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ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

SC&A REVIEW OF DCAS-TKBS-0009, REVISION 03, FOR HOOKER ELECTROCHEMICAL COMPANY

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Prepared by

William Thurber, MS

SC&A, Inc.
1608 Spring Hill Road, Suite 400
Vienna, Virginia, 22182

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland 21755

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TASK MANAGER:	William Thurber, MS [signature on file]
PROJECT MANAGER:	John Stiver, MS, CHP [signature on file]
DOCUMENT REVIEWER(S):	John Mauro, PhD, CHP [signature on file]

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
DCAS	Division of Compensation Analysis and Support
ER	evaluation report
dpm	disintegrations per minute
dpm/hr	disintegrations per minute per hour
dpm/m^2	disintegrations per minute per square meter
dpm/m^3	disintegrations per minute per cubic meter
Electromet	Electro Metallurgical Company
HCl	hydrochloric acid
Hooker	Hooker Electrochemical Company
MCNP	Monte Carlo N-Particle
MgF_2	magnesium fluoride
mr/hr	milliroentgen per hour
mrad/hr	millirad per hour
mrem/hr	millirem per hour
NIOSH	National Institute for Occupational Safety and Health
OCAS	Office of Compensation Analysis and Support
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	technical basis document
U	uranium
UF_4	uranium tetraflouride
URAWE	Uranium Refining Atomic Weapons Employers

1.0 INTRODUCTION

On April 14, 2016, SC&A was tasked (Katz 2016) to review Revision 02 to DCAS-TKBS-0009, *Technical Basis Document for the Hooker Electrochemical Company* (NIOSH 2015b; all revisions of this document hereafter referred to as "TKBS-0009") and determine whether it addressed SC&A's six findings made during its 2013 review of Revision 01 to this technical basis document (TBD) (SC&A 2013). SC&A documented the status of six findings in its June 2016 review of TKBS-0009, Revision 02 (SC&A 2016). These findings were discussed at the Uranium Refining Atomic Weapons Employers (URAWE) Work Group Meeting on July 19, 2016, which concluded that three of the findings had been resolved and three remained open. On September 13, 2016, the National Institute for Occupational Safety and Health (NIOSH) issued Revision 03 to TKBS-0009 (NIOSH 2016b), and the Work Group tasked SC&A to review Revision 03 with a view of determining whether the remaining three findings had been addressed. As discussed here, SC&A recommends that Findings 5 and 6 be closed. With regard to Finding 4, NIOSH has added an approach to addressing ingestion exposures during the residual period that had not been previously included. However, SC&A requests further clarification of the specific approach taken to develop the ingestion exposures, because there was apparent agreement, based on prior discussions with NIOSH, that the approach presented in OCAS-TIB-009, *Estimation of Ingestion Intakes*, Revision 00 (OCAS 2004; hereafter "TIB-009") was not appropriate.

2.0 BACKGROUND

The Hooker Electrochemical Company (Hooker) in Niagara Falls, New York, processed so-called "C-2 slag" from July 11, 1944, through January 15, 1946 (NIOSH 2011b). The operations at Hooker involved the treatment of C-2 slag from the nearby Electro Metallurgical Company (Electromet) with hydrochloric acid (HCl) to increase the slag's uranium content. The C-2 slag from Electromet was a byproduct of the bomb reduction process in which uranium tetrafluoride (UF_4) was exothermically reacted with magnesium metal to produce uranium metal. Dolomite was used as the refractory liner in the steel bomb at that point in time (NIOSH 2011b). After 1948, recycled magnesium fluoride (MgF_2) was used as the liner. The dolomite was high-fired or fused, resulting in a product with the approximate formula $CaO{\cdot}MgO$. The HCl was excess acid produced at Hooker under an Atomic Energy Commission contract as a byproduct from the non-radioactive P-45 process.

In 2007, NIOSH issued the original site profile for Hooker, *Site Profiles for Atomic Weapons Employers that Refine Uranium and Thorium – Appendix AA*, Revision 00 (NIOSH 2007), as Appendix AA to Battelle-TBD-6001, *Site Profiles for Atomic Weapons Employers that Refine Uranium and Thorium*, Revision F0 (NIOSH 2006; hereafter "TBD-6001"). As an appendix to TBD-6001, the Hooker site profile relied heavily on the parent document for dose reconstruction guidance. Based on a May 2010 request by the Advisory Board on Radiation and Worker Health (ABRWH), SC&A reviewed Appendix AA and reported 10 findings (SC&A 2010). Several of the findings related to TBD-6001, upon which much of Appendix AA was based. TBD-6001 was subsequently cancelled by NIOSH, and alternate modeling approaches were used in revising the Hooker site profile.

