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REPORT TO THE ADVISORY BOARD
ON RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

SC&A'S BLIND DOSE RECONSTRUCTION OF CASE #[REDACTED] FROM THE ALLIED CHEMICAL PLANT

Contract No. 200-2009-28555
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EXECUTIVE SUMMARY

Under Contract No. 200-2009-28555, SC&A has been tasked by the Advisory Board on Radiation and Worker Health (Advisory Board) to performed eight blind dose reconstructions (DRs). This report presents the methodologies and results of our DR concerning one of the eight cases selected by the Advisory Board.

To perform this blind DR, SC&A was provided with all of the Department of Energy (DOE) dosimetry records; the Department of Labor (DOL) correspondence, forms, and medical records; and the Computer-Assisted Telephone Interview (CATI) Report that were made available to the National Institute for Occupational Safety and Health (NIOSH) for constructing doses in behalf of this case. SC&A used two independent approaches to reconstruct occupational external and internal doses for this case. Both approaches used current guidance from NIOSH; however, for this case, there were no dosimetry or bioassay records. The first approach, referred to as DR–Method A, used the spreadsheets and other tools developed by NIOSH to calculate the doses, whereas the second approach, referred to as DR–Method B, manually calculated the doses.

This Executive Summary provides an overview of the case and a comparison of the results of the two independent DR methods. Section I of this report provides a detailed discussion of the approach used to reconstruct external/internal occupational radiation doses using DR–Method A, and Section II describes the reconstruction of doses using DR–Method B.

RELEVANT BACKGROUND INFORMATION

According to the DOL records and the CATI Report, this case represents an energy employee (EE) who worked at the Allied Chemical and Dye Corporation, North Claymont, Delaware [referred to in this report as the Allied Chemical Plant (ACP)], from [**redacted**] through [**redacted**], and [**redacted**] through [**redacted**]. The EE was diagnosed with **lung cancer** (ICD-9 Code 162.9) in [**redacted**].

According to the DOE records, the majority of the EE's radiation exposure was received while working as a [**redacted**]. During the course of employment, the EE was <u>not</u> monitored for external photon and neutron radiation exposure, or internal radiation exposure by in-vivo or in-vitro bioassay methods. A description of the ACP is provided in Section I-1 of DR–Method A and Section II-2 of DR–Method B.

PRESENTATION OF RESULTS

The results of both independent DR methods are shown in Table ES-1. DR–Method A derived a total lung dose of **121.435 rem** plus **0.812 WLM** of radon, with a probability of causation (POC) of **85.40%**; while DR–Method B derived a total lung dose of **0.235 WLM/yr** of radon, with a POC of **64.1%**.

Table ES-1. Derived Dose Estimates

	DR–Method A	DR–Method B
External Dose (Occupational):		
▪ **Operations Dose**		
- Photons < 30 keV	0.462	NA
- Photons 30–250 keV	0.579	NA
▪ **Residual Dose**		
- Photons < 30 keV	0.086	NA
- Photons 30–250 keV	0.108	NA
▪ **Occupational Medical Dose**		
- Photons 30–250 keV	1.886	NA
Internal Dose:		
- Plutonium/Americium (Alpha)	118.314	NA
Total	**121.435**	NA
Radon	**0.812 WLM**	**0.235 WLM/yr**

There are no technical basis documents or survey information for ACP; therefore, the dose reconstructors were required to search for surrogate data from other sites. In this case, DR–Method A performed an analysis of potential external and internal exposures and assigned doses in the Interactive RadioEpidemiological Program (IREP) Input table accordingly based on the Blockson Chemical Company TBD (DCAS-TKBS-0002), as well as *Characterization of Occupational Exposure to Radium and Radon Progeny During Recovery of Uranium from Phosphate Materials* (ORAUT-OTIB-0043) and *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). On the other hand, DR–Method B performed a partial DR using two different approaches. First, Method B calculated internal doses using an overestimate DR approach based on Texas City Chemical, Inc. (TCC), information and found this method resulted in a POC >50%. DR–Method B then employed an underestimating approach by using the U.S. Environmental Protection Agency (EPA) guideline of 4 pCi/l (as found in FIPR 1998) and determined that assigning only radon intake resulted in a POC >50% for this lung cancer case; therefore, other external and internal dose did not need to be included.

A detailed description of the DR approach used by SC&A's Method A is provided in Section I below. Section II of this report describes the derivation of doses using SC&A's DR–Method B. For the benefit of the reader, Table ES-2 provides a summary comparison of the approaches used by the two SC&A DR methods for calculating doses.

Table ES-2. Approach Used by SC&A's DR–Method A and DR–Method B for Calculating Doses for the ACP Worker

Dose Element	DR–Method A	DR–Method B
External Dose: Operations Residual Period	Used the 50th percentile external dose value of 70 mrem/yr from Table 4-1 of ORAUT-OTIB-0043.	N/C*
Occupational Medical	Assumed annual x-ray dose for each year of employment based on ORAUT-OTIB-0006.	N/C*
Onsite Ambient	N/C*	N/C*
Internal	Used the uranium intake value of 44.0 pCi/day for U-238 and 0.605 pCi/day Th-232 from Table 4-3 of ORAUT-OTIB-0043, plus the ratio values for associated radionuclides from the Blockson TBD (DCAS-TKBS-0002) and ORAUT-OTIB-0043 to derive the potential intakes during the operational period (1950–1969). DR–Method A then used these same intake values, adjusted for depletion rate according to ORAUT-OTIB-0070, for the residual period (1970–1975).	N/C*
Radon	Used the radon intake value of 0.036 WLM/yr from Table 4-4 of ORAUT-OTIB-0043 to assign yearly radon intakes for the operational years (1950–1969), and the same value, adjusted for depletion rate according to ORAUT-OTIB-0070, for the residual period (1970–1975).	Used the potential radon intake of 4 pCi/l in 50% equilibrium, which corresponds to 0.235 WLM/yr. The value of 4 pCi/l is the EPA guideline for radon as quoted in FIPR 1998, and was considered a minimizing approach.

* N/C = Not Considered in DR

SECTION I: DR–METHOD A

I.1 SUMMARY BACKGROUND INFORMATION

This report presents the results of an independent blind dose reconstruction (DR) performed by S. Cohen & Associates (SC&A) for an energy employee (EE) who worked at the Allied Chemical and Dye Company in North Claymont, Delaware, from [redacted] to [redacted], and [redacted] to [redacted]. The EE was diagnosed with [redacted] **carcinoma of the lung** (ICD-9 Code 162.9) in [redacted].

