Draft Report

A FOCUSED REVIEW OF THE NORTON COMPANY SEC PETITION EVALUATION REPORT SEC-00173 CONCERNING THE USE OF ORAUT-OTIB-0070 FOR THE RECONSTRUCTION OF DOSES FROM RESIDUAL/POST-OPERATIONAL CONTAMINATION

Contract No. 200-2009-28555

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Disclaimer

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A Focused Review of the Norton Company SEC Petition Evaluation Report SEC-00173 Concerning the Use of ORAUT-OTIB-0070 for the Reconstruction of Doses from Residual/Post-Operational Contamination	Page 2 of 14
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1.0 RELEVANT BACKGROUND INFORMATION

On January 24, 2011, NIOSH issued its Evaluation Report (ER) (NIOSH 2011) in behalf of the SEC Petition-00173 for the Norton Company located on New Bond Street, Worcester, Massachusetts. Due to the fact that NIOSH employed guidance contained in ORAUT-OTIB-0070 in modeling internal and external dose estimates, the Advisory Board (during a full Board meeting held on February 23–25, 2011) directed the Subcommittee on Procedures Review to look into the use of ORAUT-OTIB-0070 at a time when select issues had not been resolved. In response to the Board's directive, the Subcommittee, on March 22, 2011, requested SC&A to conduct a focused review of ER SEC Petition-00173.

1.1 A TIMELINE FOR THE NORTON COMPANY

The following provides a timeline for the Norton Company's operational and post-operational periods:

- Between 1945 and 1957, the Norton Company conducted Atomic Weapons Employer (AWE) radiological operations that involved the use of unspecified quantities of UO_2, U_3O_8, and thorium.
- From January 1, 1958, through October 7, 1962, Norton Company employees performed tear-down and removal of materials/equipment that had been used in AWE processes.
- Between October 8 and October 10, 1962, Norton Company employees transported decontamination and decommissioning (D&D) wastes to a Norton Company landfill.
- Following the decommissioning of the AWE operations, Norton Company continued to conduct **commercial** (i.e., non-AWE) thorium operations through 1967 under the Atomic Energy Commission (AEC) material license STB-00770. Contamination and resultant doses from Norton Company's commercial thorium activities were **not** considered in NIOSH's ER.

1.2 PETITION FOR SEC STATUS

In Petition SEC-00173, the petitioner requested that NIOSH consider the inclusion of all employees who worked at the New Bond Street facility from 1960 through 1972. Based on available data for dose reconstruction, NIOSH defined a single SEC class of employees with 250 work-days for the period between January 1, 1958, and October 10, 1962.

1.3 AVAILABILITY OF DATA USED TO DEFINE/LIMIT THE TIME PERIOD FOR THE PROPOSED SEC CLASS

Based on the availability/suitability of data needed for dose reconstruction, NIOSH stated the following in its ER in behalf of two discrete post-operational time periods:

- <u>For the Proposed SEC Class that Covers the Post-Operational Time Period of January 1, 1958, through October 10, 1962</u>

NIOSH has determined that, although AWE operations were not performed at Norton Co. after 1957, Norton Co. performed decontamination and decommissioning of AWE materials and wastes from January 1, 1958 through October 10, 1962, which potentially exposed Norton Co. workers to internal and external radiation. …

[However,] *NIOSH finds it is **not feasible** to estimate internal and external exposures with sufficient accuracy for all workers at the site from January 1, 1958 through October 10, 1962, due to decontamination and decommissioning activities conducted during that period for which NIOSH has insufficient source term and monitoring data to bound potential doses.* [Emphasis added.]

- For the Reconstruction of Worker Doses for the Remaining Portion of the Post-Operational/Residual Radiation Period of October 11, 1962, through October 31, 2009, NIOSH Stated the Following:

  *Information available to NIOSH is sufficient to document or estimate the **maximum internal and external potential exposure** to members of the evaluated class under plausible circumstances during the period from October 11, 1962 through October 31, 2009.* [Emphasis added.]

2.0 DOSIMETRY/SURVEY DATA USED BY NIOSH FOR DOSE RECONSTRUCTION DURING THE RESIDUAL CONTAMINATION PERIOD BETWEEN OCTOBER 11, 1962 AND OCTOBER 31, 2009

Due to the fact that no Site Profile has been written for the Norton Company that might provide supportive data/information for dose reconstruction, NIOSH identified the following two documents used to support dose reconstruction for the residual radioactivity period of October 11, 1962, through October 31, 2009:

- Technical Basis Document Battelle-TBD-6000: *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals*, Battelle TBD-6000, Rev. F0, December 13, 2006.

