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National Institute for Occupational Safety and Health

Preliminary Issues from SC&A's Review of NIOSH's Evaluation Report for the Weldon Spring Site, Weldon Spring, Missouri, Special Exposure Cohort Petition SEC-00143

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ABBREVIATIONS AND ACRONYMS

Advisory Board or ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
Bq	Becquerel
BZ	Breathing zone
CER	Center for Epidemiologic Research
CFR	Code of Federal Regulations
Ci	Curie
DOE	Department of Energy
DR	Dose reconstruction
DWA	Daily Weighted Average
EE	Energy Employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ER	Evaluation Report
FMPC	Feed Materials Production Center
gm	gram
HPS	Health Physics Society
k	kilo
l	liter
m^3	cubic meter
MCW	Mallinckrodt Chemical Works
MCWUD	MCW Uranium Division
mrem	millirem
mrep	millirep
MT	metric ton
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
pCi	picocurie
ppb	parts per billion
rem	Roentgen equivalent man
rep	Roentgen equivalent physical

RF	release fraction
RU	recycled uranium
SC&A	S. Cohen and Associates
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	Technical Basis Document
TIB	Technical Information Bulletin
TRU	Transuranic
TSR, Inc.	Thompson-Stearns-Rogers
WL	working level
WLM	Working Level Month
WS	Weldon Spring
WSCP	Weldon Spring Chemical Plant
WSP	Weldon Spring Plant
WSS	Weldon Spring Site
Y	Year

INTRODUCTION AND SUMMARY

At the Advisory Board on Radiation and Worker Health (Advisory Board) meeting held in Niagara Falls, New York, on May 19, 2010, the Advisory Board authorized SC&A to perform a focused review of the Weldon Spring Site (WSS) Special Exposure Cohort (SEC) Petition (NIOSH 2009b) and National Institute for Occupational Safety and Health (NIOSH) Evaluation Report (ER) (NIOSH 2010). The SEC petition requested that the time period include January 1, 1957, through December 31, 1966. NIOSH's ER of April 16, 2010, recommends that a time period of January 1, 1957, through December 31, 1967, be evaluated for SEC status. This report presents SC&A's preliminary identification of potential Weldon Spring Site SEC issues with regard to this matter, based on a review of SEC petition #00143, NIOSH's ER of SEC-00143, the Weldon Spring Site Profile, SC&A's review report of the Weldon Spring Site Profile, worker interviews (SC&A 2009), and related documents.

In reviewing these documents, SC&A found that NIOSH's ER addressed many of the important issues raised in the SEC, and several related issues. Useful data were provided for consideration, and several methods were recommended for use in situations where data were lacking. NIOSH addressed the issues from several directions and recommended solutions applicable to dose reconstruction (DR). SC&A found that considerable research had gone into bases of the ER, and that it is a helpful step in the SEC process. However, to continue the SEC process, SC&A has identified several important areas that need further investigation. SC&A finds that for the period of 1957–1966 at the WSS, there is inadequate verification of the accuracy of the records and applicability of the air monitoring data, inadequate contamination/egress control, and inadequate recommendations for radon and thoron intakes to allow the feasibility of estimating, with plausible accuracy, the maximum radiation dose, or establishing the individual doses, for skin exposures and intakes to a significant number of the production and non-production workers using technically sound methods. Additionally, there are essentially no direct data available to reconstruct external or internal doses to workers for the year of 1967. SC&A also found that the methods recommended for assignment of doses from recycled uranium (RU), neutrons, the quarry/raffinate pits, exposure geometry, and off-normal situations are inadequate as well.

1.0 ACCURACY OF RECORDS NOT SUFFICIENTLY VERIFIED

In the Evaluation Report (ER), the National Institute for Occupational Safety and Health (NIOSH) presents the following information concerning the accuracy and applicability of the present data used for dose reconstruction (DR) purposes at the Weldon Spring Site (WSS).

(a) **Internal –** NIOSH presents the availability of bioassay records on page 35 of the ER and a comparison of WSS hardcopy uranium urinalysis data to the Center for Epidemiologic Research (CER) database on page 49, and concludes that the bioassay data are accurate for 1957–1967.

(b) **Air data –** The ER provides breathing zone (BZ) and area air sampling data sources on page 40 for uranium (1958–1966) and pages 41–45 for thorium (1963–1966), and recommends using TIB-5000 (Battelle 2007) and TIB-6000 (Battelle 2006); no specific intake values are provided in the ER.

(c) **External –** NIOSH briefly addresses the availability of external dosimetry results on pages 46 and 52 of the ER, and concludes that the available external dosimetry monitoring data are available in sufficient quantity and quality to adequately represent external beta and photon dose for the Weldon Spring Plant class under evaluation for the period from January 1, 1957, through December 31, 1967.

(d) **Coworker –** NIOSH does not discuss coworker models for the WSS in the ER or the technical basis documents (TBDs); however, it is stated on pages 63 and 67 of the ER that exposures for unmonitored workers can be bound by using the monitored workers' data for both external and internal exposures. The issue of the representativeness of cohort bioassays for groups is not addressed, nor how this data would be used in a coworker model.

1.1 SUMMARY OF LACK OF VERIFICATION OF ACCURACY OF RECORDS

SC&A did not find that the accuracy and applicability of the data available for DR had been adequately verified by NIOSH. The following is a summary of the issues in each major area.

(a) **Internal –** SC&A did not find that NIOSH's comparison was sufficient to establish the accuracy of the internal dose of record. Comparison of hardcopies to the CER database does not provide sufficient evidence that the records used by the dose reconstructor are adequate and have accurately survived the transfer of data over the years. Hardcopies compared to the files that would be provided to the dose reconstructor are necessary for validation. The sequence of databases and the verification of accurate transfer of bioassay data between these databases are necessary to demonstrate that the data received by the dose reconstructor are traceable to the original data.