Subsequently, at the TBD-6001 Work Group Meeting held in Cincinnati, Ohio, on November 4, 2010, the Work Group asked SC&A to prepare a focused review of the Hooker petition evaluation report (ER) on Petition SEC-00141, prepared by NIOSH (2010). Because the ER contained new information developed since Appendix AA was issued in 2007 (NIOSH 2007), the Work Group felt that a focused review of the new information was needed. In response to this tasking, SC&A provided SCA-SEC-2011-0018, *A Focused Review of the Hooker Electrochemical Company Petition Evaluation Report for SEC-00141*, Revision 0, in January 2011 (SC&A 2011), in which SC&A made nine findings.

After the 2010 SC&A review of Appendix AA, NIOSH converted Appendix AA to a stand-alone site profile, DCAS-TKBS-0009, *Technical Basis Document for the Hooker Electrochemical Company*, Revision 00, published on April 4, 2011 (NIOSH 2011a), and issued Revision 01 to that document on June 17, 2011 (NIOSH 2011b).

According to NIOSH, the following changes were made in TKBS-0009, Revision 00 (NIOSH 2011a):

> *Changes Battelle-TBD-6001 Appendix to a stand- alone document. Revises dose models to eliminate dependence on Battelle-TBD-6001. Provides more detailed description of dose models. Incorporate review comments.*

In Revision 01 to TKBS-0009, NIOSH described the changes as follows (NIOSH 2011b):

> *Revision initiated to correct errors in Tables 2, 3, and 6* [of NIOSH 2011a]. *Renumber Tables after Table 4. Added language on page 10 to indicate 95th percentile of the airborne values was used. Corrected typographical error on pages 7 and 14.*

At the January 2013 meeting of the Procedures Work Group, SC&A was authorized to conduct a critical review of Revision 01 to TKBS-0009 (NIOSH 2011b). During that review, SC&A uncovered some information that had not been utilized in prior reviews of Hooker. This new information dealt with quantities and uranium content of the C-2 slag. The critical review resulted in six findings, which are documented in SCA-TR-SP2013-0034, *Review of NIOSH Technical Basis Document for the Hooker Electrochemical Company, DCAS-TKBS-0009* (SC&A 2013).

NIOSH issued Revision 02 to TKBS-0009 in December 2015 (NIOSH 2015b) with the following stated purpose:

> *Revision initiated to include information about a Special Exposure Cohort designation for Hooker. Revision also incorporates changes due to new information describing the operations at Hooker.*

As noted above, NIOSH issued Revision 03 to TKBS-0009 (NIOSH 2016b) on September 13, 2016, with the following stated purpose:

> *Revision initiated to include discussion about ingestion intakes. Also revised Table 4 to correct units. Revised Table 5 to correct values in the third column. Corrected photon exposures in Table 7. Various editorial changes to text.*

This report presents SC&A's review of TKBS-0009, Revision 03, and determines whether the three remaining findings from SC&A 2013 have been satisfactorily addressed.

3.0 REVIEW OF SC&A FINDINGS

3.1 FINDING 4

> *Finding 4: NIOSH should review the ingestion intake to ensure that it is calculated in a manner consistent with calculation of inhalation intake.*

SC&A recognizes that workers at Hooker have been added to the Special Exposure Cohort (SEC) for the operational period (November 1, 1945, through October 11, 1976) based on lack of air concentration data at the site for all of the operational period. However, inhalation and ingestion intakes are needed to assess operational exposures resulting in cancers not specified under the Energy Employees Occupational Illness Compensation Program Act of 2000 regulations and to calculate inhalation and ingestion exposures during the residual period.

NIOSH did not address ingestion exposures in Revision 02 to TKBS-0009 but did address this omission in Revision 03. NIOSH stated in Revision 02 that inhalation intakes during the residual period are 3.2 disintegrations per minute (dpm) per calendar-day, presumably based on resuspended surface contamination of 0.404 dpm/cubic meter (m^3), a breathing rate of 1.2 m^3/hr, an 8-hour work day, and 300 work days per 365 calendar days (NIOSH 2015b, Table 7). However, NIOSH did not address ingestion exposures during the residual period. Ingestion during the residual period has been the subject of recent deliberations by the URAWE Work Group (NIOSH 2015c), and it determined that the procedures for the operational period, as described in TIB-009, were not appropriate for the residual period. Ingestion exposures are apparently higher than inhalation exposures during the residual period because of an increase in hand-to-mouth transfer relative to inhalation in low-dust environments. For example, NIOSH has shown, for the DuPont Deepwater site, that ingestion during the residual period was 100 times the inhalation intake (NIOSH 2015a, Section 6.0).

