



A Review of ORAUT-OTIB-0087 for Extremity Doses for Mound Exposures to Plutonium-238

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ORAUT-OTIB-0087

- ◆ Issued by NIOSH September 18, 2017, rev. 00.
- ◆ Provides information that may be used to determine ratios to assist in the assignment of extremity doses.
- ◆ Some energy employees (EEs) at Mound were only assigned whole-body (WB) dosimetry.
- ◆ However, the work they performed may have included handling or working around plutonium (Pu)-238.
- ◆ It would be expected that the dose to the extremities (forearm, wrist, hand, or finger) would be elevated in comparison with the WB dose.
- ◆ If an EE's extremity dosimeter results are available, those results should be used to assign dose to the cancer site on the extremity. If not, the extremity-to-WB ratio applied to the WB dose can be used to determine the dose to the cancer site on the extremity.

SC&A review of OTIB-0087: Chronology

- ◆ **October 26, 2022:** The SPR tasked SC&A to review ORAUT-OTIB-0087, revision 00
- ◆ **April 21, 2023:** SC&A issued (not PA-cleared) “A Review of ORAUT-OTIB-0087 for Extremity Doses for Mound Exposures to Plutonium-238” to SPR and NIOSH
- ◆ **May 2023:** SC&A issued a PA-cleared version

Mound 1972 extremity dose study

- ◆ Mound initiated a study in September 1972 to determine the need for extremity monitoring for personnel involved in Pu-238 operations at the site (Bigler, 1973).
- ◆ Wrist badges for determining gamma exposure using lithium-fluoride (LiF) thermoluminescent dosimeters (TLDs) and neutron exposure using nuclear track emulsion, type A (NTA) film were selected.
- ◆ Workers who performed the operations were monitored for various lengths of time ranging from 2 to 22 weeks, with a 2-week dosimeter exchange frequency.

Mound 1972–1973 fingertip dose study

- ◆ A study (Bigler & Phillabaum, 1973) was also performed 1972–1973 with wrist and WB gamma and neutron dosimeters during work in gloveboxes where the workers were wearing leaded rubber gloves.
- ◆ The monitoring approach for detecting the gamma and neutron dose used the same monitoring approach (i.e., LiF TLDs and NTA film, respectively) as the 1972 extremity study.
- ◆ This study also involved taping TLDs to the fingertips on the second or third finger of each hand to determine the gamma dose to the fingertips. The number of days the dosimetry was worn ranged from 3 to 10 days.

NIOSH's use of data from these two studies

- ◆ NIOSH used these data to determine ratios for:
 - Left wrist-to-WB and right wrist-to-WB for gamma and neutron exposures
 - Left finger-to-left wrist and right finger-to-right wrist gamma ratios for a limited number of applications

Wrist-to-whole body gamma dosimetry data analysis

- ◆ Table 5-1 of OTIB-0087 summarizes wrist-to-WB gamma dosimetry data for the left and right wrist for 28 employees covering nine different operations involving the handling of Pu-238 at Mound.
- ◆ NIOSH found that wrist-to-WB gamma dosimetry data were best represented using a Weibull distribution.
- ◆ Figure 5-1 of OTIB-0087 provides a summary plot of the fit comparison for the gamma wrist-to-WB ratio.
- ◆ NIOSH determined the Weibull distribution values were 1.3295 (shape of curve), 1.9271 (scale), and 0.3436 (location).

Wrist-to-whole body neutron dosimetry data analysis

- ◆ Table 5-1 of OTIB-0087 summarizes wrist-to-WB neutron dosimetry data for the left and right wrist for 28 employees covering nine different operations involving the handling of Pu-238 at Mound.
- ◆ NIOSH found that the wrist-to-WB neutron dosimetry data were best represented using a lognormal distribution.
- ◆ Figure 5-2 of OTIB-0087 provides a summary plot of the fit comparison for the neutron wrist-to-WB ratio.
- ◆ NIOSH determined the most appropriate fit to be a lognormal distribution with a geometric mean of 1.5796 and geometric standard deviation of 2.5414.