(b) **Air data –** SC&A reviewed the data sources and found that they do contain periodic air sampling data for uranium and thorium, as stated in the ER. However, the ER does not provide any further evaluation of the adequacy or accuracy of this data, nor justification for using Daily Weighted Average (DWA) values, or application details for DR purposes. The use of DWA values has brought up issues at other Department of Energy (DOE) sites, some of which are expanded on in the Mallinckrodt Chemical Works (MCW) Downtown site review (SC&A 2005). This issue is applicable to a number of Atomic Energy Commission (AEC)/DOE sites and should be investigated in conjunction with methods recommended for other sites; especially those at the MCW downtown site, Fernald, and the WSS. SC&A's review of the related documents (Adam & Strom 2008, NIOSH 2009a, and NIOSH 2010) did not find that the Adam & Strom 2008 Health Physics Society (HPS) article supported the applications and assumptions in NIOSH's ER (NIOSH 2010) and the Morris article (NIOSH 2009a) for the WSS. SC&A will issue a memo outlining these differences.

(c) **External –** While the number of badges and the average gamma/beta doses are listed, there is no verification of external doses of record provided. Additionally, there are no data presented for 1967, as will be detailed in a following SEC issue. As was true for bioassay data, the sequence of databases and the verification of accurate transfer of external dose data between these databases are necessary to demonstrate that the data received by the dose reconstructor are traceable to the original data.

(d) **Coworker –** There appears to be a large amount of both bioassay and external dose data; however, until the accuracy of the data can be determined (as outlined in previous issues), it is not applicable for the creation of an external dose or internal intake coworker database for unmonitored workers. Additionally, the proposed structure of the database and its applicability need to be addressed, including how the cohort bioassays would be used.

2.0 LACK OF PERSONNEL CONTAMINATION/EGRESS MONITORING

Neither the WSS TBDs nor NIOSH's ER mentioned the lack of monitoring equipment and procedures to check workers for contamination in the work places and upon leaving the controlled areas. SC&A could not locate any documentation to verify if such procedures and equipment were used at the WSS during the operating period of 1957–1966, or during 1967. At that time, uranium was considered to be mostly a chemical hazard and control measures were mainly based on chemical toxicity limits, not radiological limits [ORAUT-TKBS-0028-5, page 11 (ORAUT 2005e)]. During worker interviews, SC&A did not find that the workers recalled any established egress monitoring, either between the operations areas and the non-operations areas (cafeteria, administration offices, labs, maintenance facilities, sidewalks, storage yards, grounds, etc.), or when leaving the plant site (guard shack, parking lots). Workers did indicate, and documents support, that they were required to change clothing when entering and leaving the operations areas (some workers showered, but this policy does not appear to have been strictly enforced); however, there is no evidence that the workers were routinely checked for contamination before leaving the controlled areas to ascertain that they were not contaminated. Documents indicate that some area monitoring (i.e., with portable survey instruments and swipes) and cleanups were performed to keep some surfaces below certain limits (MCW 1965, page 20), but there is no indication that survey instruments or hand/foot monitoring stations were available and routinely used to monitor workers as they left the operational areas or the WSS. Contamination was apparently commonplace inside the process areas, as evident by a statement in MCW Uranium Division (MCWUD) *Summary of Health Protection Practices* (MCW 1965, page 20), which states that, "Inside the process locations, surface contamination measurements have little significance." Contamination was apparently common on workers, as described in a 1960 WSS document (Burr 1960):

> [The EE's] *shoes and* [the EE's] *gloves were especially loaded with green salt. The packing was done by foot…*[The EE] *had a respirator around* [the EE's] *neck but was not using it… it was suspected that the ventilation was inadequate… the operator distributed additional green salt in the bomb by hand and visible clouds of dust could be seen around the shell top and in the working area.*

It would not be difficult to create contamination in the work areas, considering that the beta exposure rates of some operations were in the 10–35 rep/hr (rep ~ rem) range, as stated in Table I of a WSS document (MCW 1959). A small amount of scale, cuttings, or dust from these operations would quickly contaminate the work area. Several quotes from interviews with former WSS workers (SC&A 2009, pages 71 and 72) illustrate that personnel contamination was common, and that there was a lack of egress monitoring:

> *Contamination incidents occurred routinely. When there was a skin contamination incident, individuals just washed the material off. If a worker was contaminated with hot powder or acid, they would get a burn and have to go over to the dispensary to get it taken care of. The onus was put on the employee. Workers were not always successful at getting material in the cracks and crevices*

off. They were not required to call a radiation monitor to take measurements. If they did, they would never get any production done.

There were no routine contamination surveys of benches, floors, and other surfaces with smears.

WS workers were not required to monitor themselves for radiation upon exit from a radiological area. When workers left the work area, to go to the break rooms or to lunch, to go home at night, or when they got contaminated, there was no station where they could monitor themselves. Their monitor was their film badge. Some workers used neutralizer to clean their hands when they exited the operations areas.

Workers also indicated that they were allowed to smoke and drink liquids in the break rooms located inside the controlled areas without washing of hands, changing of clothes, or contamination checks. This practice could lead to undetected intakes in some individuals who were not monitored on a regular basis, especially those who were present in the work areas, but not considered as at-risk workers, such as supervisors, clerks, and security personnel.

