Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

REVIEW OF THE NIOSH SITE PROFILE FOR THE W. R. GRACE AND COMPANY IN ERWIN, TENNESSEE

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REVIEW OF THE NIOSH SITE PROFILE FOR THE W. R. GRACE AND COMPANY IN ERWIN, TENNESSEE	Page 2 of 39
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Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	01/16/2013	Initial issue
	02/14/2013	Privacy Act-cleared, 508 compliance version released. Note: One section of this report containing the authors' interpretation of a section of the *Code of Federal Regulations*, which does not affect the intent of this report, has been deleted in this version in its entirety. A minor format issue was also addressed that does not affect the technical validity of the document.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

Advisory Board	Advisory Board on Radiation and Worker Health
ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AWE	Atomic Weapons Employer
BZ	Breathing zone
CDC	Centers for Disease Control
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissioning
DCAS	Division of Compensation Analysis and Support
DHHS	U.S. Department of Health and Human Services (DHHS)
DOE	U.S. Department of Energy
dpm	disintegrations per minute
DR	Dose Reconstruction or Dose Reconstructor
DU	depleted uranium
DWE	Daily Weighted Exposures
EE	Energy Employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ERDA	Energy Research and Development Agency
HEU	Highly Enriched Uranium
keV	kilo electron volt
L	Liter
LEU	Low Enriched Uranium
LOD	Limit of Detection
m^2	square meter
m^3	cubic meter
MDA	Minimum Detectable Activity
MDL	Minimum Detectable Level
µg	Microgram
MOX	Mixed Oxide
mrem	millirem
mR	milli roentgen

NFS	Nuclear Fuel Services
NIOSH	National Institute for Occupational Safety and Health
n/p	neutron-to-photon dose ratio
NRC	Nuclear Regulatory Commission
NU	natural uranium
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
OTIB	ORAUT Technical Information Bulletin
pCi	picocuries
POC	probability of causation
rem	roentgen equivalent man
RU	recycled uranium
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	Technical Basis Document
TIB	Technical Information Bulletin
V&V	verification and validation
WRG	W. R. Grace and Company

1.0 EXECUTIVE SUMMARY

This report provides the results of a review conducted by S. Cohen and Associates (SC&A) of the site profile for the W. R. Grace and Company (WRG), in Erwin, Tennessee, developed by the National Institute for Occupational Safety and Health (NIOSH). This review was conducted during the period from July 2012–November 2012, in support of the Advisory Board on Radiation and Worker Health (Advisory Board) in the latter's statutory responsibility under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) to conduct such reviews and advise the Secretary of Health and Human Services on the "completeness and adequacy" of the EEOICPA program.

The site profile for the WRG site consists of one document (with 7 sections), ORAUT-TKBS-0043 (ORAUT 2011a). This document will be referred to in this review as the Technical Basis Document (TBD).

In this review, unless specified otherwise, the term "WRG site" will be used to refer to the W. R. Grace and Company's Erwin, Tennessee, site in general, to include the later period when the name was changed in 1964 to Nuclear Fuel Services (NFS). This includes all the facilities, ponds, burial site(s), and grounds located within the approximate 58 acres, with 21 acres located inside the security fence.

The term "Navy" in this report refers to the WRG/NFS program to supply reactor fuel for use by the U.S. Navy.

The WRG site was constructed in 1957 to convert highly enriched uranium (HEU) and low-enriched uranium (LEU) from UF_6 (or to recover uranium from scrap) to a product that met customer requirements. Thorium, depleted uranium (DU), U-233, recycled uranium (RU), and plutonium have also been processed at various times to oxides or metals with subsequent processing into the form necessary for the manufacture of nuclear fuel (ORAUT 2011a). A list of some of the important dates at this facility is provided in Table 1 below.

Table 1. WRG Timeline of Events

1957:	Construction of WRG facilities at Erwin, TN.
1958–1970:	**Operational period.** WRG processed uranium, plutonium, and thorium for the Atomic Energy Commission (AEC) weapons program, AEC research, commercial reactors, and the Navy. Which radioactive materials were involved in which programs is not well defined.
March 1958:	WRG received first material as an AEC licensee.
1958–1978:	Ponds 1, 2, 3, and 4 used for liquid waste disposal.
May 1959:	WRG received first material as an AEC contactor.
1964:	Nuclear Fuel Services (NFS) formed from merger of WRG and American Machine and Foundry Company.
October 1964:	Uranium bioassays began.
1965–1970:	Southwest Trench used for disposal of solid radioactive waste.
1966:	Plutonium processing began.
1966–1977	Low-level waste disposed in north burial grounds.
1971–Present:	**Residual period.** Processing of materials continued for commercial and Navy purposes. No material received for weapons. Decontamination and decommissioning (D&D) of some buildings. Cleanup of ponds and burial sites.

Table 1. WRG Timeline of Events

1975:	AEC split into NRC and Energy Research and Development Agency (ERDA).
1977:	Department of Energy (DOE) replaced ERDA.
1990–present	Plutonium building (#234) D&D. Called the "PU" building.
1997–2010:	NFS removed waste material from Ponds 1, 2, 3, and 4 and soil decontaminated.
1997–2010:	NFS excavated waste and soil from north burial grounds and soil decontaminated.
1999–2000:	Excavation of Southwest Trench.

The WRG facility essentially had three major phases of operations:

(1) AEC weapons/research and commercial/Navy operational period, 1958–1970.
(2) AEC/DOE non-weapons, commercial/Navy operational period, 1971–present.
(3) Cleanup of ponds, burial sites, and some buildings, 1991–present.

A brief outline of these three major periods at WRG follows.

(1) AEC weapons/research and commercial/Navy operational period, 1958–1970: During this era, activities included receiving, processing, and shipping uranium, plutonium, and thorium for use in weapons and reactor fuel elements. Additionally, recovery processes were conducted to extract uranium from scrap materials. Some unwanted materials were discharged or buried in the onsite ponds and burial grounds.

To date, documentation has not been located that provides a clear description of what radioactive materials were used only for AEC weapons or research activities, and what was used only for commercial and/or Navy purposes. In the TBD, it is assumed that uranium, thorium, and some plutonium were used during the operational period (1958–1970), and only residual uranium contamination has the potential to cause exposure during the residual period (1971–present). It appears that thorium was not actually used in AEC-related work, although there were indications that it was contemplated according to the following communication of June 2006 (NFS 2006), in which it is stated that:

> *The thorium **orders** at NFS (W.R. Grace from 1957–1964) were related to USAEC weapons program work (Th metal powder/pellets for Union Carbide Nuclear Corp., for example)…* [Emphasis added.]

However, it appears that the orders were not carried through, according to the following later information (Leiton 2011):

> *None of the evidence suggests that W.R. Grace's work with thorium was part of their AWE efforts.*

However, there is no supporting documentation that indicates that **plutonium** was not involved in the AEC weapons work at WRG during the operational period; this will be outlined further in Section 3 of this report as a finding.

(2) AEC/DOE non-weapons and commercial/Navy operational period 1971–present: During this era, activities included receiving, processing, and shipping uranium, plutonium, and

thorium for use in reactor fuel elements. Additionally, recovery processes were conducted to extract uranium from scrap materials. The TBD lists the residual period as 1971–2009; however, the exposure to residual radioactive materials extends up through the present time.

(3) Cleanup of ponds, burial sites, and some buildings, 1991–present: During this era, the ponds, burial sites, and some buildings were decommissioned (or are presently being decommissioned) and the radioactive material removed, processed/concentrated, packaged, and shipped offsite for disposal.

SC&A's Evaluation

A list of some of the important dates concerning the TBD and related issues is provided in Table 2 below.

Table 2. Timeline of TBD and Related Events

7/21/2005:	Worker Outreach meeting held.
2006:	ORAUT-TKBS-0043, Rev. 00 issued. Residual period section reserved.
2007:	WRG SEC-00082 based on lack of thorium bioassay data for 1958–1970 approved.
2008:	ORAUT-TKBS-0043, Rev. 01 issued. Residual external and internal doses based on all radioactive materials used during 1958–1970.
4/06/2011:	Worker Outreach meeting held.
2011:	ORAUT-TKBS-0043, Rev. 02 issued. Residual external and internal doses based on 1961 uranium in air measurements only, except for burial ground workers.