Finger-to-wrist gamma dosimetry data analysis

- ◆ Table 5-2 of OTIB-0087 summarizes finger-to-wrist gamma dosimetry data for the left and right wrist for six workers covering three different operations involving the handling of Pu-238 at Mound.
- ◆ NIOSH found that since the data are limited, a fit comparison could not be determined. Therefore, NIOSH recommends the use of a normal distribution model.
- ◆ From the limited dataset, NIOSH calculated an average:
 - Left-hand finger-to-wrist ratio of 3.18, with a standard deviation of 0.53
 - Right-hand finger-to-wrist ratio of 2.76, with a standard deviation of 0.85
- ◆ Unless it is known that a worker is right- or left-handed, NIOSH recommends that the higher ratio should be used (i.e., 3.18 with a standard deviation of 0.53).

SC&A's review of ORAUT-OTIB-0087

- ◆ SC&A evaluated:
 - The original recorded Mound data
 - NIOSH's use of the data in constructing tables 5-1 and 5-2 and figures 5-1 and 5-2 of OTIB-0087
 - Dose reconstruction (DR) recommendations in OTIB-0087, section 6.0
- ◆ SC&A also performed a statistical analysis of the data used in OTIB-0087

SC&A's evaluation of original Mound data used in OTIB-0087

- ◆ SC&A reviewed the tabulated Mound data (Bigler, 1973, PDF pp. 177–183; Bigler & Phillabaum, 1973, PDF pp. 203–206).
- ◆ SC&A found that the measurements were conducted using acceptable dosimetry methods.
- ◆ However, SC&A found that the quantity of data was somewhat limited:
 - Data from 28 employees for determining wrist-to-WB ratios
 - Data from 6 employees for determining finger-to-wrist ratios
- ◆ Large variations in the resulting ratio values (0.3 to 7) were listed in table 5-1 of OTIB-0087 for both gamma and neutron wrist-to-WB dose ratios.

Wrist-to-WB ratios as a function of operation

- ◆ SC&A reviewed the wrist-to-WB ratios to determine if there was a general correlation of ratio values to the operation the workers performed.
- ◆ SC&A found that the right and left wrist-to-WB ratios varied according to the type of operation being performed (for both gamma and neutron doses), as summarized in tables 1 and 2 of SC&A's review report.
- ◆ Relationship of wrist-to-WB ratios is examined in more detail in attachment A of SC&A's review report.

Caution when applying ratios to other operating periods or DOE sites

Finding 1: When applying ratios to other operating periods or DOE sites, NIOSH should have an understanding that the exposure conditions are similar to those used in OTIB-0087

- ◆ Considering the variations in wrist-to-WB ratio values as a function of operation, it is important when applying the Mound extremity ratio values to DRs from other operating periods at Mound or other U.S. Department of Energy (DOE) sites to first ascertain that the conditions of exposure to Pu-238 are encompassed by the Mound operations.

SC&A's evaluation of tables 5-1 and 5-2

Observation 1: Two entries from Mound data not located in OTIB-0087

- ◆ SC&A found that NIOSH incorporated all six entries of the Mound data for finger-wrist-to-WB exposure into table 5-2 of OTIB-0087.
- ◆ SC&A found that NIOSH incorporated the first four entries of the Mound data for finger-wrist-to-WB exposure into table 5-1.
- ◆ It does not appear that the last two entries of the Mound data for finger-wrist-to-WB exposure were incorporated into table 5-1.
- ◆ This omission would not greatly affect the results. However, it would be helpful for NIOSH to clarify why these last two entries appear to be omitted.