2.1 SUMMARY OF LACK OF CONTAMINATION/EGRESS MONITORING

Workers were apparently allowed to leave the controlled areas and the WSS without confirmation that they were not contaminated. This could have spread contamination to non-controlled areas at the site, creating chronic exposure (internal and external) to unmonitored workers, as well as leaving contamination on the workers that could lead to chronic beta exposure to the skin (especially in the folds of the skin) and internal exposure through ingestion and resuspension/inhalation. Personnel badges worn during working hours would not have picked up beta exposures from contamination on the skin that could have irradiated local skin areas for extended periods, especially in the folds of the skin around the ears, nose, neck, and arms. Additionally, because workers only periodically submitted urine samples, as described in ORAUT-TKBS-0028-5 (ORAUT 2005e), some of these individual internal intakes through this pathway could have been missed. Even with good dosimetry and records, there would be no records of these missed exposures for DR purposes. Contrary to the ER statement, neither the ER [nor ORAUT-TKBS-0028-6 (ORAUT 2005f)] specifically addressed the personnel contamination issue. This issue is applicable to numerous AEC/DOE sites and should be investigated in conjunction with methods recommended for other sites.

3.0 LACK OF INFORMATION FOR WORKERS DURING 1967

It is not explicitly stated in the TBDs when DOE employees and DOE contractors were no longer working at the WSS after operations ceased in December of 1966. In Section 2.2.2.4 of ORAUT-TKBS-0028-2 (ORAUT 2005b), page 22, it is indicated that no AEC contractors were present until August 1975 (this is reiterated on page 30 of ORAUT-TKBS-0028-2); however, Section 6.13.2, page 12 of ORAUT-TKBS-0028-6 (ORAUT 2005f), states that:

> *There is some anecdotal information to indicate that some former WSCP workers continued their employment during this period.*

And

> *"We do not feel such a contractor will need film badge services." However, it is not clear if this statement refers to a continued presence by MCW staff.*

This is referring to the 1967 to 1969 time period.

The WSS TBDs do not state if DOE employees and contractors were present or involved during 1967–1969, when the U.S. Army was attempting to decontaminate and renovate buildings located at the WS Chemical Plant. Sections 4.2.2.2 and 4.2.3.2 of ORAUT-TKBS-0028-4 (ORAUT 2005d); Sections 5.3.2, 5.4.2, 5.5.2, 5.5.3, and 5.6.2 of ORAUT-TKBS-0028-5 (ORAUT 2005e); and Sections 6.1.3.2 and 6.1.3.3 of ORAUT-TKBS-0028-6 (ORAUT 2005f) do not contain sufficient information for the dose reconstructor to be able to assess dose to claimants who may have worked for DOE or its contractors at the WSS during 1967. If DOE contract personnel were present at the WSS soon after the shutdown in December 1966, they could have been exposed to numerous radionuclides during decommissioning, cleaning out the equipment, and revamping the facility for a completely different use. Because uranium was viewed as a chemical rather than a radiological hazard at that time, sufficient controls and monitoring practices may have not have been in place. This was more likely to occur during the time period immediately following plant closure, because the MCW health and safety infrastructure at the WSS was no longer in place. Plant operating protocol would not have been enforced; buildings and equipment were considered surplus, and supplies/materials (including leftover radioactive material or contaminated material) would have been considered a nuisance and disposable. Working under these conditions could have created a mindset that radiological safety was not an issue (for both the contractor and the workers). This could have led to incidences of skin contamination, inhalation, and ingestion of radioactive materials (including uranium and thorium, as well as radionuclides contained in the raffinate concentrates and its scale/soil that had been resuspension) that were not monitored or recorded, or grossly underestimated. This potential lack of radiological control and monitoring for 1967 is illustrated by quotes from the WSS interviews (SC&A 2009, page 85):

> *The period between 1967 and 1969 should especially be considered for dose reconstruction. One WS site expert has been in contact with a construction worker who was on site from 1967–1969. At the time, Thompson-Stearns-Rogers (TSR, Inc.), based in Denver, Colorado, was the prime contractor at the site. This*

> *company was a merger of Stearns-Rogers (Denver) and Thompson (St. Louis). There were about 300 construction workers, hired out of the local labor market, working at the WS site during that period.*
>
> *The worker who provided information to the WS site expert worked in several former uranium production buildings.* [The EE's] *job was to dig up the brick floor and replace it with a concrete floor. Part of the job involved washing down the area. The worker indicated that yellow cake would trickle down between the bricks and stay there. They had to beat the bricks up to get them out. In the process, they found chunks of yellow cake, which they handled with bare hands. The T-S-R workers put in a concrete floor with an extra layer of concrete.*
>
> *The workers digging up the bricks were dressed in regular clothes with boots. Initially, boots were left on site, but later, they could be taken home. In the same area, some people were dressed in protective gear with masks (i.e., moon suits). The worker thought these people were monitors; sometimes they would take* [the EE] *out of the building and tell* [the EE] *to stay out. The individuals in the "moon suits" and the employees working on the bricks were in the same area (breathing space). There was little communication between the workers and the monitors. The worker's descriptions seemed to reflect that the operations were monitored, but the WS site expert did not know what company would have employed the monitors.*
>
> *The worker had worn a film badge on* [the EE's] *chest, although the exposure source* [the EE] *encountered was on or under the floor. The worker did not recall any bioassay having been done for* [the EE], *and* [the EE] *did not receive a dose report based on* [the EE's] *film badge reading.*

SC&A analyzed claims for workers that were employed at the WSS through 1967. It was found that some of the claimants' DOE records listed film badge and/or bioassay results for the years prior to 1967, but none had any exposure records (film badge or bioassays) for 1967. NIOSH stated in the ER, page 50, that, "The CER database does not include any results for 1967, nor does NIOSH have hardcopy urinalysis data for this year."

