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Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

A Review of ORAUT-OTIB-0040 for External Coworker Dosimetry Data for the Portsmouth Gaseous Diffusion Plant

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Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
CTW	construction trade worker
CE	co-exposure
DCAS	Division of Compensation Analysis and Support
DOE	U.S. Department of Energy
DR	dose reconstruction
EE	energy employee
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron volt
NIOSH	National Institute for Occupational Safety and Health
NP	nonpenetrating
ORAUT	Oak Ridge Associated Universities Team
PGDP	Portsmouth Gaseous Diffusion Plant
SRDB	Site Research Database

1 Statement of Purpose

To support dose reconstruction (DR), the National Institute for Occupational Safety and Health (NIOSH) and the Oak Ridge Associated Universities Team (ORAUT) assembled a large body of guidance documents, workbooks, computer codes, and tools. One of those documents is ORAUT-OTIB-0040, revision 00 PC-1, "External Coworker Dosimetry Data for the Portsmouth Gaseous Diffusion Plant" (ORAUT, 2006a; "OTIB-0040"), which provides information to allow ORAUT dose reconstructors to assign doses to Portsmouth Gaseous Diffusion Plant (PGDP) workers who have no or limited monitoring data, based on site co-exposure [1] (CE) data.

On November 16, 2023, SC&A was tasked by the Subcommittee for Procedure Reviews to review ORAUT-OTIB-0040, revision 00 PC-1 (ORAUT, 2006a).

2 NIOSH's General Approach to External Co-exposure Dosimetry Data for PGDP

2.1 Source of data

NIOSH obtained dosimetry data for monitored PGDP workers from the site in the database "HR_prior_1993.mdb." Historical external data through 1992 were in a table within the database titled, "Doseext_dat." In all cases, the reported data corresponded to individual badge readings of deep dose (i.e., penetrating gamma radiation) and shallow dose (i.e., penetrating plus nonpenetrating (NP) radiation).

2.2 NIOSH's analysis of data in ORAUT-OTIB-0040

NIOSH analyzed the recorded individual badge results for developing the CE data as summarized in the sections 2.2.1 through 2.2.6 of this report.

2.2.1 NIOSH prorated wear time

NIOSH prorated the recorded annual doses by accounting for the average fraction of a given year energy employees (EEs) worked at the PGDP. For example, if the average time worked for 1965 was 11 months, the derived CE penetrating and shallow doses for 1965 was multiplied by 12 divided by 11 to get an adjustment factor of 1.09. The data were prorated so that CE doses represented a full year of monitored employment. This permits the dose reconstructor to assign appropriate doses based on specific employment periods.

2.2.2 NIOSH included missed dose

NIOSH calculated missed doses by multiplying the number of null badge readings by the reported dosimeter limit of detection and summing the results. NIOSH provides a summary of the missed dose parameter in table 6-1 of OTIB-0040 for the period 1954–present.

NIOSH added one-half of the appropriate maximum annual missed doses from table 6-1 to the derived annual penetrating and shallow doses when annual doses were reported as zero. For reported positive doses, the maximum missed dose was reduced by one badge exchange because

[1] Co-exposure data had previously been referred to as "coworker data," but the two terms are equivalent.

it is not possible that all individual badge results were zero if a positive annual dose was reported. This method would likely be changed by the implementation of the methodology that uses a one person, one sample procedure to derive the arithmetic average of a worker's bioassay results in a time period (ORAUT, 2014; NIOSH, 2020). In the case of external dosimetry, each missed dose cycle would be evaluated and attributed to the individual worker and then incorporated into subsequent dose distributions.

2.2.3 NIOSH derived the 50th and 95th percentile annual penetrating and shallow doses

NIOSH derived the 50th and 95th percentile annual penetrating and shallow doses from the adjusted recorded penetrating and shallow doses by ranking the data into cumulative probability curves and extracting the 50th and 95th percentile doses for each year.