SC&A reviewed the WRG site TBD for the following attributes, in accordance with *Site Profile Review Procedures* (SC&A 2004):

- Completeness of Data Sources
- Technical Accuracy
- Adequacy of Data
- Consistency Among Site Profiles
- Regulatory Compliance

In preparation for this report, SC&A reviewed the WRG site TBD in detail, along with many WRG site-related documents located in the Site Research Data Base (SRDB) on the Center for Disease Control (CDC) server. SC&A also conducted an onsite visit and interviews with current and former WRG site workers in October 2012. From these reviews, SC&A developed a number of issues regarding the WRG site profile. These issues were identified, consolidated, and grouped into findings. Findings that have the potential to significantly impact the results of at least some dose reconstructions (DRs) are listed as **Primary Findings**, and those that are important, but may have less impact on the results of DRs, are listed as **Secondary Findings**. Additionally, items in the TBD that could potentially lead to incorrect dose assignments, because of errors, lack of clarity, inconsistencies, omissions, etc., are listed as text items that need to be addressed in Section 1.3 of this report.

In this section, a brief summary of the issues are presented, followed by a summary of the primary findings. (Primary Findings, along with Secondary Findings, are further detailed in

Section 3 of this report). SC&A then provides a discussion of the strengths of the TBD, followed by recommendations for improvement at the end of this section, and a list of text items that need to be addressed by NIOSH.

Summary of Issues

SC&A found that there was some documentation available describing the plant's operations and cleanup activities. External dose and bioassay records are available for most workers; however, the accuracy and completeness of these records has not been addressed in detail at this point by SC&A, NIOSH, or DOE. The TBD for the WRG site incorporated some of this material and makes recommendations for its use in performing DRs. However, SC&A has identified some shortcomings in the TBD that may lead to dose assignments during DR that are not necessarily adequate and/or accurate and employ some questionable assumptions. These concerns are summarized below, with detailed discussions provided in Section 3 of this report.

1.1 SUMMARY OF PRIMARY FINDINGS

Finding 1: Accuracy and completeness of bioassay records not addressed

The accuracy and completeness of the recorded bioassay data have not previously been addressed by either DOE or NIOSH as part of a routine "verification and validation" (V&V) database review. SC&A performed a preliminary scan of the WRG DOE files for a small sampling of claimants and did not identify any outstanding issues. However, a broader and more detailed survey should be conducted that would determine if workers who should have been monitored because of job title (i.e., chemical operator, production-line operator, etc.) and/or location (i.e., production buildings, waste facilities, burial grounds, etc.) have recorded bioassay data for the corresponding periods when working in these areas.

Finding 2: Insufficient uranium bioassay/intake data

If a worker's uranium bioassay data are not available, the TBD recommends on page 25 that the intake values in Table 3-15 be used to assign unmonitored dose during the operational period 1958–1970. There has been no documentation or substantiation of the appropriateness of using a 1961 air concentration data point for operating conditions at WRG during the entire operational period. Additional investigation of the use of the 1961 data for 1958–1970 is needed.

Finding 3: Use of operational-period plutonium results but not residual-period plutonium results, and not estimating non-bioassayed workers' plutonium doses during either period, are not consistent with the Special Exposure Cohort (SEC)

The SEC was **not** based on lack of plutonium data, and it has not been documented that plutonium was not AEC weapons-related (and indications are that it could have been, in any case). Therefore, plutonium DR during the **operational period** should be included in the DR protocol, as it was for uranium, with provisions (such as using a coworker model) to bridge gaps in bioassays, or to compensate for lack of bioassays.

Additionally, not assigning plutonium dose during the **residual period** assumes that all legacy plutonium from the operational period is still undisturbed in storage, burial grounds, ponds, buildings, duct work, etc., and creates no significant exposure hazard. However, this is not the situation during the residual period. Therefore, it appears that to substantiate that plutonium processed at WRG was **not** used in the AEC weapons program (and hence not to be included in the residual period as recommended in the TBD), NIOSH would need to locate government documents outside of the WRG/NFS company that would verify the origin, destination, and ultimate use of the plutonium material processed at the WRG facility during the operational period.

Finding 4: Lack of neutron dose assignment

SC&A did not locate any recorded neutron doses in the claimants' files reviewed to date. The TBD concludes (page 28) that there were potential neutron exposures, but "No attempt should be made to estimate neutron dose for workers not monitored for neutrons during the operational period." Site profiles for other uranium- and plutonium-handling facilities incorporate neutron doses in the DR process, usually using the neutron-to-photon ratio (n/p) method, for workers potentially exposed to neutrons. Further investigation of the potential neutron exposures and methods to assign appropriate neutron doses is needed for the WRG facility.

Finding 5: Lack of dosimetry calibration knowledge

Because of the lack of information indicating otherwise, it appears that the dosimeters for WGR workers were read and recorded by outside vendors, with WRG depending on the processing companies to provide the correct correlation between the various radiation fields at WRG and the vendor's calibration. It needs to be determined if any field measurements of the radiation energy spectra were made, and what calibration source(s) were used by the vendors. Dosimeters calibrated using higher-energy sources, such as Co-60, may not have correctly responded to the lower-energy photons from the various radionuclides present at WRG. Therefore, a correction factor may be needed, especially for determining the dose to skin and shallow organs.

Finding 6: Onsite medical x-ray exams not substantiated

It has not been substantiated that x-ray exams were performed onsite at the WRG facility during the AEC operational period of 1958–1970. Therefore, assigning offsite x-ray exams may not be consistent with ORAUT-OTIB-0079 (ORAUT 2011d) if the exams were performed offsite. While the TBD recommendations are claimant favorable, to ensure consistency with other site profiles, this is an area that needs further verification.

Finding 7: The 2011 TBD does not adequately cover environmental doses

The methods for estimating dose in the TBD do not account for airborne radioactive materials that were generated by the cleanup and processing of waste from the ponds and burial grounds during the residual period to which monitored, as well as unmonitored, non-burial ground workers may have been exposed. These non-burial grounds workers may still have been

exposed to environmental radioactive materials from the cleanup operations during the residual period.

The internal and external environmental exposures throughout the site during both the AEC period (1958–1970) and from the cleanup of the AEC legacy materials during the period 1971–present are not adequately addressed.

1.2 SUMMARY OF STRENGTHS

The WRG site TBD was written in one volume, containing seven sections, which assist the reader in accessing and analyzing the information in an orderly fashion. The TBD addressed the different time periods (operations, residual, and cleanup) relevant to the WRG site in a consistent manner. Section 2 of the TBD provided a description of the site's history from its origin in 1958 to its present-day status. The uranium intake methodology used in Section 5 was well done and followed proper protocol using appropriate methods, as recommended in TBD-6000 (NIOSH 2008).

References were well documented and editorial errors were kept to a minimum. (See Section 1.3, "Opportunities for Improvement," for text items that need to be addressed concerning some of the errors that were located during this review.) The information presented was fairly consistent across the different sections of the TBD. The current TBD is useful in the DR process, but needs to be revised to address the concerns described in the following section and the findings in Section 3 of this report.

1.3 OPPORTUNITIES FOR IMPROVEMENT

There are numerous opportunities for the TBD to be further developed, so that it would be more useful and accurate in DR by building on the basic information provided in the current version. Most of the major issues are identified in the findings described in Section 3 of this report. Additionally, SC&A has identified some areas where changes in the TBD would be beneficial to the claimant by preventing possible mistakes during DR or clarifying items to make them less ambiguous. The text items that need to be addressed by NIOSH are as follows:

Item 1 – Incomplete text
In the first paragraph on page 27 of the TBD, "1970" needs to be inserted:

> *As such, before* [1970]*, the total shallow dose is best estimated by summing the reported skin (i.e., non-penetrating dose) and whole-body (i.e., penetrating dose component) doses.*

Item 2 – Incorrect footnote notation
The last footnote for Table 4-2 on page 29 of the TBD should be labeled as **c**, not **b**:

> *c. MDL information communicated by Landauer.*

Item 3 – Incomplete reference
Although the minimum detectable level (MDL) values listed in Table 4-2 on page 29 of the TBD are consistent with other DOE sites, a check of the reference (Tester 2005) in the footnote (b) indicates that the person in the reference only states a **reporting level** of 10 mR, 1 mrem, and 10 mrem, not an **MDL of 40 mrem**, as indicated by the TBD.

Item 4 – Incorrect section number
The last row in Column 6 of Table 4-3 on page 31 of the TBD should read "See Section **4.6**," not "See Section **4.4.5**."

Item 5 – Missing reference
The last sentence of the next-to-the-last paragraph on page 31 of the TBD references **(EPA 1993a)**; however, this reference is not listed in the references on page 39 of the TBD.