3.1 SUMMARY OF LACK OF WORKERS' INFORMATION FOR 1967

The inclusion of the year 1967 in NIOSH's ER extends the evaluation of the original SEC-00143 petition for the WSS to an era unlike the production era of the original SEC petition, because the production facility was completely shut down during 1967. Examples have been given where workers were handing uranium by hand while digging up the floors to convert the building for a different use. There was no apparent local MCW and/or DOE administration oversight, health and safety organization, documentation, etc., to direct work practices, control exposures, and to keep records. Therefore, exposure records, bioassays, and environmental data do not appear to be sufficiently available for DR purposes for the year 1967. SC&A could not locate any monitoring data during the review of several claims that covered the 1967 period, and the ER does not include 1967 in any of the data provided. Neither production workers' data nor environmental data from the production era (1957–1966) can be applied to the 1967 time period, because the working conditions, exposure pathways, and potential intakes/external doses were completely different. SC&A recommends that the legal transfer date of the properties (including the WS plant, raffinate pits, and quarry) be determined and documented, and then the 1967 exposures to AEC and/or AEC contractors be addressed.

4.0 INADEQUATE RADON/THORON DETERMINATION FOR MONITORED AND UNMONITORED WORKERS

4.1 RADON

Table 5-2 of ORAUT-TKBS-0028-5 (ORAUT 2005e) describes the potential radionuclide exposure in the different buildings of the WSS. Radon is listed as a source of exposure inside Buildings 101, 103, 105, 403 and 407. However, the recommended approach in ORAUT-TKBS-0028-5 (page 37) to estimate radon doses is based on **environmental** radon concentrations **calculated** from uranium throughput for the areas within 100 meters of the assumed release point, the acid recovery plant stack [see ORAUT-TKBS-0028-4 (ORAUT 2005d), page 19 for details), but not from measurements. There were no radon measurements performed at the WSS during the operating period of 1957–1966, or during 1967, which is the period of the SEC. In ORAUT-TKBS-0028-4 (ORAUT 2005d), NIOSH used a 1985 reference (Meshkov 1986, page 47 of the pdf file) that estimated the radon released by relating it to the uranium throughput per year. In that document, it was estimated that 5k–14.5k MT/year of uranium was processed at the WSS, that the yellowcake contained 70% uranium with 1% radium, that the radon was in equilibrium with the radium, and that all the radon escaped at the acid recovery plant. This resulted in a calculated release of 12–34 Ci/y of radon.

ORAUT-TKBS-0028-4 (ORAUT 2005d), pages 17–19, then uses this 12–34 Ci/y release value, along with the simple dispersion model from NCRP Report 123 of 1996 (NCRP 1996), to derive an average concentration, adding in background radon (11 Bq/m^3), equal to 41–91 Bq/m^3. According to page 17 of ORAUT-TKBS-0028-4 (ORAUT 2005d), the 91 Bq/m^3 concentration would lead to a maximum environmental outdoor dose of 0.087 WLM/y at an intake rate of 2,400 m^3/y, using a radon daughter equilibrium factor of 0.3.

The ER (NIOSH 2010, page 28) used a maximum concentration value of 80 Bq/m^3 (which is 91 Bq/m^3 with the background radon value of 11 Bq/m^3 removed) to derive a maximum environmental outdoor dose of 0.076 WLM/y. On page 57 of the ER, NIOSH used a radon daughter equilibrium factor of 0.5 for indoor calculations and derived a value of 0.13 WLM/y (apparently the value of 1.3 should read **0.13** on page 57 of the ER when considering the surrounding contents).

The NIOSH ER (NIOSH 2010, page 57), ORAUT-TKBS-0028-4 (ORAUT 2005d, page 20), and ORAUT-TKBS-0028-5 (ORAUT 2005e, page 37) recommend the use of an indoor radon-daughter equilibrium factor of 0.5, compared to 0.3 used for outdoors. ORAUT-TKBS-0028-5, (ORAUT 2005e) page 37, states that only a **small fraction was released into the room** during processing, and that **the main concentration in the indoor work areas would be from that drawn back into the room from the environment**; hence, the indoor concentration would be equal to the calculated environmental concentration. Using this approach requires that several assumptions be made, which results in large uncertainties in an already calculated (not measured) value; especially for workers located in **indoor** workplaces.

The data from MCW St. Louis Downtown Site in ORAUT-TKBS-0005 (ORAUT 2005g) have shown that there is no correlation between outdoor and indoor radon concentration. In Table 24 of ORAUT-TKBS-0005 (ORAUT 2005g, page 209), indoor and outdoor radon measurements are listed. Indoor radon measurements in the Scalehouse and outdoor radon measurements in Scalehouse exhaust are reproduced in Table 2 for 1948. The average values for indoor measurements are approximately 4 times greater than the average values for outdoor measurements. The same pattern is observed in the indoor and outdoor measurements presented in other tables in ORAUT-TKBS-0005 (ORAUT 2005g).

Table 1. Comparison of Indoor and Outdoor Radon Measurements for the Scalehouse
(Data from Table 24 of ORAUT-TKBS-0005)

Workplaces	Measured radon concentrations for 1948 in units of 1×10^{-10} Ci/L				
	No. of samples	**Min**	**Med/Mean**	**Max**	**GSD**
Indoor areas					
Scalehouse	21	0.00	4.05	33	
Scalehouse	193	0.03	2.02	32.8	
Scalehouse Sample room	6	0.22	4.10	19	
Scalehouse Sample room	68	0.03	2.84	25	
		Average =	***3.25***		
	Yards and other outdoor areas				
Scalehouse intake/exhaust	3		0.12		2.06
Scalehouse exhaust	18		0.13		3.08
Scalehouse exhaust	1		0.93		
Scalehouse exhaust	24	0	2.2	49	
		Average =	***0.85***		

Ratio of Indoor/Outdoor = 3.25/0.85 ~ 4.

