NIOSH Response to Findings on the MCNP Analysis for Carborundum

White Paper

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EXECUTIVE SUMMARY

This paper provides a discussion of the three findings identified in SC&A's November 27, 2018, memorandum to the Carborundum Work Group. The memorandum and findings concern details of the derivation of external dose rates, using the Monte Carlo N-Particle Transport code (MCNP), from plutonium fuel pellet work at the Carborundum Company in Niagara Falls, New York (Anigstein, 2018).

The SC&A memorandum included a comparison of dose rates for ^{241}Am, as reported in the NIOSH whitepaper of August 3, 2018 (NIOSH, 2018), versus an independent calculation of the dose rate provided in the SC&A memorandum. SC&A noted some significant differences in the estimated dose rates.

NIOSH made adjustments to the calculations in response to findings 2 and 3; no changes were made for finding 1, as explained below. With the changes in the MCNP settings for findings 2 and 3, there is only a 2% difference in the NIOSH and SC&A dose rates for ^{241}Am, the selected indicator radionuclide for this review.

Once agreement is reached on resolution to the three findings, NIOSH plans to rerun MCNP with the changes discussed below for all applicable radionuclides and prepare a report of the results and estimates of annual doses to workers.

A discussion of the findings and updated dose rate is provided below.

FINDING 1

"*NIOSH used H*(10) conversion coefficients from photon fluence, based on outdated data, that resulted in a reduction of approximately 2% in the H*(10) doses from ^{241}Am.*"

Finding 1 Discussion

The NIOSH white paper of November 27, 2018, provided ambient dose equivalent rates, H*(10), which are to be used in dose reconstructions in conjunction with the organ dose conversion factors in the NIOSH External Dose Reconstruction Implementation Guideline, OCAS-IG-0001 (NIOSH, 2007).

The MCNP code provided estimates of the photon fluence rates, Φ, at fixed locations to simulate exposure to a worker. The fluence was converted to air kerma, K_a, using the K_a/ Φ coefficients from Internal Commission on Radiological Protection (ICRP) Publication 74, Table A.1 (ICRP, 1996). The air kerma rates were then converted to ambient dose equivalent, H*(10), using the H*(10)/K_a coefficients from ICRP 74, Table A.21, column 2. SC&A commented that the Table A.1 K_a/ Φ coefficients are outdated and that NIOSH should use a newer set of K_a/Φ coefficients provided in ICRP 74, Table A.21, column 4, which result in a slightly higher dose.

SC&A also pointed out that the ambient dose equivalent can be directly calculated from fluence using the H*(10)/Φ coefficients from Table A.21, column 5, rather than first converting the fluence to air kerma using coefficients from Table A.1. However, the Table A.21, column 5, $H^*(10)/\Phi$ coefficients are the product of column 2 ($H^*(10)/K_a$) times column 4 (K_a/Φ). Thus, the issue in Finding 1 is which set of K_a/Φ coefficients to use, the values in Table A.1 or the values provided in Table A.21, column 4.

SC&A pointed out that according to the footnote to Table A.21, the K_a/Φ coefficients in Table A.21 are more up to date since they are derived from a newer reference, Hubbell and Seltzer (1995), vs. the earlier values reported by Hubbell (1982) that was used in the Table A.1 K_a/Φ coefficients. To clarify the discussion in the rest of this white paper, we will refer to the older values as Hubbell 1982 and the newer values as Hubbell 1995.

NIOSH disagrees that the Table A.21, column 4 values (and thus the column 5 values) should be used. The reasons are provided below.

1) Consistency with OCAS-IG-0001

The purpose of the dose rates calculated from this effort are to estimate organ doses for EEOICPA claimants. As such, these doses will be multiplied by dose conversion factors (DCFs) found in OCAS-IG-0001 in order to calculate organ dose. For H*(10), those DCFs were derived from ICRP 74 values in Tables A.2 through A.20 divided by the column 2 values from Table A.21.

The values in Tables A.2 through A.20 come from several published studies listed in ICRP 74 Table 4. Some of those listed specifically mention Hubbell 1982 as a source of data. All the studies were completed prior to 1995 so none of them used Hubbell 1995 as a source of data.

The OCAS-IG-0001 DCFs were therefore created using values derived in part from Hubbell 1982 and no data from Hubbell 1995. Given a choice, it then appears most appropriate to use Hubbell 1982 values for the dose rate calculations. That way, the dose rate and DCFs will be consistently using the same data.

2) The variability in the values is trivial compared to the uncertainty in the other factors that go into the Probability of Causation (POC) calculation

As SC&A pointed out, the difference in the two sets of values is approximately 2%. Indeed several sources of these values have been compared in the past and shown to be in good agreement.

As stated earlier, the dose estimate derived from this model will be multiplied by the applicable DCF to arrive at an organ dose to be entered into IREP. Since the photon energies are binned together in only three categories, there is a wide uncertainty assigned to the DCFs. A cursory review of OCAS-IG-001 shows the difference between the lower and upper bounds of the DCFs to be much larger than 2% for all organs. Furthermore, the purpose of the calculated dose rates is ultimately to calculate a POC for a claimant. It is therefore important to realize the uncertainty in that POC will include uncertainty in the dose values as well as uncertainty in the DCFs, uncertainty in the radiation effectiveness factors and uncertainty in the cancer model. These uncertainties combine to form an overall uncertainty in the POC large enough to consider the 2% difference in these values to be trivial.