Item 6 – Incorrect units in equation on page 32
The equation on page 32 of the TBD reads:

air concentration ***pCi/m^3*** *× 31,536,000 s/yr × 0.00075 m/s = surface activity dpm/m^2 (Eq.1)*

when it should read:

air concentration ***dpm/m^3*** *× 31,536,000 s/yr × 0.00075 m/s = surface activity dpm/m^2 (Eq.1)*

Item 7 – Missing text on page 35
The end of the first sentence in the next to the last paragraph on page 35 of the TBD needs the word "electrons" added to it as follows:

> *The external doses are from penetrating photons with energies between 30 keV and 250 keV and* ***electrons*** *>15 keV…*

2.0 SCOPE AND INTRODUCTION

The review of the WRG site profile was conducted during the period July 2012–November 2012 by an SC&A senior health physicist. WRG, located near Erwin, Tennessee, was considered a "job shop" and as such, received, processed, and shipped material without many details concerning its origin, properties, and end use; therefore, most work was not classified.

SC&A understands that site profiles are living documents, which are revised, refined, and supplemented with NIOSH technical information bulletins (TIBs) as required to help dose reconstructors. Site profiles are not intended to be prescriptive or necessarily complete in terms of addressing every possible issue that may be relevant to a given DR. However, future revisions of the WRG site TBD would serve to mitigate some of the gaps and issues raised in this report.

It is noteworthy that the WRG facility was granted an SEC for January 1, 1958, through December 31, 1970. Section 1.3 of the TBD defines the SEC as follows:

> *NIOSH has determined, and the Secretary of the U.S. Department of Health and Human Services (DHHS) has concurred, that it is not feasible to reconstruct internal radiation dose for (Leavitt 2007):*
>
> > *Atomic Weapons Employer (AWE) employees who were monitored or should have been monitored for potential exposure to thorium while working in any of the 100 series buildings or Buildings 220, 230, 233, 234, 301, or 310 at the W. R. Grace site at Erwin, Tennessee, for a number of work days aggregating at least 250 work days from January 1, 1958, through December 31, 1970, or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort.*
>
> *Therefore, only internal dose from uranium and plutonium is considered in Section 3.0 of this site profile. Because of the identified dose reconstruction infeasibility, all dose reconstructions for all workers having employment during the SEC class period are considered partial dose reconstructions. If monitoring data are available for workers included in the SEC class, this data may be used to refine the dose reconstruction; however, such dose reconstructions are still considered partial dose reconstruction*

SC&A's understanding of the current NIOSH policy is that, although thorium intakes during the operational period (1958–1970) were not AEC weapons work-related, thorium must be taken into consideration; and therefore, the SEC is applicable. However, during the residual period (1971–present), thorium intakes are not required to be included in DR, because it was not AEC weapons-related material.

Given the SEC, this review focuses on those portions of the site profile where the TBD claims it can reconstruct doses, namely internal and external exposures to uranium and plutonium during the operations and residual periods. In addition, as will be discussed, the TBD appears to

indicate that external exposures could also be reconstructed during the operational and residual period; however, the definition of the SEC is silent regarding this matter.

2.1 REVIEW SCOPE

Under the EEOICPA, the Advisory Board is mandated to conduct an independent review of the methods and procedures used by NIOSH and its contractors for DR. As a contractor to the Advisory Board, SC&A has been charged to support this effort by independently evaluating a select number of site profiles that correspond to specific facilities at which energy employees worked and were exposed to ionizing radiation.

This report provides a review of the site profile document, ORAUT-TKBS-0043 (ORAUT 2011a), for the WRG site in Erwin, Tennessee. To date, this document has not been supplemented by site-specific TIBs, but there are several generic TIBs that provide additional guidance to the dose reconstructor.

Implementation guidance is also provided by so-called "workbooks," which have been developed by NIOSH for selected sites to provide more definitive direction to the dose reconstructors on how to interpret and apply the TBD, as well as other available information. To date, no WRG site-specific workbooks have been developed.

SC&A, in support of the Advisory Board, has critically evaluated the WRG site TBD for the following:

- Determine the completeness of the information gathered by NIOSH in behalf of the site profile, with a view to assessing its adequacy and accuracy in supporting individual DRs
- Assess the technical merit of the data/information
- Samples of some of the internal and external data in the claimant files that will be used for DR purposes

SC&A's review of this site profile document focuses on the quality and completeness of the data that characterized the facility and its operations, and the use of these data in DR. The review was conducted in accordance with *Site Profile Review Procedures* (SC&A 2004), which was approved by the Advisory Board.

The review is directed at "sampling" the site profile analyses and data for validation purposes. The review does not provide a rigorous quality control process, whereby actual analyses and calculations are duplicated or verified. The scope and depth of the review are focused on aspects or parameters of the site profile that would be particularly influential in deriving DRs, bridging uncertainties, or correcting technical inaccuracies.

The WRG site TBD serves as a site-specific guidance document used in support of DRs. These site profiles provide the health physicist who conducts DRs on behalf of NIOSH with consistent general information and specifications to support their individual DRs. This report was prepared by SC&A to provide the Advisory Board with an evaluation of whether and how the TBD can

support DR decisions. The criteria for evaluation include whether the TBD provides a basis for scientifically supportable DR in a manner that is adequate, complete, efficient, and claimant favorable. Specifically, this review was conducted using the criterion of whether DRs based on the TBD would provide for robust compensation decisions.

The basic principle of DR is to characterize the radiation environments to which workers were exposed, and determine the level of exposure the worker received in that environment through time. The hierarchy of data used for developing DR methodologies is dosimeter readings and bioassay data, coworker data and workplace monitoring data, and process description information or source term data.

2.2 ASSESSMENT CRITERIA AND METHODS

SC&A is charged with evaluating the approach set forth in the site profiles that is used in the individual DR process. These documents are reviewed for their completeness, technical accuracy, adequacy of data, consistency with other site profiles, and compliance with the stated objectives, as defined in SC&A's *Site Profile Review Procedures* (SC&A 2004). This review is specific to the WRG site profile and supporting TIBs; however, items identified in this report may be applied to other facilities, especially facilities with similar source terms and exposure conditions. The review identifies a number of issues and discusses the degree to which the site profile fulfills the review objectives delineated in SC&A's *Site Profile Review Procedures*.

2.2.1 Objective 1: Completeness of Data Sources

SC&A reviewed the site profile with respect to Objective 1, which requires SC&A to identify principal sources of data and information that are applicable to the development of the site profile. The two elements examined under this objective are (1) determining if the site profile made use of available data considered relevant and significant to DR, and (2) investigating whether other relevant/significant sources are available, but were not used in the development of the site profile.

2.2.2 Objective 2: Technical Accuracy

Objective 2 requires SC&A to perform a critical assessment of the methods used in the site profile to develop technically defensible guidance or instructions, including evaluating field characterization data, source term data, technical reports, standards and guidance documents, and literature related to processes that occurred at the WRG site. The goal of this objective is to analyze the data according to sound scientific principles, and then evaluate this information in the context of DR.

2.2.3 Objective 3: Adequacy of Data

Objective 3 requires SC&A to determine whether the data and guidance presented in the site profile are sufficiently detailed and complete to conduct DR, and whether a defensible approach has been developed in the absence of data. In addition, this objective requires SC&A to assess the credibility of the data used for DR. The adequacy of the data identifies gaps in the facility data that may influence the outcome of the DR process. For example, if a site did not monitor all

workers exposed to neutrons who should have been monitored, this would be considered a gap, and therefore an inadequacy in the data. An important consideration in this aspect of our review of the site profile is the scientific validity and claimant favorability of the data, methods, and assumptions employed in the TBD to fill in data gaps.

2.2.4 Objective 4: Consistency among Site Profiles

Objective 4 requires SC&A to identify common elements within site profiles completed or reviewed to date, as appropriate. In order to accomplish this objective, the WRG site TBD was compared to other TBDs previously reviewed. This assessment was conducted to identify areas of inconsistencies, and determine the potential significance of any inconsistencies with regard to the DR process.

2.2.5 Objective 5: Regulatory Compliance

Objective 5 requires SC&A to evaluate the degree to which the site profile complies with stated policy and directives contained in 42 CFR Part 82. In addition, SC&A evaluated the TBD for adherence to general quality assurance policies and procedures utilized for the performance of DRs.

2.3 DOSE RECONSTRUCTION UNDER EEOICPA

SC&A's draft report and preliminary findings will undergo a multi-step resolution process. Prior to and during the resolution process, the draft report is reviewed by the DOE Office of Health, Safety, and Security to confirm that no classified documents or information have been incorporated into the report. Resolution includes a transparent review and discussion of draft findings with members of the Advisory Board Working Group, petitioners, claimants, and interested members of the public. This resolution process is intended to ensure that each finding is evaluated on its technical basis in a fair and impartial basis. A final report will then be issued to the Advisory Board for deliberation and a final recommendation.

All review comments apply to Rev. 02 of the WRG site TBD, which is the most recently published version (ORAUT 2011a), unless otherwise stated.

