Summary of good cleanup and decontamination practices for workplaces with Beryllium-containing dust

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Introduction

This document presents a summary of good cleanup and decontamination practices for workplaces where beryllium (Be) is found, based on a review of scientific and technical documentation. Its objective is to inform on-site staff about these good practices, and encourage broader discussion on how current knowledge can be applied to the Quebec context. The second step will involve drafting a decontamination guide, complete with a prevention program for workers directly involved in decontamination exercises.

The content of this document summarizes good practices recommended by the Department of Energy (DOE),[1,2,3] the U.S. Occupational Safety and Health Administration (OSHA)[4], the Cardiff Atomic Weapons Establishment[5] of the United Kingdom, and the U.S. company Brush Wellman Inc.[6,] and adapts them to the Quebec context. It also revisits the major ideas expressed in the Info-Beryllium newsletter[7] and refers to the sampling and analysis methods of renowned organizations (NIOSH – National Institute for Occupational Safety and Health, OSHA, IRSST (*Institut de recherche Robert-Sauvé en santé et en sécurité du travail*))[8,9,10,11,] as well as to Quebec regulations[12,13,14].

This document does not address the following aspects of the issue: the natural occurrence of Be in soil; the waste processing, transportation and elimination; wastewater treatment; medical and environmental monitoring of workers who perform decontamination or cleanup operations; emergency situations.

It is important to clearly understand that the cleanup and decontamination of workplaces where beryllium is found is but one element of a potential chronic beryllium disease prevention program. This document therefore presupposes the existence of prevention and health programs. The authors furthermore inform the reader on pratices and on reference values used by the various authorities. In no case should the present document be interpreted as a statement of position in relation to Quebec regulations.

1. Field of application

Industries and workstations where workers are exposed to concentrations that exceed regulated or reference values, set according to the best scientific knowledge available, must be considered a health hazard for workers. Such environments must therefore be subjected to prevention measures, such as the applicable cleanup and decontamination procedures for beryllium-containing dust.

In practice, the *Sampling Guide for Air Contaminants in the Workplace*[15] provides the "Decision flowchart for exposure evaluation" that applies to all potential workplace contaminants, including beryllium. According to this flowchart, contaminant concentration in the worker's breathing zone is the parameter that triggers the prevention program's various measures. However, breathing-zone concentration results cannot be interpreted without setting a permissible exposure limit (PEL) or selecting a reference value.

The DOE has set the action threshold at 0.2 µg/m^3, measured in the breathing zone using an 8-hour time-weighted average. It defines this concentration as being the trigger for implementing their prevention program's protection measures. These measures notably involve housekeeping, clearance criteria, waste elimination, etc.

In Quebec, the permissible exposure limit (PEL) is 2 µg/m^3, but the CSST's Beryllium Action Committee has set a reference value of 0.2 µg/m^3 in this respect. Some industries use a reference value of 0.1 µg/m^3. The CSST's Technical Committee 3.69 is currently reviewing the PEL and reference value.

2. Definitions

Either of the two definitions below can refer to the products, compounds and alloys to which prevention measures apply:

- **Be-containing material:** all material in which the beryllium concentration is higher than 0.1%;
- **Beryllium:** elemental beryllium, as well as any insoluble compound or alloy containing at least 0.1% beryllium that can be released into the air as dust.
  (It should be noted, however, that certain processes can concentrate Be content.)

Action level: 8-hour time-weighted average concentration in the breathing zone that triggers the implementation of preventive measures.

Breathing zone: the area within a 300 millimetre-radius hemisphere extending in front of the face, with the centre on an imaginary line connecting the ears.

Authorized person: all persons who must enter controlled areas to perform their tasks.

Controlled area: specified area within which the beryllium concentration exceeds or may exceed the action level.

High Efficiency Particulate Air (HEPA) filter: filter capable of trapping and holding at least 99.97 % of monodispersed, 0.3 micrometre (µm) airborne particles.

Rectifiable contamination: beryllium (Be) accumulation that can be eliminated from surfaces by non-destructive procedures, such as accidental contact, wiping, dusting, brushing, washing or vacuuming.

3. Description of uses

The technical documentation describes three situations that may require decontamination or cleanup due to the presence of beryllium-containing dust:

- A company that is currently using Be and will continue to use it must monitor the contamination level regularly and set up a housekeeping program.
- The recovery of a workplace where manufacturing processes involved Be use, to convert it to a Be-free environment.
- The recovery of equipment, facilities or other objects used in a building contaminated by Be dust, to put them at the public's disposal.

