Cleanup of Beryllium Contaminated Laboratory and Machine Shop

Todd Chervenick, Cort Horton, Larry Nee
Battelle Columbus Laboratories Decommissioning Project
505 King Avenue, Columbus, OH 43201-2693
Tel: (614) 424-7567 / Fax: (614) 424-3723
Control #1381

BACKGROUND

Battelle Memorial Institute (BMI) entered into Contract No. W-7405-ENG-92 with the Manhattan Engineering District on April 16, 1943, to perform atomic energy research and development (R&D) activities. Initial activities were performed at the Battelle Columbus Operations (BCO) King Avenue site. Future expansion in atomic energy R&D activities resulted in a research complex in West Jefferson, approximately 15 miles west of the King Avenue site. As a result of this research, a total of 15 buildings were radiologically contaminated, including 9 buildings, or portions thereof, at King Avenue and 6 buildings at the West Jefferson site.

Although the type and extent of contamination varies, the contaminants at the King Avenue site and at the 3-building complex at the West Jefferson South site consist mainly of uranium, thorium, and associated daughter products. The West Jefferson North site contaminants consist of transuranic (TRU), mixed waste products, and activation product contamination.

In 1986, the Battelle Columbus Laboratories Decommissioning Project (BCLDP) was formed to perform decontamination and decommissioning (D&D) activities to restore these facilities, which are all owned by Battelle, without radiological restrictions. As of July 1995, a total of 6 buildings, 3 at West Jefferson South and 3 at King Avenue, have been completed.

The BCLDP consists of 3 distinct groups integrated into a successful project team. Battelle Columbus Operations provides management support to the project as well as technical, oversight, and regulatory compliance support; APEX Environmental Inc., provides safety, industrial hygiene, and environmental support; and Applied Radiological Control (ARC) provides both health physics and decontamination labor support for the project.

BERYLLIUM CONTAMINATION

Beryllium is a grey lightweight metal possessing high tensile and yield strength. The nuclear industry has used beryllium in reactor systems including fuel cladding systems, fuel diluent, flow channels, pressure tubes, moderator canning, moderator reflector, and core structure. The aerospace industry used beryllium in a variety of ways including reentry systems for missiles, guidance system components and housings, spacers, and optical mirrors.

In addition to safety and health requirements needed for radiological protection, additional safeguards were instituted for the cleanup of the toxic element beryllium. Beryllium, in a powder or fume form, is an inhalation hazard that potentially causes acute and/or chronic lung disease. It may also produce dermatitis if allowed to remain in contact with skin. The Occupational Safety and Health Administration has established a Permissible Exposure Limit (PEL) of 2 micrograms per cubic meter of air (g/m3), with a ceiling level of 5 g/m3 and a 30-minute peak exposure limit of 25 g/m3.

Beryllium research was conducted at Battelle in two different areas, the KA-3 beryllium powder laboratory and the KA-5 beryllium machine shop. In the KA-3 powder laboratory, beryllium and various other metal powders were heated in ovens to form parts and components, mostly for the aerospace industry. The newly formed material was then transferred to the KA-5 machine shop for final shaping, grinding and polishing. "Green Machining" (cold pressing the beryllium alloy powder into shapes) was also conducted in the KA-5 machine shop.

The KA-3 powder laboratory consisted of approximately 2,500 square feet and lab hoods, benches and walk-in hoods, work benches, and ovens. All metal powders were also stored in the area. A large number of hand tools associated with the process were also in this area. Surface wipe samples revealed beryllium residue on the majority of surfaces. Thus, the clean up effort was very extensive and involved decontaminating all items, tools, fixtures, lab hoods, duct-work, etc., contained in the laboratory. HEPA ventilation for the lab hoods and supply only for thermal comfort was included. A large amount of surplus beryllium powder and other powder metals was present when the clean up task began. The first step was to consolidate all like powders and clean the containers for removal from the lab. Most of the pure beryllium powder was sold back to the manufacturer.

The KA-5 machine shop consisted of approximately 1500 square feet and contained lathes, grinders, cutting devices, and other metal working machinery. Beryllium dust control consisted of three methods, local exhaust ventilation, wet machining, and enclosure, with local exhaust as the primary method. Initially it was thought that the extent of beryllium residue contamination should be minor; however, surface wipe samples revealed elevated levels throughout the laboratory. Samples were collected with caution to avoid picking up large particles/shavings that could skew the results.

This paper will focus on the King Avenue site in general and the D&D work performed in the beryllium powder lab and machine shop operations in particular, and will emphasize methods to remediate the beryllium hazard to allow further radiological D&D work to continue.

