NIOSH Investigation into the Issues Raised in Comment 19 from SCA-TR-TASK1-005

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Revision 0

March 11, 2014

This response has been generated to support the NIOSH Response to Comment 19 in SCA-TR-TASK1-0005

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1.0 PURPOSE

The purpose of this white paper is to summarize the results of an investigation that was performed by NIOSH in regards to the issue stating that NIOSH should provide angular dependence (anatomic geometry) correction factors for external gamma doses in ORAUT-TKBS-0007-6. The results of this investigation are intended to assist NIOSH with its response to Comment 19 in SCA-TR-TASK1-0005 (SC&A 2006).

2.0 SUMMARY OF RESULTS

Even though the higher level guidance in the *External Dose Reconstruction Implementation Guideline* (NIOSH 2007) already permits the dose reconstructors to adjust the doses for organs to account for non-uniform exposure geometries and that the *Technical Information Bulletin: Best Estimate External Dose Reconstruction for Glovebox Workers* (DCAS 2010) already provides specific guidance regarding adjusting doses to the organ in the lower torso, NIOSH will add some additional guidance to ORAUT-TKBS-0007-6.

3.0 BACKGROUND

Comment 19 was made in regards to the information provided in Revision 00 of the document titled *Technical Basis Document for the Idaho National Engineering and Environmental Laboratory (INEEL) – Occupational External Dosimetry* (ORAUT 2004). Even though the current version of this document is Revision 03, Comment 19 is still considered to be a valid comment, since changes have been made to this document that would affect this comment (ORAUT 2004, 2011). However, it should be noted that the title of this technical basis document has been changed to *Technical Basis Document for the Idaho National Laboratory and Argonne National Laboratory-West – Occupational External Dosimetry* for Revision 03 (ORAUT 2011). In addition, to simplify identifying and/or referring to this technical basis document (**TBD**) in the subsequent sections of this white paper, all versions of this document will be referred to as the ***external TBD***.

3.1 Summary of the Issue

Comment 19 as stated in the INL Issue Resolution Matrix for Findings and Key Observations (i.e. Attachment 5 of SCA-TR-TASK1-0005) (SC&A 2006).

> Issue 19: (5.1.4.1.4) Angular Dependence Correction Factor for Gamma Dose - NIOSH should provide angular dependence (anatomic geometry) correction factors for external gamma doses, particularly for low-photon energies, where the angular dependence of the sensitivity of the dosimeter is most pronounced. These correction factors are used to account for, for example, the bias introduced by a dosimeter worn at the neck level and the higher doses received by tissues/organs below the waist.

The section regarding Comment 19 that is in the main body of the INL site profile review (i.e. Section 5.1.4.1.4 of SCA-TR-TASK1-0005) (SC&A 2006) is provided below.

> 5.1.4.1.4 Angular Dependence Correction Factor for Gamma Dose
>
> NIOSH should provide an angular dependence (anatomic geometry) correction factor for external photon doses. This correction factor would be used to account for the bias of a dosimeter worn at the neck level and the higher doses received by tissues/organs below the waist. The angular dependence of the sensitivity of the dosimeter is most pronounced at low-photon energies (SC&A 2005, pp. 143–145).

Reference "SC&A 2005, pp.143–145" is Attachment 9 to the Third Supplemental Review of the Mallinckrodt Site Profile (SCA-TR-TASK1-0002, Revision 1 dated March 10, 2005). The entire Third Supplemental Review to SCA-TR-TASK1-0002 can be found in ORAUT's Site Research Database as Reference 37623. The primary portion of this reference being used in Section 5.1.4.1.4 of the INL site profile review has been excerpted and provided below.

> Radiological Uncertainty. When a film badge is worn by a worker, additional uncertainties must be considered that reflect the (1) long wear period(s), (2) potentially complex radiation fields and photon energies, and (3) dosimeter's variable and reduced response at incident angles other than zero.
>
> This last factor is known as angular dependence and has been assessed in behalf of DuPont 510 film, which was commonly used as the industry standard.

Table 1 identifies the relative film badge sensitivity for photon incident angles, as reported by Hine and Brownell (1956).

Table 1. Angular Sensitivity for DuPont 510 Film Dosimeters

Angle of Incidence	Photon Energy		
	0.11 MeV	**0.20 MeV**	**1.2 MeV**
0^o (perpendicular)	1.00	1.00	1.00
22.5^o	0.87	0.92	0.97
45^o	0.46	0.73	0.91
67.5^o	0.33	0.45	0.92
90^o	0.16	0.41	0.94

Inspection of Table 1 shows that angular dependence increases with angle and is most pronounced at low photon energies. For example, at 67.5º incidence, the dosimeter's response to 200 keV photons is reduced to 45% of its response under laboratory or 0º incidence exposure conditions.

