium-containing phosphors manufacturing fluorescent light bulbs.[4] Family members of beryllium workers, who apparently inhaled beryllium dust carried home on workers' clothes, also developed CBD.[5–7] The wives of beryllium-exposed workers reported that clothing was often covered with a fine, gray-black soot which they shook off before washing.[8] Eisenbud estimated that as much as 17 μg of beryllium could be inhaled during the laundering of work clothes[6]; CBD is not necessarily associated with massive exposures to beryllium. CBD was also documented among residents in neighborhoods surrounding beryllium refineries and among non-production workers with comparatively lower beryllium exposures than production workers, indicating that relatively low beryllium exposure levels could cause CBD in sensitive individuals.[6,9,10]

Workers may carry contaminants from the work site into their personal environment on their skin, hair, clothing, or shoes. Previous studies have shown that workers' taking home workplace contaminants, such as lead,[11] asbestos,[12] beryllium,[6,9] and polycyclic compounds,[13] has affected the health of their

families. No studies have examined the influence that work practices have on the extent of beryllium taken home from the workplace. In some workplaces where beryllium is used, hygiene programs have been established requiring workers to shower and change out of their work clothes before leaving the work site for home. However, no controlled studies have been conducted on this intervention strategy to evaluate its acceptance in the workplace and its effectiveness in reducing take-home exposures.

Beryllium exposure from natural sources is at very low levels. Possible sources of beryllium which can contribute to exposures in residential environments include the smoking of cigarettes and contamination from the burning of coal and fuel oil; however, contamination from these sources is low and measurements for beryllium in the ambient air have usually been below the 0.01 $\mu g/M^3$ standard set by the Environmental Protection Agency (EPA) in 1973.[14] Therefore, the primary source of beryllium contamination on workers' hands and clothes, inside their automobiles, and in their homes is linked to exposures at work.

Study Objectives and Hypotheses

The objective of this study was to characterize the potential for workers in a precision machine shop, manufacturing beryllium products, to carry beryllium away from the work site and into their personal environments. Beryllium contamination was measured on the hands of workers at the end of their shifts as they were leaving for home, and inside their automobiles. The purpose of the measurements was to determine to what degree machine shop employees carried beryllium away from work and to what degree workplace hygiene practices (e.g., use of showers and changing clothes before leaving work) influenced beryllium removal from the work site. This study is the most recent examination of potential take-home beryllium exposure in beryllium manufacturing industries since Eisenbud evaluated exposures associated with laundering.

METHODS

Description of Plant and Study Participants

The plant began operations in 1972, manufacturing a variety of specialty products using beryllium, aluminum, titanium, stainless steel, and other alloyed metals. Metal stock is inspected and stored until distributed to appropriate workstations. Initially, metal stock is machined in the milling or lathe departments. Many of the parts then are refined at the deburring workstation and in the precision grinding department. Some parts are taken to the lapping department where they are finished to a specified tolerance using both machine and hand lapping. In the E-cell room located near the lathe and grinding areas, only parts made from beryllium oxide composites are milled and lapped. In the chemistry department, a small number of parts have excess metal removed in acid baths. Machining production is supported by workers in engineering and design, sales and administration (office), management supervision, material handling, toolmaking, inspection, and maintenance.

Most individuals do not work with beryllium containing metal on every workday, but beryllium products are manufactured somewhere within the plant each day and constitute the majority of metal used in the plant. Although every worker in the plant has the potential to be exposed to beryllium, individuals working with beryllium-containing metal have the greatest potential exposure.

Workers are provided with uniforms consisting of shirts and pants, or they may choose to wear shop coats over their street clothes. The workers are also provided shoes which may be left at the work site. Five clean uniforms for each worker are delivered weekly by a professional uniform supply company; the uniforms are hung on racks in a passageway near the machining area until worn by the employees. Used uniforms are placed inside large baskets located within passageways until collected once per week by the uniform supply company. Dressing rooms including showers are located within the plant, but to enter and leave them workers must pass through production areas where beryllium is used.

The plant has two main work areas. The office area is in the front of the building separated by walls and doors from the machining area. The machining area is a large open space including the machining, lathe, and grinding departments; production workers rarely enter the office area, but managers and other office workers often pass through the machine shop areas.

