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

SC&A's Review of NIOSH's White Paper, "Neutron Dose Assignment for K-25 and Portsmouth Gaseous Diffusion Plants"

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Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
GDP	gaseous diffusion plant
HEU	highly enriched uranium
IREP	Interactive RadioEpidemiological Program
LOD	limit of detection
MeV	mega-electron volt
N:P	neutron-to-photon
NIOSH	National Institute for Occupational Safety and Health
NTA	nuclear track emulsion, type A (film)
QRA	quantile regression analyses
TLD	thermoluminescent dosimeter
Y-12	National Security Complex

1 Introduction and Background

The National Institute for Occupational Safety and Health (NISOH) issued on May 6, 2019, the white paper, "Neutron Dose Assignment for K-25 and Portsmouth Gaseous Diffusion Plants" (NIOSH, 2019; hereafter referred to as the "white paper"). The purpose of the white paper was to determine a reasonable neutron-to-photon (N:P) ratio that can be used to assign dose for gaseous diffusion plant (GDP) energy employees during periods when neutron dose data were not reliable, not available, or not recorded. For K-25, this time period was prior to 1992. For Portsmouth, this time period was prior to 1995. SC&A was tasked on June 27, 2019, with reviewing the white paper.

2 Outline of White Paper

2.1 Development of approach

The white paper presents the potential data that could be used to develop N:P values. These are outlined on page 3 of the white paper as follows:

- Uranium hexafluoride cylinder yard survey (Paducah)
- Highly enriched uranium (HEU) storage cylinder dose rates (Portsmouth)
- HEU storage vault/storage cylinder measurements (Portsmouth)
- Area monitoring: neutron and photon dose measurements (Portsmouth)
- Personnel monitoring: neutron and photon dose measurements (Portsmouth)
- Neutron dose rate survey results (K-25)
- Neutron and photon dose rate modeling for cylinder yards (K-25)
- Neutron and photon survey data area and area monitoring results (K-25)
- Personnel monitoring: neutron and photon dose measurements (K-25)
- Static dosimetry measurements (National Security Complex (Y-12 Plant))
- Neutron and photon survey data (Y-12 Plant)
- Personnel monitoring: neutron and photon measurements (Y-12 Plant)

2.2 Data available for Paducah, Portsmouth, K-25, and Y-12

A summary and a brief analysis of the available neutron and photon dose measurements from various GDPs are presented in the white paper, pages 3 through 10.

- **Paducah** – Page 3. Surveys around cylinder storage resulted in N:P ratios ranging from 0.14 to 0.42, with an approximate average of 0.2.

- **Portsmouth** – Pages 3–6. Thermoluminescent dosimeter (TLD) data for 1992–2013 from 161 records indicate an N:P ratio of 0.369.

- **K-25** – Pages 7–9. TLD data for 1989–2012 from 369 records indicate an N:P ratio of 0.420.

- **Y-12 –** Page 10. Dosimetry film data for 1955–1959 from 89 records were included in the quantile regression analyses (QRA) of the N:P data. SC&A's analysis of the 89 records indicated an N:P ratio of approximately 0.828.

2.3 Quantile regression analyses

In addition to the derivation of average N:P ratio values, the white paper provides QRA of the Portsmouth, K-25, and Y-12 dosimetry data on pages 10 through 15. The results are summarized in table 6, page 18, of the white paper.

2.4 Conclusions

The white paper used the personnel dosimetry measurements (as opposed to using area survey or cylinder storage survey dose data) to derive the recommended assignment of neutron dose for unmonitored workers at the GDPs. NIOSH used the QRA method to derive the recommended neutron dose equations, as listed in table 6, page 18, of the white paper, and reproduced below:

50th neutron = 0.195 [photon (rem)] + 0.002 (rem)
95th neutron = 0.846 [photon (rem)] + 0.002 (rem)

2.5 Appendix A

Appendix A of the white paper provides a brief description of the application of QRA and the Monte Carlo simulation method to be used when assigning neutron dose in the Interactive RadioEpidemiological Program (IREP).

3 SC&A's Evaluation of the White Paper

The following is a summary of SC&A's evaluation of the white paper.

3.1 Selection of available data to use for estimating N:P ratios

SC&A concurs with NIOSH's use of personnel dosimetry measurements (as opposed to using area survey or cylinder storage survey dose data) to derive the N:P ratio values to assign neutron dose for unmonitored workers at the GDPs. Dosimetry data are much more relevant in determining N:P ratios than area surveys or cylinder storage survey measurements because dosimetry data more realistically reflect workers' exposure as a function of time and location.