2.2.4 NIOSH derived nonpenetrating doses

The individual doses were recorded in the database as penetrating gamma and shallow doses. NIOSH derived NP dose by subtracting the penetrating from the shallow dose. NP dose is to be assigned as >15 kiloelectron volt (keV) electrons, with correction factors applied to account for clothing attenuation or other applicable considerations.

2.2.5 NIOSH's summary of penetrating and nonpenetrating doses

NIOISH summarizes the 50th and 95th percentile annual penetrating ("Gamma") and NP ("Non-pen") CE doses for 1954–1992 in table 8-2 of OTIB-0040. NIOSH recommends:

- The 50th percentile dose be used as a best estimate of a worker's dose when professional judgment indicates the worker was likely exposed to intermittent low levels of external radiation. The 50th percentile CE dose should not be used for workers who were routinely exposed.

- For routinely exposed workers (i.e., workers who were expected to have been monitored), the 95th percentile CE dose should be applied.

- For workers who are unlikely to have been exposed, external onsite ambient dose should be used rather than CE doses.

NIOSH notes that a "zero" value in table 8-2 for NP dose will not result in a dose of zero being assigned to an organ such as the skin. For example, the 50th percentile CE dose to the skin in 1960 would be assigned entirely as 0.195 rem of photons. This approach does not result in an underestimation of probability of causation because assigning beta dose as gamma dose in the Interactive RadioEpidemiological Program (IREP) has no negative effect, since the radiation effectiveness factors are the same for >15 keV electrons and >250 keV photons and are higher for 30–250 keV photons.

2.2.6 NIOSH adjusted penetrating dose for construction trade workers

NIOSH adjusted the derived penetrating annual CE doses per recommendation in ORAUT-OTIB-0052, revision 00 (ORAUT, 2006b). NIOSH summarizes the 50th and 95th percentile annual CE penetrating dose for construction trade workers (CTWs) for 1954–1992 in table 8-3 of OTIB-0040.

3 SC&A's Review of ORAUT-OTIB-0040

SC&A reviewed the original recorded PGDP dosimetry data, evaluated NIOSH's analysis of the data and recommendations, and evaluated NIOSH's use of the data in constructing tables 8-2 and 8-3 of OTIB-0040 as outlined in sections 3.1 through 3.3 of this report.

3.1 SC&A's review of original PGDP data used in OTIB-0040

SC&A reviewed the PGDP dosimetry data in the "Portsmouth Pen" and the "Portsmouth Shallow" files supplied by NIOSH. SC&A found that the "Portsmouth Pen" file contains a spreadsheet with the individual recorded dosimetry data entered as "DDE_mrem" for deep dose equivalent by year for 1954–1992. The "Portsmouth Shallow" file contains a spreadsheet with the individual recorded dosimetry data entered as "SDE_mrem" for shallow dose equivalent dose by year for 1954–1992. The dosimetry entries include recorded zeros as well as positive dose values. NIOSH analyzed the deep dose and shallow dose entries further to derive the 50th and 95th percentile dose values for 1954–1992 and the average duration the dosimeters were worn each year. NIOSH then derived the 50th and 95th percentile deep and shallow dose equivalent values adjusted for the wear period for each year for 1954–1992. NIOSH used the recorded positive dose values along with the recorded zeros in deriving the adjusted dose values. These time-adjusted dose values were used to calculate the doses listed in table 8-2 of OTIB-0040.

SC&A analyzed the methods and calculations NIOSH used to derive the dose values in table 8-2 of OTIB-0040 from the individual recorded dosimetry data in the Portsmouth files. SC&A found that NIOSH correctly converted the recorded dosimetry data to the dose values in table 8-2 as outlined in section 3.3 of this report.

3.2 SC&A's evaluation of NIOSH's analysis of PGDP dosimetry data and recommendations

SC&A's evaluation of NIOSH's analysis of the data and recommendations in sections 6.0 and 7.0 of OTIB-0040 is summarized in sections 3.2.1 through 3.2.9 of this report.