- Technical Information Bulletin ORAUT-OTIB-0070: *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities.*

In brief, the ER proposed the use of Battelle-TBD-6000 and ORAUT-OTIB-0070 to support the reconstruction of bounding external and internal exposure from residual contamination as summarized in Section 3.0.

3.0 DATA AND METHOD SELECTED BY NIOSH TO DERIVE BOUNDING ESTIMATES OF EXPOSURE

3.1 INTERNAL EXPOSURE

The ER identified the following air sampling data used by NIOSH for determining bounding estimates for internal dose:

From Section 6.1, p. 20 of the ER

> *Forty-two sample results (short-lived and long-lived alpha-emitters) were reported for 21 samples collected on May 13, 1958 by the Massachusetts Department of Labor and Industries. Sixteen of the sample results (**from eight samples**) could be associated with the thorium processing area; six of the sample results (from three samples) could be associated with the uranium processing area. The system's **counting efficiency** and **MDA are not indicated**. Results are listed in units of µCi/ml.* [Emphasis added.]

From Section 7.2.2, p. 27 of the ER

> *NIOSH evaluated air monitoring data in the form of long-lived gross-alpha results obtained on **May 13, 1958** (reported on May 28, 1958) by the Massachusetts Department of Labor and Industries to **derive the air concentration starting on October 11, 1962 through the end of the residual radiation period, October 31, 2009**. The average of the long-lived alpha results was calculated from the data shown in Table 7-1 to estimate the starting air concentration (4.662 dpm/m^3) on October 11, 1962.*

Table 7-1: Air Monitoring Results, Long-Lived Alpha Emitters				
Sample Number	***Time Sampling Complete (hours)***	***Location***	***Long-Lived Alpha Emitters (µCi/mL)***	***Thorium Air Concentration (dpm/m)***
1M	*9.2*	*End of hood – thoria area*	*4E-13*	*–*
7M	*2.5*	*End of hood – thoria area*	*4E-13*	*–*
13	*2.5*	*End of hood – thoria area*	*2E-12*	*–*
5M	*1.15*	*Thoria processing area*	*2E-12*	*–*
3	*10*	*General area on bench*	*2E-12*	*–*
7	*11.2*	*Hood – thoria area*	*1E-12*	*–*
11	*2*	*Bench near thoria area*	*2E-12*	*–*
14	*2.5*	*By glass cutting wheel*	*7E-12*	*–*
		Average – thoria area samples	*2.1E-12*	*4.662*

> *Average daily intake rates for inhalation and ingestion were calculated based on an inhalation rate of 1.2 m^3/hr, 8-hour workday, and 250 workdays per year, resulting in a value of 30.654 dpm/day for the period from October 11, 1962 through December 31, 1963. **Intake rates for the following years through October 31, 2009 have been adjusted due to source term depletion per guidance***

> ***in ORAUT-OTIB-0070*** [see Table 7-2 below]. *The air monitoring results are reported in units of gross alpha and are not isotopic-specific; therefore, the most claimant-favorable radionuclide and solubility class will be assigned by NIOSH. The Norton Co. processed both uranium oxide and thoria. Because Norton Co. processed both uranium and thorium oxides, uranium can be assumed to be U-234 (Types M and S) and thorium can be assumed to be Th-232 (Types M and S).* [Emphasis added.]

Table 7-2: Intake Rates for Uranium or Thorium

Applicable Period	*ORAUT-OTIB-0070 Adjustment*	*Inhalation (dpm/day)*	*Ingestion (dpm/day)*	*Distribution*
01/1958	*not feasible*	*not feasible*	*not feasible*	*N/A*
10/11/1962 – 12/31/1963	*1*	*30.654*	*0.747*	*Constant*
01/01/1963 – 12/31/1964	*0.03*	*0.920*	*0.022*	*Constant*
1965 and later	*0.0007*	*0.021*	*0.001*	*Constant*

Note: Not included for discussion herein is NIOSH's model for bounding internal exposures from airborne alpha emitters associated with thoron-220 and its short-lived daughters (see Tables 7-3 and 7-4 in SEC Petition Evaluation Report SEC-00173). Here too, data for the eight samples reported by Pagnotto and Bavley 1958 were used and adjusted using the identical ORAUT-OTIB-0070 adjustment factors cited in Table 7-2 above.