SC&A's evaluation of figures 5-1 and 5-2

Observation 2: Discrepancies in number of ratios and values between table 5-1 and figures 5-1 and 5-2

- ◆ Figure 5-1 reports that 55 values were used to construct the histogram and fit the Weibull curve. However, only 45 valid wrist-WB gamma ratios are reported in table 5-1.
- ◆ The mean ratio is reported as 2.116 in figure 5-1, but the mean of the wrist-WB gamma ratios in table 5-1 is 2.143.
- ◆ Figure 5-2 reports that 53 values were used to construct the histogram and fit the lognormal distribution. However, there are only 43 valid wrist-WB neutron ratios in table 5-1.
- ◆ Figure 5-2 lists minimum and mean neutron ratio values of 0.179 and 2.551, respectively. The minimum wrist-WB neutron ratio listed in table 5-1 is 0.27, and the mean wrist-WB neutron ratio in the table is 2.502.

SC&A's statistical analysis of available data

- ◆ The sparsity and variation of the data in table 5-1 suggests that the estimated ratios in OTIB-0087 are likely quite imprecise. There are several issues that suggest this:
 - **Sparsity of data:** A relatively small number of observations are used in the estimation.
 - **Outliers:** Some large outliers in the ratio measurements affect the ability to accurately fit empirical distributions.
 - **Linear relationship:** The use of ratios to estimate wrist doses from WB doses assumes a linear relationship between the two types of doses. The linear relationship is not entirely evident from the data in table 5-1.
 - **Operation type:** There are indications that the relationship between wrist doses and WB doses differs by operation type, which suggests the need for different estimated ratios by operation type for imputations to be valid.

Result of SC&A's analysis of available data

- ◆ Attachment A of SC&A's review report summarizes SC&A's analysis of the data.
- ◆ As a result of this analysis, SC&A had the finding 2 about the ratio values.
- ◆ **Finding 2:** Use of upper bound may be more appropriate in dose reconstruction
 - Considering the limitations of the data, SC&A suggests that it would be more claimant favorable to use an upper bound ratio, such as the upper limit of the confidence interval, instead of a distribution or average ratio value.

NIOSH's recommendations in OTIB-0087, section 6.0

- ◆ **To determine the gamma dose to the wrist:** Use the Weibull distribution in conjunction with the gamma WB dose.
- ◆ **To determine the neutron dose to the wrist:** Use the lognormal distribution in conjunction with the neutron WB dose.
- ◆ **When evaluating the finger-to-wrist extremity dose:**
 - Use the ratio value of 3.18 times the wrist dose for the left finger dose
 - Use the ratio value of 2.76 times the wrist dose for the right finger.
 - If it is not known if the worker was right- or left-handed, use the greater of the ratio values, 3.18.

SC&A's conclusions

- ◆ SC&A evaluated the original recorded Mound data, its use in constructing tables 5-1 and 5-2, and the DR recommendations
- ◆ SC&A also performed a statistical analysis of recorded data
- ◆ SC&A identified two findings and two observations:
 - **Finding 1:** Caution when applying ratios to other operating periods or DOE sites
 - **Finding 2:** Use of upper bound may be more appropriate in dose reconstruction
 - **Observation 1:** Two entries from Mound data not located in OTIB-0087
 - **Observation 2:** Discrepancies in number of ratios and values between table 5-1 and figures 5-1 and 5-2

References

Bigler, W. A. (1973). *Extremity monitoring study of personnel in plutonium operations*. Monsanto Research Corporation, Mound Facility, Miamisburg, Ohio. SRDB Ref. ID 003281, PDF pp. 177–191

Bigler, W. A., & Phillabaum, G. L. (1973). *Wrist and fingertip dose measurements for plutonium-238 processing operations*. Monsanto Research Corporation, Mound Facility, Miamisburg, Ohio. SRDB Ref. ID 003281, PDF pp. 203–206

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<https://www.cdc.gov/niosh/ocas/pdfs/tibs/or-t87-r0.pdf>

SC&A, Inc. (2023). *A review of ORAUT-OTIB-0087 for extremity doses for Mound exposures to plutonium-238* (SCA-TR-2023-PR087, rev. 0).