According to Department of Labor (DOL) records, the EE worked as a **[redacted]** during both employment periods. No employee monitoring records or site survey records were found.

In the early 1950s, Allied Chemical was involved in research and development of small pilot-scale operations on uranium recovery from a phosphoric acid plant at North Claymont. The work was performed on a small scale under contract for the Atomic Energy Commission (AEC). Former employees estimated that, at most, only a few pounds of uranium concentrate were produced (DOE 1987).

The site was owned and operated by General Chemical Corporation. At the time of the contract with AEC, the company was known as the General Chemical Division of the Allied Chemical and Dye Corporation. Operations at the phosphoric acid plant ceased in the late 1960s, and the plant was demolished in the early 1970s. The contractor, Cleveland Wrecking, salvaged reusable building materials and disposed of the remaining rubble in local landfills. The exact location on the site where the AEC work was performed is not known.

The Department of Energy (DOE) Oak Ridge Operations Office contacted Allied Chemical on July 16, 1977. A contact report, furnished to DOE Headquarters on December 12, 1977, concluded that the potential for measurable contamination at this site was insignificant due to the limited scale of operations (DOE 1987). Since exact dates of operations are unknown, the operational period is assumed to be 1950 to 1969, and the residual period from 1970–1977.

I.1.1 SC&A Blind DR Approach

SC&A reviewed all of the DOL records provided on behalf of this employee and all of the NIOSH procedures relevant to this case. There is no site-specific Technical Basis Document (TBD) available for this site. Therefore, information on the phosphoric acid process was obtained from the Blockson Chemical Company TBD (DCAS-TKBS-0002); ORAUT-OTIB-0043, *Characterization of Occupational Exposure to Radium and Radon Progeny During Recovery of Uranium from Phosphate Materials*; and ORAUT-OTIB-0070, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities*. Using the guidance provided in these documents, SC&A manually calculated reasonable, claimant-favorable annual organ doses shown in Table I-1. Appendix I-A provides a list of SC&A's annual organ doses and also includes IREP input parameters, such as energy range, distribution type, and uncertainty for each year.

Table I-1. Summary of SC&A-Derived External/Internal Dose Estimates

	Appendix A Exposure Entry No.	Lung Dose (rem)
External Dose (Occupational):		
▪ **Operations Dose ([redacted]–[redacted])**		
- Photons 30–250 keV	26–44	0.462
- Photons >250 keV	45–63	0.579
▪ **Residual Dose ([redacted]–[redacted])**		
- Photons 30–250 keV	64–69	0.086
- Photons >250 keV	70–75	0.108
▪ **Occupational Medical Dose**		
- Photons 30–250 keV	1–25	1.886
Internal Dose ([redacted]–[redacted]):		
- Alpha	76–107	118.314
Total		**121.435**
Radon Exposure ([redacted]–[redacted]):	1–25	**0.812 WLM**

SC&A determined the probability of causation (POC) for this case using these annual doses as input into the IREP program. The total dose shown in Table I-1 produced a POC of **85.40%**

I.2 EXTERNAL DOSES

Since the worker was neither provided with film badge or thermoluminescent dosimeters (TLDs) to measure external exposures, nor were bioassays performed to estimate internal exposures, exposures experienced by the worker were estimated using the Blockson Chemical Company TBD (DCAS-TKBS-0002), ORAUT-OTIB-0043, and ORAUT-OTIB-0070. In the sections that follow, a description is provided of how DR–Method A reconstructed the external dose to the lung.

I.2.1 Photon Doses

Since there are no dosimetry or radiological survey data upon which to reconstruct the EE's external radiation exposure, Method A used the external exposure parameters given in ORAUT-OTIB-0043, Section 4.1. During chemical separation in the wet acid process, radium scale builds up in the processing equipment. The radiation levels peak in the acid wash section, with dose rates as high as 10 mrem/hr (Lardinoye and Weterings 1982). Considering the nature of their duties, duration of work activities, and frequency of such work, a maximally exposed worker could receive up to 220 mrem/yr (Lardinoye and Weterings 1982). NCRP (1993) reports exposures for a 2,000 hr/yr occupancy at phosphogypsum stacks as 70 mrem, while Laiche and Scott (1991) estimated a range for that occupancy of 48 to 68 mrem. As stated in ORAUT-OTIB-0043, Table 4-1, page 12, the above data may be represented with a lognormal distribution having a geometric mean (GM) of 70 mrem/yr, a 95th percentile value of 220 mrem/yr, and a geometric standard deviation (GSD) of 2.00.

For the purposes of this DR, SC&A assumed a lognormal distribution with a GM of 0.070 rem/yr and a GSD of 2.00. The energy fraction and organ dose conversion factors (DCFs) for the lung from Appendix A of OCAS-IG-001, *External Dose Reconstruction Implementation Guideline*, are shown in Table I-2.

Table I-2. Effective Dose Conversion Factors and Energy Distributions

Allied Chemical Uranium Extraction Process		
	Photons	
Energy Range	30–250 keV	>250 keV
Energy Fraction	50%	50%
Organ DCF	0.695	0.87
$DCF_{Effective}$	0.3475	0.435

I.2.1.1 Operational Period

Although the exact dates are unknown, the period of operation is assumed to have occurred from 1950 through 1969. SC&A calculated the photon dose to the lung for this time period assuming a whole body exposure of 0.070 rem/yr. Applying the $DCF_{Effective}$ from Table I-2 gives the following annual doses during the operational period 1950–1969.

Table I-3. Annual Photon Doses from Operations

Year	Annual Photon Dose	
	30–250 keV photons	>250 keV photons
1950–1969	0.024 rem/yr	0.030 rem/yr

The total photon dose is 1.041 rem and is shown as IREP entries #26–#63 in Appendix I.A. These photon doses were entered into IREP as a lognormal distribution with an uncertainty of 2.00.

I.2.1.2 Residual Period

The residual period begins in 1970, after the completion of operations, and is assumed to last until 1977 when DOE submitted its site assessment (DOE 1977). DR–Method A calculated the EE's exposure to residual contamination using the guidance found in ORAUT-OTIB-0070, *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, from 1970 until the EE's last year of employment in [redacted].

ORAUT-OTIB-0070 provides guidance and adjustment factors to account for depletion of source term during the residual period. The adjustment factors are based on an average depletion rate of 0.00067 per day.