In October 2012, site expert interviews were conducted with current and former WRG site workers to help SC&A obtain a comprehensive understanding of the radiation protection program, site operations, and historic exposure experience. The interviewees included a good cross-section of current and former WRG site workers, including production, maintenance, safety, office, and radiological safety personnel that worked at the WRG/NFS site at some point during the operational and/or the residual period. The interviews were conducted at the NFS training center in Erwin, Tennessee, and the United Steelworkers of America Local 5-3677 union hall in Erwin, Tennessee. Each interview session was summarized by SC&A, and then reviewed by the interviewee before including the summary in an amendment to this report; the amendment will be issued later to prevent delaying the release of this evaluation report in a timely manner. Documents pertinent to the WRG site and its operations were reviewed at the NFS in Erwin, Tennessee, prior to release.

Because of the singularity of purpose, limited operating period, and relatively small size of the WRG site (as opposed to other DOE sites or national laboratories), SC&A did not submit a list of questions to NIOSH as part of its evaluation of the WRG site TBD. SC&A believed that the resources and time that would have been involved in submitting questions and obtaining responses could be more effectively spent in performing document research, site interviews, and other tasks for this site profile review.

2.4 REPORT ORGANIZATION

In accordance with directions provided by the Advisory Board and with *Site Profile Review Procedures* (SC&A 2004) prepared by SC&A and approved by the Advisory Board, this report is organized into the following sections:

(1) Executive Summary
(2) Scope and Introduction
(3) Vertical Issues
(4) Overall Adequacy of the Site Profile as a Basis for Dose Reconstruction

3.0 VERTICAL ISSUES

SC&A developed the issues for the WRG site profile document using the five objectives defined in SC&A's review procedures (SC&A 2004). The issues were identified, consolidated, and grouped into findings. Findings that could substantially impact the results of DR for some workers are listed as Primary Findings, and those that are important, but may have less impact on the results of DR, are listed as Secondary Findings. SC&A has also identified some areas where changes in the TBD would be beneficial to the claimant by preventing possible mistakes during DR, or where clarification of items would make them less ambiguous; these were listed as text items that need to be addressed in Section 1 of this report.

3.1 FINDINGS

3.1.1 Occupational Internal Dose, Section 3 of ORAUT-TKBS-0043

Background and Introduction

Section 3 for internal dose, pages 16–26, was written to provide the dose reconstructor with recommendations concerning internal DR at the WRG site during the period of AEC/ commercial/Navy operations (1958–1970), and also during the AEC/DOE residual period and commercial/Navy operations (1971–present). This section provides some information concerning:

- Internal exposure from uranium, RU, plutonium, and thorium
- 1959 and 1961 uranium air measurements
- Uranium and plutonium bioassay urinalyses
- Internal DR assumptions

In addition to the operational period (1958–1970) covered by Section 3, Section 5 (pages 31–34) covers internal dose during the residual period of 1971–present. The following is a brief outline of the contents of Section 3 and Section 5 for internal dose:

Section 3 Internal – AEC Operational Period 1958–1970

1. **Internal Exposure Potential** –
   - 1958–1970: During the AEC operational period, the main source of internal exposure was from uranium, RU, thorium, and plutonium (starting in 1966) dust.
   - There was DU, NU, uranium enriched from 3.5% (LEU) to 93% (HEU) in U-235; there were also U-232 and U-233 present. Recycled uranium potentially contained Tc-99, Np-237, Th-232, Ru-106, and Pu-238. These are summarized in Table 3-1, page 17 of the TBD. Table 3-2 on page 17 of the TBD lists the uranium types and activity fractions. Table 3-3 on page 18 of the TBD lists the Shippingport U-233 activity fractions.

2. **Uranium Air Samples** –

   - AEC 1959: Air samples were taken during the recovery of 93% HEU from scrap. The average daily weighted exposures (DWE) in dpm/m^3 for different operators/operations/areas are listed in Tables 3-4, 3-5, and 3-6 on pages 18–19; additionally, the geometric means and other statistics are provided in each table.
   - AEC 1961: Air samples were taken during the recovery of 3.6% LEU from scrap. The average DWE in dpm/m^3 for different operators/operations/areas are listed in Tables 3-7, 3-8, and 3-9 on pages 19–20; additionally, the geometric means and other statistics are provided in each table.
   - The maximum DWE of **578.38 dpm/m^3** [at the 95% confidence level from Table 3-8 for the 1961 breathing zone (BZ) samples] was used by NIOSH in the remainder of this TBD to derive potential intakes and exposures.
   - These air samples were analyzed by determining the total alpha activity; therefore, knowledge of the uranium enrichment is not necessary to assign intake and doses, using the default radionuclide of U-234 to be claimant favorable.
   - Table 3-10 on page 22 lists the derived annual uranium **inhaled** intakes using the DWE of 578.38 dpm/m^3, **2,000 hours/year**, and a breathing rate of 1.2 m^3/hr.
   - Table 3-11 on page 22 lists the derived annual uranium **ingested** intakes using the DWE of 578.38 dpm/m^3, **2,000 hours/year**, and a factor of 0.2 (as recommended in OCAS-TIB-009 (NIOSH 2004).

3. **Recycled Uranium** –

   - Table 3-12 on page 23 provides a list of the radioactive contaminants associated with RU at WRG.

4. **Uranium Bioassays** –

   - Urinalysis for uranium began in October 1964.
   - A uranium minimum detectable activity (MDA) of 2 dpm/L or 10 dpm/L should be used.
   - Uranium lung counts began in 1970. An MDA value of 120 µg should be used. Table 3-13 on page 23 provides chest count conversions for uranium.

5. **Plutonium Exposures** –

   - Plutonium may have arrived in 1966.
   - Plutonium could have been reactor, fuel, or weapons grade. NIOSH selected 12% fuel-grade Hanford plutonium to be used in the DR process; Table 3-14 on page 24 lists the activity of this plutonium.

6. **Plutonium Bioassay** –

   - Plutonium urinalysis was performed for Pu-239 during the time period 1967–February 1973.
   - The TBD states on page 24:

     *The bioassay data should be used for assessing a worker's plutonium dose. **No attempt** should be made to estimate plutonium dose for **unmonitored workers** during the operational period.* [Emphasis added.]

   - A plutonium MDA of 0.06 dpm/L should be used.
   - Pu-239 chest counts started at WRG around 1987. The MDAs for this system were large; therefore, urinalysis results should be used if possible.

7. **Uranium-233** –

   - U-233/Th-232/Th-228 was used in the production of the Mixed Oxide (MOX) fuel.

8. **Internal DR Assumptions** –

   - According to the WRG SEC, it is infeasible to reconstruct internal **thorium** dose adequately during the AEC operational period January 1, 1958, through December 31, 1970; dose estimates for this period are considered partial dose estimates (NIOSH 2007), as stated in the TBD.
   - Use uranium, thorium, and plutonium bioassays if available. If uranium bioassays are not available, use the intakes derived in Table 3-15. If thorium bioassays results are or are not available, it will be considered a partial DR because of the SEC. If an individual was not monitored for plutonium exposures through bioassay, **no attempt** should be made to estimate plutonium dose during the operational period, and the DR is to be considered a partial internal assessment.
   - Table 3-15 on page 26 lists the uranium exposure summary for the AEC operational period of 1958–1970. This includes inhaled and ingested uranium and RU components. Table 3-15 is based on the information in Tables 3-10 and 3-11, and **365 day/year** intake.

Section 5 Internal – Residual Period 1971–2009

1. **Remediation –**

   - Ponds 1, 2, 3, and 4, and the burial grounds were remediated during the time period of 1991–2009.

2. **Assignment of Internal Intakes – Non-Burial Grounds Workers**

   - According to page 32, the TBD recommends:

     During the residual radioactivity period at W.R. Grace (1971 through October 2009), personnel might have been internally exposed to uranium in the workplace. Internal monitoring data could exist for plutonium or thorium

during the residual period; however, ***only operations involving uranium*** *were part of the nuclear weapons-related program.* [Emphasis added.]

- If the uranium bioassay data are available, it may be used, but must be adjusted downward by the source term depletion rate of 0.00067/day, as listed in Table 5-1 on page 32 (this is according to SC&A's present understanding of the recommendations of the TBD on page 32).
- If uranium bioassay data are not available, the intakes from **inhaled** uranium and RU are obtained from Table 5-2 on page 33. This table is based on the 1961 DWE data. Additionally, intakes from **ingested** uranium and RU are listed in Table 5-3 on page 34; this table is based on the 1961 DWE data and OCAS-TIB-009, *Estimation of Ingestion Intakes* (NIOSH 2004).