After a machinist at the plant was diagnosed with CBD in 1994, a medical screening study of the workforce and a large industrial hygiene survey to evaluate airborne beryllium exposures inside the plant were initiated. This study—a cross-sectional survey measuring contamination on the hands and inside the personal vehicles of workers—was a supplement to the larger study of in-plant inhalation exposures. The results of the air sampling study are reported separately.[15]

Samples were collected during the first and second shifts over a 5-day period. All workers were potentially eligible to participate, but due to time constraints wipe samples could logistically only be collected from the hands of and inside vehicles belonging to a few individuals (10 to 15) during each day. From a roster of employees, a subset of workers representing every major job category was randomly selected without any prior knowledge about their individual characteristics or work practices. For estimation of background beryllium levels, wipe samples were collected inside control vehicles belonging to individuals from other workplaces in the vicinity of the plant with no beryllium exposure; air samples were also collected in the parking lot around the machining plant.

Study participants completed an interviewer-administered questionnaire concerning their work history, job duties, the wearing and handling of work clothes, frequency of showering and washing hands, eating and smoking habits, and demographic information.

Sampling and Analytical Methods

Hand wipe samples were obtained by study participants wiping their hands using commercial wet wipes (Wash'n Dri-Moist Towelettes®) after they had performed their normal routine, such as washing their hands and changing clothes, and before they left the work site at the end of their shift. They were instructed to lift a fresh wet wipe from its opened container and to wipe both hands thoroughly (including the front and back, up to the wrists, and each finger), removing as much visible dirt as possible. The hand wiping exercise was supervised and timed for 30 seconds by NIOSH investigators to ensure consistency from subject to subject. A tracing of the right hand of each participant was measured to estimate the total surface area of each of the participants' hands.

Wipe samples were collected inside the workers' vehicles while they were parked within 200 yards of the plant entrance in the employee parking lot. Wipe samples were collected inside each vehicle from the following locations: steering wheel, driver's door armrest, driver's seat, floor beneath steering wheel, front passenger's seat, and front passenger's floor. Wipe samples were collected on the dash from approximately half the vehicles, and if a child's restraining seat was present, it was sampled as well.

Before collecting the wipe samples from floor and seat locations, the surface area was outlined using a disposable plastic template with interior dimensions of 17.5 × 17.8 cm (0.335 ft^2). The surface areas of the armrests and steering wheels were measured directly using a flexible measuring tape. A single wet wipe was firmly drawn across each sample surface using a series of horizontal strokes, followed by vertical strokes, and finally a series of diagonal strokes, for a total of three passes over the surface area sampled.[16]

Field survey information was collected using standardized forms. The make, model, and age of each vehicle was recorded, as well as how long the worker had owned the vehicle, the last time the vehicle was reported vacuumed, a subjective evaluation by investigators of the cleanliness of the vehicle (dirty, moderate, clean), and the type of surface that was being sampled (cloth, carpet, or vinyl). The activities that workers performed and the number of times they washed their hands on the day they submitted a hand wipe sample were also recorded.

Wipe samples were placed into beryllium-free plastic vials and labeled for shipment to the laboratory for analysis. Each day, wipe samples which contacted no potentially contaminated surfaces were submitted as field blanks and blank corrections were made to the vehicle and hand wipe sample results. Wipe samples spiked with known amounts of beryllium were also submitted for quality control evaluation of the analytical technique; the results of these samples were within ± 10 percent of the spiked concentrations.

Samples were analyzed for beryllium using inductively coupled argon plasma-atomic emission spectroscopy (ICP-AES) according to NIOSH Method 7300.[16] The wipe samples were digested on hotplates in the presence of concentrated nitric acid and 30% hydrogen peroxide. The samples were analyzed using a Perkin Elmer 3000DV inductively coupled plasma emission spectrometer controlled by ICP WinLab software. The estimated limit of detection (LOD) for this method was 0.01 μg of beryllium per sample. The results of the hand samples were reported for both hands in $\mu g/ft^2$. Results for vehicle wipe samples were also reported in $\mu g/ft^2$.

Air samplers were placed in the parking lot and near the particle collection exhaust system at the rear of the plant. These samples were collected on 37-mm cellulose ester filters at a flow rate of 2 L/min for over 10 hours and chemically analyzed for beryllium content using the same method as that used for wipe samples.