Table I-4. Residual Photon Doses

Year	Adjustment Factor	Photon Dose (rem)	
		30–250 keV photons	>250 keV photons
[redacted]	1.000	0.024	0.030
[redacted]	0.783	0.019	0.024
[redacted]	0.613	0.015	0.019
[redacted]	0.480	0.012	0.015
[redacted]	0.376	0.009	0.011
[redacted]	0.294	0.007	0.009

The total photon dose is 0.194 rem and is shown as IREP entries #64–#75 in Appendix I.A. The recorded photon doses were entered into IREP as a lognormal distribution with an uncertainty of 2.00.

I.3 OCCUPATIONAL MEDICAL DOSE

In addition to the estimated dose received from site operations and residual contamination, the doses received from diagnostic x-ray procedures that were required as a condition of employment were also included in the overall dose. Since no medical records for the EE were found, the x-ray dose was based on an annual PA chest exam and the dose information in Table A-7 of ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures*. For the years [redacted] to [redacted], the EE's annual lung dose from medical exams was 0.084 rem/yr. For the years [redacted] to [redacted], the medical dose was 0.042 rem/yr.

The EE's total occupational medical dose of 1.886 rem is shown in IREP entries #1–#25 of Appendix I.A.

In order to provide the most claimant-favorable results, the annual occupational medical dose values were entered into IREP as a normal distribution with 30% uncertainty and a photon energy range of 30–250 keV.

I.4 INTERNAL DOSES

I.4.1 Uranium and Thorium Doses

There are no process records, survey records, or dosimeter records from the Allied Chemical and Dye site in Claymont, Delaware. However, the wet chemical phosphoric acid treatment process used there is similar to the process used in Building 55 at the Blockson Chemical Company site.

The following assumptions for isotopic ratios in the phosphoric acid stream are based on information in the Blockson Site Profile (DCAS-TBKS-0002) and ORAUT-OTIB-0043, *Characterization of Occupational Exposure to Radium and Radon Progeny during Recovery of Uranium from Phosphate Materials*:

(1) 85% of U reports to phosphoric acid (DCAS-TKBS-0002); ORAUT-OTIB-0043 cites "approximately 86%."

(2) 4% of Ra-226 reports to acid (DCAS-TKBS-0002).

(3) Thorium reports to the acid in same proportion as uranium (DCAS-TKBS-0002, ORAUT-OTIB-0043).

(4) U-238:Th-232 radioactivity ratio in Blockson's rock was 30:1. However, ORAUT-OTIB-0043 uses a U-238/Th-232 ratio of 72:1 based on material averages from several facilities. Since the exact composition of the Allied material is unknown, the U-238/Th-232 ratio of 72:1 is used for this DR. Th-232 progeny are assumed to be in equilibrium. Although most of the Ra-228 would have been separated and removed with

the phosphogypsum, it is assumed to be in equilibrium with Th-232 for dose modeling to allow for ingrowth over the operational and residual contamination period (DCAS-TKBS-0002).

(5) Pb-210 and Po-210 assumed to report to the acid the same as U-238 (DCAS-TKBS-0002, ORAUT-OTIB-0043).

(6) The daily 8-hour U-238 intake (in equilibrium with progeny) and Th-232 intake (in equilibrium with progeny) are 44.0 pCi/day (1.63 Bq/day) and 0.605 pCi/day (0.0224 Bq/day), respectively (using best-estimate hourly intake values from Table 4-3, page 13 of ORAUT-OTIB-0043).

(7) The U_3O_8 product produced from wet phosphoric acid by filtering the precipitated uranium most closely corresponds to the clearance rate associated with Type M uranium material (DCAS-TKBS-0002).

(8) Thorium could have been Type M or Type S, and polonium could have been F or M. Therefore, the thorium and polonium solubility types were selected based on the types that deliver the largest dose to the target organ (DCAS-TKBS-0002). For this case, the solubility types of thorium and polonium are S and M, respectively. Pb-210 is Type F.

These assumptions result in the following ratios and intakes:

Table I-5. Relative Radionuclide Concentrations and Intakes

Radionuclide	Ratio to U-238	Daily Intake		Solubility Type
		pCi/day	Bq/day	
U-238	1	44.0	1.628	M
U-234	1	44.0	1.628	M
Th-230	1	44.0	1.628	S
Po-210	1	44.0	1.628	M
Pb-210	1	44.0	1.628	F
Ra-226	4% = 0.040	1.76	0.0765	M
Th-232	1/72 = 0.014	0.605	0.0224	S
Th-228	1/72 = 0.014	0.605	0.0224	S
Ra-228	1/72 = 0.014	0.605	0.0224	M

I.4.1.1 Operations Period

The daily intakes listed in Table I-5 were assumed to have occurred during the operations period from 1950 through 1969. The EE's internal doses for the operations period were calculated assuming a chronic exposure to the intakes listed in Table I-5 during the periods [**redacted**]–[**redacted**] and [**redacted**]–[**redacted**].

I.4.1.2 Residual Period

No survey data were available to estimate the levels of residual radiological contamination. The residual period began in 1970, after the completion of operations, and is assumed to have lasted until 1977, when DOE submitted its site assessment. SC&A's DR–Method A calculated the EE's internal exposure to residual contamination using the guidance found in ORAUT-OTIB-0070, *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, from 1970 until the EE's last year of employment in [redacted].

ORAUT-OTIB-0070 provides guidance and adjustment factors to account for depletion of source term during the residual period. The adjustment factors are based on an average depletion rate of 0.00067 per day. The adjustment factors were applied to all the intakes shown in Table I-5. Table I-6 shows how the factors were applied to the U-238 and Th-232 intakes; the adjustment factors were also applied to the other radionuclides.

Table I-6. Adjusted Intakes for Uranium and Thorium during the Residual Period

Year	Adjustment Factor	Adjusted Intake (pCi/d)	
		U-238	Th-232
[redacted]	1.000	44.0	0.014
[redacted]	0.783	34.4	0.011
[redacted]	0.613	27.0	0.009
[redacted]	0.480	21.1	0.007
[redacted]	0.376	16.5	0.005
[redacted]	0.294	12.9	0.004

The EE's internal doses from [redacted]–[redacted] and [redacted]–[redacted] are shown in Table I-7.

Table I-7. Summary of Internal Doses

Radionuclide	Solubility Type	Dose (rem)
U-238	M	16.962
U-234	M	21.795
Th-230	S	50.611
Po-210	M	22.348
Pb-210	F	0.492
Ra-226	M	1.031
Th-232	S	1.096
Th-228	S	3.867
Ra-228	M	0.112
	Total:	**118.314**

The internal doses are shown as IREP entries #76–#107 in Appendix I.A and were entered as a lognormal distribution with an uncertainty of 1.270.

