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A Review of ORAUT-OTIB-0036 for Internal Coworker Bioassay Data for the Portsmouth Gaseous Diffusion Plant

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Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
CW	coworker
dpm	disintegrations per minute
dpm/day	disintegrations per minute per day
dpm/ml	disintegrations per minute per milliliter
GSD	geometric standard deviation
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
ml	milliliter
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
PORTS	Portsmouth Gaseous Diffusion Plant
U	uranium

1 Statement of Purpose

To support dose reconstruction, 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-0036, revision 00, Internal Coworker Bioassay Data for the Portsmouth Gaseous Diffusion Plant (ORAUT, 2005; "OTIB-0036"). The purpose of OTIB-0036 was to provide information to allow ORAUT dose reconstructors to assign doses to Portsmouth Gaseous Diffusion Plant (PORTS) workers who have no or limited monitoring data, based on site coworker (CW) data.

On November 16, 2023, the Subcommittee for Procedure Reviews tasked SC&A with reviewing ORAUT-OTIB-0036, revision 00 (ORAUT, 2005).

2 SC&A's Evaluation of NIOSH's Methods Used to Derive Coworker Intake Values

SC&A reviewed the urinalysis table in the PORTS site database "HR_prior_1993." SC&A found that historical internal excretion data for 1955 through 1988 were contained in the table within the field "RES_Alpha." SC&A analyzed the database and spreadsheets used by NIOSH to derive the CW intake values for PORTS in tables A-1, 4-1 through 4-3, and 5-1 through 5-3 of OTIB-0036. Appendix A of this report summarizes SC&A's evaluation of the methods NIOSH used to derive the CW intake values. SC&A concurs with NIOSH's methodology and had no methodology-specific findings or observations.

3 NIOSH's General Approach to Internal Coworker Bioassay Data for PORTS

3.1 Source of data

NIOSH obtained bioassay data for monitored PORTS workers from the urinalysis table in the PORTS site database "HR_prior_1993." Historical internal data for 1955–1988 were contained in the table within the field "RES_Alpha." The reported data corresponded to individual gross alpha bioassay results in units of disintegrations per minute per 100 milliliters (dpm/100 ml) and/or total uranium in units of milligrams per liter of urine.

3.2 NIOSH's analysis of data in ORAUT-OTIB-0036 and recommendations

NIOSH analyzed and modeled the recorded individual bioassay results for developing the CW data as outlined in sections 3 through 5 of OTIB-0036 and summarized in sections 3.2.1 through 3.2.5 of this report.

3.2.1 NIOSH's analysis of individual urinalysis results

There were a large number of individual bioassay results for the period 1955–1988. NIOSH analyzed the bioassay data as follows:

- The gross alpha measurements had approximately 30 percent nonzero values recorded, while the total uranium results had approximately 4 percent nonzero values. Therefore,

gross alpha results were used in this analysis because they were considered a more robust data set.

- Because of the number of sample results, data were analyzed by quarter, with the exception of 1955, when the analysis was for the entire year.
- The effective bioassay date was set equal to the midpoint of the analysis period.
- A lognormal distribution was assumed, and the 50th and 84th percentiles were calculated for each quarter (year for 1955), using the method described in revision 00, ORAUT-OTIB-0019 (ORAUT, 2004b).
- Table A-1 in attachment A of OTIB-0036 lists the results of the statistical analysis of the gross alpha bioassay results.

3.2.2 NIOSH's intake modeling

NIOSH used the Integrated Modules for Bioassay Analysis (IMBA) program, Expert OCAS-Edition, to analyze the bioassay data results as follows:

- Because the bioassay results were recorded in units of dpm/100 ml, they were multiplied by 14 to obtain the results in dpm per day (dpm/day).
- Each bioassay result was assumed to be normally distributed, and a uniform absolute error of one was applied to all results, thereby weighing all results equally.
- A chronic exposure pattern was assumed; while this is unlikely for workers at PORTS, it approximates a series of acute intakes with unknown intake dates. Yearly data for 1955 and quarterly data from 1956 through 1988 were fitted as a series of chronic intakes.
- Intakes were assumed to be by inhalation using a default breathing rate of 1.2 cubic meters per hour and a 5-micrometer activity median aerodynamic diameter particle size distribution.
- Bioassay results were recorded as gross alphas. NIOSH assumed the activity was from uranium (U)-234 for IMBA modeling as this is claimant favorable.
- Uranium at PORTS could be present in material with solubility types F, M, or S lung clearance rates. Therefore, all three material types were evaluated.
- PORTS began enrichment operations in September 1954; there are no gross alpha bioassay results before 1955 in the database. Intake modeling was based on the 1955 and later data; however, uranium intakes should be considered possible as early as September 1, 1954.