By means of interpolation, reasonable estimates may be obtained for other angles as well as composite angles defined by isotropic and rotational exposure geometries. For example, 200 keV photons incident at 60º will likely cause a film badge to under-respond by a factor of about two.

The reference "Hine and Brownell (1956)" is a book titled *Radiation Dosimetry* (Hine et al. 1956). This reference indicates that the data in **Table 1** above is data obtained on the National Bureau of Standards (NBS) film dosimeter, and references NBS Handbook 57 (Ehrlich 1954) as the source of that information. The reference also indicated that the NBS dosimeter consisted of DuPont 510 film, with the electron equilibrium layer of 8.25 mm Bakelite adjacent to the film and absorbers of 1.07 mm Sn and 0.3 Pb outside the Bakelite.

4.0 NIOSH RESPONSE

When appropriate, the *Technical Information Bulletin: Best Estimate External Dose Reconstruction for Glovebox Workers* (DCAS-TIB-0010) allows the dose reconstructors to apply a special geometry correction factor to the doses to organs in the lower torso to account for the angular dependence associated with working with radioactive materials in gloveboxes or other benchtop work environments (referred to as just glovebox work after this point) (DCAS 2010). The use of the approach described in DCAS-TIB-0010 to adjust the doses to the organs in the

lower torso when glovebox work was performed has since been approved by the Procedures Subcommitte. Even though the ***external TBD*** does not refer to DCAS-TIB-0010, the ***external TBD*** does refer to *External Dose Reconstruction Implementation Guideline* (OCAS-IG-001), which allows dose reconstructors to adjust organ doses to account for non-uniform exposure geometries (NIOSH 2007).

Although the higher level guidance in OCAS-IG-001 already permits the dose reconstructors to use DCAS-TIB-0010 to adjust the doses for organs in the lower torso when the circumstances are appropriate, NIOSH will add the following to Section 6.4 of ORAUT-TKBS-0007-6 as additional guidance for the dose reconstructors.

> An underestimation of external dose can occur for organs in the lower torso when workers spend a significant amount of their time working with radioactive materials in gloveboxes or other benchtop work environments (referred to as just glovebox work after this point). At the INL site, glovebox work involving radioactive materials was predominately performed in laboratory settings, uranium processing areas, some settings requiring work in an inert atmosphere, certain maintenance applications, and at sample collection stations.
>
> In general, DCAS-TIB-0010 adjustments to the measured and missed external photon and neutron doses should be considered for cancer organs in the lower torso when glovebox work is indicated in claim documents (e.g. the computer assisted telephone interview) and when the identified places of work or work activities would have included glovebox work.

6.0 REFERENCES

Hine, G. J., and G. L. Brownell, 1956, *Radiation Dosimetry,* Academic Press, Inc., New York, New York.

DCAS (Division of Compensation Analysis and Support), 2011, *Technical Information Bulletin: Best Estimate External Dose Reconstruction for Glovebox Workers, Rev 4*, DCAS-TIB-0010, November 28. [SRDB Ref ID 104815]

Ehrlich, M., 1954, *Photographic Dosimetry of X- and Gamma Rays*, NBS Handbook 57, U.S. Department of Commerce, National Bureau of Standards, Washington D.C., August 20. [http://www.orau.org/ptp/Library/NBS/NBS%2057.pdf]

NIOSH (National Institute of Occupational Safety and Health), 2007, *External Dose Reconstruction Implementation Guideline, Rev 3*, OCAS-IG-001, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio, November 21. [SRDB Ref ID 38864]

ORAUT (Oak Ridge Associated Universities Team), 2004, *Technical Basis Document for the Idaho National Engineering and Environmental Laboratory (INEEL) – Occupational External Dosimetry*, ORAUT-TKBS-0007-6, Rev 00, Oak Ridge, Tennessee, April 6. [SRDB Ref ID: 19521]

ORAUT (Oak Ridge Associated Universities Team), 2011, *Technical Basis Document for the Idaho National Laboratory and Argonne National Laboratory-West – Occupational External Dosimetry*, ORAUT-TKBS-0007-6, Rev 03, Oak Ridge, Tennessee, April 19. [SRDB Ref ID: 94104]

SC&A (S. Cohen & Associates), 2005, *Third Supplemental Review of the Mallinckrodt Site Profile Revision 1,* Third Supplement to SCA-TR-TASK1-0002, August 16. [SRDB Ref ID: 15451]

SC&A (S. Cohen & Associates), 2006, *Review of the NIOSH Site Profile for the Idaho National Laboratory, Idaho*, SCA-TR-TASK1-005, January 25.