I.4.2 Dose from Radon

Radon exposure was assessed using guidance from ORAUT-OTIB-0043, Section 4.2. This guidance is based on data from the Florida Institute of Phosphate Research Report (FIPR 1998) for activities relevant to uranium extraction. The combined measurements formed a set of 130 data points that have a GM of 0.751 pCi/L and a GSD of 1.989 (ORAUT-OTIB-0043, Table 4-4, page 14). The exposure to the respiratory tract from radon progeny, in working levels per year (WLM/yr), was calculated based on an equilibrium factor of 0.4 and a conversion of 1 WL per 100 pCi/L.

$$\text{WLM/yr} = 0.751 \text{ pCi/L} \times 0.4 \times 1 \text{ WL}/100 \text{ pCi/L} \times 12 \text{ M/yr}$$
$$\text{WLM/yr} = 0.036 \text{ WLM/yr}$$

The annual exposure was calculated to be 0.036 WLM/yr during operations. This value was applied for the years [**redacted**]–[**redacted**] and [**redacted**]–[**redacted**].

In the absence of any residual radon information, the adjustment factors shown in Table I-6 were applied to the annual radon exposure of 0.036 WLM/yr for years [**redacted**]–[**redacted**]. The EE's total radon exposure is 0.812 WLM, which is shown as IREP entries #1–#25 under "Radon Exposure Inputs" in Appendix I-A, and were entered as a lognormal distribution with an uncertainty of 1.989.

I.4.3 Environmental Dose

Since the EE was assessed an internal dose for the entire employment period, no additional environmental dose was calculated.

I.5 RADIOLOGICAL INCIDENTS

No site or EE records were found. Therefore, no radiological incidents were identified.

I.6 SUMMARY CONCLUSIONS

The EE worked at the Allied Chemical and Dye Company in Claymont, Delaware, from [**redacted**] to [**redacted**] and [**redacted**] to [**redacted**] as a [**redacted**]. There are no site or employee monitoring records available. The EE was diagnosed with lung cancer in [**redacted**]. The DR derived a total external and internal dose of **121.435 rem** to the lung, plus 0.812 WLM of radon. The total POC for the primary lung cancer was calculated using the NIOSH IREP (v.5.7) and determined to be **85.40%**.

I.7 REFERENCES

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APPENDIX I-A: IREP INPUT – LUNG

EXPOSURE INFORMATION							
Number of exposures							
107							
Exposure #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
1	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
2	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
3	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
4	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
5	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
6	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
7	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
8	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
9	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
10	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
11	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
12	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
13	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
14	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
15	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
16	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
17	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
18	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
19	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
20	[redacted]	acute	photons E=30–250keV	Normal	0.084	0.025	0.000
21	[redacted]	acute	photons E=30–250keV	Normal	0.042	0.013	0.000
22	[redacted]	acute	photons E=30–250keV	Normal	0.042	0.013	0.000
23	[redacted]	acute	photons E=30–250keV	Normal	0.042	0.013	0.000
24	[redacted]	acute	photons E=30–250keV	Normal	0.042	0.013	0.000
25	[redacted]	acute	photons E=30–250keV	Normal	0.042	0.013	0.000
26	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
27	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
28	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
29	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
30	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
31	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
32	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
33	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
34	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
35	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
36	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
37	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
38	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
39	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
40	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
41	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
42	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
43	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
44	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
45	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000

Appendix I-A: IREP Input – Lung (continued)

46	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
47	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
48	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
49	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
50	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
51	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
52	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
53	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
54	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
55	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
56	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
57	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
58	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
59	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
60	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
61	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
62	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
63	[redacted]	chronic	photons E>250keV	Lognormal	0.031	2.000	0.000
64	[redacted]	chronic	photons E=30–250keV	Lognormal	0.024	2.000	0.000
65	[redacted]	chronic	photons E=30–250keV	Lognormal	0.019	2.000	0.000
66	[redacted]	chronic	photons E=30–250keV	Lognormal	0.015	2.000	0.000
67	[redacted]	chronic	photons E=30–250keV	Lognormal	0.012	2.000	0.000
68	[redacted]	chronic	photons E=30–250keV	Lognormal	0.009	2.000	0.000
69	[redacted]	chronic	photons E=30–250keV	Lognormal	0.007	2.000	0.000
70	[redacted]	chronic	photons E>250keV	Lognormal	0.030	2.000	0.000
71	[redacted]	chronic	photons E>250keV	Lognormal	0.024	2.000	0.000
72	[redacted]	chronic	photons E>250keV	Lognormal	0.019	2.000	0.000
73	[redacted]	chronic	photons E>250keV	Lognormal	0.015	2.000	0.000
74	[redacted]	chronic	photons E>250keV	Lognormal	0.011	2.000	0.000
75	[redacted]	chronic	photons E>250keV	Lognormal	0.009	2.000	0.000
76	[redacted]	chronic	alpha	Lognormal	3.645	1.270	0.000
77	[redacted]	chronic	alpha	Lognormal	4.347	1.270	0.000
78	[redacted]	chronic	alpha	Lognormal	4.552	1.270	0.000
79	[redacted]	chronic	alpha	Lognormal	4.693	1.270	0.000
80	[redacted]	chronic	alpha	Lognormal	4.797	1.270	0.000
81	[redacted]	chronic	alpha	Lognormal	1.231	1.270	0.000
82	[redacted]	chronic	alpha	Lognormal	4.237	1.270	0.000
83	[redacted]	chronic	alpha	Lognormal	4.784	1.270	0.000
84	[redacted]	chronic	alpha	Lognormal	4.891	1.270	0.000
85	[redacted]	chronic	alpha	Lognormal	4.963	1.270	0.000
86	[redacted]	chronic	alpha	Lognormal	5.018	1.270	0.000
87	[redacted]	chronic	alpha	Lognormal	5.062	1.270	0.000
88	[redacted]	chronic	alpha	Lognormal	5.099	1.270	0.000
89	[redacted]	chronic	alpha	Lognormal	5.129	1.270	0.000
90	[redacted]	chronic	alpha	Lognormal	5.155	1.270	0.000
91	[redacted]	chronic	alpha	Lognormal	5.178	1.270	0.000
92	[redacted]	chronic	alpha	Lognormal	5.199	1.270	0.000
93	[redacted]	chronic	alpha	Lognormal	5.217	1.270	0.000
94	[redacted]	chronic	alpha	Lognormal	5.234	1.270	0.000
95	[redacted]	chronic	alpha	Lognormal	5.249	1.270	0.000
96	[redacted]	chronic	alpha	Lognormal	5.263	1.270	0.000