For convenience to the reader and verification of data, data for the eight air samples reported by Pagnotto and Bavley 1958 are enclosed below as Exhibit 1.

Exhibit 1: Results of Eight Air Samples from Pagnotto and Bavley 1958

58-59 May 28, 1958

To: Dr. Elkins
From: Mr. Pagnotto and Mr. Bavley
Subject: Norton Company, Worcester
Persons Interviewed: Dr. Karl Benedict, Medical Director
Mr. Richard S. Johnson, Industrial Hygienist
Date of visit: May 13, 1958

This visit was made to check the atmosphere in the areas where uranium and thorium are handled. The results are as follows:

TABLE I

Sample Number	Time sampling completed	Location	Alpha emitters Uc/ml. Short-lived	Long-lived
1M	9.20	End of hood - thoria area	3.3×10^{-11}	$.04 \times 10^{-11}$
7M	2.50	End of hood - thoria area	4.0×10^{-11}	$.04 \times 10^{-11}$
13	2.50	End of hood - thoria area	3.6×10^{-11}	$.2 \times 10^{-11}$
5M	1.15	Thoria processing area	4.2×10^{-11}	$.2 \times 10^{-11}$
3	10.00	General air on bench	5.2×10^{-11}	$.2 \times 10^{-11}$
7	11.20	Hood - thoria area	4.1×10^{-11}	$.1 \times 10^{-11}$
11	2.00	Bench near thoria oven	22.6×10^{-11}	$.2 \times 10^{-11}$
14	2.50	By glass cutting wheel	3.1×10^{-11}	$.7 \times 10^{-11}$
		Average - thoria area samples	6.2×10^{-11}	$.2 \times 10^{-11}$
3M	10.40	Uranium pressing	2.3×10^{-11}	$.1 \times 10^{-11}$
4M	11.70	Laboratory hood area	$.2 \times 10^{-11}$	.00
6M	2.00	Near kiln 140, uranium area	4.8×10^{-11}	$.1 \times 10^{-11}$
		Average - uranium area	2.6×10^{-11}	$.1 \times 10^{-11}$
10	1.15	Bench, among thoria castings	54.3×10^{-11}	$.3 \times 10^{-11}$
1	9.70	Operator's exposure crushing	5.6×10^{-11}	$.9 \times 10^{-11}$
2	9.70	Operator's exposure crushing	4.2×10^{-11}	$.6 \times 10^{-11}$
2M	10.00	Operator's exposure crushing	5.2×10^{-11}	1.4×10^{-11}
4	10.00	Operator's exposure crushing	4.1×10^{-11}	$.3 \times 10^{-11}$
5	10.40	Operator's exposure screening	4.7×10^{-11}	$.8 \times 10^{-11}$
6	10.40	Operator's exposure screening	4.4×10^{-11}	$.9 \times 10^{-11}$
8	11.70	Operator's exposure crushing	5.0×10^{-11}	2.2×10^{-11}
9	1.15	Operator's exposure screening & crushing	3.3×10^{-11}	1.7×10^{-11}
12	2.00	" " screening&jaw crush.	3.4×10^{-11}	1.3×10^{-11}
		Average screening and crushing	4.4×10^{-11}	1.1×10^{-11}
		Maximum Allowable Concentration	1000×10^{-11}	5×10^{-11}

3.2 EXTERNAL EXPOSURE

To derive bounding external doses, NIOSH assumed that exposures would have resulted from residual surface contamination and from immersion of resuspended surface contamination. By means of the same eight air samples reported by Pagnotto and Bavley 1958 (see Exhibit 1 above) and the methods cited in Battelle-TBD-6000, NIOSH derived post-1962 external doses using the following assumptions:

> *In order to determine the feasibility of bounding potential external doses received from exposures to residual radiation, NIOSH evaluated air monitoring data obtained during the operations period. The 95th percentile of the gross alpha air dust results was calculated to estimate the highest contamination levels present after the AWE materials had been buried starting on October 11, 1962. It is assumed that the material deposited on the floor with a* ***deposition velocity of 0.00075 m/s*** *from October 11, 1962 through December 31, 1963. This results in a maximum contamination level of 1.83×10^{6} dpm/m^{2}. Using these assumptions, daily doses can be calculated based on the maximizing potential radionuclide. The external doses are from penetrating photons with energies between 30 and 250 keV and electron energy range of >15 keV for penetrating exposures.* ***Table 7-5 shows the external dose rates for the residual radiation period adjusted for source term depletion per the guidance provided in ORAUT-OTIB-0070 and Battelle-TBD-6000.*** … [Emphasis added]