Statistical Analysis

Statistical Analysis System (PC-SAS®) computer software was used for all statistical analyses.[17] Because the distributions of the beryllium measurements were right skewed, the measurements were transformed using the natural logarithm. Therefore, geometric means (GM) and geometric standard deviations (GSD) of the measurements were reported. For purposes of calculating the GM (GSD), wipe samples reported to have a nondetectable concentration of beryllium were given a value of the LOD/$\sqrt{2}$.[18] Analyses of covariance and student's *t*-test were used to test differences in the mean beryllium measurements across various job and work practice categories. Since the causes of beryllium contamination inside workers' vehicles were multifactorial, multivariable linear regression was used to test the influence of various factors on beryllium concentrations.

RESULTS

Descriptive Characteristics of Subjects

Sixty-one workers provided hand wipe samples at the end of their shifts and had the interiors of their vehicles sampled for beryllium. Only two workers who were asked to participate in the study refused. The samples were collected during one week in mid-September while daytime temperatures were 21° to 25°C. Most of the participants in the study were white (98%) and male (89%) and in their 30s and 40s. The average job tenure was 14 years. Most of the participants were selected from production jobs with the greatest number of workers—milling, lathe, and lapping—but all major job categories were represented. Six (9.8%) of the participants were office workers who had limited contact with beryllium.

Distribution of Potential Risk Factors for Beryllium Inside Workers' Vehicles

About 80 percent of the production workers reported that they always or usually changed their shirt before going home or wore a shop coat over street clothes while working (Table I). In this study, wearing a shop coat was considered equivalent to changing one's shirt. However, slightly over half of the workers

TABLE I
Distribution of production workers by factors which may influence beryllium concentrations inside their vehicles

	# Workers*	%
Change shirt before going home or wore shop coat		
Always	39	70.9
Usually	5	9.0
Sometimes	1	1.8
Never	10	18.2
Change pants before going home		
Always	26	47.3
Usually	5	9.1
Sometimes	2	3.6
Never	22	40.0
Change shoes before going home		
Always	29	52.7
Usually	0	0.0
Sometimes	3	5.5
Never	23	41.8
Use vehicle during lunch break without changing work clothes		
Yes	22	40.0
No	33	60.0
Length of time owned vehicle (years)		
≤ 0.75	13	23.6
> 0.75–2	15	27.3
> 2–4	13	23.6
> 4	14	25.5
Cleanliness of vehicle		
Clean	21	38.2
Average	21	38.2
Dirty	13	23.6
Time since last vacuumed vehicle (months)		
≤ 0.5	15	27.3
> 0.5–1	13	23.6
> 1–4	14	25.5
≥ 5	13	23.6

*The six office workers who participated in the study are excluded from this table.

always or usually changed their work pants and shoes before going home. Also, 40 percent of the workers reported that they used their vehicle during lunch breaks without changing work clothes or shoes. The length of time the participants had owned their vehicles, the time since they recalled having last vacuumed them, and the relative cleanliness are also reported in Table I. Office workers are excluded from this table because they spent the majority of their time in the office area and none of them wore the company-supplied uniforms. Although all of the workers reported washing their hands before going home, none showered before leaving work.

Beryllium Concentrations Inside Workers' Vehicles

The beryllium concentrations detected on wipe samples from inside workers' vehicles and control vehicles are presented in Table II. The greatest amount of beryllium was found on wipe samples from the driver's floor (GM = 19 $\mu g/ft^2$, GSD = 4.9). The next highest geometric mean values were considerably less: 4.9 $\mu g/ft^2$ for the passenger's floor and 4.5 $\mu g/ft^2$ for the driver's armrest. The measurements from all locations varied across a wide range, up to several hundred $\mu g/ft^2$ in some workers' vehicles, many times the GM. Only 29 dashboard samples were collected and the levels were relatively low with only one sample exceeding 25 $\mu g/ft^2$. No beryllium was detected on samples from the three child safety seats that were tested.

Ten vehicles—three rental cars, five vehicles belonging to restaurant and hotel workers, and two vehicles belonging to roofers—were sampled to provide estimates of background beryllium contamination (controls). Beryllium was detected in 21 of the 70 (30%) wipe samples collected from these vehicles. The driver's floor samples contained the greatest amounts of beryllium, but only one sample from the floor of a roofer's vehicle exceeded 1 $\mu g/ft^2$. No beryllium was detected on eight air samples collected around the parking lot and near the plant exhaust system.