Appendix I-A: IREP Input – Lung (continued)

97	[redacted]	chronic	alpha	Lognormal	4.485	1.270	0.000
98	[redacted]	chronic	alpha	Lognormal	3.725	1.270	0.000
99	[redacted]	chronic	alpha	Lognormal	3.088	1.270	0.000
100	[redacted]	chronic	alpha	Lognormal	2.559	1.270	0.000
101	[redacted]	chronic	alpha	Lognormal	2.125	1.270	0.000
102	[redacted]	chronic	alpha	Lognormal	0.928	1.270	0.000
103	[redacted]	chronic	alpha	Lognormal	0.657	1.270	0.000
104	[redacted]	chronic	alpha	Lognormal	0.550	1.270	0.000
105	[redacted]	chronic	alpha	Lognormal	0.473	1.270	0.000
106	[redacted]	chronic	alpha	Lognormal	0.414	1.270	0.000
107	[redacted]	chronic	alpha	Lognormal	0.369	1.270	0.000

LUNG CANCER INPUTS					
Exposure from	Smoking History				
Radon + Other Sources	[redacted]				
Radon Exposure Information					
Number of radon exposures					
25					
Exposure #	Exposure Year	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
1	[redacted]	Lognormal	0.036	1.989	0
2	[redacted]	Lognormal	0.036	1.989	0
3	[redacted]	Lognormal	0.036	1.989	0
4	[redacted]	Lognormal	0.036	1.989	0
5	[redacted]	Lognormal	0.036	1.989	0
6	[redacted]	Lognormal	0.036	1.989	0
7	[redacted]	Lognormal	0.036	1.989	0
8	[redacted]	Lognormal	0.036	1.989	0
9	[redacted]	Lognormal	0.036	1.989	0
10	[redacted]	Lognormal	0.036	1.989	0
11	[redacted]	Lognormal	0.036	1.989	0
12	[redacted]	Lognormal	0.036	1.989	0
13	[redacted]	Lognormal	0.036	1.989	0
14	[redacted]	Lognormal	0.036	1.989	0
15	[redacted]	Lognormal	0.036	1.989	0
16	[redacted]	Lognormal	0.036	1.989	0
17	[redacted]	Lognormal	0.036	1.989	0
18	[redacted]	Lognormal	0.036	1.989	0
19	[redacted]	Lognormal	0.036	1.989	0
20	[redacted]	Lognormal	0.036	1.989	0
21	[redacted]	Lognormal	0.028	1.989	0
22	[redacted]	Lognormal	0.022	1.989	0
23	[redacted]	Lognormal	0.017	1.989	0
24	[redacted]	Lognormal	0.014	1.989	0
25	[redacted]	Lognormal	0.011	1.989	0

SECTION II: DR–METHOD B

II-1 DOSE RECONSTRUCTION OVERVIEW

Section II of this report presents the results of SC&A's blind DR for Case #[redacted] using DR– Method B.

For this case associated with work at the Allied Chemical Plant in North Claymont, Delaware, there are neither dosimetry/bioassay records, nor a site profile. There are, however, a number of records in NIOSH's Site Research Database (SRDB) for this facility, along with the CATI Report and information from other sites that, in theory, can serve as useful surrogates to help assign upper bound external and internal doses to this worker.

II.2 RELEVANT BACKGROUND INFORMATION

According to the DOL records, this case represents an EE who worked at the Allied Chemical Plant in North Claymont, Delaware, from [redacted] to the beginning of [redacted]. The EE was diagnosed with lung cancer in [redacted].

It is worth noting that the type and extent of the Atomic Weapons Employers (AWE) activities performed at the Allied Chemical facility in the North Claymont, Delaware, were very different than those performed at the Allied Chemical facility near Metropolis, Illinois. We mention this because the facility near Metropolis has received a great deal of attention by NIOSH; a site profile was prepared for the facility, and SC&A has performed a review of the site profile. In addition, a Special Exposure Cohort (SEC) petition evaluation report was prepared by NIOSH for the Metropolis facility, and the Advisory Board recommended an SEC for the facility. The Allied Chemical facility in North Claymont bears very little resemblance to the Allied Chemical facility near Metropolis and cannot be used as a surrogate for this facility. This is apparent when reviewing the Formerly Utilized Remediation Report prepared by DOE (DOE 1985) for the North Claymont facility. It is also apparent that, due to the lack of a site profile for the North Claymont facility and the lack of any dosimetry or bioassay data for this EE, reconstructing the doses for this worker will likely require the use of surrogate data, if such data can be identified.

Inspection of the CATI and DOL files revealed that this EE was employed by Allied Chemical from [redacted] to [redacted], and that the EE worked as a [redacted] and [redacted]. The CATI also reveals that the EE worked some overtime, and the interviewee had no knowledge regarding whether the EE was assigned dosimetry, was monitored under a bioassay program, was involved in any radiological incidents, or received medical x-ray examinations as a condition of employment. Also, inspection of the records for this claimant as provided by NIOSH for this blind DR reveals that there are no film badge or bioassay data for this EE. In addition, there is no site profile for this facility. As a result, this blind DR is performed using information in the SRDB for this facility, the CATI, and surrogate data, as applicable.

II.3 FACILITY DESCRIPTION AND DR STRATEGY

Because of the lack of a site profile, we reviewed the SRDB and found about 60 citations pertinent to Allied Chemical and Dye Corporation in North Claymont, Delaware. A review of these documents revealed that Allied Chemical and Dye Corporation was formed in December 1920 as a means of ending foreign domination of the chemical industry with respect to the production and manufacturing of a broad range of plastics, industrial and agricultural products, and also chemicals (Monti 2009). *Formerly Utilized Sites Remedial Action Program, Elimination Report for Allied Chemical Corporations, Chemical Company, North Claymont, Delaware* (DOE 1985) explains that:

> *In the early 1950's Allied Chemical was involved in research and development and small pilot scale operations on uranium recovery from a phosphoric acid plant at North Claymont. The work under AEC contracts AT(59-1)-610 and AT(49-6)-913 was performed on a small scale. Former AEC employees estimated that, at most, only a few pounds of uranium concentrate were produced.*
>
> *These operations ceased in the late 1960's and the plant was demolished in the early 1970's.*

According to discussions with former Oak Ridge Division of Raw Materials (DRM) staff, (1) [**Redacted**], (2) [**Redacted**] and (3) [**Redacted**], the contract operations were small and the uranium separated and recovered during the contract period was only a few pounds. It was noted that the North Claymont facility work focused on filtration development and was not apparently successful. As a result of the insignificant amount of uranium recovered during the contract period, further investigation to locate and access the AEC contract work area was not warranted in 1977 and no further assessment of the Allied Chemical site was made (Mott 1977).