4. Surface contamination

The sampling of surface dust is used to help detect the presence of Be within establishments and, where relevant, to discover the sources of Be contamination, to check the effectiveness of routine housekeeping or cleanup activities, and to make sure that the premises and various objects used in a Be-containing environment have been cleaned thoroughly enough to be used in a Be-free area. In short, the monitoring of surface contamination levels is an essential tool to ensure the control of Be emissions. Surface contamination can be assessed using swipe samples or by collecting settled dust. The location and distribution of surface contamination levels can help detect Be emission and dissemination sources. It is therefore important to follow a sampling strategy that takes into account the objective of the exercise.

Sampling intervals should be set according to the risk of exposure. Samples can be collected occasionally, or at each work shift. Occasional sampling may be enough for activities that are not likely to increase surface contamination levels, such as:

- isolated operations in ventilated enclosures;
- offices adjacent to premises where Be dust may be released into the air.

However, sampling at each work shift may be required in industries where activities are likely to contaminate work surfaces on a regular and ongoing basis. During housekeeping, surface sampling should be performed after normal cleanup at the end of the shift and during periods when the premises are unoccupied.

The only practical method for monitoring surface contamination is to set one or more reference levels based on the objective of the exercise, and to keep surface contamination below that or those limits.

- In Quebec, for diagnostic purposes, the Environmental Sub-Committee on Be has proposed reference levels of 0.2 µg/100 cm^2 in swipe samples and 10 ppm for settled dust samples as criteria for the presence of beryllium.
- However, for housekeeping follow-up, the DOE has decided that, when an industry has material containing Be, work surfaces should not be contaminated by more than 3 µg/100 cm^2. These measurements are taken by swipe samples collected during work stoppage periods.
- The Cardiff Atomic Weapons Establishment (United Kingdom) has set its contamination level at 1 µg/100 cm^2 (or 10 µg/ft^2).

- Furthermore, the DOE has set a rectifiable contamination level not exceeding either 0.2 µg/100 cm^2, or the Be concentration in soils at the time of decontamination or use. This limit thus becomes the criteria for clearing premises, equipment, facilities and objects for use by the public or in processes that do not use Be.

Surface dust concentrations cannot be used to try to assess workers' exposure level. The results of swipe samples or settled dust analyses are not always correlated with results from the measurement of Be particles in the workers' breathing zone.

5. Surface contamination swiping and analysis

5.1 Taking surface samples

There are several surface sampling or swipe sampling methods currently in use. The variety of materials used to collect dust makes it difficult to compare between workplaces, given their differences in both size (from 1080 mm^2 to 6400 mm^2), and composition (sterile cotton gauze, paper filter, damp hand towelette, mixed cellulose ester filters). Dry surface sampling may be used on occasion, but wet sampling is advocated due to the possibility of losing dust through dry sampling methods (up to 10 times higher, according to *Cardiff*). A single sampling method is recommended, in order to reduce result variability.

The NIOSH 9100 sampling method for lead-contaminated surfaces can be adapted to swipe sampling of Be-contaminated surfaces. OSHA, *Brush-Wellman* and the IRSST recommend similar sampling methods. The sampling areas are defined according to a template that generally covers a 100 cm^2 or 1 ft^2 surface area. All of these methods emphasize the precautions that must be taken to avoid any cross-contamination of samples, and of the various premises or industries.

5.2 Surface sample analysis

The swipe samples are analyzed according to the analytical procedures described in the NIOSH 7300 method, using induced coupled plasma mass spectroscopy (ICP-MS) or in methods using graphite furnace atomic absorption (GFAA) spectroscopy, such as NIOSH 7102, OSHA ID-125G, IRSST 351 or equivalent methods. The detection limits for these various methods range from 0.001 to 1 µg of beryllium per sample. Certain concentrations of aluminum can interfere with the beryllium determination process in GFAA spectroscopy; the presence of aluminum must therefore be indicated in the analysis request.

Analyses must be conducted by a laboratory that is certified for metal testing by the *American Industrial Hygiene Association* (AIHA)[16] or a laboratory that can provide evidence of an equivalent quality assurance program.

5.3 Protective measures for persons taking samples and for laboratory staff

Protective measures for technicians or professionals taking samples, laboratory staff and technicians in charge of pump and sampling-material maintenance must be applied to minimize the staff's exposure to beryllium dust and the spread of beryllium dust outside contaminated areas.