3.2 Analyses of dosimetry data

SC&A analyzed the Portsmouth, K-25, and Y-12 dosimetry dose data and derived an average N:P ratio of 0.412 for Portsmouth, 0.420 for K-25, and 0.828 for Y-12; which are similar to the N:P ratios stated in the white paper (i.e., NIOSH derived an N:P ratio of 0.369 for Portsmouth and 0.420 for K-25). SC&A also analyzed the overall dosimetry data from Portsmouth, K-25, and Y-12 (giving equal weight to each N:P ratio value) and derived an average N:P ratio of 0.474, a 50th percentile ratio of 0.251, and a 95th percentile ratio of 0.901. These values are summarized in table 1 of this report. SC&A does not consider the N:P values are known to the third significate figure (as would be indicated by the numbers listed) but provides them for comparison and obtaining averages.

Table 1. Summary of N:P ratios

Analysis	Portsmouth	K-25	Y-12	Weighted average	50th %	95th %	QRA 50th %	QRA 95th %
SCA	0.412	0.420	0.828	0.474	0.251	0.901	NA	NA
White paper	0.367	0.420	(0.828) [(a)]	0.465	NA	NA	0.195	0.846

(a) SC&A-derived from NIOSH's dosimetry data for Y-12.

The N:P ratio values were derived from TLD data for Portsmouth and K-25 and from film dosimetry data for Y-12. Neutron dose measurements using nuclear track emulsion, type A (NTA) film is sometimes questionable, considering it has a 0.5 mega-electron volt (MeV) neutron energy threshold, unless it is calibrated to account for the neutron energy spectra less than 0.5 MeV, or unless most of the neutron dose equivalent is greater than 0.5 MeV. Therefore, the NTA film data from Y-12 could have been questionable. However, its results were similar to the TLD results, were slightly claimant favorable, and did not constitute a majority of the total data. Therefore, including it did not appear to be an issue in this situation.

3.3 SC&A's evaluation of NIOSH's recommendations

SC&A concurs with NIOSH's analyses of the available neutron and photon dosimetry data up through page 9 of the white paper (to include the Y-12 data with an average N:P ratio of 0.828), with the following observation:

Observation 1: apparent inconsistency in use of limit of detection

The white paper lists the following concerning the application of the lower limit of detection (LOD) in the use of dosimetry data:

- **Portsmouth** – Page 5 of the white paper states, "result that exceeded the neutron limits of detection (LOD) of 10 mrem," and page 6 states, "neutron dose values greater than the LOD of 10 mrem."

- **K-25** – Page 8 of the white paper states, "Results from 369 neutron dosimeters were greater than *or equal* to the LOD," and page 9 states, "neutron doses greater than *or equal* to the LOD of 10 mrem" (emphasis added). However, the next sentence on page 9 states, "An analysis of dosimeters with paired photon and neutron doses *greater than* the LOD was performed" (emphasis added).

The use of the neutron dosimetry data and photon dosimetry data that were *equal to* the LOD values needs to be clarified; i.e., were "equal to" values used in NIOSH's analysis, or only values that were greater than the LOD? A set method should have been consistently applied to the dosimetry data used from the three sites.

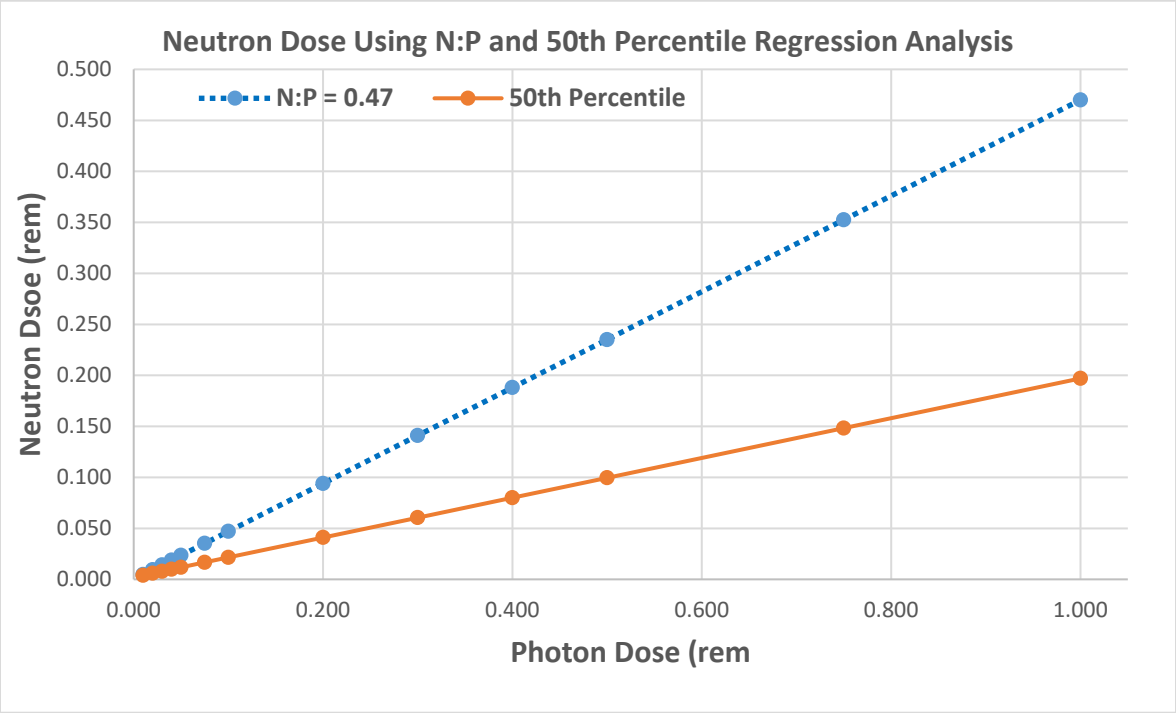
Observation 2: use of Portsmouth dosimetry values near zero