None of the documents on the SRDB provided any information or estimate on the amount of phosphate ore that was processed and handled during the AT-(49-1)-610 and AT-(49-6)-913 contracts period in order to obtain the few pounds of uranium. It is also unknown if the phosphate ore processed at Allied Chemical was part of their regular operations or only part of the pilot scale research and development contract with AEC. There was quite a bit of redundancy among the documents on the SRDB; however, ERDA 1976 and Mott 1977 provide the most information.

The implications of the material we were able to review are that (1) the AWE period covers approximately a 15- to 20-year period; (2) during this time, it is likely that phosphate rock was on site and processed, and workers may have been exposed to the naturally occurring radionuclides associated with phosphate rock and its processing; (3) it appears that the North Claymont plant was involved in ongoing production of phosphoric acid during this time; (4) pilot studies were performed to separate uranium from the phosphoric acid, which we presume was produced from phosphate rock; and (5) a few pounds of a yellowcake-type material was actually produced, which also could have resulted in external and internal exposure to uranium oxide, probably yellowcake. This understanding sets the stage for performing a blind DR. However, it also creates a dilemma; it seems inconceivable that a worker could have experienced a protracted

exposure to uranium over a 15- to 20-year time period if the operations were limited to a pilot scale study involving only a few pounds of uranium.

DOE 1985 further concludes that, due to the small quantities of uranium processed at the facility, and the fact that the building was demolished and the rubble removed, any residual contamination would be negligible and no further action was necessary. This conclusion is supported by a letter from W.E. Mott, Director, Division of Environmental Control Technology (Mott 1977).

Our review of the SRDB was unable to uncover any information regarding specific quantities of phosphate ore processed, the amount and type of uranium produced (except that it was only a few pounds), the methods used to separate and purify the uranium from phosphate ore, airborne dust loadings of phosphate ore or uranium, radon levels, radiation fields, or external or internal dosimetry of any type. As best we can tell, it is likely that the activities at the North Claymont facility might have been conceptually similar to the activities that took place at Blockson Chemical Company and TCC, which were both previously evaluated in depth by NIOSH, the Advisory Board, and SC&A. However, the main difference between Blockson and TCC and the North Claymont facility is that Blockson produced relatively large quantities of yellowcake (U_3O_8), about 5,000 pounds per month; TCC produced a total of about 300 pounds of yellowcake; and the Claymont facility produced only a few pounds of yellowcake from phosphate rock.

In light of this information, we decided to begin our blind DR by considering an efficiency approach, in accordance with the provisions of 40 CFR Part 82 (k), which states the following:

> (*k) At any point during steps of dose reconstruction described in paragraphs (f) through (j) of this section, NIOSH may determine that sufficient research and analysis has been conducted to complete the dose reconstruction. Research and analysis will be determined sufficient if one of the following three conditions is met:*
>
> *(1) From acquired experience, it is evident the estimated cumulative dose is sufficient to qualify the claimant for compensation (i.e., the dose produces a probability of causation of 50% or greater);*
>
> *(2) Dose is determined using worst case assumptions related to radiation exposure and intake, to substitute for further research and analyses; or,*
>
> *(3) Research and analysis indicated under steps described in paragraphs (f)–(j) of this section have been completed. Worst-case assumptions will be employed under condition 2 to limit further research and analysis only for claims for which it is evident that further research and analysis will not produce a compensable level of radiation dose (a dose producing a probability of causation of 50% or greater), because using worst-case assumptions it can be determined that the employee could not have incurred a compensable level of radiation dose. For all claims in which worst-case*

> *assumptions are employed under condition 2, the reasoning that resulted in the determination to limit further research and analysis will be clearly described in the draft of the dose reconstruction results reported to the claimant under § 82.25 and in the dose reconstruction results reported to the claimant under § 82.26.*

As a first step in our strategy, DR–Method B considered using surrogate data employing a bounding approach by using the DR protocols adopted for use at the TCC and Blockson facilities. However, given the quantities of uranium involved and the presumed quantities of phosphate rock involved, any dose reconstructed using the information, data, and records at Blockson and TCC would result in a gross overestimate of the exposures that this EE might have experienced at the North Clayton facility. Hence, it is our judgment that these facilities cannot be used as a surrogate for the North Claymont facility to grant compensation, but could be used to deny compensation.

We have taken this position based on the following statement provided in Section J, *Use of Efficiency Methods*, in Section II, *Summary of Public Comments* in the preamble to the rule:

> *Dose estimates sufficiently high to qualify a claimant for compensation definitively cannot be based on worst case assumptions employed as an efficiency measure to abbreviate research and analysis.*

Our strategy also considered the possibility of performing a minimizing analysis, which would assign the lowest plausible dose that this EE might have experienced, and if the POC exceeds 50%, the analysis is complete and a recommendation to compensate this worker can be made. The following sections present how we implemented each strategy and their results.

II.4 INFORMATION USEFUL IN DEVELOPING AND IMPLEMENTING A DR STRATEGY FOR THIS WORKER

Based on the very limited information summarized above, the EE likely experienced exposure to the radionuclides associated with handling and processing of phosphate ore during the AWE period (i.e., from the early 1950s to the late 1960s), including radon, and also some exposure to uranium during the pilot-scale uranium separations studies that produced a few pounds of yellowcake. Clearly, the dilemma is that apparently only a few pounds of uranium were produced, and it is difficult to conceive of a circumstance where such small quantities of uranium could represent a significant chronic source of exposure over approximately a 15- to 20-year time period. However, in many respects, the potential for exposure at the North Claymont facility appears to be similar to that of the TCC facility. Like the North Claymont facility, the Texas City facility processed phosphate rock and produced relatively small quantities of yellowcake, but even these small quantities (i.e., about 300 pounds) are much greater than the quantities of uranium produced at the North Claymont facility (i.e., a few pounds).

