TECHNICAL GUIDANCE FOR RELEASE OF INDUSTRIAL HYGIENE BREATHING ZONE SAMPLES BASED ON RADIOLOGICAL AIR SAMPLING RESULTS

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ABSTRACT

Workplace air sampling poses special challenges when industrial hygiene (IH) breathing zone (BZ) samples contain both chemical (i.e., non-radiological) and radiological contaminants. The amount of radiological contamination on the sampling medium and cassette interior will determine whether the IH BZ sample must be controlled and shipped as radioactive material. In addition, laboratories accredited by the American Industrial Hygiene Association (AIHA) performing these IH analyses may not be licensed to possess radioactive material. This paper provides technical guidance documenting how these types of samples do not qualify as radioactive material according to radiological and transportation regulations. Supporting evidence includes: 1) the radiological screening process has not reported any measurable contamination above the filter media and the collection device interior *de minimus* levels, respectively; 2) the IH BZ samples are shipped as “routine”; 3) the quantities of hazardous metals and radioactive materials that might be collected on these filters are insignificant and do not pose any shipment hazards; and 4) these types of IH BZ samples typically do not meet any other transportation hazard definitions. Therfore, the IH BZ samples can then be shipped off site for analyses using either government or private carriers. Any non-NRC-licensed AIHA-accredited laboratory would be able to analyze these samples without concerns about inadvertently possessing radioactive material.

INTRODUCTION

Sorting, treating and repackaging hazardous wastes can generate airborne constituents consisting of mists, vapors, gases, dusts or fumes. These airborne constituents can create hazardous work environments and employee exposures resulting from either inhalation into the lungs or absorption through the skin. The Activity Hazard Review (AHR)/Activity Hazard Analysis (AHA) process developed by Potts, Hylko and Douglas systematically identifies, assesses, and controls these types of work place hazards through engineering, administrative or personal protective equipment controls (1). Also, the method developed by Thompson and Hylko quantifies employee exposure levels using similar exposure groups and exposure profile results in order to assign exposure risk ratings (ERR) (2). Therefore, the information obtained from the AHR/AHA and ERR evaluations determines the need to perform workplace air sampling.

However, workplace air sampling poses special challenges when an industrial hygiene (IH) breathing zone (BZ) sample, defined as the area within a 15.2 cm-to-22.9 cm (6 inch-to-9 inch) radius from the center of an employee's face, could contain both chemical (i.e., non-radiological) and radiological contaminants. The results are then compared against the appropriate limits [e.g., Permissible Exposure Limit (PEL), Threshold Limit Value (TLV), Time-Weighted Average (TWA)] to determine individual exposures to these non-radiological airborne contaminants (3).

The challenge arises when an IH BZ sample is collected in an area requiring a Radiation Work Permit (RWP) for entry. The RWP is an administrative control that restricts access to an area where a particular radiological source term exists, for example, loose/airborne contamination or solid sources. The RWP then identifies what engineering, administrative and personal protective equipment controls required to mitigate employee exposure. As a result, collecting an IH BZ sample in this RWP-controlled area may result in radiologically contaminating the sampling cassette exterior, the cassette interior, and the sampling medium.

Survey controls (e.g., swipes, direct instrument readings) are in place through the Department of Energy's (DOE's) occupational radiation protection regulations to verify the cassette exterior is free of any radiological contamination (4). If radiological contamination is detected on the cassette exterior, it can be decontaminated very easily, resurveyed, and then removed from the RWP-controlled area. However, the amount of radiological contamination on the cassette interior and sampling medium will determine whether the BZ sample is shipped as radioactive material according to U.S. Department of Transportation (DOT) regulations (5). Furthermore, laboratories accredited by the American Industrial Hygiene Association (AIHA) (6) performing these IH analyses may not be licensed to possess radioactive material according to Nuclear Regulatory Commission (NRC) regulations (7).