Although not specific to the WSS, this example shows that the assumption of equal radon concentrations in the indoor areas compared to the outdoor areas, as recommended in NIOSH's ER and ORAUT-TKBS-0028-5 (ORAUT 2005e), is not supported by actual measurements.

4.2 THORON

NIOSH addressed thoron (a decay product of thorium with a 55-sec half-life) on pages 28 and 57 of the ER and concludes the following:

> *Given the specific activity of thoron in thorium feed materials, and assuming the feed materials were received with at least a one-year delay since processing, it is possible to calculate the amount of thoron in process per day (approximately 0.3 Ci thoron) during the period of the maximum production rate. By assuming a conservative equilibrium factor for a plant configuration with large buildings and engineered ventilation (0.02), it is possible to determine the concentration of thoron and its daughters to achieve 1 WL* [working level]. *The release fraction (RF) can be calculated by measuring the particulate thorium in the working environment of the process equipment, compared to the inventory amounts in process. The thoron releases are expected to be less than the particulate materials, since the gaseous state will be more easily captured by the ventilation*

systems. Maximizing assumptions can be applied on a case-by-case basis to occupancy factors, release fractions, and diffusion rates.

4.3 SUMMARY OF INADEQUATE RADON AND THORON DETERMINATION

4.3.1 Radon

The outdoor environmental radon concentration was calculated, not measured, and was based on a non-documented point of release. Additionally, ground releases cannot be reliably modeled by a simple dispersion model, especially for indoor exposures. The assumption of equal radon concentrations in the indoor areas compared to the outdoor areas, as recommended in NIOSH's ER and ORAUT-TKBS-0028-5 (ORAUT 2005e), is not supported by actual measurements performed at the Destrahan Street site. These are potential SEC issues for both non-production and production workers, unless NIOSH can propose a more reliable and claimant-favorable approach to assess the radon exposure, especially for indoor operations areas for the WSS.

4.3.2 Thoron

There were no specific measurements for thoron decay products made at the WSS. Therefore, NIOSH recommends a modeling method based on certain assumptions. However, this method is not detailed concerning the procedure to be used and how the values of the variables are tied to the WSS during the operational period. Additionally, there are no provisions for the intake of thoron decay products if thorium was stored onsite before 1963, from the raffinate pits, or from the disposal of thorium in the quarry, since the recommended method would only apply to processed thorium. NIOSH states on page 67 of the ER that there are DWA concentration air monitoring data from the years 1957 through 1966, and that the data (1957–1966) encompass the span of thorium processing at the site. However, the thorium data on page 41 of the ER only cover the period 1963–1966.

5.0 INADEQUATE RECOMMENDATION FOR ASSIGNING RECYCLED URANIUM DOSE

According to the TBD, recycled uranium (RU) was contained in some of the uranium materials received at the WSS starting around 1961.

ORAUT-TKBS-0028-5, page 15, addresses RU at the WSS as follows:

> ***5.2.4 Recycled Uranium***
>
> *The extent of the processing of recycled uranium at WSP is not well known (ORAU 2005b, Section 2.2.3)* [ORAUT 2005b]. *The DR should make the claimant-favorable assumption that all of the uranium processed at WSP **after 1961** was recycled uranium. This assumption is consistent with that in Ohio Field Office Recycled Uranium Recovery Report (DOE 2000b)* [DOE 2000], *which assumed that all uranium receipts at WSP **after 1961** were recycled uranium in lieu of better information.* [Emphasis added.]
>
> *Contaminant radionuclides in recycled uranium that could be dosimetrically significant are plutonium (assume ^{239}Pu), neptunium (^{237}Np), and technetium (^{99}Tc). Site-specific data for the mass fractions of these contaminants are not available. The DR should consider the factors in Table 5-11 of Technical Basis Document for the Fernald Environmental Management Project – Occupational Internal Dose (ORAU 2004a)* [ORAUT 2004]. *These factors, when multiplied by the assessed uranium gram-value intake, result in the activity per gram of uranium of the contaminants at the levels of **100 ppb ^{239}Pu, 3,500 ppb ^{237}Np, and 9,000 ppb ^{99}Tc.*** [Emphasis added.]

The section in Fernald that ORAUT-TKBS-0028-5 is referring to reads as follows:

> *Though the long-term average RU contaminant levels in the plant are below 10 ppb U for plutonium, there are places and materials in the plant that could have provided RU contaminants above these average values. Based upon the preceding facts and conditions, the most technically defensible and claimant-favorable approach to assure that missed internal dose from unmonitored and/or undetected TRU activities (that were present throughout all of the Fernald plants from 1961) were accounted for is to determine the uranium intake and add a ratio of TRU to that intake. Therefore, it would be reasonable and claimant favorable to add 100 ppb U for ^{239}Pu, 3500 ppb U for ^{237}Np, and 9,000 ppb U for ^{99}Tc to the calculated uranium gram value intakes calculated by the dose reconstruction staff from uranium **after 1961**. Table 5-11 lists conversion factors for this approach:* [Emphasis added.]

Table 5-11. PPB conversion factors.

RU Contaminant	*ppb U × (value) = pCi gm^{-1}*	*ppb U × (value) = Bq gm^{-1}*	*ppb U × (value) = dpm gm^{-1}*
Pu-239	*62.89*	*2.327*	*139.6*
Np-237	*0.714*	*0.0264*	*1.59*
Tc-99	*17.15*	*0.6346*	*38.07*

The chemical forms of the RU contaminants are not known, although it is apparent from the chemical processes to which the materials were subjected during uranium processing, a variety of forms would be expected. Hence the dose reconstructor should assume the most claimant-favorable solubility type for the target organ.