NIOSH evaluated the bioassay results for patterns of potential intakes and divided the intake periods into intervals that had similar bioassay result magnitudes. If the data indicated a significant sustained change in the bioassay results, a new chronic intake period was started. By this method, NIOSH divided the period from 1955 through 1988 into four chronic intake periods.

- January 1, 1955, through December 31, 1956
- January 1, 1957, through December 31, 1958
- January 1, 1959, through June 30, 1961
- July 1, 1961, through December 31, 1988

NIOSH used the bioassay results to fit the potential intakes for types F and M U-234 in IMBA for each of these four periods considering all the bioassay data from 1955 through 1988. However, type S uranium has very long radiological and biological half-life. Therefore, to avoid potential underestimation of intakes for energy employees who worked at PORTS for relatively short periods, NIOSH fitted each of the four chronic intake periods of type S material independently, using only the bioassay results from each single intake period. This will result in an overestimate of intakes for assumed type S exposures extending through multiple intake periods.

The results of using the four time periods to derive the 50th and 84th percentile CW intakes and the recorded quarterly bioassay values are compared in figures A-1 through A-4 for type F and M uranium, and in figures A-5 through A-8 for type S uranium (with each time period independent of each other). Additionally, figures A-9 and A-10 compare all the bioassay data to the fitted 50th and 84th percentile values for type S uranium. These figures indicate that there is reasonable correlation between the fitted CW intake modeling and the recorded quarterly bioassay values.

Using this modeling method, NIOSH derived the potential 50th and 84th percentile daily uranium intake values for types F, M, and S in units of dpm/day. NIOSH derived the geometric standard deviation (GSD) by dividing the 84th percentile value by the 50th percentile value.

NIOSH lists the results in table 5-1 for type F, table 5-2 for type M, and table 5-3 for type S. These tables are the same as tables 4-1, 4-2, and 4-3, respectively, except (1) the start date is 9/1/1954 instead of 1/1/1955, and (2) the GSD is rounded to two significant figures in tables 5-1, 5-2, and table 5-3.

3.2.3 NIOSH's evaluation of recycled uranium contaminants

Uranium streams at PORTS could have contained recycled uranium; therefore, the dose from the added constituents, including plutonium, neptunium, and technetium radionuclides, must be included. NIOSH recommends using information in the PORTS site profile, ORAUT-TKBS-0015-5, revision 00 (ORAUT, 2004a), concerning intake values for recycled uranium constituents in relation to the CW uranium intake amounts.

3.2.4 NIOSH's dose assignment recommendations

In section 5.3 of OTIB-0036, NIOSH recommends the following dose assignment methods:

- Use the 50th-percentile intake rates to derive the internal organ dose.
- Derive the annual organ doses for types F, M, and S solubility. Use the material type resulting in the largest probability of causation for the organ of concern.
- Recycled uranium contaminants, when appropriate for the period, are a factor in determining the most claimant favorable solubility type.
- Use a lognormal distribution in the IREP program. Apply the annual dose in parameter one and the GSD in parameter two.

3.2.5 Attachment A – NIOSH's table and IMBA fitting plots

Attachment A contains the following information:

- Table A-1, "Summary of quarterly uranium 24-hour urinary excretion rate analyses, 1955–1988," provides a summary, by quarters in units of dpm/day, of the bioassay data used to derive the CW intake values.
- Figures A-1 through A-4 contain the results of NIOSH's 50th and 84th percentile fittings analysis for types F and M uranium using the bioassay data for the period 1955–1988.
- Figures A-5 through A-8 contain the results of NIOSH's 50th and 84th percentile fittings analysis for type S uranium using the bioassay data for the four individual periods during 1955–1988.
- Figures A-9 and A-10 contain the results of NIOSH's predicted 50th and 84th percentile urinary excretion rates of type S uranium from 1955 through 1988 based on four independent intake periods, along with the bioassay data used to generate the predicted intake values.

4 SC&A's Review of ORAUT-OTIB-0036

SC&A reviewed the original recorded PORTS bioassay data and NIOSH's accompanying calculation and analysis spreadsheets to evaluate (1) NIOSH's analysis of the bioassay data and recommendations and (2) NIOSH's use of their analysis in constructing the intake tables in OTIB-0036. SC&A's review is outlined in section 4.1 and 4.2 of this report.

4.1 SC&A's evaluation of NIOSH's analysis of PORTS bioassay data and recommendations

SC&A's evaluation of NIOSH's analysis of the data and modeling in sections 3.0 through 5.0 of OTIB-0036 is summarized in sections 4.1.1 through 4.1.6 of this report.