3.2.1 SC&A's evaluation of NIOSH's validation of data used for CE dose development

NIOSH outlines the validation of data used for CE dose development in section 6.0, page 6, of OTIB-0040. In summary, NIOSH performed a validation of the data use in the CE dose development by comparing a sampling of 10 claimants' dosimetry data from the NIOSH DCAS Claims Tracking System to the data used in the CE dose development for each of the 10 claimants. This covered more than 130 worker-years of monitored employment at PGDP. The comparison indicated excellent agreement (greater than 99 percent) between the two data sets.

SC&A reviewed NIOSH's data validation process and concurs that the results indicate the data used for CE dose development is valid. The CE data would also appear to meet the criteria set forth in a later report, ORAUT-RPRT-0086, revision 00 (ORAUT, 2017).

3.2.2 SC&A's evaluation of NIOSH's prorating of wear time

NIOSH outlines their method for prorating recorded doses by accounting for the average fraction of a given year EEs worked at PGDP in section 7.0, item 1, page 8, of OTIB-0040. NIOSH's method was summarized previously in section 2.2.1 of this report.

SC&A reviewed NIOSH's approach for prorating recorded doses and concurs with their method.

3.2.3 SC&A's evaluation of NIOSH's adjustment for missed dose

NIOSH outlines their method for adjusting for missed dose in section 6.0, pages 6 and 7, and section 7.0, item 2, page 8, of OTIB-0040. NIOSH's method was summarized previously in section 2.2.2 of this report.

SC&A reviewed NIOSH's method for adjusting for missed dose and the missed dose data used in table 6-1 of OTIB-0040. SC&A verified that the data used in table 6-1 is correct according to ORAUT-OTIB-0017, revision 01 (ORAUT, 2005a), and ORAUT-TKBS-0015-6, revision 00 (ORAUT, 2005b). SC&A had no findings about NIOSH's adjustment for missed dose but did have one observation.

Observation 1. Incorrect guidance in table 6-1 footnote

Footnote h in table 6-1 should read "See ORAUT-OTIB-0017 (Attachment D) for an explanation," instead of "See ORAUT-OTIB-0017 (Attachment C) for an explanation."

3.2.4 SC&A's evaluation of NIOSH's derivation of the 50th and 95th percentile annual penetrating and shallow doses

NIOSH outlines their method for deriving the 50th and 95th percentile annual penetrating and shallow doses in section 7.0, item 3, page 8 of OTIB-0040. NIOSH's method was summarized previously in section 2.2.3 of this report.

SC&A reviewed NIOSH's method for deriving the 50th and 95th percentile annual penetrating and shallow doses and concurs with their process.

3.2.5 SC&A's evaluation of NIOSH's derivation of nonpenetrating doses

NIOSH outlines their method for deriving NP annual doses in section 7.0, item 4, page 8, of OTIB-0040. NIOSH's method was summarized previously in section 2.2.4 of this report.

SC&A reviewed NIOSH's approach for deriving NP annual doses and concurs with their method.

3.2.6 SC&A's evaluation of NIOSH's summary of penetrating and nonpenetrating doses

NIOSH outlines their recommendations for the use of the CE penetrating and NP doses in section 7.0, item 5, page 8, of OTIB-0040. NIOSH's recommendations were summarized previously in section 2.2.5 of this report. NIOSH recommended penetrating and NP CE doses are listed in table 8-2.

SC&A reviewed NIOSH's recommendations for use of the CE penetrating and NP doses and concurs with their method. SC&A concurs that a "zero" value in table 8-2 for NP dose will not result in lack of dose being assigned to an organ such as the skin. However, NIOSH did not provide a reference concerning the statement that radiation effectiveness factors are the same for >15 keV electrons and >250 keV photons and are higher for 30–250 keV photons, as indicated in the last paragraph on page 8 of OTIB-0040. Therefore, SC&A has the following observation.