There is little documentation on specific precautions to protect workers sampling on site or analyzing samples in the laboratory from exposure to beryllium. While it does not specifically address this problem, an OSHA newsletter on preventing beryllium exposure risks in dental laboratories does urge caution with regard to airborne beryllium emissions and recommends taking precautions to avoid inhalation. For comparison

purposes, let us note that dental alloys can contain from 0.5 to 2% beryllium. The OSHA newsletter recommends that dental laboratories use certain measures to reduce dental technicians' exposure to Be:

- local ventilation using systems equipped with high efficiency (HEPA) filters;
- good work practices:
    - to reduce exposure – manual processes, proper use of ventilation, HEPA vacuum cleaners to clean equipment and surfaces, prohibiting the use of compressed air, air sampling, limiting the number of workers with access to beryllium-containing areas, proper respiratory protection;
    - to minimize skin contact and reduce the possibility of taking dust home or into non-contaminated work areas – wearing protective clothing (lab coat, shoe covers, gloves and sleeves, etc.); washing face, hands and forearms before eating, drinking, smoking or applying cosmetics; storing street clothes away from Be-contaminated clothing;
- proper respiratory protective equipment – it is not recommended to wear a surgical mask because it cannot be adjusted properly, and does not filter fine particles effectively.

In Quebec, t*he Regroupement provincial des hygiénistes* (Provincial Group of Hygienists) has made the following recommendations on the protective measures that should be taken for the persons involved in the sampling, and on the prevention of sample contamination during beryllium operations in the smelting and prime metal manufacturing sector[17]:

- Training and information on risks and preventive measures;

- Personal protection measures:
  - Disposable coveralls with shoe covers and hood;
  - Air-purifying respiratory protection device equipped with a 100-series filter (N, P or R class) and a half-mask with airtight goggles or a full-facemask;
  - Disposable gloves;
- Measures linked to work methods:
  - If possible, gather information (data sheets, etc.) outside the contaminated area (office);
  - Do not stay near sources longer than necessary during sampling;
- Administrative measures
  - Reduce the number of persons assigned to sampling operations;
  - Reduce the number of interventions within the establishments;
  - Keep an updated list of establishments where the presence of Be is confirmed;
  - Make this information accessible to workers assigned to sampling and to laboratory analyses;
- Other measures to prevent the contamination of samples and inter-establishment contamination:
  - Wear a protective suit, gloves, etc., and dispose of them on site;
  - Clean sampling instruments with a disposable damp cloth;
  - Perform periodic swipe tests in instrument rooms or laboratories.

In general, it is necessary to follow the good laboratory practices that apply to handling toxic substances, such as mercury, lead, asbestos, crystalline silica, pesticides, cyanides, etc.

6. Housekeeping

Proper housekeeping measures, applied regularly, must prevent the accumulation of Be-containing dust and limit the spread of contamination to other areas. However, housekeeping itself can cause exposure to Be-containing dust. When performing housekeeping, the emphasis must be placed on preventing the spread of dust and the re-release of dust into the air.

When there is Be-containing material within an industry, a situation in which the rectifiable contamination of work surfaces exceeds set limits triggers an immediate cleanup process that goes beyond routine activities. Surface contamination levels are checked regularly, during work stoppages, using swipe sampling performed according to a set template. These swipe samples must make it possible to assess the situation in at-risk areas, and are therefore not performed within closed systems, such as equipment enclosures, glove boxes, enclosures with remote or automatic operation, ventilation systems, etc.

6.1 Preventing re-release into the air

Work areas where beryllium is used must be delimited and maintained at negative pressure in relation to adjacent areas, in order to prevent the spread of contamination. When enclosures are required on work sites where there is high-risk work likely to create asbestos dust emissions, the *Safety Code for the Construction Industry* requires a ventilation system that meets the following requirements:

- it must be equipped with a high efficiency filter;
- it must provide at least four air changes per hour;
- it must ensure negative pressure of between 1 and 4 Pascals.

Contamination must be confined to the smallest possible work area within any premises. The floors and walls of such premises must be made of smooth and non-porous material, in order to facilitate housekeeping and potential decontamination.

Accumulations (piles) of dust on all work surfaces where there is material that contains Be must be avoided, in order to reduce the amount of dust that may become airborne. Special attention must be paid to floors, work surfaces, equipment and furniture, windows and windowsills, doors and doorframes, roofs and other support structures.

When Be-contaminated parts, equipment or equipment components need to be moved, they must be stored in plastic bags, or exposed surfaces must be completely covered with tape.