The beryllium concentrations inside workers' vehicles are shown by job category in Table III. Wipe samples from vehicles owned by workers in E-cell, where beryllium oxide parts were continuously machined, tended to have higher concentrations of beryllium, followed by vehicles owned by milling machinists and deburrers. Little beryllium was found in the vehicles owned by office workers; in fact, only samples from the vehicle floors contained detectable amounts of beryllium. The beryllium concentrations in all locations were highest in the vehicles of productions workers (including milling machinists, lathe operators, grinders, lappers, E-Cell workers, and deburrers). The beryllium concentrations inside the vehicles of production support workers (including manufacturing supervisors, inspectors, and stock and material handlers) were somewhat lower, but the concentrations in the vehicles of both these work groups were higher than in office workers' vehicles.

Multiple factors which may influence beryllium concentrations inside workers' vehicles—such as changing from work shoes and clothing before leaving work, using vehicles on lunch breaks, time since the vehicle was last vacuumed, and number of years the worker owned the vehicle—were evaluated. The number of months since the vehicle was last vacuumed was significantly ($p < 0.05$) associated with beryllium concentrations on the driver's and passenger's floor, the driver's seat, driver's armrest, and the steering wheel, indicating that beryllium concentrations tended to be lower in vehicles which had been cleaned more recently. The only variable consistently associated with

TABLE II
Beryllium concentrations inside machine shop workers' vehicles and control vehicles by location

	Wipe samples from machine shop workers' vehicles				Wipe samples from 10 control vehicles	
Location	No. samples	GM (GSD) $\mu g/ft^2$	Maximum concentration $\mu g/ft^2$	% Samples > 25 $\mu g/ft^2$	No. samples > LOD	Maximum concentration $\mu g/ft^2$
Steering wheel	61	2.3 (2.9)	49	3.3	1	0.03
Driver's armrest	61	4.5 (4.9)	369	9.8	2	0.07
Driver's seat	61	2.4 (3.7)	148	6.6	1	0.006
Driver's floor	61	19.0 (4.9)	714	44.3	6	2.1
Passenger's seat	61	1.7 (2.9)	70	4.9	3	0.04
Passenger's floor	61	4.9 (5.7)	234	21.3	3	0.06
Dash	29	1.9 (2.9)	40	3.4	5	0.13
Child seat	3	< LOD	< LOD	0.0	—	—

GM = geometric mean.
GSD = geometric standard deviation.
LOD = analytical lower limit of detection for beryllium.

beryllium levels in the various vehicle locations was time since the vehicle was reported last vacuumed, with beryllium concentrations increasing as time since last vacuuming increased. Beryllium concentrations in vehicles of workers who claimed they had ever changed their shirts, pants, or shoes at the end of a shift were not significantly lower than in the vehicles of workers who reported they never changed. No differences in beryllium concentration were found by type of surface sampled—cloth, carpet, or vinyl.

Beryllium Concentrations on Hand Wipe Samples

Beryllium concentrations from hand wipe samples are presented by job category in Table IV. Beryllium was detected on the hand wipe samples from all of the machining, lathe, and deburring operators. In comparison, only two of six office workers had detectable, yet low, beryllium concentrations on their hand wipes. Workers who reported handling beryllium products on the day their hand wipe sample was collected had significantly greater amounts of beryllium on their hands than did workers who did not handle beryllium products (GM = 7.3 versus GM = 2.2, $p = 0.0002$). No relationship was observed between the concentrations on the hands and the number of times that workers reported washing their hands during the shift, but the amount of beryllium on hand wipe samples was somewhat correlated with beryllium concentrations on samples from the steering wheel ($r = 0.45$, $p = 0.0003$) and driver's armrest ($r = 0.41$, $p = 0.001$).

TABLE III
Comparison of beryllium concentrations inside workers' vehicles by job area