And on pages 25–26, the ER states the following:

5.2.1.3 Recycled Uranium

In 1999, DOE initiated the complex-wide Recycled Uranium Mass Balance Project, which identified the Weldon Spring Plant as a site that likely received recycled uranium in relatively small quantities of materials ***after 1961*** *(ORAUT-TKBS-0028-2). The significance of these shipments of recycled uranium is that this material contained trace amounts of residual transuranic elements (including plutonium and neptunium), fission products (such as technetium), and reactor-produced uranium isotopes (such as uranium-236) (DOE, 2000).* [Emphasis added.]

Contaminant radionuclides in recycled uranium that could be dosimetrically significant are plutonium (assume plutonium-239), neptunium (neptunium-237), and technetium (technetium-99). Site records do not include the level of detail needed for an accurate estimate of the amount of recycled material received and processed at the Weldon Spring Plant site. However, greater than 99% (by weight) of the slightly enriched uranium received at the Weldon Spring Plant site was from Fernald (DOE, 2000, p. 1,130). For the purpose of this evaluation, the uranium source term is considered to be:

- *Prior to 1961, natural uranium*
- *1961–1967, recycled uranium.*

For the periods that included recycled uranium, Table 5-6 contains maximum values for the recycled uranium contaminants as a fraction of uranium intake based on material that is likely to have been received by Weldon Spring (DOE, 2000, p. 1,140).

Table 5-6: Maximum Recycled Uranium Contaminant Levels

Contaminant	Average Concentration (ppbU)	Observed Range (ppbU)	Bounding Value[a]		
			ppbU	pCi/µgU	pCi/pCiU
Plutonium	2.9	0.60–15	6.3	3.9E-04	5.7E-04
Neptunium-237	390	5–3,200	1,800	1.3E-03	1.9E-03
Technetium-99	8,600	800–19,000	21,000	0.36	0.53

Note:
[a] Calculated as the 95th percentile of an unblended uranium trioxide PUREX source, assuming a lognormal distribution. This provides the highest values for the two subgroups of recycled uranium likely received by Weldon Spring (DOE 2000).

And on page 65 of the ER, it states the following:

> *7.4.3 Recycled Uranium*
>
> *SEC-00143: The petitioner is concerned that the Weldon Spring Plant site was identified as a site that likely received recycled uranium in relatively small quantities of materials **after 1961**, and site records do not include the level of detail needed for accurate estimates of the amount of recycled material received and processed at Weldon Spring Plant. It is known that the plant received shipments from other DOE sites that processed and shipped recycled uranium, in fiscal years **1962** through 1967, but amounts of recycled uranium versus natural uranium are not known.*
>
> *Response: NIOSH investigated the receipts and processing of recycled uranium at the Weldon Spring site and acknowledges that limited quantities of recycled uranium were received at Weldon Spring for processing. The fact that the quantities of recycled uranium are unknown led DOE to assume, as a worst case, that all uranium received **after 1962** was recycled uranium. DOE acknowledges that this assumption leads to the worst-case quantities of transuranic elements. These quantities do not represent what was actually processed, and in fact, DOE estimates these quantities to be significantly less (0.0 gm* [grams] *of plutonium-239, 12.3 to 15.3 grams of neptunium-237, and 4.9 to 6.1 grams of technetium-99, as compared to the worst case **2.4 grams, 330 grams, and 7,200 grams** of plutonium, neptunium, and technetium respectively). For the purpose of defining the ability to bound dose for the evaluated class in this report, the maximum quantities have been considered as the source term for this evaluation.*
> [Emphasis added.]

SC&A did not locate a DR Guide for the WSS. The DR Guide for the Fernald site, page 1, (ORAUT 2007) only contains the following statement concerning RU:

a. *Recycled uranium was introduced to FMPC in 1961.*

Radionuclide	Scenario 1	Scenario 2	Scenario 3
U-234	F	M	S
Pu-239	M	M	S
Np-237	M	M	M
Tc-99	F	M	M

5.1 SUMMARY OF INADEQUATE RECYCLED URANIUM DOSE ASSIGNMENT RECOMMENDATIONS

SC&A found the year that the dose reconstructor is to start assigning all RU doses from the uranium analysis is not consistent within the documents quoted above. If materials potentially containing RU started to be processed in 1961 at the WSS, then the dates should be consistently stated as "prior to 1961" and "1961 and after," not "after 1961" or "after 1962." Additionally, it has not been verified that the WSS did not receive RU before 1961.

SC&A found that ORAUT-TKBS-0028-5, page 15, recommends that 100 ppb Pu-239, 3,500 ppb Np-237, and 9,000 ppb Tc-99 be added to the intake, based on the uranium intake value. SC&A deciphered the contents of Fernald ORAUT-TKBS-0017-5, Table 5-11, conversion factors as follows:

#pCi Pu-239 = (100 ppb-Pu/U) × (62.89 pCi-Pu/gm-U per 1ppb-Pu/U) × (#gm-U in bioassay)

Where: 1ppb-Pu/U = (1E-9 gm-Pu/gm-U) × (6.21E-2 Ci-Pu/gm-Pu) × (1E12 pCi/Ci)
$\underset{\sim}{}$ 62.89 pCi-Pu/gm-U
6.21E-2 Ci-Pu/gm-Pu is the specific activity of Pu-239.