Table 7-5: External Dose Rates for the Residual Radiation Period

Applicable Period	***ORAUT-OTIB-0070 Adjustment***	***Gamma (rem/year)***	***Beta (rem/year)***
01/1958 – 10/10/1962	*not feasible*	*not feasible*	*not feasible*
11/11/1962 – 12/1963	*1*	*0.026*	*0.233*
01/1964 – 12/1964	*0.03*	*0.001*	*0.007*
1965 onward	*0.0007*	*<0.001*	*<0.001*

4.0 SC&A'S COMMENTS AND ASSOCIATED FINDINGS

For the reconstruction of bounding internal and external dose estimates from residual contamination for the period of October 11, 1962, to October 31, 2009, NIOSH employed air sampling data taken at the Norton Company on May 13, 1958, and guidance contained in Battelle-TBD-6000 and ORAUT-OTIB-0070.

Finding 1: Both the internal and external dose estimates are based on a single set of air samples taken on May 13, 1958, which has limited credibility.

Exhibit 1 above and Table 7.1 of the ER (reproduced herein in Section 3.1) identify the **eight air samples** that form the basis of derived internal and external doses. The credibility of derived doses that are based on this data set may be questioned for the following reasons:

- Limited Number of Air Samples. The Norton Company facility is principally defined by Building 112, which the ER describes as ". . . **50,000 square-feet** building where Norton Company conducted AWE radiological operations from 1945 through 1957." [Emphasis added.]

- Restricted Air Sampling Time. For the eight air samples, Exhibit 1 identifies air sampling times that ranged from 1.15 hour to 11.2 hours. While Exhibit 1 provides no specific information regarding air flow rates for this data set, the ER references two other air sampling surveys on page 20: (1) 20 liters/minute for air samples collected by the Liberty Insurance Company in 1955; and (2) 19.8 liters/minute for air samples collected in a 1958 survey also performed by the Liberty Mutual Insurance Company.

  If the flow rate of 20 liters/minute may be assumed to apply to the 8 air samples taken on May 13, 1958, then air volumes ranging from 1.4 m^3 to 13.4 m^3 can be estimated. These low air volumes should be compared to conventional volumes of 160 to 320 m^3 taken by a standard air sampler with a flowrate of 4 ft^3/minute and sampling times of 24 to 48 hours.

- No Data are Provided Regarding the Counting Efficiency, Counting Time(s), Background Count Rates, or MDA Values for the Analyses of Air Samples. As acknowledged in the ER "…The system's counting efficiency and MDA are not indicated." Thus, the standard error/uncertainty of individual activity levels can not be assessed. For example, Exhibit 1 identifies **Sample 5M** as having an activity level of 0.2×10^{-11} µCi/ml. With an air sampling time of 1.15 hours and an assumed airflow of 20 liters/minute, the total volume of collected air of ~1.4 m^3 would have produced an activity level of 5 **dpm** on the filter. Assuming a 10-minute count and a maximum counting efficiency (i.e., cpm/dpm) of 50%, a total observed **net** count of about 25 would have been expected (or **about 2.5 cpm**).

  In the absence of knowing the background count rate, neither the MDA nor the standard error of cited activity levels can be estimated in behalf of the eight air samples.

Finding 2 (Conditional): To derive both external and internal bounding dose estimates, NIOSH employed a source term depletion factor that is a simplified version of the default value of 0.01 day^{-1} (or 1% per day) as defined in ORAUT-OTIB-0070.

Dose estimates from residual contamination used time-dependent adjustment factors of (1) 0.03 for the year 1964, and (2) 0.0007 for 1965 through 2009 (see Tables 7.2 and 7.5 in the ER and reproduced here in Sections 3.1 and 3.2). These adjustment factors represent a simplified version of the 0.01 day^{-1} source term depletion factor recommended in ORAUT-OTIB-0070.

The use of this default source term depletion factor has been cited by SC&A in its review of ORAUT-OTIB-0070 (SC&A 2008) as Finding #2. To date, this finding has not been resolved.