3. **Assignment of Internal Intakes – Burial-Grounds Workers**

   According to page 34 of the TBD, remediation activities at the burial grounds should be assessed based on individual bioassay records. It is not stated if this is to include plutonium bioassays along with uranium (however, it is stated on page 32 that only uranium is to be considered in assigning dose from AEC activities); what areas the term "burial grounds" includes, or how burial grounds workers are to be identified.

   SC&A reviewed Sections 3 and 5 of the TBD in accordance with the guidance provided in *Site Profile Review Procedures* (SC&A 2004) and has the following findings.

3.1.1.1 Internal Dose Primary Findings

Finding 1: Accuracy and completeness of bioassay records not addressed

The accuracy and completeness of the recorded bioassay data have not previously been addressed. SC&A performed a preliminary scan of the WRG DOE files for several of the claimants and found some recorded bioassay data for uranium in urine (in units of dpm/L) starting in 1964, plutonium in urine (in units of dpm/L) starting in 1968, and in-vivo chest counts for U-235 (in units of microgram U) starting in 1974. There may have been early start dates for these bioassays, but these are the earliest listed in the claims scanned to date by SC&A; the recorded bioassays located appeared legible.

SC&A performed a preliminary scan of 25 WRG claims for energy employees (EEs) that worked at WRG sometime during the period 1957–1970, and had job titles that would indicate the potential need for bioassays (such as operator, chemical operator, production, etc.). A qualitative review indicated that bioassays were not performed before 1964 (which concurs with the evaluation given in the TBD), and that a relatively small fraction of the workers were bioassayed, mostly for uranium by urinalyses. SC&A found that, on the average, approximately 17% of the 25 workers were bioassayed each year for the total time period of 1957–1970, and 37% were bioassayed during the time period 1964–1970 (a partial year of employment was counted as a year worked in this qualitative analysis). These results are summarized in Figure 1 below.

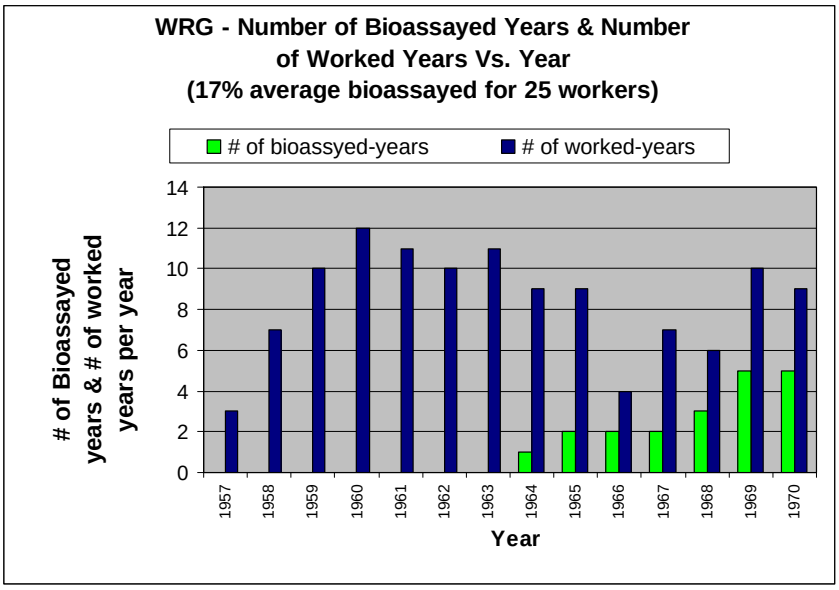


Figure 1. Number of Uranium Bioassayed Years and Number of Years Worked vs. Year

A more detailed survey may need to be conducted that would determine if workers who should have been monitored because of job title (i.e., chemical operator, production line operator, etc.) and/or location (i.e., production buildings, waste facilities, burial grounds, etc.) have recorded bioassay data for the corresponding periods when working in these areas.

Scanning the same claimant files for plutonium bioassays indicates that they were not evident until after the operational period ended (1970).

Given the fact that the bioassay data appear to be incomplete for both uranium and plutonium during the operational period, coworker models are needed. This issue is examined in more detail in the following two findings.

Finding 2: Insufficient uranium bioassay/intake data

In reviewing the claimant files, SC&A concurs with NIOSH that it appears uranium urinalyses did not start until late in 1964 at WRG (page 22 of the TBD). If a worker's uranium bioassay data are not available, the TBD recommends on page 25 that the intake values in Table 3-15 be used to assign unmonitored dose during the period 1958–1970. The intake values in Table 3-15 are based on values listed in Tables 3-8, 3-10, and 3-11, which basically were derived from the 578 dpm/m^3 maximum measured DWE value in 1961. The use of this one data point would mostly impact the 1958–1964 time period when no uranium bioassays were obtained. There has been no documentation or substantiation of the appropriateness of using a 1961 air concentration data point for operating conditions at WRG prior to 1961, nor after 1961. Operating conditions and health regulations may not have remained relatively constant during the entire 1958–1970 period, and the 1961 measurement may not have been representative of this entire operational period.

Additional investigation of the use of the 1961 data for 1958–1970 is needed.

Finding 3: Use of operational-period plutonium results, but not residual-period plutonium results, and not estimating non-bioassayed workers' plutonium doses during either period is not consistent with SEC

Operational Period (1958–1970)
The lack of plutonium data was not stated as a part of the basis for the SEC (only the lack of thorium data, according to NIOSH 2007). The TBD, page 25, recommends using plutonium bioassay results if available for DR purposes during the operational period; an excerpt from page 25 of the TBD is as follows:

> *Uranium and plutonium (and associated radionuclides) intakes during the operational period (1958–1970) should be based on actual bioassay monitoring results for the individual.*

Additionally, page 11 of NIOSH's SEC Evaluation Report for WRG (NIOSH 2007) states:

> *Plutonium operations at W. R. Grace began in 1966. All AEC weapons-related work (including work with plutonium) ended in 1970.*

This statement indicates that AEC weapons work at WRG included plutonium. However, on page 25 of the TBD, it is also stated:

> *In addition, if an individual was not monitored for plutonium exposures through bioassay,* ***no attempt should be made to estimate plutonium dose during the operational period****, and the dose reconstruction is to be considered a partial internal assessment.* [Emphasis added.]

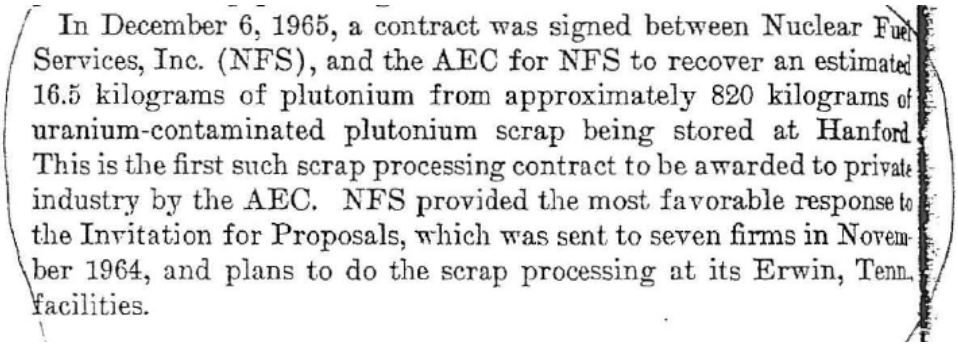
As previously stated, the SEC was **not** based on lack of plutonium data, and it has not been documented that plutonium was not AEC weapons-related (and indications are that it could have been); therefore, plutonium DR during the operational period should be included in the DR protocol (as it was for uranium) with provisions (such as using a coworker model) to bridge gaps in bioassays, or to compensate for lack of bioassays.

Residual Period (1971–present)
On page 32 of the TBD, it is stated:

> *During the residual radioactivity period at W.R. Grace (1971 through October 2009), personnel might have been internally exposed to uranium in the workplace. Internal monitoring data could exist for plutonium or thorium during the residual period; however, only operations involving uranium were part of the nuclear weapons-related program, and are covered during the residual period for dose reconstruction under EEOICPA (Leiton 2011).*

Although it is not explicitly stated that the plutonium was used in the AEC weapons/research activities, the following excerpt, shown below in Exhibit A, confirms plutonium from Hanford was processed during the AEC weapons era at WRG (AEC 1966):

Exhibit A. Plutonium Contract Between AEC and NFS



In December 6, 1965, a contract was signed between Nuclear Fuel Services, Inc. (NFS), and the AEC for NFS to recover an estimated 16.5 kilograms of plutonium from approximately 820 kilograms of uranium-contaminated plutonium scrap being stored at Hanford. This is the first such scrap processing contract to be awarded to private industry by the AEC. NFS provided the most favorable response to the Invitation for Proposals, which was sent to seven firms in November 1964, and plans to do the scrap processing at its Erwin, Tenn. facilities.