This is not made very clear in ORAUT-TKBS-0028-5 (ORAUT 2005e), page 15, or ORAUT-TKBS-0017-5 (ORAUT 2004), page 17, but is applicable if used correctly. The same analysis applies to Np-257 and Tc-99. SC&A's review of WSS claims indicates that this method was correctly applied in one of the full DR best-estimate cases SC&A analyzed. However, in several of the DR cases, where the probability of causation was <50% and a full DR should have been performed and the EE worked during the 1961–1966 time period, no internal intakes from RU were assigned. This is technically a DR issue and not an SEC issue, but the oversight during DR may have resulted from lack of clarity in ORAUT-TKBS-0028-5 (ORAUT 2005e).

Additionally, Table 5-6, page 27, of the NIOSH ER lists values not found elsewhere in the documents quoted above; hence, there does not appear to be a consistency between the ER and the TBDs. It is not obvious how the values listed in Table 5-6 of the ER were derived from DOE 2000, why they are lower than the recommended values found in the WSS TBD, and how they are to be applied in the DR process. The reference provided in the ER was DOE 2000, page 1140; however, there is no indication in the ER how the data in Table 1 on page 1140 and the following pages, generated the values listed in Table 5-6 of the ER. SC&A found that a 1964 WSS document (MCW 1964) provided some qualitative analyses of alpha and gamma activities and energy spectra, and comparative external exposure rates of two feed materials sampled in 1964. However, this does not provide quantitative values of Pu-239, Np-237, and Tc-99 by which to derive ppb-U values to compare to the Fernald values, or the values recommended in the ER.

Even if the greater concentration values of 100 ppb Pu-239, 3,500 ppb Np-237, and 9,000 ppb Tc-99 are used, it has not been documented that these values are necessarily correct or bounding. SC&A reviewed the source of these concentration values, which is a document entitled, *DOE Ohio Field Office Recycled Uranium Project Report* (DOE 2000), as referenced in the ER.

However, this document does not provide defined sources for its recommended values of the radionuclide concentrations; therefore, these concentration values appear to be estimates or assumptions, rather than measured values. Because both the WSS TBD and the ER base the RU composition and throughput at the WSS on Fernald RU data, then the Fernald issues are relevant to the WSS issues and, as SC&A has pointed out in their review of the Fernald SEC (SC&A 2007), there are contradictions within the Fernald TBDs, the DOE 2000 document, and the DOE 2003 document; hence, "it is likely that the DOE 2000, which is the basis for the data on RU, is incorrect even for the basic value relating to uranium receipts at Fernald" (SC&A 2007, page 35).

6.0 NEUTRON DOSIMETRY RECORDS NOT AVAILABLE

NIOSH states the following on page 33 of the ER:

> *… those employees that processed the slightly-enriched uranium were assigned special neutron dosimeter badges to be worn in conjunction with their regular film badge dosimeters. Neutron dose results for these Weldon Spring employees have not been located, plausibly because there was no measured neutron dose.*

NIOSH concludes on page 61 that it has considered the potential source of neutrons resulting from alpha-neutron reactions and determined that in the cases where NIOSH needs to apply unmonitored neutron dose for members of the class, it can apply the methods approved in ORAUT-OTIB-0024 (ORAUT 2005h) to support bounding the neutron dose. The applicability of this method will be assessed on a case-by-case basis for individual DRs. Additionally, it states that in the absence of measured dosimeter doses, the primary method for assigning potential neutron dose is in the determination of missed neutron dose, as described in the NIOSH document, *External Dose Reconstruction Implementation Guideline* (OCAS-IG-001).

6.1 SUMMARY OF NEUTRON DOSIMETRY RECORDS NOT AVAILABLE

In the WSS profile review (SC&A 2009), SC&A did not agree with the recommended method in ORAUT-TKBS-0028-6 (ORAUT 2005f) concerning using a one-time measurement at Fernald to assign neutron doses at the WSS. Additionally, SC&A does not find that there is sufficient information available for WSS workers to assign neutron doses based on the worker's location/job function, and/or that assigning neutron dose based on missed dose is technically correct, because missed dose can only be assigned if the badge reading is available and the recorded reading was less than ½ the lower limits of detection. This is a situation where exposure could have occurred, but no recorded dose data are available.

7.0 QUARRY AND RAFFINATE PITS EXPOSURES INADEQUATELY ADDRESSED

NIOSH states on page 28 of the ER that radon measurements in the quarry area in the late 1970s and early 1980s (before remediation) averaged 0.65 ± 0.41 pCi/L, indicating that the quarry was not a major source of radon, and that as in the case of the raffinate pits, this value would be limiting for the operational period. NIOSH also states the following on page 28 of the ER:

> *Prior to 1963, the quarry only contained drummed thorium wastes that were likely submerged and not a significant source of radon. In 1963 and 1964, an estimated 38,000 m^3 of uranium- and radium-contaminated rubble, equipment, and soil were placed in the quarry following demolition of the Destrehan Street site, with a majority of this waste not submerged, providing a potential source of radon exposure (Unknown, 1967; ORAUT-TKBS-0028-4). Measurements in the quarry area in the late 1970s and early 1980s (before remediation) averaged 0.65 ± 0.41 pCi/L, indicating that the quarry was not a major source of radon (Meshkov, 1986, p. 101). As in the case of the raffinate pits, this value would be limiting for the operational period.*

On page 56 of the ER, NIOSH states the following:

> *Measurements of the activity concentrations in Raffinate Pits 1, 2, and 3 can be used to determine the relationship between thorium-230 and other impurities during the initial uranium processing in Building 101 before any separations occurred. The shorter-lived decay products for which no raffinate measurements were made (e.g., lead-210 and polonium-210) can be assumed to be present at the same activity as their radium-226 parent in the mill concentrate feeds. The other uranium streams (e.g., recycled uranium) had been previously processed and contained essentially no thorium. Table 7-4 gives the results of a statistical analysis of raffinate pit measurements. The data were taken from the 1989 Waste Assessment Radiological Characterization of the Weldon Spring Site Raffinate Pits (MK-Ferguson, 1989).*

NIOSH assumes that measurements made in later years would bound the operational years, because the ingrowth of decay products would be greater as time progressed.