The adjustment factors cited above in Table 7-2 were based on guidance provided in Table 3-1 of OTIB-0070. Table 3-1 is reproduced below with an additional column (K=1E-06/m) added for reasons discussed below:

Table 3-1. Adjustment Factors to Account for Depletion of Source Term during Residual Contamination Period

Year	Factor (K=8E-05/m)	Factor (K = 1E-06/m)
1	1	1
2	0.03	0.96
3 on	0.0007	0.92

The factors for year 2 and year 3 in Column 2 are based on a source depletion rate of 1% per day (e.g., exp(-0.01*365 = 0.026). The source term is assumed to remain constant after 3 years. The depletion rate of 1% per day is calculated in Section 2.6 of OTIB-0070 as follows:

$$\lambda = 24KnH$$

where

K – resuspension factor (8E-05/m)
n – air change rate (1/hr)
H – room height (5 m)

If the resuspension rate were 1E-06/m as been suggested by NRC for cleaned-up facilities (Abu-Eid et al. 2002), the source term half-life would be reduced to 1.2E-02%/day and, as shown in the 3rd column of Table 3-1, intakes would be substantially higher.

As SC&A has discussed in the past, use of an exponentially decaying source term is a reasonable concept. However, the depletion rate must be based on a resuspension rate, which is consistent with site conditions. A one-size-fits-all approach is not scientifically justified and may not be bounding. In the case of Norton, a resuspension factor of 1E-06/m seems more appropriate, given the clean-up activities undertaken at the beginning of the residual period. This would result in higher source term adjustment factors than used in the ER.

5.0 SUMMARY CONCLUSIONS

In its SEC Petition ER for the Norton Company (Petition SEC-00173), NIOSH stated that it has sufficient data to bound internal and external doses associated with residual contamination for the period from October 11, 1962, through October 31, 2009. SC&A critically evaluated the quality and quantity of survey data, as well as applied model parameters used by NIOSH for deriving bounding internal and external doses.

As stated in Finding 1, SC&A concludes that the air sampling data that represent the basis for deriving internal and external doses suffer from multiple deficiencies. Deficiencies include (1) the limited number of air samples, (2) the restricted number of sample locations, (3) short duration(s) of air sampling and (assumed) low air flow rate, and (4) lack of critical data surrounding the analyses of air samples (i.e., sample counting times, background count levels, counting efficiency, etc.).

Finding 2 is a conditional finding that centers around the use of the default source term depletion factor of 0.01 day^{-1} (or 1% per day) recommended in ORAUT-OTIB-0070. Use of this default has been questioned by SC&A and discussed by the Advisory Board's Subcommittee on Procedures Review. To date, however, use of this source term depletion remains an unresolved finding. Use of a source term depletion factor of 1% per day does not appear to be consistent with the expected resuspension factors for post-clean-up contamination at Hooker.

6.0 REFERENCES

Abu-Eid, R. M., R. B. Coddell, N. A. Eisenburg, T. E. Harris, and S. McGuire, 2002. *Re-evaluation of the Indoor Resuspension Factor for the Screening Analysis of the Building Occupancy Scenario for NRC's License Termination Rule*, NUREG-1720, Draft Report for Comment, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, Washington, DC, June. [SRDB Ref ID: 22400]

Battelle-TBD-6000. 2006. *Site Profiles for Atomic Weapons Employers that Worked with Uranium and Thorium Metals*, Rev. F0, Battelle Team Dose Reconstruction Project for NIOSH. December 13, 2006.

NIOSH. 2011. *SEC Petition Evaluation Report for Petition SEC-00173 (January 1, 1958 through October 31, 2009), Norton Company*, National Institute for Occupational Safety and Health, Cincinnati, Ohio. January 24, 2011.

ORAUT-OTIB-0070. 2008. *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities, Rev. 00.* Oak Ridge Associated Universities Team: Cincinnati, Ohio. March 10, 2008.

Pagnotto, L. and H. Bavley, 1958. *Study of Air Samples and Urinalysis Data (From May 13, 1958 Visit) in Regards to Thoria Handling*, correspondence to Harvey Elkins, May 28, 1958.

SC&A. 2008. *Review of ORAUT-OTIB-0070: Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities.* SCA-TR-TASK3-0009, Rev. 0. SC&A, Inc.: Vienna, Virginia.