As previously pointed out, there are indications that there was use of plutonium in the AEC weapons programs at WRG during the operational period; therefore, not assigning plutonium dose during the residual period assumes that all legacy plutonium from the operational period is still undisturbed in storage, burial grounds, ponds, buildings, duct work, etc., and creates no significant exposure hazard. However, it is known that this material has been disturbed, dug up, handled, processed, packaged, and shipped, and buildings have been decommissioned during the residual period, resulting in potential plutonium exposures to workers.

The results of SC&A's investigation of the use of radioactive materials besides uranium (i.e., plutonium and thorium) in the AEC weapons program during the operational period indicates that for many contracts, neither the company (WRG) nor the workers were privileged to the origin, destination, or ultimate use of the materials that passed through the WRG facility. The WRG facility was a "job shop" that performed a service for various government agencies and commercial sectors. Therefore, it appears that to substantiate that the plutonium processed at WRG was **not** used in the AEC weapons program (and hence not to be included in the residual period as recommended in the TBD), government documents outside of the WRG/NFS company would have to be obtained to verify the origin, destination, and ultimate use of the plutonium material processed at the WRG facility during the operational period.

Burial Grounds Workers and Definition Issue

On page 34 of the TBD, it is stated:

> ***Remediation of the Burial Grounds***
> *Remediation activities of the burial grounds should be assessed based on individual bioassay records per guidance in Section 3.*

However, it is not clear if this is to include plutonium bioassay results or only uranium. Additionally, since many workers changed job locations/duties frequently (an "operator" at WRG could be doing anything from mixing chemicals, pressing pellets, digging a ditch, or operating a bulldozer), it would be difficult for the dose reconstructor to determine if a specific

worker was involved in burial grounds activities. Also, it is not clear if the term *Burial Grounds* includes the trenches and ponds, where a large of amount of the cleanup took place in the residual period, or just the North Burial site, as indicated in Figure 2-2 of the TBD.

3.1.1.2 Internal Dose Secondary Findings

Secondary Finding A: Table 3-15, Table 5-2, and Table 5-3 based on 365 days instead of 250 days per year

SC&A found that Tables 3-10 and 3-11 on page 22 of the TBD are based on 250 days/year (i.e., 2,000 hours/year × 1 day/8 hours = 250 days/year); However, Table 3-15 on page 26, Table 5-2 on page 33, and Table 5-3 on page 34 are all based on 365 days/year, but use the data from Tables 3-10 and 3-11 that are based on 250 days/year. Therefore, the values in Table 3-15, Table 5-2, and Table 5-3 are too small by a factor of 365/250 = 1.46, and need to be revised upward in value by a factor of 1.46 to be correct.

Secondary Finding B: AEC material buried and removed from ponds and grounds not documented or accounted for

SC&A has not found sufficient documentation of the materials that were buried and then removed from the ponds, burial grounds, and trenches to allow for the determination of the potential exposure to workers, especially the ability to separate the AEC legacy weapons/ research-related materials from the other materials. Although it is stated on page 31 of the TBD that, "The contents and locations of most disposal pits are well documented," there are no references provided.

3.1.2 Occupational External Dose, Section 4 of ORAUT-TKBS-0043

Background and Introduction

Section 4 for external dose, pages 26–31, was written to provide the dose reconstructor with recommendations concerning external DR at the WRG site during the period of AEC/ commercial/Navy operations (1958–1970), and also during the AEC/DOE residual period and commercial/Navy operations (1971–2009). This section provides some information concerning external non-penetrating, penetrating, neutron, extremity, and missed doses, and external DR recommendations. In addition to the operational period (1958–1970) covered by Section 4, Section 5 (pages 35–36) covers external exposures during the residual period of 1971–2009. The following is a brief outline of the contents of Section 4 and Section 5 for external dose:

Section 4 External – AEC Operational Period 1958–1970

1. **Badging** –
    - At one time, all WRG workers were badged
    - Later, office workers were not badged

2. **Reporting** –

- Before 1970, the reported skin dose represented only the non-penetrating dose component; therefore, the total shallow dose is best estimated by summing the reported skin (i.e., non-penetrating dose) and whole-body (i.e., penetrating dose component) doses.
- Beginning January 1, 1970, the reported skin dose included the shallow dose from both the non-penetrating and penetrating dose components.
- Table 4-1 on page 27 lists the dosimetry characteristics for WRG badges.
- Photon dose should be assigned as 30–250 keV photons, and plutonium doses are to also include <30 keV photons.

3. **Neutrons** –

Page 28 of the TBD states:

> *There were no documented neutron exposures at W.R. Grace. However, the use of uranium hexafluoride and uranium fluoride, and the possible presence of plutonium can generate neutrons through an alpha-neutron reaction between the uranium and the fluorine (DOE 2004). Neutrons can also arise from HEU and during plutonium processing operations (DOE 2006).*
>
> *Personnel exposure records are used to evaluate radiation exposure. No attempt should be made to estimate neutron dose for workers not monitored for neutrons during the operational period.*

4. **Extremity Doses** –

Extremity doses while working in gloveboxes are addressed on page 28.

5. **Missed Dose** –

Table 4-2 on page 29 provides a summary of the types of dosimeters used at WRG, their period of use, MDL values, and maximum annual missed doses.

6. **External DR Assumptions –**

- Non-penetrating dose should be assigned as >15 keV electrons or <30 keV photons for plutonium workers with non-skin cancers
- Photon dose is to be assigned as 30–250 keV photons, and exposure dose conversion factors are to be used
- DCAS-TIB-0010 (NIOSH 2010) recommendations should be used for glovebox workers at WRG
- For U-233 workers, use dose as recorded

Section 5 External – Residual Period 1970–2009

1. **Non-Burial Grounds Workers –**
   - Use the dosimetry parameters listed in Table 5-4, page 35
   - Records may be used to limit dose
   - Otherwise, use doses listed in Table 5-5, page 36, which is derived from the DWE of 578.38 dpm/m^3, settling rates, Table 5-1 depletion rate, surface contamination, and resuspension factors

2. **Burial-Grounds Workers –**
   - Use the dosimetry parameters listed in Table 5-4, page 35
   - Dose may be assessed based on individual monitoring records
   - It is not stated what areas the term *burial grounds* includes, or how burial grounds workers are to be identified

SC&A reviewed Sections 4 and 5 of the TBD in accordance with guidance provided in *Site Profile Review Procedures* (SC&A 2004) and has the following findings.

3.1.2.1 External Dose Primary Findings

Accuracy and completeness of external exposure records not addressed

The accuracy and completeness of the recorded external doses have not previously been addressed. SC&A performed a preliminary scan of the WRG DOE files for several of the claimants and found some external dose records available, and those located were generally legible. Gamma doses (in units of rem) were recorded on a varying frequency (i.e., weekly, biweekly, monthly, etc.). Beta doses (in units of rem) were sporadically recorded, as if on an as-needed basis. No neutron doses were recorded in the files scanned by SC&A.

SC&A's performed a preliminary scan of 25 WRG claims for EEs that worked at WRG sometime during the period 1957–1970 and had job titles that would indicate the potential need for external monitoring (such as operator, chemical operator, production, etc.). A qualitative review indicated that external monitoring was implemented for most of the operational years for production workers. This was only a qualitative analysis, in that any external monitoring during a calendar year was counted as monitoring for that year, and any portion of a year worked was counted as a full year. SC&A found that, on average, approximately 97% of the 25 workers were monitored for external exposure (badged) each year for the period of 1957–1970. These results are summarized in Figure 2 below.

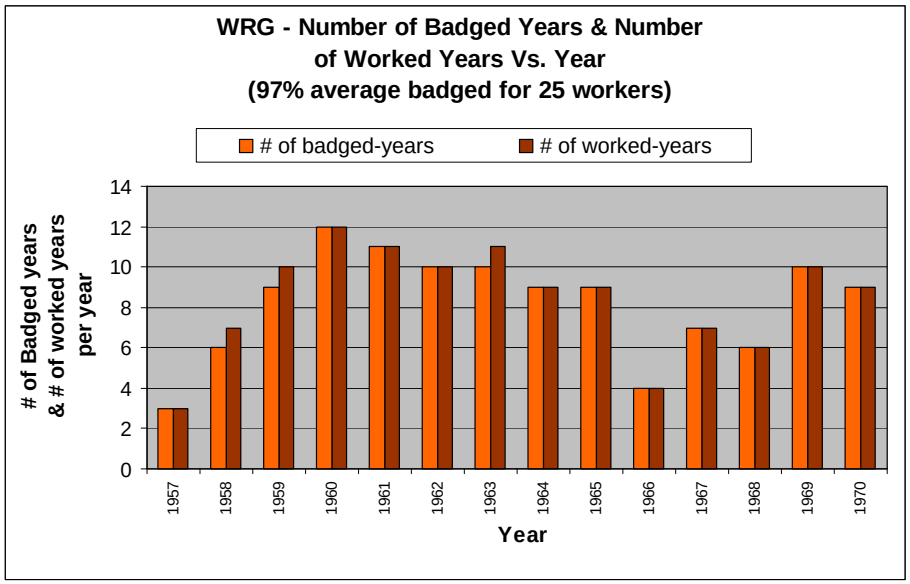


Figure 2. Number of Badged Years and Number of Years Worked vs. Year

This was only a qualitative review of 25 potentially exposed workers; a more detailed survey (expand workers' job categories, investigate months monitored during each year, etc.) may need to be conducted that would determine if workers who should have been monitored because of job title and/or location have recorded external dose data entries for the corresponding periods of time worked in areas with potential exposures. However, at this time, SC&A has no indication that external dose records are not reasonably accurate and complete for DR purposes.