	Location Geometric mean (geometric standard deviation) $\mu g/ft^2$					
Job area (# samples)	Steering wheel	Driver's armrest	Driver's seat	Driver's floor	Passenger's seat	Passenger's floor
Milling (16)	3.9 (3.0)	12.0 (4.4)	3.7 (5.1)	38.0 (4.2)	3.0 (4.6)	16.0 (4.8)
Lathe (6)	3.7 (2.9)	6.0 (9.9)	3.0 (2.6)	28.0 (6.8)	1.1 (1.3)	2.6 (6.0)
Grinding (3)	1.8 (1.7)	3.0 (3.8)	2.6 (3.3)	51.0 (1.2)	1.2 (1.4)	3.7 (8.9)
E-Cell (4)	13.0 (3.4)	26.0 (1.6)	8.1 (4.0)	71.0 (5.1)	1.7 (2.1)	11.0 (7.0)
Lapping (12)	1.4 (1.9)	2.2 (4.0)	1.5 (2.1)	11.0 (2.4)	1.6 (2.9)	2.8 (4.6)
Debur (2)	3.2 (5.1)	13.0 (1.1)	3.5 (6.0)	7.9 (2.2)	2.2 (3.1)	5.4 (4.9)
Production Support (12)	1.4 (1.6)	2.4 (2.6)	1.8 (4.4)	18.0 (5.1)	1.5 (2.5)	3.6 (6.6)
Office (6)	< LOD	< LOD	< LOD	2.2 (2.6)	< LOD	1.6 (2.2)

LOD = analytical lower limit of detection for beryllium.

TABLE IV
Beryllium concentrations on hand wipe samples by job area

Job area	No. samples	GM (GSD) $\mu g/ft^2$	Maximum concentration $\mu g/ft^2$
Milling	16	6.3 (2.3)	19.0
Lathe	6	8.0 (2.9)	30.0
Grinding	3	5.6 (1.0)	5.8
E-Cell	4	30.0 (1.9)	54.0
Lapping	12	2.3 (2.7)	10.7
Debur	2	21.0 (1.5)	29.0
Production support	12	4.5 (4.2)	43.0
Office	6	1.0 (1.1)	1.3

DISCUSSION AND CONCLUSIONS

This is the first reported study to examine potential take-home beryllium exposure in the modern beryllium machining industry. The measurements collected during this 1-week study show that many workers had residual beryllium on their hands when they left work and beryllium contamination inside their vehicles. The highest beryllium levels were on the driver's side of vehicles, particularly the floor, indicating that workers were potentially carrying beryllium home with them on their hands, clothing, and shoes. Office workers could not be considered truly unexposed since their workstations were closely associated with the beryllium production areas which they occasionally entered, but samples collected inside their vehicles and the vehicles of individuals from other workplaces with no beryllium exposure clearly indicated that background beryllium contamination from environmental sources is very low.

The location of beryllium inside vehicles indicates its potential source. Beryllium on steering wheels and armrests is probably deposited by workers' hands and shirtsleeves, and beryllium on seats and floors probably comes from workers' clothing and shoes. The beryllium found on the dashboards may be from the airborne settling of suspended beryllium particles from workers' clothing or other surfaces inside the vehicle. Beryllium concentrations on the dashboards of control vehicles and vehicles owned by office workers were very low and no beryllium was detected on air samples around the parking lot, supporting the conclusion that beryllium from environmental sources is unlikely to be the source of beryllium found in workers' vehicles.

Unexpectedly, average beryllium concentrations were not lower on the floors and seats of the cars of workers who claimed they routinely changed clothes and shoes before leaving work. Several reasons may explain this observation. Some workers, who reported wearing the company-supplied uniform, occasionally used their vehicles during their lunch breaks without changing clothes. Even infrequent wearing of beryllium-laden clothing inside the vehicles could result in substantial contamination over time. Workers possibly contaminated their street clothing because the locker rooms were not divided into clean and dirty sides such to prevent street clothes from contacting contaminated work clothes. In addition, as workers went to and from the locker rooms they passed through plant areas where beryllium was used. Workers reported that due to working overtime shifts they occasionally did not have enough clean uniforms for every workday and had to wear their street clothes.

The wipe samples have several limitations for estimating beryllium concentrations inside workers' vehicles. Beryllium is probably not evenly distributed over the sampled surfaces. Depending on workers' positions as they drive, areas with relatively high beryllium concentrations may be adjacent to areas with very little beryllium. Therefore, sampling relatively small surface areas could either underestimate or overestimate total beryllium contamination inside vehicles. Also, samples collected over a 1-week period may not represent the typical beryllium concentrations inside vehicles, since seasonal variations resulting from the wearing of different types of clothing or changes in beryllium products over time could not be detected by this short-term survey. Because hand wipe samples were only collected once from each worker, they may not accurately reflect the usual amount of beryllium on workers' hands when they leave work.