NIOSH stated in Section 4.1 of TKBS-0009, Revision 02, that the operational airborne concentration was used in the residual contamination section to calculate the surface contamination and the resulting internal and external doses. Applying this statement, the surface concentration based on 30 days of continuous deposition is:

> 208 dpm/m^3 (avg. air conc.) × 0.00075 m/s × 3,600 sec/hr × 24 hr/day × 30 days = 404,352 dpm/m^2

This is a very conservative approach, because it assumes 24-hour-per-day deposition and no degradation of surface contamination during the 30-day deposition period. As noted above, using this limiting surface concentration, the inhalation intake is 3.2 dpm per calendar day. Using the approach from DCAS-TKBS-0006, *Technical Basis Document for DuPont Deepwater Works, Deepwater New Jersey*, Revision 02 (NIOSH 2015a), and the hand-to-mouth transfer factor from NUREG/CR-5512, *Residual Radioactive Contamination from Decommissioning* (NRC 1992), to calculate the ingestion intake results in the following:

1.1E-04 m^2/hr × 404,352 dpm/m^2 = 44.5 dpm/hr

44.5 dpm/hr × 9.6 hr/work day × 250 work-days/365 calendar-days = 293 dpm/calendar-day

However, in Revision 03 to TKBS-0009, NIOSH assumes that the average airborne concentration during the operating period (not the resuspended concentration from surface deposition) is bounding for the residual period and calculates that ingestion during the residual period is as follows, based on the procedures in TIB-009 (OCAS 2004):

208 dpm/m^3 × 0.2 (m^3/day) × 9.6 hr/day/8 hr/day × 250 work-days/yr ÷ 365 calendar-days/yr = 34.2 dpm/calendar-day.

Thus, the approach used in Revision 03 to TKBS-0009 produces a result that is a factor of 8.5 lower than that obtained by applying the DuPont Deepwater Site approach to Hooker (NIOSH 2015a).

More important than the magnitude of the difference between the two approaches is a clear explanation of why the approach used in TKBS-0009, Revision 03, is more appropriate than the approach used in DCAS-TKBS-0006 (NIOSH 2015a). NIOSH needs to clarify why it chose to use TIB-009 procedures that are based on the fallout of airborne particulates from operations, rather than the approach used in DCAS-TKBS-0006, which is based on a hand-to-mouth transfer factor. This issue was extensively discussed at the URAWE Work Group Meeting on January 22, 2015 (NIOSH 2015c, pp. 59–61). The following exchange between Messrs. Allen (NIOSH), Mauro (SC&A), and Thurber (SC&A) from the January 22 transcript highlights the discussion:

> *MR. ALLEN: So the way to look at it is that the ingestion is truly related to the surface contamination. In TIB-9, we related that to the airborne which caused that surface contamination.*
>
> *DR. MAURO: Yeah.*
>
> *MR. ALLEN: That airborne is gone in the residual period.*
>
> *MR. THURBER: Wouldn't you then think that the residual period number would be lower? And it's much, much higher.*
>
> *MR. ALLEN: No, actually you would think — the common sense would be that, if the ingestion is caused by contamination, the day you stop operations, the contamination doesn't change unless, of course, there's a cleanup of some kind.*

DR. MAURO: Yeah, but the air goes away. Yeah, I think I've got it.

MR. ALLEN: The air goes away, but the ingestion rate should —

DR. MAURO: So the 0.2 can't work because the air just went away.

MR. ALLEN: Right.

Similarly, at the July 16 meeting of the URAWE Work Group (NIOSH 2016a, p. 11), NIOSH (J. Neton) stated:

> *So, we're still debating on how we're going to do that. In principle, though, we totally agree with SC&A's comments. And I think we are going to have to put together a little more formal response to how we're going to deal with that issue, whether it's 1.1 times 10 to the minus 4 independently or whether we add back in this contaminated coffee cup, because they were derived from somewhat different principles and I think we're kind of mixing modalities a little bit.*

Given the cited discussions, there appears to be general agreement that the TIB-009 approach was not acceptable during the residual period. In spite of this discussion and general agreement, NIOSH chose in Revision 03 to TKBS-0009 to use an estimation approach based on TIB-009. NIOSH needs to clarify why it did not use the same procedure, as was done at DuPont Deepwater, based on an established hand-to-mouth transfer factor.