6.2 Cleanup by vacuuming and/or wet process

The use of compressed air is prohibited, except within a confined ventilation system designed to trap dust. **The use of dry processes, such as shoveling, sweeping or brushing is prohibited**, except within completely closed enclosures, such as glove boxes or closed rooms with remote control that isolate workers from dust using a physical barrier.

Wet process and/or high efficiency filter vacuuming methods must be used to clean floors and other surfaces, so as to minimize the possibility of airborne emissions of dust containing Be. It may be necessary to repeat decontamination procedures several times on a given surface before obtaining swipe results below the chosen reference value. The employer must continue using swipe samples to check the effectiveness of decontamination, until Be levels are below the set value.

Wet processes include the use of low-pressure water jets, mobile scrubbing units that use water, and damp dusting using sponges or cloths soaked in water containing a wetting agent or commercial soap, cloths imbued with a sticky substance, and wet mops. If a whitish deposit appears after drying, it means that further cleanup is required.

However, adsorbent or porous surfaces, such as ceiling tiles or furniture upholstery (outer surface) can be cleaned more effectively with a high efficiency vacuum cleaner than with a wet process.

Mobile or portable vacuum cleaners and other cleanup equipment for work areas where there is Be-containing material must feature a label to that effect, and must not be used in Be-free work areas. This equipment contains dust with Be content, and could become a source of contamination if emptied or handled outside areas where Be use is authorized. Consequently, proper facilities must be foreseen to prevent staff exposure to dust and dust dispersion when vacuum cleaners are emptied and the high efficiency filter is replaced.

Be-contaminated dust and debris collected by a portable (mobile) vacuum cleaner or central (stationary) vacuum system, **must not be returned to the work area's atmosphere.** Vacuum systems designed for this purpose, be they portable or central, must be equipped with high efficiency filters to trap Be-containing dust. Central vacuum systems with outside exhausts must comply with environmental requirements.

6.3 Vacuum system (vacuum cleaner) maintenance

Periodic maintenance of the vacuum systems is essential to their proper operation. Filter maintenance is particularly critical, because a partially or completely blocked filter can seriously compromise the vacuum system's operation. The high efficiency filters of portable or mobile vacuum cleaners must be replaced during periodic maintenance.

Maintenance normally involves:

- a pressure drop (decrease) test to determine whether the filter is blocked or needs to be cleaned or replaced;
- an aerosol penetration test to make sure that the high efficiency filter is airtight (see section 4.2.5.2 of DOE G 440.1-7A p. 50). This last test is therefore performed when a new filter is installed, to check its position and make sure there are no dust leaks around the filter.

It should be noted that specific details on applying these tests are currently being revised.

Workers who perform the aerosol penetration tests and maintenance tasks also risk exposure to Be dust. Proper measures must be foreseen to minimize their exposure to the dust and protect them. A maintenance program is also recommended for fixed (permanent) systems, such as central vacuums.

7. Recovery of a Be-contaminated workplace to convert it into a Be-free environment

Certain specific practices apply to decontaminating a building or premises. Areas requiring decontamination must first be isolated from the rest of the building or facilities by sealing all entrances and openings in the walls with polyethylene. A system with a high efficiency filter must be installed to maintain negative pressure in the decontamination area. This practice resembles recommended precautions on sites with high risk of asbestos exposure. Cleanup must be performed logically, so that clean zones are not recontaminated.

- Begin cleanup at the point farthest from the air exhaust duct of the negative pressure maintenance system. The exterior exhaust duct must meet local regulations regarding public and environmental protection.

- First clean equipment and objects that will be kept, and store them in a non-contaminated area. Then clean components that will be discarded or destroyed, and transport them to a holding area delimited for this purpose, or place them in a waste transportation bin with a cover and a protective inner lining, or in airtight bags or sealed containers. Clean component surfaces using a vacuum cleaner equipped with a high efficiency filter, followed by wet methods unless they constitute a safety hazard due to close proximity to electrical installations, for example.

- Be it for destruction, replacement, or change of layout, special precautions are recommended when removing air exhaust ducts from heating systems, ventilation, and air conditioning systems, exhaust hoods, and tubing from stationary (central) vacuum systems:
  - Clean duct exteriors. Dismantle with care, closing and sealing all extremities of components as soon as they are dismantled. Remove all ducts in sections and transport them to a preparation area. All dismantling or cutting operations must be performed while maintaining ducts in negative pressure using an air evacuation system equipped with a high efficiency filter.
  - Inspect the interior of ducts and, if necessary, clean areas where dust has accumulated, using a vacuum cleaner equipped with a HEPA filter.
  - Separate or cut sections into manageable lengths. Sections must be separated by mechanical cutting or dismantling at connection points. Do not use a cutting torch.