Finding 4: Lack of neutron dose assignment

The TBD mentions neutron doses on pages 9, 26, and 28, and concludes on page 28 that there were potential neutron exposures, but no neutron dose will be assigned:

> *There were no documented neutron exposures at W.R. Grace. However, the use of uranium hexafluoride and uranium fluoride, and the possible presence of plutonium can generate neutrons through an alpha-neutron reaction between the uranium and the fluorine (DOE 2004). Neutrons can also arise from HEU and during plutonium processing operations (DOE 2006).*
>
> *Personnel exposure records are used to evaluate radiation exposure. No attempt should be made to estimate neutron dose for workers not monitored for neutrons during the operational period.*

SC&A did not locate any recorded neutron doses in the claimants' files reviewed to date. Section 2.3.1 of DOE 2004 provides an outline of the neutron doses from uranium, which indicates that there are measurable neutron exposures for workers spending a reasonable amount of their work time near uranium fluoride compounds, or container storage facilities, and states on page 2-20:

> *Neutron sensitive personnel monitoring badges are recommended for operations dealing with uranium fluoride compounds.*

This statement indicates that neutron exposures should be considered for uranium facilities. Also, site profiles for other uranium- and plutonium-handling facilities incorporate neutron doses in the DR process, usually using the n/p method, for workers potentially exposed to neutrons. Further investigation of the potential neutron exposures and methods to assign appropriate neutron doses is needed for the WRG facility.

Finding 5: Lack of dosimetry calibration knowledge

Because of the lack of information indicating otherwise, it appears that the dosimeters for WGR workers were read and recorded by outside vendors, with WRG depending on the processing companies to provide the correct correlation between the various radiation fields at WRG and the vendor's calibration. This is also indicated in the communication between NFS and OCAS in 2005 (Tester 2005). However, the operations at WRG resulted in varying radiation fields of photon, beta, and neutron energies, as indicated on page 27 of the TBD:

> *The W.R. Grace/NFS distribution of low-energy photons is dependent on the amounts, separation and enrichments of uranium, and the age and type of plutonium used at the site.*

Additionally, a number of different radionuclides are listed on page 16 of the TBD that would encompass a variety of photon and beta energy ranges:

> *Uranium enrichment levels included DU, natural uranium (NU), LEU (3.5%), and HEU (93%) as well as ^{232}U and ^{233}U. Uranium-233 contains ^{232}U as an impurity due to nuclear reactions from the neutron irradiation of ^{232}Th. The ^{232}U impurity results in elevated gamma and beta dose rates due to the ingrowth of ^{232}U progeny (^{228}Th and its progeny). Uranium from recycling operations would have included small activities of non-uranium isotopes such as ^{99}Tc, ^{237}Np, ^{232}Th, ^{106}Ru, and ^{238}Pu. There was one indication of RU processing in the case of a recycled ^{233}U pellet.*

It needs to be determined if any field measurements of the radiation energy spectra were made, and what calibration source(s) were used by the vendors. Dosimeters calibrated using higher-energy sources, such as Co-60, may not have correctly responded to the lower-energy photons from the various radionuclides present at WRG. Therefore, a correction factor may be needed, especially for determining the dose to skin and shallow organs.

3.1.2.2 External Dose Secondary Findings

Secondary Finding C: Burial Grounds workers and definition issue

On page 36 of the TBD it is stated:

> ***Remediation of the Burial Grounds***
> *Remediation activities of the burial grounds should be assessed based on individual monitoring records per guidance in Section 4 and Table 5-4.*

Because many workers changed job locations/duties frequently (an "operator" at WRG could be doing anything from mixing chemicals, pressing pellets, digging a ditch, or operating a bulldozer), it would be difficult for the dose reconstructor to determine if a specific worker was involved in burial grounds activities. Also, it is not clear if the term *Burial Grounds* includes the trenches and ponds, where a large of amount of the cleanup took place in the residual period, or just the North Burial site, as indicated in Figure 2-2 of the TBD.

Secondary Finding D: Methods used to derive Table 5-5 not provided

External annual exposure rates for the residual period (1971–present) are provided on page 36 of the TBD. Presumably, the data in this table were derived from the maximum DWE of 578 dpm/m^3 coupled with the average depletion rate of 0.00067/day from Table 5-1. However, it is not stated how the values in Table 5-5 were calculated; i.e., what resuspension rate was used, how the penetrating versus non-penetrating doses were derived, or whether rather this residual contamination is on the floor, work surfaces, ground, etc., and if this includes components of RU.

3.1.3 Occupational Medical Dose, Section 4 of ORAUT-TKBS-0043

Background and Introduction

The current version of the WRG site TBD contains a relatively short section (one paragraph on page 30) concerning occupational medical doses. This section recommends the use of ORAUT-OTIB-0006 (ORAUT 2011b) for occupational medical dose assignment.

Finding 6: Onsite medical x-ray exams not substantiated

It has not been substantiated that x-ray exams were performed on site at the WRG facility during the AEC operational period of 1958–1970. On page 18 of the worker outreach meeting notes of April 2011 (ORAUT 2011c), it states:

> *After some discussion, the attendees agreed that X-rays are done annually at the hospital in Erwin…*

SC&A's interviews conducted in October 2012 confirmed this statement. Therefore, assigning offsite x-ray exams may not be consistent with ORAUT-OTIB-0079 if the exams were performed offsite, because ORAUT-OTIB-0079 (ORAUT 2011d), Section 2.0, page 5, states:

> *If it is **known** that occupational medical X-ray dose was received at a location other than a covered facility (i.e., an offsite physician's office, clinic, or local community hospital), it **shall not** be included in dose reconstruction. If there is doubt about where the X-ray exposure was received, dose reconstructors should assume that the dose was received at a covered facility.* [Emphasis added.]

The TBD states on page 30 that:

> *To date, no site-specific information is available for W.R. Grace workers in relation to the type or frequency of occupationally required medical X-ray examinations.*

In the preliminary scanning of the DOE files for WRG claimants, SC&A has not located any files concerning x-ray exams, either at onsite or offsite locations. While the TBD recommendations are claimant favorable, to ensure consistency with other site profiles, this is an area that needs further verification.

3.1.4 Occupational Environmental Dose, Section 6 of ORAUT-TKBS-0043

Background and Introduction

The current version of the WRG site TBD contains a relatively short section (one paragraph on page 37) concerning occupational environmental doses.

Finding 7: The 2011 TBD does not adequately cover environmental doses

Section 6 of the TBD, page 37, states:

> *It is not necessary to include an environmental dose component for W.R. Grace worker dose because all workers are assumed to have been exposed to operational conditions, and dose has been assigned accordingly.*

For **internal** dose assignments, this statement apparently refers to:

- Operational period – The use of the uranium intake values as listed in Table 3-15 (derived from the 1961 air samples) for assigning unmonitored doses. The dose reconstructor is not to attempt to assign any dose from thorium or plutonium if the worker was not bioassayed (pages 10 and 25, respectively, of the TBD).

- Residual period – The use of the uranium intake values as listed in Tables 5-2 and 5-3 (derived from the 1961 air samples, uranium settling and resuspension factors, and modified by the depletion rate from Table 5-1) for assigning internal doses [for both

bioassayed and unmonitored workers; i.e., do not use the uranium, plutonium or thorium bioassays (page 32), unless the worker was involved in burial ground activities, then apparently the DR is to only use the uranium bioassays (page 34)]. The DR may use uranium bioassays if adjusted by the depletion factor in Table 5-1 (page 32).

However, these methods do not account for airborne uranium materials that were generated by the cleanup and processing of waste from the ponds and burial grounds during the residual period to which monitored, as well as unmonitored, workers may have been exposed; although, these workers may not be considered to have been directly involved in the cleanup activities.