During the course of this review of Hooker TKBS-0009, Revision 03, SC&A revisited the methodology for estimating ingestion dose during operations as described in TIB-009. Two ingestion mechanisms are considered in TIB-009. In Mode 2, airborne contamination generated from operations is assumed to fall on the surface of a cup of coffee. In Mode 3, airborne contamination is assumed to fall on a work surface and is subsequently ingested by hand-to-mouth transfer from the work surface. According to TIB-009, in Mode 3, "the only removal mechanism is the transfer of material from the surface to an individual's hands. An equilibrium contamination level can then be calculated in which the deposition of contamination (from the settling of airborne contamination) is equal to the removal rate (from transfer to hands)." TIB-009 states, "Also note that the time interval is 24 hours. That accounts for the possibility of 24 hour per day operations." It is not clear why, for a particular operator, the time interval should be 24 hours per day rather than for a single shift. NIOSH needs to explain why 24 hours rather than about 8 hours should be used in the Mode 3 calculation.

3.2 FINDING 5

> *Finding 5: NIOSH should confirm that the correct units of measure are cited in Tables 2 and 3.* [Tables 3 and 4 in NIOSH 2015b]

In its prior review of TKBS-0009, Revision 01, SC&A noted that the photon exposure was expressed differently in Tables 2 and 3 (SC&A 2013). The titles of both tables include the phrase "External Dose Rate," but the units of measure in Table 2 (now Table 3) are milliroentgen per hour (mr/hr), while the units in Table 3 (now Table 4) are millirem per hour (mrem/hr). Based on the information in the text of Revisions 01 (NIOSH 2011b) and 02 (NIOSH 2015b) to

TKBS-0009, SC&A concluded that the units of measure in Table 2 should be mrem/hr and noted that the distinction was important because it can have a significant impact when selecting organ dose conversion factors from OCAS-IG-001, *External Dose Reconstruction Implementation Guidelines*, Revision 03 (OCAS 2007).

In its 2013 review, SC&A also noted that, in Table 2, the beta dose is expressed in units of millirad per hour (mrad/hr), while in Table 3 the units are in mrem/hr. SC&A recognizes that, for beta dose, the units are equivalent but, in the interests of clarity, consistent units should be used.

In its 2013 review, SC&A also uncovered some concerns about Table 5 in Revision 02 to TKBS-0009. The dose rates in the third column of that table are not correct. The correct value of the exposure (not dose) rate should be 2.74E-04 mr/hr (6.79E-10 mr/hr per dpm/m^2 × 404,314 dpm/m^2). Based on a 9.6-hr work day, 50 weeks per year, the photon exposure rate would be 0.659 mr/yr, which agrees with the value in Table 6. So, the error in Table 5 was not propagated. Similarly, the beta dose rate in Table 5 should be 2.44E-02 mrem/hr (58.6 mrem/yr), not 1.669 E-02 mrem/yr. Again, the error in the Table 5 beta dose rate was not propagated into Table 6.

Revision 03 to TKBS-0009 makes all of the needed corrections discussed above for Tables 3, 4, and 5. Table titles were also revised to indicate that the information presented was for exposure rates, not dose rates.

SC&A notes that the Monte Carlo N-Particle (MCNP) surface contamination conversion factors in Table 5 of TKBS-0009, Revision 02, were based on the dose rate (or exposure rate) at 1 foot from the contaminated surface. This is in contrast to the methodology in Revision 01 to Battelle-TBD-6000, *Site Profiles for Atomic Weapons Employers that Worked Uranium Metal* (NIOSH 2011c; hereafter "TBD-6000"), where the dose rate was determined at 1 meter from the contaminated surface. While the calculational approach for Hooker is more claimant favorable, it is not apparent why the already vetted values from TBD-6000 were not used.

SC&A's 2013 review also noted an error in Table 7 of TKBS-0009, Revision 02. The photon doses for the residual period were incorrect. The stated photon doses were actually beta doses to the skin. This error has also been corrected in TKBS-0009, Revision 03. Therefore, SC&A recommends that Finding 5 be closed.

3.3 FINDING 6

> *Finding 6: NIOSH should review the units of measure for the photon dose conversion factors in Table 4* [now Table 5] *and determine if they are correct. If they are correct, the companion text needs to be revised to discuss exposure rates rather than dose rates.*

Table 4 of TKBS-0009 listed the photon conversion factor as 6.79E-10 mr/hr per dpm alpha/square meter ($m^{2)}$ and the dose rate as 1.90E-04 mr/hr. If the units are correctly stated, then the table and the text need to refer to the photon parameters as exposure rates.

This was corrected in Revision 03 to TKBS-0009. Therefore, SC&A recommends that Finding 6 be closed.

4.0 REFERENCES

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