SAFE WORK PLANS

All work conducted at the BCLDP originates with a work instruction document generated by operations management. The work instruction identifies the scope of work, applicable procedures, manpower requirements, work schedule, and charge account number. The Safety and Health Department, Waste Management Department, and Health Physics Department review the work instruction and add checklists and radiological work permits. Safe Work Plans (SWPs) are developed for work activities that have a potential for greater risk to the safety and health of personnel. The work instruction process along with the checklists and SWPs allow for a very proactive approach to successfully completing the mission, in a safe and cost-effective manner. SWPs typically address the following key issues: training requirements, operational tasks, engineering controls, personal protective equipment (PPE), respiratory protection, emergency planning, and waste disposal.

In addition to mandatory general hazard communication training (Hazcom), specific beryllium Hazcom is required for all personnel involved with the beryllium clean up task. The training includes an in-depth look at the health hazards associated with beryllium and addresses the control measures that have been implemented to protect personnel from overexposure.

The operational tasks are clearly defined to ensure a well coordinated effort and to eliminate costly down time. The operational tasks include verifying that training has been conducted, PPE is available, and engineering controls have been established. The SWP addresses the exact sequence of proceeding with the clean up. The specific clean up methods are discussed in another section of this paper.

Negative ventilation was used to keep exposures as low as possible to employees and to prevent airborne beryllium from migrating outside of the contained work area. Both laboratories contained HEPA ventilation which allowed negative pressure to be established. Plastic sheeting was used to cover doorways and other unwanted openings. Portable HEPA negative ventilation units were used for remote work including the removal of duct work on the roof. HEPA vacuums were used to clean up as much visible beryllium residue as possible.

PPE included disposable coveralls with hood and booties, rubber gloves, and full-face negative pressure respirators with HEPA cartridges. Industrial hygiene monitoring was routinely conducted to asses the adequacy of the PPE. Monitoring results are discussed later in this paper.

Battelle has established a highly effective emergency response plan. The BCLDP is part of this plan. In addition, the SWP addresses task-specific information such as the location of the nearest telephone, eye wash, and fire extinguishers.

Waste disposal included burial, incineration, and reclamation, and is discussed in detail in a later section of this paper.

CLEAN UP METHODS

HEPA vacuuming and wet wiping was the predominant clean up method used for the KA-3 powder lab and the KA-5 machine shop. All surfaces of materials to be released were HEPA vacuumed and then wet wiped. Spray-Nine and De-Solv-It were used as wetting agents. Spray-nine is an industrial cleaner routinely used in the nuclear industry. De-Solv-It is an orange citrus cleaner that is especially effective for greased items. Both cleaners are exclusively approved for the BCLDP waste stream. Because the KA-3 powder lab had many lab hoods, it was advantageous to use the ventilation systems already in place. All items that were small enough were transferred to a lab hood where the wet wiping took place. Larger items were cleaned in place. Both cleaning agents were applied using a spray method.

Neither Spray-Nine nor De-Solv-It dissolves the beryllium residue. Both spray solutions release the residue from the substrate which is collected on the paper cloth wipe. A corrosive solution can actually dissolve beryllium residue; however, a large amount of liquid waste would be generated, which is very difficult and costly for disposal.

Strippable paint was used in conjunction with duct removal and wall and floor decontamination in the KA-3 powder laboratory. The lab is fully contained and is located inside a high bay area. All associated duct work for the lab hoods was located on the roof of the lab. All the small lines were tied into a large duct which preceded the blower unit located on top of the main roof. The HEPA filters were located in front of the blower unit. Because much of the duct work was not in an enclosed area, a method was required to prevent the beryllium powder from becoming airborne and migrating into clean areas. Strippable paint offered a viable solution to lock down the beryllium powder. The duct work was then transferred to another area for additional processing.

HEPA vacuums were used to remove the gross contamination prior to applying paint. The ventilation system remained in operation to help collect powder that became airborne. The duct work was disassembled by removing screws and by using electric tin snips. Sawz-alls were not used due to the potential for creating excessive dust. The duct work was then horizontally cut in half and opened for application of strippable paint. After drying, the painted sections were moved to another area for stripping. Due to the large extent of surface contamination in the powder laboratory, strippable paint was also applied to the walls and floor. Strippable paint was not used in the machine shop.

Bag enclosure was used to dismantle the duct work in the KA-5 machine shop. The gross beryllium powder was removed with a HEPA vacuum, and a plastic bag was used to enclose the duct section. Finally, the section was brought to floor level and sealed tightly.