This paper provides technical guidance for releasing IH BZ samples based on radiological air sampling and survey results. These results, along with sample collection information prescribed by the National Institute for Occupational Safety and Health (NIOSH) (8), document how these types of samples do not qualify as radioactive material according to radiological and transportation regulations. The IH BZ samples can then be shipped off site for analyses using either government or private carriers. Therefore, any non-NRC-licensed AIHA-accredited laboratory would be able to analyze these samples without concerns about inadvertently possessing radioactive material.

IH AND RAD BZ SAMPLES

The IH BZ samples are part of a sampling train. A sampling pump, consisting of a battery-operated vacuum pump capable of being calibrated and remaining at a reasonably constant flow rate, is used to draw air through a collection device. The collection device is comprised of a cassette containing a filter or a tube containing a sorbent material. Pre-sampling pump calibration is performed in accordance with the appropriate sampling procedure to ensure all components are functional and are for the specific contaminants of interest. The inlet orifice of the sample collection device is opened prior to starting the sampling pump and is placed in a downward vertical position within the employee's breathing zone. This is accomplished by attaching the device to the employee's lapel in such a way as to avoid interference with performing work. Pump operation is observed to ensure a stabilized flow rate. Once the sampling has been completed, the pump is turned off and inlet orifices to the device are sealed/closed immediately. Post-sampling pump calibrations are performed in the same manner as pre-calibration to verify the pump remained operational for the duration of the sampling event. A Chain-of-Custody (CoC) form accompanies each shipment. Table I summarizes the typical flow rates and run times for each of these sampling designs.

Table I: Industrial Hygiene Sampling Designs and Parameters

Designs	Flow rate (l/minute)		Run time (minutes)		Air volume (liters)	
	Low	High	Low	High	Low	High
Filter cassette	2	2	15	480	30	960
Sorbent tube	0.2	0.8	15	120	3	96

In addition to IH BZ samples, radiological BZ samples are collected in locations and have similar IH BZ sampling parameters. The typical air volume collected for a radiological BZ sample is 825 liters.

Another check to determine the presence of any airborne radiological contamination is using either high volume ("hi-vol") or low volume ("lo-vol") samplers. The volume of air sampled with these devices typically range from 20,000 to 30,000 liters for the lo-vol and hi-vol samplers, respectively. Comparing IH sampler (960 liters) and "low-vol" sampler (20,000 liters) volumes collected over the same time scale, the 20-times difference in collection volume and the sensitivity of detecting low levels of radioactivity would provide additional evidence if any measurable airborne radioactivity was present on the IH BZ sample.

Radiological Screening to Detect Radioactivity in Excess of Background Radioactivity

The radiological contamination deposited on the IH BZ sample should be uniformly distributed and, therefore, proportional to the radiological contamination collected by the radiological BZ sample (C_{RAD}). Assuming equal collection efficiencies for the IH and radiological samples, the radiological contamination on the IH BZ sample can then be calculated by multiplying the volume of air sampled by the IH sampler (V_{IH}) and the radiological air concentration (C_{RAD}) as shown in equation 1:

$$A_{IH} = V_{IH} * C_{RAD} * c \qquad \text{(Eq. 1)}$$

Where:
A_{IH} = radiological contamination on the IH BZ sample (dpm)
V_{IH} = the volume of air sampled by the IH sampler (ml)
C_{RAD} = the radiological air concentration (uCi/ml)
c = conversion factor (2.22E+6 dpm/uCi)

Depending on V_{IH}, A_{IH} would be expected to increase proportional to C_{RAD}. However, if radioactivity was not detected on C_{RAD}, then from a radiological control perspective, A_{IH} would be evaluated as being free of any radiological contamination, i.e., “no rad added”.

To eliminate differences between IH and radiological sampling media and collection parameters, additional IH BZ samples are worn by employees in the field such that a pre-determined number of IH BZ samples can be “sacrificed” for analysis. For a pre-determined sample, the collection medium is removed from its cassette or sorbent tube housing and counted on a system to screen for any detectable radioactivity in excess of background radioactivity. Background radioactivity consists of cosmic radiation that continuously bombards the earth’s atmosphere and the existence of natural radioactivity in the environment. This background radioactivity produces a signal in all radiation detectors. The background signal varies greatly with the size and type of detector, and can be reduced depending on the amount of detector shielding. Although an RWP identifies controlled area access requirements, the activities performed by the employees and monitored using BZ samples do not always result in a radiologically contaminated IH BZ sample. Instead of counting added radioactivity, the background signal variations can produce from thousands of counts per second for large volume scintillators to less than a count per minute for specialized applications. Because the magnitude of the background ultimately determines the detection capability of the measurement system, it becomes most significant in these types of situations involving low-level source term applications. Such is the case with IH BZ samples.