3) The older values are not outdated

In 2017, the International Commission on Radiation Units & Measurements (ICRU) and the ICRP released for public comment a draft report on the Operational Quantities for External Radiation Exposure (ICRU/ICRP, 2017). Table A.6 of that report once again provides values for the parameter in question (K_a/Φ) that more closely resembles Table A.1 than Table A.21 of ICRP 74. The table below demonstrates that comparison.

Table 1: Conversion Coefficients for Air Kerma (pGy/cm^2)

Photon Energy	Hubbell 1982	Hubbell 1995	Draft ICRU/ICRP (2017)
10	7.43	7.60	7.400
15	3.12	3.21	3.125
20	1.68	1.73	1.684
30	0.721	0.739	0.7217
40	0.429	0.438	0.4289
50	0.323	0.328	0.3229
60	0.289	0.292	0.2889
80	0.307	0.308	0.3067
100	0.371	0.372	0.3714
150	0.599	0.600	0.5994
200	0.856	0.856	0.8567
300	1.38	1.38	1.383
400	1.89	1.89	1.892
500	2.38	2.38	2.379
600	2.84	2.84	2.844
800	3.69	3.69	3.702
1000	4.47	4.47	4.481
1500	6.14	6.12	6.147
2000	7.54	7.51	7.557
3000	9.96	9.89	9.977

Finding 1 Conclusion

Values for K_a/Φ can be found in a number of publications that all vary a small amount. The differences appear to be small in comparison to the overall uncertainty in the POC calculations. NIOSH feels that the most appropriate set of data would be the set that is most consistent with the derivation of the DCFs in OCAS-IG-0001. That set would be the Table A.1 values from ICRP 74 (Hubbell 1982) rather than the values in column 4 of Table A.21 (Hubbell 1995).

FINDING 2

"*NIOSH used incorrect source biasing in the MCNP Analyses.*"

Finding 2 Discussion

NIOSH used MCNP version 6.1 for the dose estimates provided in the whitepaper of August 3, 2018, which were significantly higher than the independent analysis performed by SC&A. SC&A investigated the issue and determined that the MCNP version 6.1 code had a glitch that, when code settings are not changed to allow for it, results in an overestimate of the dose rate.

Finding 2 Conclusion:

NIOSH has recalculated the ^{241}Am dose rate using MCNP version 6.2, which does not have the glitch. The new dose rate (when also adjusted for the Finding 3 issue) is similar to the dose rate estimated by SC&A. See the *UPDATED DOSE RATE* section below.

FINDING 3

Finding 3: *"The simulated dosimeters in the glovebox geometry modeled by NIOSH are partially shielded by the floor of the glovebox, which reduces the calculated doses."*

Finding 3 Discussion

This issue is about the geometry configuration of the dosimeter in the MCNP glovebox model. In the MCNP code, NIOSH modeled "dosimeters" in a location such that part of the dosimeter was shielded by the work surface of the glovebox, as seen in Figure 1 of the SC&A memorandum of November 27, 2018.

NIOSH concurs with the recommendation by SC&A to reposition the dosimeters and pellet location in the glovebox model to eliminate the shielding of the dosimeter. The settings in MCNP were modified such that the source (pellet) and dosimeters are now at a height 24 cm above the work surface of the glovebox.

Finding 3 Conclusion:

MCNP was rerun for ^{241}Am with changes made to eliminate shielding of the dosimeter. The new dose rate is similar to the dose rate estimated by SC&A. See the UPDATED DOSE RATE section below.

UPDATED DOSE RATE

As indicated above, changes were made to the MCNP modeled dose for Findings 2 and 3. For the purpose of this paper, only the ^{241}Am dose rate at one foot and one meter have been revised, which provides a means to directly compare the NIOSH estimate with the SC&A estimate provided in Table 3 of their November 27, 2018, memorandum.

Table 2: NIOSH Updated H*(10) Photon Dose Rates from ^{241}Am, pSv per dis[a]

Distance	NIOSH Update	SC&A[b]	Percent Difference[c]
1 ft	4.32E-7	4.41E-7	-2.06%
1 m	4.13E-8	4.20E-8	-1.68%

a. Dose units are ambient dose equivalent in pSv per disintegration.
b. Dose rate reported by SC&A in Table 3 of the November 27, 2018 memorandum.
c. Percent difference calculated as: (column 2 ÷ column 3) - 1.

The 4.32E-7 pSv per disintegration value in Table 2 corresponds to about 4.8 rem per year ambient dose equivalent from ^{241}Am photons for an Operator (when adjusted for a bounding quantity of material for an Operator exposure at one foot for 1,000 hours per year). The ^{241}Am accounts for a majority of the dose; however, updated photon and neutron doses for the various radionuclides and for the dose for the various worker categories will be based on updated dose rates at one foot and one meter for the sum of the dose for the various radionuclides.

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