4.1.1 SC&A's evaluation of NIOSH's analysis of individual urinalysis results

SC&A concurs with NIOSH's use of the gross alpha measurements for developing an internal coworker model, since the gross alpha measurements had approximately 30 percent nonzero values recorded compared to the total uranium results that had approximately 4 percent nonzero values. Both data sets contained approximately 150,000 bioassay results. While the use of the gross alpha measurements would appear to result in a more robust dataset, the total uranium results could potentially contain higher intakes when they were positive. Present CW modeling would likely compare the results of both data sets.

SC&A also concurs with NIOSH's grouping of bioassay data by quarterly intake periods for years 1956 through 1988 because of the large number of bioassay results. For 1955, when there were fewer numbers of bioassay samples, all results were analyzed for the entire year.

SC&A reviewed the entries in table A-1 of OTIB-0036 in view of NIOSH's data analysis as outlined in section 3.2 of this report and did not identify any issues concerning the entries. However, SC&A suggests that the title of the table should be "Table A-1. Summary of quarterly gross alpha 24-hour urinary excretion rate analyses, 1955–1988" instead of "Table A-1.

Summary of quarterly uranium 24-hour urinary excretion rate analyses, 1955–1988," since the bioassay data used were gross alpha measurements, not uranium results.

4.1.2 SC&A's evaluation of NIOSH's intake modeling

SC&A concurs with the following NIOSH's modeling methods:

- Bioassay results were multiplied by 14 to obtain the results in dpm/day based on standard excretion rate because the bioassay results were recorded in units of dpm/100 ml.
- NIOSH's use of a chronic exposure pattern to approximate a series of acute intakes with unknown intake dates.
- Using the 1955 yearly and 1956 through 1988 quarterly data to fit a series of chronic intakes that resulted in four distinct chronic intake periods.
- Assumed breathing rate of 1.2 cubic meters per hour and a 5-micrometer activity median aerodynamic diameter particle size distribution.
- Assumed the activity was from U-234 for IMBA modeling because this is claimant favorable. SC&A found that the effective dose coefficient for U-234 is greater than for U-235, U-236, or U-238 per International Commission on Radiological Protection (ICRP) Publication 68 (ICRP, 1994, p. 68).
- Solubility types F, M, and S could be present and should be evaluated.

SC&A reviewed the uranium bioassay data and found that NIOSH's evaluation of the bioassay patterns and the use of four chronic intake periods for 1955–1988 was reasonable. SC&A concurs with NIOSH using the bioassay data for each of the four periods in fitting the potential intakes for type F and M uranium, and use of four independent periods for type S uranium.

4.1.3 SC&A's evaluation of NIOSH's derived intakes

SC&A reviewed the entries in tables 4-1 through 4-3 and tables 5-1 through 5-3 of OTIB-0036 using the bioassay data analysis as outlined in section 3.2 of this report and did not identify any issues with the entries.

4.1.4 SC&A's evaluation of NIOSH including recycled uranium contaminants

SC&A concurs with NIOSH that recycled uranium contaminants should be accounted for according to recommendations in the PORTS site profile, ORAUT-TKBS-0015-5 (ORAUT, 2004a), concerning intake values in relation to the CW uranium intakes. Because lower solubility materials remain in the lungs for longer periods, while higher solubility materials are transferred to the systemic organs, it is necessary to compare the annual doses on a case-by-case basis to determine which will deliver the larger dose to the organ of interest. When recycled uranium contaminants are included, the highest solubility type for each radionuclide is used.

4.1.5 SC&A's evaluation of NIOSH's dose assignment recommendation

SC&A concurs with NIOSH that the 50th percentile intake rates should be used to derive the annual internal organ doses from type F, M, and S U-234 and the annual doses that result in the largest probability of causation for the organ of concern should be assigned. Recycled uranium contaminants should be included in determining the most claimant favorable solubility type.

4.1.6 Attachment A – SC&A's evaluation of NIOSH's IMBA fitting plots

SC&A reviewed and analyzed a select number of the IMBA runs as depicted in attachment A of OTIB-0036 and did not identify any issues and found them helpful in following NIOSH's overall analysis of the bioassay data.

4.2 SC&A's evaluation of NIOSH's use of bioassay data for constructing tables in OTIB-0036

SC&A reviewed the entries in the tables in OTIB-0036 in view of SC&A's evaluation of NIOSH's data analysis as outlined in section 4.1 and appendix A of this report and did not identify any issues with the entries. However, SC&A had the following observation.

Observation 1: NIOSH did not use the 1989–1991 bioassay data

The PORTS site database "HR_prior_1993" contains recorded bioassay results for the period 1989–1991 as well as for 1955–1988, with some positive bioassay results recorded during all years. NIOSH developed CW internal intake values for 1955–1988 but not for 1989–1991. SC&A requests that NIOSH clarify why they did not analyze the later data to develop CW internal intake values for 1989–1991.