Items were free released after surface wipe samples showed concentrations less than 25 micrograms per foot squared -- a guideline recommended by Brushwellman, Inc. A visual and hands-on inspection of all items was conducted prior to wipe sampling. If visible powder was found on the items or if the wipe sample contained abnormal amounts of debris, the items were returned for re-cleaning. Items were grouped into lots and sampled on a percentage wise basis. Initially, 100 percent was sampled; however, after clean up methods proved successful, the sampled amount was decreased. Equipment that was re-used or sold to the public was identified as previously used for beryllium machining and that disassembly may result in exposure to the beryllium.

INDUSTRIAL HYGIENE RESULTS

Due to the serious health hazards associated with overexposure to beryllium powder, a conservative approach was taken. Some literature exists on air concentrations related to certain types of machining activities. Data was not available from other clean up projects. Some recommendations were received from a supplier of beryllium powder. Standard safety and industrial hygiene practices for dealing with toxic powdered metals were employed.

The PPE initially required for the clean up task remained the same throughout both projects. Initially it was thought that the level of PPE, especially respiratory protection, might be able to be downgraded. However, exposure assessments conducted throughout the clean up revealed elevated airborne concentrations during most of the clean up activities.

Personal breathing zone samples were collected during the various tasks involved in both laboratories. Monitoring results for the KA-3 powder are presented in Table 1. Area air samples were collected outside the contained areas to ensure no outward migration of beryllium and the negative ventilation was adequate. Results are presented in Table 2. All sampling was conducted and analyzed in accordance with NIOSH Method 7102. Wipe surface samples were collected to determine if the clean up methods were successful. The samples were collected and analyzed in accordance to Brushwellman protocol.

WASTE MANAGEMENT

The large volume of waste material from the beryllium lab and machine shop turned the focus to cost-effective waste reduction methods. Waste was segregated into radiological and non-radiological categories, and each category was broken down into like materials for proper cost- effective disposal.

A radiologically clean and RCRA listed P015 category contained empty beryllium carboys from the powder consolidation process and miscellaneous incinerable material from handling the beryllium. This waste stream was shipped to a U.S. Environmental Protection Agency (EPA)-approved incinerator for disposal. Total amount of this waste stream was approximately 560 cu ft. Machines and equipment from the machine shop that were radiologically free-released, but not releasable under the beryllium criteria, were shipped for concrete encapsulation and disposal.

Scrap material which was radiological and beryllium free-released were disposed of locally. Usable lab and machine shop equipment that was also free-released was returned to Battelle for future use.

Radiologically contaminated material was segregated into defined waste streams, based on type of material, and sent for incineration, super-compaction, or shipped directly for burial. Defined waste streams included metals including duct work, PPE and other cleaning materials, strippable coatings, and miscellaneous lab and shop equipment. With the exception of the machines and equipment that were concrete encapsulated, the waste stream from this project was reduced from an estimated 3,000 cu ft to 125-130 cu ft.

LESSONS LEARNED

The SWPs developed for the clean up task provided a clear mission that allowed us to incorporate safety requirements into the entire process. Everything was well planned and scheduled to ensure the project goals were met in a cost-effective manner with little or no delays. The SWPs provided a work plan that was easy to follow by all groups involved. SWPs have since been used for work activities where there is a potentially hazardous situation or condition that can cause harm to the work force or environment. Documentation of training sessions and pre-job briefings are essential. Although a core group of personnel were trained, workers were occasionally assigned to different project tasks. To eliminate training new personnel and to provide continuity for this non-routine task, it is suggested that the core group of personnel remain on the task until completion.

All clean up methods used were successful, and, depending on the specific situation, some methods were used more extensively than others. HEPA vacuuming was the critical first step in all situations. Gross amounts of powder needed to be removed prior to wet wiping or painting. Attempts to wet wipe gross beryllium powder resulted in just moving the powder around. A large amount of cloth wipes were needed for this process. In some cases, a wash sink filled with Spray Nine or De-Solv-It was used to "dunk" small items instead of spraying them with a hand sprayer.

Strippable coatings serve a dual purpose. The contamination particles are held and then removed in place with the coating, and the coating is also durable enough to provide a walking/working surface before removal. The coating can be applied over any dry surface to include concrete, metal, floor tile, floor tile mastic, wood, and glass. Rough and porous surfaces were no more difficult to decontaminate with strippable coatings than smooth surfaces. Intricate geometrical shapes proved more difficult to strip. Fortunately, these shapes represented a relatively small amount of the total work scope so the coating was not used on further intricate designs. The coating can be left in place for extended periods and can be reactivated for removal by application of an additional topcoat. Final removal of the coating from walls and floor surfaces was accomplished without any difficulties.

