Draft White Paper

EVOLUTION OF DOSE RECONSTRUCTION APPROACH AT DOW MADISON AND USE OF SURROGATE DATA

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At the February 5, 2010, meeting of the SEC Issues Work Group, SC&A was tasked by Chairman Melius to prepare an outline to insure that all the relevant points related to Special Exposure Cohort (SEC) issues at Dow Madison had been addressed. Based on the discussion at the meeting, SC&A determined that this request has two parts. The first is to delineate the extent to which surrogate data are used for dose reconstruction, based on the most recent NIOSH position presented in Appendix C of Battelle-TBD-6000, and the second is to summarize the extent to which SC&A's findings (based on its August 24, 2009, review of Appendix C) have been addressed. These two items are covered in separate brief white papers. This white paper describes SC&A's understanding of the extent to which surrogate data are proposed to be used at Dow Madison, based on the material provided in Appendix C to TBD-6000. Table 1 summarizes the extent of proposed surrogate data usage for dose reconstruction. The ensuing paragraphs expand upon this summary.

Table 1. Proposed Usage of Surrogate Data for Dose Reconstruction at Dow Madison Based on Appendix C to Battelle-TBD-6000

Exposure Period	Source Term	Is Surrogate Data Used?
Operating	Internal Uranium	Yes
Operating	External Uranium	Yes
Operating	Internal Thorium	Dose reconstruction not feasible
Operating	External Thorium	Yes
Residual	Internal Uranium	Yes
Residual	External Uranium	Yes
Residual	Internal Thorium	No
Residual	External Thorium	Yes
Residual	Thoron	No

BACKGROUND

In its Petition Evaluation Report for SEC-00079, dated April 13, 2007, NIOSH concluded the following (NIOSH 2007a):

> *NIOSH has documented herein that it cannot complete the dose reconstructions related to this petition where doses resulted from exposure to thorium-containing materials. The basis of this finding is specified in this report, which demonstrates that NIOSH does not have access to sufficient information to estimate with sufficient accuracy either the maximum radiation dose incurred by any member of the class or to estimate such radiation doses more precisely than a maximum dose estimate. Members of this class at the Dow Chemical Company site in Madison, Illinois, may have received unmonitored internal and external radiological exposures from thorium radionuclides at the plant. NIOSH lacks sufficient information, which includes sufficient personnel and workplace monitoring data and radiological source term information, to allow NIOSH to estimate the potential total internal thorium exposures to which the proposed class may have been exposed.*

With the data currently available to NIOSH, it is feasible to reconstruct with sufficient accuracy the external and internal doses resulting from exposure to uranium metal during the Dow Madison AWE operational period (January 1, 1957 through December 31, 1960), and during the residual radiation period (January 1, 1961 through December 31, 1998). NIOSH also considers the reconstruction of medical dose for Dow Madison workers to be feasible.

After the Petition Evaluation Report was issued, NIOSH obtained about 700 pages of additional information from Dow. Based on this new documentation, NIOSH issued Addendum 1 to the Petition Evaluation Report (NIOSH 2007b). In Addendum 1, NIOSH concluded that the additional information did not provide sufficient data to change its original conclusion regarding the infeasibility of reconstructing internal Th doses during the operating period. NIOSH further concluded that sufficient information was available to conduct a bounding estimate of external doses from thorium exposure during the operating period.

In January 2008, the U.S. Department of Energy (DOE) provided information to the Department of Labor (DOL) that some Mg-Th alloys could have been purchased by Mallinckrodt for atomic weapons applications (DOE 2008). Prior to this, it was assumed that exposures to thorium only need be considered during the operational period, since Mg-Th alloys were presumed to be produced for strictly commercial purposes during the operational period when some special uranium fabrication had been done by Dow to support the weapons program (January 1, 1957, through December 31, 1960). Previously, only uranium exposures had been considered during the residual radiation period (initially defined as January 1, 1961, through December 31, 1998).

In response to the DOL information, NIOSH prepared Addendum 2 to the Dow Madison SEC Petition Evaluation Report to address the new DOE information that Mg-Th alloys had been used in weapons (NIOSH 2008a). One consequence of the new DOE information was that thorium exposures from weapons material production would need to be evaluated during the residual radioactivity period. NIOSH also updated the end date for the residual radioactivity period to October 31, 2006, and concluded that thorium doses during the residual radioactivity period could be reconstructed with sufficient accuracy.