Observation 2: Reference needed for radiation effectiveness factors

SC&A requests that NIOSH provide a reference concerning the radiation effectiveness factors for >15 keV electrons, >250 keV photons, and 30–250 keV photons to allow SC&A to verify NIOSH's statement. OCAS-IG-001, revision 3 (NIOSH, 2007, p. 58), indicates that for the skin the dose conversion factor for 30–250 keV photons is not always greater than for >250 keV for all exposure geometries.

SC&A reviewed the doses in table 8-2 and found them correct. However, SC&A noted that table 8-2 should be labeled 8-1, since it is the first table in section 8.0.

3.2.7 SC&A's evaluation of NIOSH's adjustment of penetrating dose for construction trade workers

NIOSH outlines the method for deriving the CE penetrating dose for CTWs in section 8.0 of OTIB-0040, using recommendations from ORAUT-OTIB-0052 (ORAUT, 2006b). NIOSH's recommendations were summarized previously in section 2.2.6 of this report. NIOSH's recommended penetrating CE doses for CTWs are listed in table 8-3.

SC&A reviewed NIOSH's process for deriving the CE penetrating dose for CTWs and concurs with their method. SC&A reviewed the doses in table 8-3 and found them correct. However, SC&A noted that table 8-3 should be labeled 8-2, since it is the second table in section 8.0.

3.2.8 SC&A's evaluation of NIOSH's addressing neutron dose

NIOSH discusses PGDP neutron dose in item 3 of section 4.0, page 5, of OTIB-0040. NIOSH found that there were no neutron dosimetry results recorded in the PGDP EEs' files. NIOSH recognizes that there was potential for neutron exposure at PGDP in certain areas and facilities. Therefore, NIOSH recommends that ORAUT-TKBS-0015-6 (ORAUT, 2005b) be used for neutron dose assignment when appropriate.

SC&A concurs with NIOSH's evaluation of neutron dose. SC&A reviewed ORAUT-TKBS-0015-6 (ORAUT, 2005b) and found that section 6.5.3 recommends that a neutron-to-photon ratio of 0.2 be applied to the photon dose to assign neutron dose for the years prior to 1997, if appropriate (after 1996, neutron monitoring was performed if the potential for neutron exposure was present). NIOSH later issued ORAUT-RPRT-0060, revision 00 (ORAUT, 2019), which provides additional and updated information and recommendation for assignment of neutron dose applicable to DR for PGDP claimants.

3.2.9 SC&A's evaluation of NIOSH's use of ambient dose

NIOSH recommends that ambient external dose not be assigned when CE dose is assigned, per item 4 of section 4.0, page 5, of OTIB-0040.

SC&A concurs with NIOSH's recommendation of not assigning ambient external dose when CE dose is assigned per ORAUT-PROC-0060, revision 01 (ORAUT, 2006c, p. 14).

3.3 SC&A's evaluation of NIOSH's use of the data in tables 8-2 and 8-3

SC&A evaluated how NIOSH derived the entries in tables 8-2 and 8-3 of OTIB-0040 and if they were correct, in view of the available recorded dosimetry data outlined in section 3.1 of this report. SC&A's evaluation is summarized in sections 3.3.1 through 3.3.3 of this report.

3.3.1 SC&A's evaluation of NIOSH's derivation of penetrating dose values in table 8-2

NIOSH derived the penetrating doses as follows:

- NIOSH derived the 50th and 95th percentile external penetrating doses by using the individual recorded external dosimetry data, including positive and zero dose values, from NIOSH's file "Portsmouth Pen" that is contained in the "Ctrl-Alt_F" tab of the spreadsheet.

- NIOSH further analyzed the 50th and 95th percentile penetrating doses as shown in the "Summary Stats" tab of the spreadsheet to adjust for the average dosimeter wear period each year for 1954–1992 to obtain a full year of CE dose.

  An example for 1955:

  Wear-period-adjusted 50th percentile dose = 0.090 rem × (1/0.826) = 0.109 rem

- NIOSH included potential missed dose in deriving the annual CE doses by using the missed dose information in table 6-1 of OTIB-0040. If there were positive recorded doses for a given year, NIOSH reduced the number of exchanges by one, because all exchanges could not have resulted in recorded zeros in that situation.