Additionally, as pointed out in a previous finding (assuming that plutonium was used in the weapons program), the methods recommended do not account for intakes of plutonium for unmonitored workers during the operational period, or plutonium during the residual period for both monitored and unmonitored workers.

For **external** dose assignments, this statement is apparently based on:

- Operational period – Page 26 of the TBD states: "Claimant-specific data should be used for analysis of the external radiation dose," and "At one time, everyone in the W.R. Grace plant was badged."

- Residual period – The use of the external dose from residual uranium contamination as listed in Table 5-5 (derived from the 1961 air samples, uranium settling and resuspension factors, and modified by the depletion rate from Table 5-1) for assigning external doses [for both monitored and unmonitored workers; i.e., do not use external dose records (page 35), unless the worker was involved in burial ground activities and only then use the recorded external dose (page 36)].

However, in contrast to this, page 26 also states, "No attempt should be made to estimate external radiation doses for **unmonitored** workers during the operational period," [emphasis added] and "At a later time, office workers were not assigned dosimeters." These statements indicate that some workers may not have been monitored for external exposure during the operational and residual periods; hence, requiring coworker or environmental external dose assignments.

The internal and external environmental exposures throughout the site during both the AEC period (1958–1970) and from the cleanup of the AEC legacy materials during the period 1971–present are not adequately addressed.

4.0 OVERALL ADEQUACY OF THE SITE PROFILE AS A BASIS FOR DOSE RECONSTRUCTION

The SC&A procedures call for both a "vertical" assessment of a site profile for purposes of evaluating specific issues of adequacy and completeness, as well as a "horizontal" assessment pertaining to how the site profile satisfies its intended purpose and scope. This section addresses the latter objective in a summary manner by evaluation of (1) how, and to what extent, the site profile satisfies the five objectives defined by the Advisory Board for ascertaining adequacy; (2) the usability of the site profile for its intended purpose (i.e., to provide a generalized technical resource for the dose reconstructor when individual dose records are unavailable); and (3) generic technical or policy issues that transcend any single site profile that need to be addressed by the Advisory Board and NIOSH.

4.1 SATISFYING THE FIVE OBJECTIVES

The completeness, accuracy, and adequacy of data (to include data to be used for monitored workers' individual DRs and data to be used in deriving coworker databases for unmonitored workers) should be validated to demonstrate its usefulness. SC&A has performed extensive document searches and found approximately 400 WRG documents. SC&A also reviewed some of the approximately 200 WRG claims to assess the information available in the energy employees' dose records and their applicability to DR and coworker databases. In addition, SC&A conducted 2 days of onsite interviews with current and former WRG site workers to obtain information concerning working conditions and exposure potentials that may impact the completeness and usefulness of dose records. The following is a summary of SC&A's evaluation of the present resources available (TBD, dose records, site documents, etc.) to the dose reconstructor for reconstruction of dose to WRG site workers with reasonable completeness and accuracy.

4.1.1 Objective 1: Completeness of Data Sources

During the review of the WRG site TBD and associated documents, SC&A found that the bioassay records used for DR have not been analyzed to determine that they are sufficiently complete and accurate for DR purposes. SC&A has not found documented evidence that there are missing bioassay records, but neither has this issue been addressed by NIOSH for the WRG site. Additionally, NIOSH has not addressed the need for creating coworker models for uranium and plutonium intakes in view of the lack of complete bioassay monitoring during the operational period.

Because WRG was mostly a "job shop" operation (i.e., basis material in, processed, material out), there is not a large number of operational documents and other WRG-related documents available for the AEC operational period (1958–1970), especially documents detailing the radioactive materials used, source terms, handling, and operating conditions for AEC weapons/research-related activities. What information is available for the 1958–1970 operational period does not sufficiently differentiate the AEC weapons/research processes and materials from the AEC non-weapons/research, commercial, and Navy processes/materials to allow assessment of doses related to only AEC weapons/research activities. Therefore, it

appears that to substantiate that plutonium processed at WRG was **not** used in the AEC weapons program (and hence, not to be included in the residual period as recommended in the TBD), NIOSH would need to obtain government documents outside of the WRG/NFS company to verify the origin, destination, and ultimate use of the plutonium materials processed at the WRG facility during the operational period.

4.1.2 Objective 2: Technical Accuracy

SC&A found that the WRG TBD generally presents technically accurate information. However, as described in the findings in Section 3 of this report, there are numerous situations where there is a lack of sufficient information or investigation of an issue. As addressed in detail in the findings in Section 3 of this report, there is a lack of technical details concerning the accuracy of the recorded doses, investigation of dosimetry calibration factors, lack of neutron monitoring, and other recorded dose-related issues. The TBD assumes that the dose of record is complete, accurate, and applicable without the need for further verification or adjustments; this opens up the potential for incorrect and/or incomplete dose assignments.

4.1.3 Objective 3: Adequacy of Data

There appears to be some information concerning operating conditions and potential exposure conditions at WRG for use in DR. The individual dose data records are apparently available from NFS and the workers' personnel files. However, as discussed in Section 3 of this report, there has not been any verification of the individual dose records to ensure that they are complete, and therefore, adequate for DR. SC&A's preliminary review of some of the claims indicates that there are external and bioassay monitoring records, although some individual records show sporadic monitoring results, especially for internal monitoring. This indicates that WRG coworker models for uranium and plutonium internal intakes need to be considered for DR purposes.

4.1.4 Objective 4: Consistency Among Site Profiles

When compared to other site profiles, SC&A's review of the WRG site profile TBD did not find major inconsistencies that would significantly impact DR or create claimant-unfavorable situations. However, SC&A did find that the WRG TBD did not recommend a method for assigning neutron doses, although neutron fields were listed as a potential radiation exposure source. On the other hand, the TBD recommended assigning occupational medical dose when it has not been confirmed that the x-ray examinations were conducted onsite. These recommendations are inconsistent with protocol for most other uranium/thorium/plutonium-handling sites.

4.1.5 Objective 5: Regulatory Compliance

No regulatory compliance issues were identified by SC&A in the WRG site TBD.

4.2 USABILITY OF SITE PROFILE FOR INTENDED PURPOSES

Because the purpose of a site profile is to support the DR process, it is critical that the site profile assumptions, analytic approaches, and procedural directions be clear, accurate, complete, and auditable (i.e., sufficiently documented). The WRG site TBD generally provided some methods of assessing workers' external, internal, and occupational medical dose; however, SC&A has some concerns in the use of this TBD for DR as follows:

4.2.1 Lack of Defined AEC Weapons and Research Activities During Operational Period

What activities were considered AEC weapons- or research-related compared to the commercial and Navy activities at WRG during the operational period of 1958–1970 has not been well defined, nor does this appear to be well documented. AEC-related source terms during the operational period that could cause exposures in the residual period (1971–present) have not been sufficiently defined to ensure claimant-favorable DR.

4.2.2 Lack of Defined Use of Plutonium During Operational Period

To date, documentation has not been located that provides a clear description of what radioactive materials were used only for AEC weapons or research activities, and what was used only for commercial and/or Navy purposes. This information is necessary if plutonium is to be correctly accounted for during both the operational and residual period; this is especially applicable if plutonium intakes are not to be assigned during the residual period, as recommended in the current TBD.

4.2.3 Incomplete Information and DR Recommendations for Neutrons

The TBD does not sufficiently investigate the potential neutron exposures at WRG, nor does it make claimant-favorable recommendations to the dose reconstructor concerning assigning neutron doses.

4.2.4 Location of X-ray Examinations Not Sufficiently Addressed

The WRG site TBD does not provide any verification that the occupational medical x-ray exposures received by WRG workers occurred on the WRG property in order to recommend assigning dose according to ORAUT-OTIB-0006 (ORAUT 2011b). This is in conflict with recommendations in ORAUT-OTIB-0079 (ORAUT 2011d) that recommends not assigning occupational medical dose if it is known that the exams were performed offsite.

4.3 UNRESOLVED POLICY OR GENERIC TECHNICAL ISSUES

A number of issues identified in the WRG site TBD review represent potential generic policy issues that transcend other individual site profiles. These include a lack of analyses of recorded dose and bioassay data for adequacy/accuracy, lack of sufficient environmental data for onsite unmonitored workers, insufficient knowledge/documentation of some source terms and radiation fields (especially neutrons), lack of dosimetry geometry factors, and lack of addressing the need

for coworker models for uranium and plutonium intakes. Additionally, there is a lack of information concerning the types, frequency, doses, and location of occupational medical x-ray exams. These issues are discussed in detail as findings in Section 3 of this report.

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ATTACHMENT 1: SITE EXPERT INTERVIEW SUMMARY

(The site interview summary will be provided as an amendment to this report)