As previously discussed in this review, dosimetry values equal to, or greater than, the LOD value were used to derive N:P ratios. However, when the white paper used the QRA method for the Portsmouth dosimetry data, as illustrated in figures 2 and 4 of the white paper, it appears from the plots (and from the number of data points (N), i.e., 3,727 on page 13 versus 161 on page 6)

that recorded data with values as low as near zero might have been used. This is not consistent with the use of dosimetry that is equal to or greater than the LOD.

SC&A calculated neutron doses over the normal personnel exposure range using both the standard N:P ratio method and the QRA method; the results are summarized in figure 1 of this report.

Figure 1. Neutron dose using N:P ratio and 50th percentile regression analysis



As can be seen from this example, the use of the QRA method results in approximately half the neutron dose being assigned compared to using the standard N:P ratio method.

Observation 3: use of the standard N:P ratios versus the quantile-regression and Monte Carlo approach

SC&A concurs with the N:P ratios derived using standard analyses of the dosimetry data for Portsmouth, K-25, and Y-12. However, analyzing the QRA method recommended in the conclusions (page 16) of the white paper indicates that the resulting neutron doses assigned at the 50th percentile in IREP for dose reconstruction purposes would be approximately half of that assigned by the standard N:P averaged ratio method. The QRA method is not claimant favorable, nor consistent with neutron dose assignments at other U.S. Department of Energy sites.

4 Summary and Conclusions

SC&A's review of the white paper found that NIOSH N:P ratios derived using dosimetry data from Portsmouth, K-25, and Y-12 were reasonable and technically verifiable. SC&A had no finding in this review. However, S&A did have the following observations:

- **Observation 1: apparent inconsistency in use of limit of detection** – The white paper lists the following concerning the application of the lower LOD in the use of dosimetry data:

  – **Portsmouth** – Page 5 of the white paper states, "result that exceeded the neutron limits of detection (LOD) of 10 mrem," and page 6 states, "neutron dose values greater than the LOD of 10 mrem."

  – **K-25** – Page 8 of the white paper states, "Results from 369 neutron dosimeters were greater than *or equal* to the LOD," and page 9 states, "neutron doses greater than *or equal* to the LOD of 10 mrem" (emphasis added). However, the next sentence on page 9 states, "An analysis of dosimeters with paired photon and neutron doses *greater than* the LOD was performed" (emphasis added).

  The use of the neutron dosimetry data and photon dosimetry data that were *equal to* the LOD values needs to be clarified; i.e., were "equal to" values used in NIOSH's analysis, or only values that were greater than LOD? A set method should have been consistently applied to the dosimetry data used from the three sites.

- **Observation 2: use of Portsmouth dosimetry values near zero** – As previously discussed in this review, dosimetry values equal to, or greater than, the LOD value were used to derive N:P ratios. However, when the white paper used the QRA method for the Portsmouth dosimetry data, as illustrated in figures 2 and 4 of the white paper, it appears from the plots (and from the number of data points (N), i.e., 3,727 on page 13 versus 161 on page 6) that recorded data with values as low as near zero might have been used. This is not consistent with the use of dosimetry that is equal to or greater than the LOD.

- **Observation 3: use of the standard N:P ratios versus the quantile-regression and Monte Carlo approach** – SC&A concurs with the N:P ratios derived using standard analyses of the dosimetry data for Portsmouth, K-25, and Y-12. However, analyzing the QRA method recommended in the conclusions (page 16) of the white paper indicates that the resulting neutron doses assigned at the 50th percentile in IREP for dose reconstruction purposes would be approximately half of that assigned by the standard N:P averaged ratio method. The QRA method is not claimant favorable, nor consistent with neutron dose assignments at other U.S. Department of Energy sites.

5 Reference

National Institute for Occupational Safety and Health (NIOSH). (2019). *Neutron dose assignment for K-25 and Portsmouth gaseous diffusion plants* [White paper]. Retrieved from SRDB Ref. ID 176609