  An example for 1955, which includes the wear period adjustment and missed dose:

  50th percentile dose = 0.109 rem + (0.030/2) rem × (52 − 1) = 0.874 rem

  95th percentile dose = 0.339 rem + (0.030/2) rem × (52 − 1) = 1.104 rem

  These dose values of 0.874 rem and 1.104 rem correspond to the 1955 CE 50th and 95th percentile penetrating dose values in table 8-2 of OTIB-0040, respectively.

SC&A concurs with NIOSH's methodology and did not identify any issues with the recommended penetrating CE dose values in table 8-2 of OTIB-0040.

3.3.2 SC&A's evaluation of NIOSH's derivation of NP dose values in table 8-2

NIOSH derived the 50th and 95th percentile external CE NP doses using the recorded shallow minus the penetrating external dosimetry data in NIOSH's files "Portsmouth Shallow" and "Portsmouth Pen," respectively, adjusted for wear period.

An example for 1955, which includes the wear period adjustment and missed dose:

50th percentile dose = [0.109 rem + ((0.030/2) rem × (52 − 1))] − [0.109 rem + ((0.030/2) rem × (52 − 1))]
= 0.000 rem

95th percentile dose = [0.387 rem + ((0.030/2) rem × (52 − 1))] − [0.339 rem + ((0.030/2) rem × (52 − 1))]
= 0.048 rem

These dose values of 0.000 rem and 0.048 correspond to the 1955 CE 50th and 95th percentile NP dose values in table 8-2 of OTIB-0040, respectively.

An example for 1992, which includes the wear period adjustment and missed dose:

50th percentile dose = [0.000 rem + ((0.040/2) rem × (4 − 0))] − [0.000 rem + ((0.010/2) rem × (4 − 0))]
= 0.060 rem

95th percentile dose = [0.103 rem + ((0.040/2) rem × (4 − 1))] − [0.039 rem + ((0.010/2) rem × (4 − 1))]
= 0.109 rem

These dose values of 0.060 rem and 0.109 rem correspond to the 1992 CE 50th and 95th percentile NP dose values in table 8-2 of OTIB-0040, respectively.

SC&A was able to derive the NP doses listed in table 8-2 by using the shallow dose (adjusted for wear time and missed dose) minus the penetrating dose (adjusted for wear time and missed dose). SC&A concurs with NIOSH's methodology and did not identify any findings or observations with the recommended NP CE dose values in table 8-2 of OTIB-0040.

3.3.3 SC&A's evaluation of NIOSH's derivation of values in table 8-3 for CTWs

NIOSH derived the 50th and 95th percentile external penetrating CE doses for CTWs in table 8-3 by using the recorded external dosimetry data in NIOSH's spreadsheet "Portsmouth Pen" (to include recorded zeros and adjusted for wear time) multiplied by a factor of 1.4 as recommended in ORAUT-OTIB-0052 (ORAUT, 2006b).

An example for 1955:

50th percentile CTW CE dose = (0.109 rem × 1.4) + (0.030/2) rem × (52 − 1) = 0.918 rem

95th percentile CTW CE dose = (0.339 rem × 1.4) + (0.030/2) rem × (52 − 1) = 1.240 rem

These dose values of 0.918 rem and 1.240 rem correspond to the 1955 CTW CE 50th and 95th percentile penetrating dose values in table 8-3 of OTIB-0040, respectively.

SC&A concurs with NIOSH's methodology and did not identify any issues with the recommended penetrating CTW CE dose values in table 8-3 of OTIB-0040.

4 Conclusions

SC&A reviewed the original recorded PGDP dosimetry data, evaluated NIOSH's analysis of the data and recommendations, and evaluated NIOSH's use of the data in constructing tables 8-2 and 8-3 of OTIB-0040. SC&A identified no findings but did have two observations:

- Observation 1: Incorrect guidance in table 6-1 footnote
- Observation 2: Reference needed for radiation effectiveness factors

5 References

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