- Clean ceiling tiles, grids and retaining rods. Ceiling tiles should only be cleaned with a vacuum cleaner equipped with a high efficiency filter (do not use wet cleaning methods on ceiling tiles) and wrapped in plastic bags if they are to be discarded.

- Be it for destruction or recovery (uses without Be), clean walls and fixed building structures after all moveable components have been removed, discarded, or stored. Removal and/or cleanup of permanent components (structures, walls) should, in each room, begin at the ceiling and proceed towards the floor.

- Clean the surfaces of walls and construction structures that will remain inside the building using a vacuum cleaner equipped with a high efficiency filter, followed by wet cleaning. The wet cleaning procedure must be applied with water containing soap or a wetting agent, wringing the cleaning cloths to avoid dripping water along the walls and being sure to treat the entire surface as uniformly as possible. Pressure washing can sometimes be used.

- Cover all rough, porous, or difficult-to-clean surfaces with paint or any other durable coating to prevent Be dust from being released into the air. Label all such surfaces to indicate the presence of Be.

- Where relevant, demolish walls and other building elements as required. Spray with a soft jet of water to minimize dust emissions into the air, taking potential safety hazards into account.

- Decontaminate all tools and other equipment used in the decontamination process. Rinse all floor traps.

- Verify compliance with clearance criteria by using an appropriate strategy and respecting set limit values.

8. Recovery of Be-contaminated equipment and other objects

Equipment and other objects contaminated by Be must be cleaned to reduce their contamination level as much as possible before making them available to the public or to a Be-free industrial facility. "Other objects" include tools, merchandise, documents, etc., but not buildings. Before clearing equipment or other articles for use in a Be-free environment, it is necessary to make sure that:

- rectifiable contamination levels do not exceed set values. For example, the DOE uses the higher of the two following values: 0.2 µg/100 cm^2 or the Be concentration in the soil at that location;
- equipment and objects are labeled according to the rules in effect;
- the recipient agrees to apply proper controls to prevent Be exposure during future use, considering the nature of the equipment and the possibility of residual Be contamination.

It may be necessary to decontaminate internal equipment surfaces. For example, a lathe or other machine tool may be free of rectifiable contamination on the surface, making it usable in a Be-free environment. However, that same equipment may contain dust inside its components and this dust could become airborne and cause risks for others during equipment repair, for example. If it is not feasible to decontaminate the inside of a piece of equipment, all of its components must be labeled to warn workers who may have to dismantle it in the future.

Documents (papers) located inside an area containing beryllium are also considered to be contaminated. A photocopy can be made on a machine inside a controlled zone, with copies exiting towards a clean zone and the originals remaining in the contaminated zone until they are discarded as Be-contaminated waste.

9. Hygiene measures

There must be no eating, drinking or smoking in controlled zones. Hands, forearms, and face must be washed after any exposure to beryllium and before eating, smoking, or applying cosmetics.

While workers are exposed to beryllium, two dressing rooms must be made available (one for work clothes, and the other for street clothes), as set out in Quebec regulations.

Generally, work clothes must be put on before entering controlled work zones and must be kept as clean as possible during the work period. Work clothing and shoes must never be worn outside contaminated areas. The dressing room used for dirty clothes must be maintained at negative pressure to reduce Be dispersion into clean zones.

Showers, sinks, and toilets must be available to workers and must be used before leaving controlled zones. Rest areas free of Be contamination must be accessible to workers, and workers must never enter them with their work clothes or other equipment from controlled zones.

10. Respiratory protection

A respiratory protection program must be applied throughout decontamination and cleanup procedures for beryllium-contaminated premises or facilities. This program must meet *Regulation Respecting Occupational Health and Safety* requirements and comply with the CSA Z94.4-93 standard, "Selection, Use and Care of Respirators". Selected equipment must appear in the *Guide des appareils de protection respiratoire utilisés au Québec*, published by the Institut de recherche Robert-Sauvé en santé et en sécurité du travail.

11. Protective clothing and equipment

In order to avoid Be contact with skin, wounds, and eyes, protective clothing and equipment must be worn whenever Be concentration in the air is greater than the set action level or whenever contamination levels are greater than set levels. Protective clothing and equipment must be worn and maintained properly.

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