A review of the TCC SEC petition evaluation report on the NIOSH website (NIOSH 2010) reveals that an SEC was granted for the TCC facility due to the inability to reconstruct radon

exposures, but other exposures could be reconstructed. Specifically, the SEC petition evaluation report states the following:

> *Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it does not have access to sufficient information to: (1) estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class; or (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. Information available from resources is not sufficient to document or estimate the maximum internal dose to members of the evaluated class under plausible circumstances during the specified period.*
>
> *The NIOSH dose reconstruction feasibility findings for TCC are based on the following:*
>
> *• Principal sources of internal and external radiation dose for members of the proposed class included exposures to technologically enhanced concentrations of naturally-occurring uranium and decay products and naturally-occurring thorium and decay products present in phosphate rock.*
>
> *• NIOSH finds there are insufficient data to estimate dose with sufficient accuracy from workers exposed to radon in the phosphoric acid plant at Texas City Chemicals. NIOSH has found no radon monitoring for the facility neither during the AEC period nor of the plant when it was in operation. Radon data is available from surveys of the site in the 1980s after the phosphate plant was shut down. NIOSH also determined that it lacks needed information to model radon exposures from processing phosphate rock; dose from processing phosphate rock is only applicable to EEOICPA dose reconstructions through September 1955. Although the source term is known, available information on the building size, layout, and process activities are insufficient to model maximum radon exposures with sufficient accuracy.*
>
> *• NIOSH finds that it is feasible to bound occupational external dose from uranium extraction operations at Texas City Chemicals using source term and process information.*
>
> *• NIOSH finds that it is feasible to bound occupational internal dose from uranium extraction operations based on data from uranium ore concentrate processing at other facilities.*
>
> *• NIOSH finds that is feasible to bound occupational external and internal dose, other than radon, for phosphate workers exposed to technologically enhanced naturally occurring radioactive material using data from other phosphate facilities.*

For Method B, SC&A believes that the activities at the TCC facility, including our very limited knowledge of the facility, are in many ways analogous to the North Claymont facility. Accordingly, this first step in this blind DR takes guidance from the TCC SEC petition evaluation report with regard to DR protocols.

As described in Section 4.1 of NIOSH 2010, the DR protocols employed for TCC workers not covered by the SEC take guidance from site profiles from the following facilities and also from the following technical information bulletins and procedures:

Site Profiles

- *Technical Basis Document for Atomic Energy Operations at Blockson Chemical, Joliet, Illinois*; OCAS-TKBS-0002, Rev. 02; November 21, 2007; SRDB Ref ID: 36611.

- *Basis for Development of an Exposure Matrix for Blockson Chemical Company, Joliet, Illinois; Period of Operation: March 1, 1951 through March 31, 1962*, ORAUT-TKBS-0002, Rev. 01; June 29, 2004; SRDB Ref ID: 19480.

- *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium*, Battelle-TBD-6001, Rev. F0; December 13, 2006; SRDB Ref ID: 30673.

- *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium, Appendix BH – International Minerals and Chemical Corporation*, Battelle-TBD-6001, App. BH, Rev. 0; July 16, 2007; SRDB Ref ID: 35365.

Technical Information Bulletins and Procedures

- OCAS-PR-004, *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, Rev. 0, September 23, 2004; SRDB Ref ID 32022.

- OCAS-TIB-009, *Estimation of Ingestion Intakes*, Rev. 0, April 13, 2004; SRDB Ref ID: 22397.

- ORAUT-OTIB-0006, *Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, Rev. 3 PC-1; December 21, 2005; SRDB Ref ID: 20220.

- ORAUT-OTIB-0024, *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*, Rev. 00; April 7, 2005; SRDB Ref ID: 19445.

- ORAUT-OTIB-0043, *Characterization of Occupational Exposure to Radium and Radon Progeny during Recovery of Uranium from Phosphate Materials*, Rev. 00; January 6, 2006; SRDB Ref ID: 22596.

- ORAUT-OTIB-0070, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, Rev. 00, March 10, 2008; SRDB Ref ID 41603.

II.5 RECONSTRUCTION OF INTERNAL DOSES USING A MAXIMIZING APPROACH

Section 7.2 of NIOSH 2010 presents the methods NIOSH has adopted to reconstruct internal doses at TCC. The internal doses include intakes associated with the processing of phosphate rock and also intakes associated with uranium recovery.

II.5.1 Internal Exposures from Phosphates

The primary data used by NIOSH in the assessment of internal doses at TCC was taken from a 1998 report by the Florida Institute of Phosphate Research (FIPR) on dose at Florida phosphate plants that processed phosphate rock from central Florida, and a 1978 U.S. Environmental Protection Agency report of exposure to workers at an Idaho phosphate plant (FIPR 1998; EPA 1978). A detailed discussion of the data is provided in Section 7.2 of NIOSH 2010 and is not repeated here. As explained in NIOSH 2010, the data used to reconstruct the TCC doses likely grossly overestimated the exposures, because the phosphate processing facilities from which the data were taken handled much larger quantities of phosphate rock than did TCC, as is also the case for the North Claymont facility. Some of the key assumptions are as follows:

- To estimate intakes of airborne radioactivity at TCC from phosphate plant operations, the 50.4 mg/m^3 maximum measured dust concentration at the Idaho plant will be used as a bounding maximum average dust concentration.

- A 2,500-hour work-year is assumed. Exposure to 50.4 mg/m^3, at a breathing rate of 1.2 m^3/hr, results in an annual inhalation intake of 151.2 g of dust per year. The annual total dust inhalation intake is multiplied by the 95 pCi/g value for U-238 in Table 5-6 to determine an annual U-238 intake of 1.44 × 10+4 pCi. Conversion of the result into a calendar-day intake results in a 39 pCi/day chronic inhalation of U-238. The other radionuclides identified in the source term in Table 5-6 of NIOSH 2010 were calculated similarly and the inhalation intakes are provided in Table II-1.

Table II-1. Intakes from Operation of the Phosphate Plant

Radionuclides	Inhalation pCi/day	Ingestion pCi/day
U-238, Th-230, U-234, Ra-226, Pb-210, Po-210	39	0.79
Pa-231, Ac-227	1.8	0.036
Th-232, Ra-228, Th-228	1.3	0.026

Excerpted directly from Table 7.3 of the TCC SEC Petition Evaluation Report

II.5.2 Internal Exposures from Uranium Recovery

As explained in Section 7.2.2 of NIOSH 2010, inhalation intakes for workers engaged in uranium recovery work at TCC are estimated based on worker exposure to airborne uranium concentrates at other facilities. During the 10-year period from 1948 through 1958, the Health and Safety Laboratory (HASL) of the AEC conducted 60 complete evaluations of occupational hazards in seven uranium refining plants (AEC 1958). The evaluations consisted of

measurements of more than 20,000 individual dust samples. These data are summarized in a paper published in November 1960 by the American Academy of Occupational Medicine entitled, "The Industrial Hygiene of Uranium Refining" (Christofano 1960). In this paper, data are presented for various uranium refining operations, including ore handling, ore sampling, uranium concentrate sampling, ore digestion, solvent extraction, denitration, oxide reduction, hydrofluorination, drum transfer operations, reduction to metal, recasting, fluorination, and scrap recovery.