A spray system is the preferred method of application, but the coating can also be brushed on with similar results. The brush method worked well to coat odd-shaped duct assemblies and to eliminate any overspray if using a spray system. ARC is a pioneer in strippable coatings technology and provided the expertise to make the use of strippable coatings in the beryllium lab and associated ductwork a successful operation.

At the start of the project, all items, including duct work, were cleaned to a level recommended by Brushwellman. It was later decided it would be more cost-effective to dispose of some items, especially duct work, as beryllium contaminated. The duct work was especially hard to clean. Other materials (wood, metal, glass, plastic, etc.), were equally as challenging to clean as the duct work. For spray cleaning, smooth surfaces were easily cleaned; rough or porous surfaces were difficult. If items were disposed of as beryllium contaminated, they were sealed in plastic to prevent releasing the beryllium while in transit to the waste disposal container.

Personal and area air samples were collected on a frequent basis during many different types of activities. Results revealed concentrations that varied even when personnel were working on the same task. This could be attributed to work style of the individual or the amount of beryllium powder on the surface. Since the KA-3 powder lab contained most of the raw beryllium powder, air concentrations were higher. Most of the items were cleaned in a lab hood, so we believe that elevated airborne levels occurred when items were moved into the lab hoods. Because personal breathing zone samples revealed inconsistent concentrations, frequently exceeding the PEL, personal protective equipment, including respiratory protection, was used throughout the duration of both projects. Also, high concentrations were recorded during powder consolidation, even though closed system transfer and use of lab hoods were standard practice. Supplied air respirators are recommended for this task.

Air concentrations were considerably lower during clean up of the KA-5 machine shop. This could possibly be attributed to the surface areas containing grease and oil, preventing excessive airborne release. The greased machines were also difficult to clean. Waste regulations prohibit most of the better industrial cleaners. Several applications were needed on most machines. Strippable paint was not used because of the difficulty in removing the paint.

Surface samples provided a way of determining the extent of beryllium contamination and the success of clean up methods. No correlation was made between the amount of surface contamination and resulting air concentrations.

The beryllium decontamination project provided various challenges in areas of worker protection, decontamination methods, and waste segregation and disposal. The challenges of this task were met by innovative personnel working as a team to complete the task in a timely and cost-efficient manner. Although beryllium is a non-routine contaminant, a simplistic approach can be successfully used to remediate the contamination.

Table 1. Personal Breathing Zone Results

Activity	8-hr TWA g/m3, Range			30 min STEL g/m3, Range		
KA-3 Powder Laboratory						
Set-up	<0.025	--	0.38		--	
Cleaning Chemical Containers	<0.025	--	5.35		17.7	
Powder Consolidation		72.3			581	
Equipment Decontamination	<0.026	--	9.0	<0.025	--	0.071
Peeling Strippable Paint	0.02	--	1.14		--	
Disassembling Ductwork	3.25	--	4.04	14.0	--	37.0
Health Physics Surveys	0.03	--	14.2		--	
KA-5 Machine Shop						
Health Physics Survey	<0.11	--	0.28		--	
Set-up, Trash Collection	0.21	--	0.91		--	
Filter Changeout	0.11	--	17.3		--	
General Cleanup	<0.11	--	19.2	<1.6	--	<1.7
Equipment Disassembly & Cleanup	<0.10	--	1.91		--	
Beryllium Chip/Shavings Consolidation	1.41	--	8.52		--	
Vacuuming/Cleaning Overheads	<0.10	--	0.15		--	
Duct Removal	1.4	--	8.8		--	

Table 2. Area Air Samples

<table>
<tr><td colspan="4">KA-3</td><td colspan="4">KA-5</td></tr>
<tr><td>Location</td><td colspan="3">Concentration, g/m3, Range</td><td>Location</td><td colspan="3">Concentration, g/m3, Range</td></tr>
<tr><td>Inside Laboratory</td><td>0.025</td><td>--</td><td>0.71</td><td>Outside Shop</td><td><0.11</td><td>--</td><td>0.058</td></tr>
<tr><td>Inside Clean Room</td><td><0.025</td><td>--</td><td>0.19</td><td colspan="4" rowspan="4">Note: Due to the low concentrations recorded from breathing zone samples, inside area samples were not collected. Also the ductwork for the KA-5 machine shop was internal to the lab up to the HEPA filter, thus additional outside samples were not collected.</td></tr>
<tr><td>Outside Laboratory</td><td><0.025</td><td>--</td><td>0.03</td></tr>
<tr><td>On Roof</td><td><0.15</td><td>--</td><td>1.11</td></tr>
<tr><td>Hallways Below</td><td><0.05</td><td>--</td><td>1.32</td></tr>
</table>