5 Conclusions

SC&A reviewed the original recorded PORTS bioassay data, evaluated NIOSH's analysis of the data and recommendations, and evaluated NIOSH's use of the data in constructing the tables in OTIB-0036 for assigning CW uranium intakes. Although CW modeling methods have changed since the issuance of OTIB-0036, this document appears to be the current document for use for PORTS CW dose assignments. SC&A identified no findings but did have one observation:

- Observation 1: NIOSH did not use the 1989–1991 bioassay data

6 References

International Commission on Radiological Protection. (1994). Dose coefficients for intakes of radionuclides by workers (Publication 68). *Ann. ICRP, 24*(4). SRDB Ref. ID 22731

Oak Ridge Associated Universities Team. (2004a). *Technical basis document for Portsmouth Gaseous Diffusion Plant – Occupational internal dose* (ORAUT-TKBS-0015-5, rev. 00). SRDB Ref. ID 20167

Oak Ridge Associated Universities Team. (2004b). *Technical information bulletin – Analysis of coworker bioassay data for internal dose assignment,* (ORAUT-OTIB-0019, rev. 00). SRDB Ref. ID 19439

Oak Ridge Associated Universities Team. (2005). *Internal dosimetry coworker data for Portsmouth Gaseous Diffusion Plant* (ORAUT-OTIB-0036, rev. 00). SRDB Ref. ID 19463

Appendix A: SC&A's Evaluation of NIOSH's Methods to Derive Coworker Intake Values

As indicated in section 4 of this report, SC&A reviewed the urinalysis table in the PORTS site database "HR_prior_1993." SC&A found that historical internal data for 1955 through 1988 were contained in the table within the field "RES_Alpha." SC&A analyzed the database and spreadsheets that NIOSH use to derive the CW intake values for PORTS. SC&A found that NIOSH used the following methods to construct tables A-1, 4-1 through 4-3, and 5-1 through 5-3 of OTIB-0036.

- NIOSH grouped the gross alpha bioassay results, in units of dpm/100 ml, from the "RES_Alpha" column of the PORTS database, contained in the "Urinalysis_DayOfWeek" tab, by year for the years 1955–1988, as shown in the files contained in NIOSH's "stats" folder.

- NIOSH ranked the gross alpha bioassay results from minimum to maximum value for each quarter for each year (except for the entire year for 1955) and then extracted the 50th and 84th percentile values for each quarter for each year as shown in the "Year" tab of each spreadsheet. This resulted in the creation of 34 files in NIOSH's "stats" folder, along with a 35th file that contains a summary of the quarterly 50th and 84th percentile bioassay results for the 34 years, 1955–1988, in units of dpm/100 ml.

- NIOSH converted the 50th and 84th percentile bioassay values from dpm/100 ml to dpm/day by multiplying the 50th and 84th percentile values by a factor of 14 to account for the standard excretion rate of 1,400 ml/day. The results of this process are contained in NIOSH's "PORTS GA Modeling Results full upload" file. NIOSH summarized these excretion rates in table A-1 of OTIB-0036, which contains 129 values each for the 50th and the 84th bioassay values, in units of dpm/day.

- NIOSH reviewed the 50th and 84th percentile bioassay values by quarter and determined that the best fit of the bioassay results were divided into four major periods according to the overall pattern of the bioassay values, as described in section 3.2.2 of this report.

- NIOSH used the 50th and 84th percentile bioassay values as summarized in table A-1 of OTIB-0036 as bioassay data input into the IMBA program to derive the projected uranium-234 intakes for solubility types F, M, and S for the four major periods of potential CW intakes. NIOSH's "intake modeling" folder contains a summary spreadsheet of the quarterly 50th and the 84th percentile bioassay input values (in units of dpm/day) for use in the IMBA program. The 12 IMBA runs using the 50th and 84th percentile bioassay input values are contained in NIOSH's "intake modeling" folder. NIOSH summarized the results of the 12 IMBA runs in tables 5-1, 5-2, and 5-3 of OTIB-0036.

- NIOSH's "intake modeling" folder also contains two additional IMBA runs that illustrate the predicted 50th and 84th percentile urinary excretion of type S uranium from 1955 through 1988, based on four independent intakes. In these two IMBA runs, NIOSH also compared the predicted bioassay results to the bioassay data.

Using the NIOSH-provided files, SC&A performed an independent analysis on a sample of the data used to assess intake values. Based on SC&A's analysis, we were able to match NIOSH's values. Therefore, SC&A concurs with NIOSH's methodology and had no findings or observations.