Subsequent to the publication of these three petition evaluation review reports, NIOSH released Appendix C to TBD-6000 (Battelle 2006) on September 8, 2008, which specifically deals with the Dow Madison site. Appendix C tabulates and consolidates data and guidance that can be used to calculate internal (inhalation and ingestion) and external doses from uranium exposures during both the operating and residual periods. Appendix C also provides data that can be used to calculate external thorium exposures during the operating period and both external and internal (inhalation, ingestion, and thoron) exposures during the residual period. In Appendix C, the end of the residual period was defined as July 31, 2000, for uranium and November 30, 2007, for thorium.

Operating Period Summary – January 1, 1957, through December 31, 1960

Since Dow Madison workers during this period have been added to the SEC, the only concerns revolve around the ability to conduct dose reconstructions for workers with non-presumptive

cancers. NIOSH originally determined in the SEC Petition Evaluation Review Report for SEC-00079 that internal and external uranium doses can be calculated using sources such as ORAUT-OTIB-0004, *Estimating the Maximum Plausible Dose to Workers at Atomic Weapons Employer Facilities* (ORAUT 2006). It should be noted that ORAUT-OTIB-0004 relies on surrogate data. External exposures are modeled with MCNP or MicroShield® for a worker standing near a large mass of uranium metal. Inhalation exposures are based on measurements of air concentrations made at various Atomic Weapons Employer (AWE) facilities.

Subsequently in Appendix C, NIOSH refined its guidance regarding uranium dose reconstruction. For external exposures, they cited the generic guidance in TBD-6000 to calculate photon doses. These surrogate data were derived from MCNP calculations using uranium shapes typical of those handled at AWE facilities. For internal uranium exposures during 1957 and 1958, NIOSH used surrogate data from Table 7.2 of TBD-6000, which summarizes information on air concentrations associated with extrusion at various AWE facilities. Similarly for 1959 and 1960, NIOSH used surrogate data from Table 7.7 of TBD-6000, which summarizes information on air concentrations associated with rod straightening at various AWE facilities.

Based on the additional information provided by Dow and examined by NIOSH in Addendum 1, NIOSH concluded that it was still not feasible to evaluate thorium internal doses, but the new data provided sufficient information for a bounding reconstruction of external Th doses (NIOSH 2007b, p. 3). The ability to bound external dose was based on additional direct radiation readings, coupled with film badge results from the Dow Bay City facility, where the same operations were performed (NIOSH 2007b, p. 4). It appears that film badge monitoring was not used at Dow Madison, but was used at Dow Bay City for a single 13-day period. It was NIOSH's position in Addendum 1 that use of the direct radiation measurements at Dow Madison, together with the surrogate data from Bay City, provided sufficient data to bound the external exposures.

NIOSH did not address external Th exposures during the operating period in Addendum 2.

In Appendix C, NIOSH noted that a more prescriptive approach to external exposure had been presented in Attachment 2 of Addendum 2 for the **residual period**. In Addendum 2, NIOSH stated that, "The highest recorded exposure rate (0.7 mr/hr at one foot) was obtained near the thorium storage area and scrap bins, where AWE era materials were stored" (NIOSH 2008a, p. 31). This was equivalent to an annual exposure of 1,400 mrem/yr. This assumes that an operator spends 100% of his time 1 foot from the highest observed Th photon source and is based on measured data at Dow Madison.

If NIOSH had applied the same exposure scenario as recommended in TBD-6000 (i.e., 50% of the time at 1 foot), the annual external dose would have been 700 mrem for the **operating period**. Instead, for Appendix C, NIOSH selected surrogate data from film badge measurements made during a 13-day period at Bay City. The 95th percentile annual dose was 1,095 mrem, yielding a more claimant-favorable result than using the measured data from Dow Madison. The beta dose at all distances was assumed to be equal to the gamma dose at 1 foot. NIOSH does not

provide the reasoning for using surrogate data rather than measured data for external Th exposure.

Thus, any dose reconstructions for non-presumptive cancers in the operating period would rely largely on surrogate data, supplemented in the case of Th with direct radiation measurements.