The wipe sampling technique is a somewhat crude, semiquantitative method for estimating beryllium levels on vehicle and skin surfaces. The wiping action may cause particles to smear across surface areas or penetrate deeper into carpet fibers without being collected. No testing has been done to determine what proportion of the true amount of beryllium is likely to be collected on the wipes or if wipe sample concentrations represent potential inhalation exposures. Although the sampling technique has limitations, it was applied consistently for all survey participants and clearly indicates that at least a portion of the workers leave the plant with beryllium on their hands and clothing and transfer beryllium into their vehicles.

Surface wipes are useful for monitoring potential contamination and the effectiveness of cleaning efforts, but they are too imprecise and there is no quantitative relationship between surface contamination and air concentration for them to serve as health standards for reducing the potential risk for developing CBD.[19,20] No legally mandated health standards for beryllium surface contamination or beryllium measurements from the hands and vehicles of other workers are available to compare to measurements collected in this study.

Some facilities have used 25 $\mu g/ft^2$ as an index of cleanliness for beryllium surface contamination.[21-23] Limits currently in use for surface contamination in areas where beryllium is not being processed or for facilities and equipment that are released to the public range from 1 $\mu g/ft^2$ to 25 $\mu g/ft^2$.[24] Only one company (Brush Wellman) uses a limit of 25 $\mu g/ft^2$ which is based on sampling with wet wipes. Wet wipes have been reported to collect several times more beryllium than dry wipes.[24] Fifty-six out of 398 samples (14%) in our survey were greater than 25 $\mu g/ft^2$ and some samples exceeded this level by several times.

Because a safe or recommended minimum concentration of beryllium on the surfaces of hands and automobiles is not known,

it is difficult to evaluate the health risks associated with the levels found for the workers at this machining plant. The presence of beryllium which may become airborne in nonoccupational environments increases the potential risk of CBD for both workers and their families. Beryllium sensitization and CBD can occur even after average exposures below the 2 $\mu g/M^3$ air standard and can affect family members who have had only take-home exposures.[9,25,26] There does appear to be an exposure-response relationship for CBD, and an association linking immune-response genes to CBD risk raises the possibility that even low levels of exposure may be hazardous for susceptible individuals.[26,27] Therefore, it is prudent to reduce as much as possible the potential for workers to carry beryllium away from the work site.

The potential for workers to contaminate their homes was not evaluated in this study, but it is unlikely that take-home exposures would match those reported by Eisenbud in 1949.[6] During that era, airborne beryllium exposures in the workplace were much greater and work clothes worn home were more conspicuously contaminated by beryllium.

RECOMMENDATIONS

The following recommendations are offered to reduce the potential for workers to carry beryllium away from the work site.

The most direct means of preventing the migration of beryllium is to ensure that contaminated clothing remains in the workplace. Therefore, workers should never wear beryllium-contaminated clothing home or while they are operating personal vehicles. Before entering work areas where beryllium is used, workers should change into work clothes which include, at a minimum, shirt, pants, and shoes.

At the end of the shift, workers should shower, thoroughly cleaning their hands and hair, before changing into their street clothing. Locker rooms should follow a design with which contaminated clothing does not contact street clothing and airflow patterns prevent the contamination of clean changing areas. The change areas and showers should be located so workers do not enter areas where beryllium is used while wearing their street clothing, and the clothes they wear home should be left in an area free from potential beryllium contamination.

If they wish to leave the plant site before the end of the shift, they should first change into their street clothes.

Individuals laundering the work clothes should be warned about beryllium contamination and take precautions to reduce their inhalation exposures. These precautions should include wetting the clothes and wearing a respirator and protective clothing. In some workplaces, beryllium-contaminated clothing is placed inside dissolvable bags which are put into the washing machine without requiring the launderer to handle contaminated clothing directly. High concentrations of beryllium have also been found in the lint traps of dryers used to dry beryllium-contaminated clothing, so care should be taken when removing the lint.

The primary emphasis in reducing take-home beryllium exposures should be on preventing migration of beryllium from the plant. Vehicles already contaminated with beryllium should be cleaned and exposure precautions taken when doing so. Airborne beryllium exposures levels while vehicles are being cleaned is not known, but a respirator with at least dust, fume, and mist collection capability should be worn to reduce potential inhalation. Vacuums with high-efficiency particle capturing filters (HEPA), rather than typical home vacuums, should be used to prevent release of collected dust back into the air. Employers should provide a HEPA vacuum cleaner and controlled environment for vehicle decontamination at the plant site.

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DISCLAIMER

Mention of company or product names in this article does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH) or the Centers for Disease Control and Prevention (CDC).

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