Therefore, to improve the reliability that IH BZ samples do not contain any added radioactivity in excess of background radioactivity, the detection limit (L_d) of a measurement system is calculated using equation 2:

$$L_d = 3 + 4.65 * \sqrt{B} \qquad \text{(Eq. 2)}$$

Conceptually, the L_d represents the smallest quantity of radioactivity that can be detected under specified conditions (e.g., the 95% confidence limit). The L_d is a very useful criterion for evaluating the measurement system performance. For example, a measurement system becomes increasingly more sensitive in its ability to detect and quantify the presence of any added radioactivity in a sample as the L_d continues to decrease. In addition, to quantify a value compared to an administrative action level, the measurement system parameters should be established so the L_d is one order of magnitude below the expected measurement system response at that action level (9). Dividing the L_d by a conversion factor (K) and time (t) provides the minimum detectable activity (MDA) that is calculated using equation 3:

$$MDA = (3 + 4.65 * \sqrt{B})/(K*t) \qquad \text{(Eq. 3)}$$

Where:

K = Counter efficiency, conversion factors
t = Sample and background counting time

If a background count rate (e.g., counts per second, counts per minute) is reported, B must be in the same units as t. Various derivations of equation 3 are available in the literature (10, 11, 12, 13).

The major factors affecting the MDA of a measurement are:

- Background of the detection system
- Collection efficiency of the sample media
- Counting time
- Efficiency of the detection system
- Percent abundance of the nuclide of interest

Of these factors, the greatest control is over background and efficiency. Therefore, to obtain useful MDAs in the shortest amount of counting time, the measurement system should have the lowest possible background and highest efficiency. Requirements for establishing and maintaining a characterization program for analyzing samples containing radioactivity in excess of background radioactivity are discussed elsewhere (14).

Radiological Screening to Determine if IH BZ Samples are Subject to the U.S. Department of Transportation (DOT) Hazardous Material Regulations (HMR)

In accordance with 49 CFR Part 173.22 – *Shipper's responsibility*, it is the shipper's responsibility to properly class, describe, and prepare a hazardous material for shipment in commerce (15). Therefore, the purpose of this radiological screening process is to verify that any radioactive material measured on an IH BZ sample is below the DOT *de minimus* level, i.e., the IH BZ sample does not contain any radioactivity and thus does not qualify as radioactive material. According to 49 CFR Part 173.403 - *Definitions*, the DOT *de minimus* level for radioactive material means any material having a specific activity greater than 70 Becquerels per gram (Bq/g) (2 nanocuries per gram) (5). The specific activity of a radionuclide means the activity of the radionuclide per unit mass of that nuclide. The specific activity of a material in which the radionuclide is uniformly distributed is the activity per unit mass of the material. By demonstrating that any measured radioactivity on the IH BZ sample does not meet this defining criterion, the IH BZ samples are not subject to Hazardous Material Regulations (HMRs). Also, this screening process eliminates any secondary concerns associated with laboratory NRC licensing issues. Another precautionary measure would be to have the AIHA-accredited laboratory possess an NRC license.

When considering project history, process knowledge and the radiological screening process, the IH BZ samples collected in RWP-controlled areas have not resulted in any measurable contamination, i.e., specific activities have been less than the 70 Bq per gram (2 nCi/g) limit. Furthermore, the IH BZ samples would not be expected to qualify as hazardous materials or dangerous goods based on the following factors:

1) Samples collected using NIOSH analytical methods (e.g., NIOSH analytical method 7300, *Elements by ICP*) references shipping as “routine” (i.e., not requiring any special precautions during shipment) using government and commercial carriers. For example, the IH BZ samples are not required to be maintained below a certain temperature using dry ice while in shipment.