Using data from these seven uranium refining plants, Table 7-4 of NIOSH 2010 presents the intake rates associated with uranium recovery operations. Table II-2 is excerpted directly from Table 7-4.

Table II-2. Intake Rates from Operation of the Uranium Recovery Plant

Radionuclides	Uranium Plant Inhalation (pCi/week)
U-238, Th-230, U-234, Pb-210, Po-210	1,027
Pa-231, Ac-227	48.0
Ra-226	48.3
Th-232, Ra-228, Th-228	33.9

*Not included are intakes from the fertilizer plant because we are assuming that, since the Claymont facility was a uranium separations pilot plant, it was not involved in commerce-scale phosphate production.

Selectively excerpted from Table 7.4 of NIOSH 2010

An argument can be made that the intakes in Tables II.1 and II.2 cannot be applied to the North Claymont facility because it does not appear that it was a commercial phosphate production facility and the amounts of uranium produced were extremely small; i.e., these intakes are grossly unrealistic overestimates of the possible intakes at the North Claymont facility. The only possible rationalization that could support the use of the TCC protocols is that the airborne concentrations of the radionuclides at the North Claymont facility might have been comparable to those at larger facilities if the operations were confined to a small area. Under these conditions, it is possible that a small number of workers could have been exposed to comparable airborne radionuclide concentrations that existed in the larger facilities, at least for a relatively short period of time. In addition, since we are performing a bounding analysis, and if the analysis results in a POC less than 50%, the DR is compatible with the provisions of 42 CFR Part 82 as an efficiency method. At some time in the future, if an SEC is granted for this facility, as was done for TCC due to an inability to reconstruct radon exposures, then this worker would be compensated.

An alternative strategy would be to prorate the doses based on the amount of uranium produced at the TCC Plant. Prorating would entail reducing the exposures derived using the protocols adopted in the TCC SEC Petition Evaluation report by about 100 (i.e., 300 pounds versus a few pounds of uranium), and perhaps reducing the duration of exposure from 15 to 20 years to 5 years. Both strategies (prorating and not prorating) were considered in this blind DR, and resulted in POC greater than 50%, which could still be considered a gross overestimate of exposures.

II.5.3 Radon Exposures

Page 85 and Appendix C of FIPR 1998 present a compendium of the radon concentration levels plus progeny associated with the phosphate industry, which were used as surrogate data for reconstructing radon exposures at the TCC facility. The report provides the following conclusions:

> *Radon Levels*
> *Radon measurements made in this study using E-perm electret ion chambers were all well below the EPA 4 pCi/l guideline for residences, except for the rock tunnels. A total of 28 samples were collected as follows: mine area (11), rock (5), phosphoric acid (7), dry products (4), and shipping (1). The results can be found in Appendix C. The tremendous volume of industry-generated data already described was also scrutinized by the project team. The EPA uses an extremely conservative scenario of continuous home occupancy and exposure to derive this limit. Therefore, the application of this standard to far less occupancy time and an adult workforce leads to the conclusion that background exposures are not exceeded and an attributable dose above background does not usually occur.*
>
> *Working Levels*
> *The working level (WL) is a convenient one-parameter measure of the concentration of radon progeny in air that can be employed as a measure of exposure hazard. One WL is defined as any combination of ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po (the short-lived progeny of radon) in one liter of air, under ambient temperature and pressure, that will result in the ultimate emission of 1.3E+5 MeV of alpha particle energy. This is about the total amount of energy released over a long period of time by the short-lived daughters in equilibrium with 100 pCi of radon. Therefore, the conversion from pCi/l to WL, if one assumes equilibrium in the environment, is made by division by 100. However, most environments are not in equilibrium. The EPA assumes 50% equilibrium of daughters and thus the conversion of 4 pCi/l to 0.02 WL.*
>
> *Some radon working levels were measured as support for the e-perm results. The raw results are tabulated in Appendix C. The levels were consistently low. Even in rock tunnels where the radon levels can be high, the working levels were less than 0.95 milliWL. This suggests that the tunnels are ventilated frequently enough so that equilibrium concentrations of radon progeny do not accumulate.*

Based on these data, it is likely that no worker at the TCC facility experienced chronic radon exposures above 4 pCi/L, which translates to about 0.02 WL or about 12 m/yr × 0.02 WL = 0.23 WLM/yr.

DR–Method B used the surrogate data employed at TCC for exposure to phosphate ore dust, separated uranium, and radon, to derive maximizing doses for the North Clayton facility and obtained a POC well in excess of 50% at the 99% confidence level. However, we felt that this

approach was a maximizing approach, and that compensation could not be awarded using such a method, for the reasons described above. As a result, we proceeded to use a minimizing approach to determine if the POC exceeded 50% even when using a minimizing approach.

II.6 DR USING A MINIMIZING APPROACH

The next step in our analysis of this unusual case is to use the minimizing approach, which, if found to result in doses that exceed a POC of 50%, would complete the DR, and compensation could be granted based on the provisions of Part 82 (k) (1).

In light of the above discussion and supporting analysis, Method B elected to derive a minimized dose to the lung and its associated POC by only considering radon exposures at a very low level, i.e., 4 pCi/L, which translates to 0.235 WLM/yr at 50% equilibrium. Based on this analysis, DR–Method B derives a POC of 64.1% at the 99% confidence level.

II.7 CONCLUSIONS

This analysis resulted in an unexpected result. In developing DR–Method B, SC&A made every effort to find surrogate data that might apply to this facility, but had difficulty finding data that might apply. As a result, we elected to apply an efficiency approach, beginning with maximizing approach to determine if a POC of <50% could be derived. However, every effort at deriving a maximizing dose resulted in a POC >50%. Hence, Method B changed strategy and applied a minimizing approach; i.e., assume that the worker was only exposed to radon during the AWE period and at very low levels (i.e., 4 pCi/L). Surprisingly, this analysis also resulted in a POC >50%. Hence our analysis was completed, and it resulted in a conclusion that the worker should be compensated.

II.8 REFERENCES

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