Residual Period Summary – January 1, 1961, through October 31, 2006

NIOSH concluded, in the initial petition evaluation review report for Dow Madison, that it was feasible to calculate internal and external doses for uranium during the residual period (NIOSH 2007a). NIOSH stated that, "Potential internal doses received from inhalation and/or ingestion of re-suspended uranium during the residual contamination period can be reconstructed, as indicated by the model dose reconstructions covering the period January 1, 1957 through December 31, 1998." NIOSH provided no citations to support that position. NIOSH made the same statement with regard to external doses during the residual period (NIOSH 2007a, Section 6.2). No new uranium information was provided in either Addendum 1 or Addendum 2.

In the initial petition evaluation review report and Addendum 1, NIOSH did not consider thorium exposures during the residual period, because it was presumed that all Mg-Th alloy production during the operations period was related to applications not involving atomic weapons. However, based on more recent information about the possible use of Dow Mg-Th alloys in atomic weapons, Th exposures during the residual period were examined in Addendum 2. Inhalation exposures from dust were modeled using an exponential decay function and air sampling measurements taken prior to the beginning of the residual period on January 1, 1961, and a bounding sample taken during final cleanup in 2006. Thoron exposures were similarly modeled. External exposures were based on the assumption that, "The highest recorded exposure rate (0.7 mr/hr at one foot) was obtained near the thorium storage area and scrap bins, where AWE era materials were stored" (NIOSH 2008a, p. 31).

In Appendix C of TBD-6000, NIOSH proposed the same exponential decay approach to Th internal exposures as was presented in Attachment 2 to Addendum 2. To calculate external doses from Th, it was assumed during the first year of the residual period that doses were based on the surrogate film badge data from Bay City. External exposures were then assumed to decay at the same exponential rate as internal exposures. NIOSH notes that, "The external estimate is considered a bounding estimate because the majority of the external dose recorded on the film badges likely came from the in-process thorium material itself rather than residual contamination" (Battelle 2006, Appendix C, p. 7).

SUMMARY

NIOSH's approach to dose reconstruction has undergone a series of refinements since the Petition Evaluation Report for SEC-00079 was issued. This evolution, which ended with the publication of Appendix C to TBD-6000, is summarized in Table 2. It can be seen that use of surrogate data is proposed for all source terms except for thoron exposures and internal thorium exposures during the residual period. Reliance on use of surrogate could possibly be reduced by

using direct radiation measurements at Dow Madison, rather than film badge data from Dow Bay City.

Table 2. Evolution of Dose Reconstruction Approach for Dow Madison

Exposure	SEC-00079 Evaluation Report	SEC-00079, Addendum 1	SEC-00079, Addendum 2	Appendix C
Operating Period				
U Internal*	Doses can be reconstructed using surrogate data sources, such as in OTIB-0004.			Can be reconstructed using generic guidance for TBD-6000, including air sampling from AWE facilities.
U External*	Doses can be reconstructed using surrogate data sources, such as in OTIB-0004.			Can be reconstructed using generic guidance for TBD-6000, including MCNP calculations of doses from large U shapes.
Th Internal	Cannot reconstruct.	Cannot reconstruct.	Cannot reconstruct.	Cannot reconstruct.
Th External*	Cannot reconstruct.	Can be reconstructed using direct radiation measurements and surrogate data from Bay City.		Used surrogate film badge data from Bay City. (Could have used direct radiation measurements from Dow Madison.)
Residual Period				
U Internal	Doses can be reconstructed, but approach not presented.			Assumed resuspension of uranium deposited in 1960. Uranium deposition based on surrogate data from TBD-6000 and constant resuspension factor of 1E-06/m.
U External	Doses can be reconstructed, but approach not presented.			Used constant surface contamination data from TBD-6000. (Reported data are in error and must be corrected.)
Th Internal	Not considered.	Not considered.	Doses modeled using measured data and time-dependent exponential decay function.	Doses modeled using measured data and time-dependent exponential decay function.
Th External	Not considered.	Not considered.	Based on bounding direct radiation measurements.	External exposures assumed to decay at the same exponential rate as internal exposures from initial value based on surrogate film badge data from Bay City.
Thoron	Not considered.	Not considered.	Doses modeled using measured data (95^{th} percentile from 1959 data) and same time-dependent exponential decay function as for Th internal.	Doses modeled using measured data (95^{th} percentile from corrected 1959 data) and same time-dependent exponential decay function as for Th internal.

* - Since workers in the operating period were added to SEC, these exposures are only needed for dose reconstructions involving non-presumptive cancers.

REFERENCES

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