7.1 SUMMARY OF QUARRY AND RAFFINATE PITS EXPOSURE ISSUES

SC&A agrees that the ingrowth of decay products would increase as a function of time. However, the exposure conditions were not necessarily the same during the operational phase as during the later years at the WSS. The quarry and raffinate pits were actively being used during the operational period, with radioactive materials being dumped into them, but were idle during the following years when the measurements of constituents, air samples, and external doses were performed. The difference in physical and chemical compositions and usage negates the extrapolation of the later measurements to the operational era without at least some minimal comparison measurements to validate such extrapolations. For example, how do the values obtained in later years compare with those found in the Mason document of 1958 (Mason 1958)? While the intakes and external exposures for unmonitored workers may be bound by the data from monitored workers in the plant, workers exposed to the raffinate pits and quarry have no counterpart for dose assignment if they were not monitored for external exposures or bioassayed for the specific radionuclides present in these locations.

8.0 INSUFFICIENT INVESTIGATION & DOCUMENTATION OF OFF-NORMAL SITUATIONS AND ACCIDENTS/INCIDENTS

NIOSH states on page 33 of the ER that the Health and Safety Division maintained annual logbooks of forms and memos for employees with high urinary uranium concentrations. Investigation reports were also included in the logs (for Action Level 2 exposures and above). Descriptions of the data forms in Table 5-10 of the ER are included to demonstrate Weldon Spring's management of and response to high bioassay results.

And on page 66 of the ER, NIOSH states the following:

> *NIOSH has conducted a thorough investigation into documentation that gives no indication of significant accidents or incidents at the facility. While several events were identified through document searches and interviews with former workers, there were no indications of events that could have resulted in exceptionally high personnel exposures or exposures that are not already accounted for within the data in the available records.*

8.1 SUMMARY OF INSUFFICIENT INVESTIGATION

The issue to be addressed is not if **identified** high levels of exposures were investigated; normally these would have been investigated under the direction of the AEC. Instead, it is the off-normal situations and accidents/incidents that were not sufficiently identified at the time as radiological events.

Off-normal Situations – An area not addressed by either the ER or the TBDs are exposure potentials not normally encountered in routine operations at the plant. For example, WSS workers transported material and spent some time at the MCW St. Louis site, the quarry where Destrehan Street material was dumped, and the airport site; were these workers appropriately monitored? Another example is the workers that transported and handled the material sent to the Bevatron; were they appropriately monitored? How were exposures from episodical plant releases accounted for?

Accidents/Incidents – During onsite interviews with former WSS workers, the subject of accidents/incidents was often brought up, with the concern that MCW did not identify and document radiological events sufficiently, either through lack of knowledge of the radiological hazards or as a manner of policy at that time. SC&A's preliminary investigation of several cases indicates that the accidents described by former workers were not evident or were not recorded sufficiently in the workers' DOE files. For example, a serious furnace accident occurred in 1960; however, the only mention of it in the worker's DOE records was a couple of brief sentences describing the **medical** aspect of the worker's complaints; no investigation into the radiological aspect of the accident was evident. There was no other documentation of the accident in the worker's files that SC&A could locate. Another serious accident apparently occurred in 1961; the only reference in the worker's DOE file was an entry in the "PERSONAL MONITORING SUMMARY RECORD," which stated that "Data included in Feb. Accident File." There was no other record of it in the worker's DOE records. Fortunately, this accident was written up in a MCW report and the dose reconstructor evaluated the dose received from the accident during the DR process. However, this may not always be the case.

9.0 GEOMETRY AND EXTREMITY ISSUES NOT ADDRESSED

NIOSH states in the ER (page 67) that the petitioner's concerns of a lack of a documented badging policy with geometry correction factors were among several broad statements that were the basis for qualifying the petition. NIOSH stated that these concerns resulted in the evaluation of the petition for the Weldon Spring Plant, and that NIOSH's response to these concerns were encompassed in the ER. However, SC&A could not find that the ER or ORAUT-TKBS-0028-6 (ORAUT 2005f) addressed these issues.

9.1 SUMMARY OF GEOMETRY AND EXTREMITY ISSUES

The problems associated with handling uranium material [contact work as stated on page 20 of ORAUT-TKBS-0028-6 (ORAUT 2005f)] close to the body/hands and having the dosimeter badge located on the chest area was not addressed in the ER, ORAUT-TKBS-0028-6 (ORAUT 2005f), or other WSS documents. A film badge does not register the same dose as the worker's tissue/organs are receiving from the beta and low-energy photons when handling, machining, scooping, etc., uranium-containing materials. For example, a 1958 (MCW 1959) office memo illustrates the fact that the shielding on a lathe greatly affects the beta dose measured; i.e., decreases it from an average of 122 mrep/hr to 0 and Table I of that document lists non-trivial beta doses as high as 10,000 to 35,000 mrep/hr (mrep ~ mrem). Therefore, any material/distance between the beta source and the badge on the worker's chest that is not between the beta source and the worker's trunk area will cause an under-response in the recorded dose.

Compounding the geometry issue is the fact that there does not appear to have been any extremity monitoring at the WSS, which, as indicated above, was needed. Contrary to the ER statement, neither the ER [nor ORAUT-TKBS-0028-6 (ORAUT 2005f)] addressed the geometry or extremity issues. This issue has been encountered at other AEC/DOE sites and should be investigated in conjunction with methods recommended for other sites.

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