2) The total quantity of material collected on each filter is typically less than 2 milligrams (or as specified in the particular NIOSH method) most of which are the same materials that exist in airborne dust.
3) The quantities of hazardous metals that might be collected on these filters are insignificant, on the order of micrograms that do not pose any shipment hazards.
4) The flow path for “most” of the airborne radioactive material would be directed through the filter media. While a portion of the radioactive material would tend to plate out on the walls of the collection device interior (i.e., a surface contaminated object [SCO]), one would expect this deposition to be qualitatively less than what is collected on the filter media. Since past analyses have reported filter media to be less than its specific activity *de minimus* level, the collection device’s optimized airflow design would suggest its interior to be less than the *de minimus* levels for an SCO (16).
5) These types of samples do not meet any of the other DOT or International Air Transport Association (IATA) hazard definitions (17).

PREPARING FOR OFF-SITE SHIPMENT

The IH BZ samples that are potentially contaminated with radioactive material on their exterior surfaces are surveyed to verify that removable and total surface contamination levels, including external dose rates, are below all administrative limits prior to being released for off-site shipment using a governmental or private carrier. These administrative limits, usually set at 80% of the unrestricted release limits, are found in 10 CFR 835 - *Occupational Radiation Protection* (4).

CONCLUSION

The shipping of IH BZ samples for off-site analyses that may contain residual amounts of radioactive material prompted the search for an innovative approach to comply with DOE, DOT and NRC regulations. The intent of these regulations is to protect those employees and members of the general public that may come in contact with these types of suspect IH BZ samples. However, instead of relying on unnecessary conservative assumptions that tend to overestimate risks to the general public, the guidance discussed herein provides a consistent, streamlined decision process for releasing these samples from a radiological and DOT perspective.

The information used to accomplish this consists of a combination of radiological air sampling results, existing NIOSH method information and process knowledge. A simple method of verifying the maximum amount of internal radiological contamination in the IH BZ sample is to multiply the radiological air concentration by the volume of air sampled by the IH BZ air sampler. The radiological air concentration would have been determined by results obtained from either a radiological BZ sample or a sacrificed IH BZ sample. Although IH and radiological BZ samples may have been collected in an RWP-controlled area, the lack of any detectable contamination on either sample cassette or filter media would signify the absence of any airborne radioactivity. Therefore, the IH BZ samples would not be subject to DOE and NRC regulations governing radioactive material. Actual field results have shown that IH BZ samples are unlikely to contain any radiological contamination if corresponding radiological air samples do not report any detectable contamination. Furthermore, the quantities of hazardous metals and radioactive materials that might be collected on these filters are insignificant, on the order of micrograms and do not pose any shipment hazards.

However, if any radioactivity were detected on either the filter media taken from the “sacrificed” IH BZ sample or the corresponding radiological air sample, a small percentage of radioactivity would likely be detected on the interior of the collection device prompting the evaluation of the device as an SCO. Therefore, the filter media and the collection device are considered separately when calculating the DOT specific activity and SCO for the IH BZ sample, respectively. The filter media results can then be compared to the DOT specific activity *de minimus* level of 70 Bq/g (2 nCi/g). The sample collection device (i.e., a potentially-contaminated SCO) may be considered excepted from classification as Class 7 (radioactive) material if: (1) contamination when averaged over each 300 cm^2 (46.4 $inches^2$) of all surfaces is less than its *de minimus* level of 0.4 Bq/cm^2 (10^{-5} uCi/cm^2) for beta and gamma emitters and low toxicity alpha emitters, and is also less than its *de minimus* level of 0.04 Bq/cm^2 (10^{-6} uCi/cm^2) for all other alpha emitters, and (2) the object itself has an average specific activity less than 70 Bq/g (2 nCi/g) (16). Nevertheless, if radioactive material was detected on the IH BZ sample that exceeded prescribed radiological and DOT requirements, appropriate controls would be upgraded accordingly, e.g., establishing a radioactive material area, performing a limited quantity shipment.

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FOOTNOTES

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