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ADVISORY BOARD ON RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

REVIEW OF THE NIOSH SITE PROFILE FOR ALLIED CHEMICAL CORPORATION PLANT, METROPOLIS, ILLINOIS

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ABBREVIATIONS AND ACRONYMS

ACCP	Allied Chemical Corporation Plant
AEC	Atomic Energy Commission
AWE	Atomic Weapons Employer
cm^2	square centimeter
dpm	disintegration per minute
CATI	Computer-Assisted Telephone Interview
DCAS	Division of Compensation Analysis and Support
DCF	dose conversion factor
DOE	U.S. Department of Energy
FMPC	Feed Materials Production Center
HHS	Health and Human Services
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron volt
MCNP	Monte Carlo N-Particle Transport Code
MeV	megaelectron volt
NOCTS	NIOSH OCAS Claims Tracking System
µg/l	microgram per liter
mrem/hr	millirem per hour
NIOSH	National Institute for Occupational Safety and Health
NRC	Nuclear Regulatory Commission
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
OSHA	Occupational Safety and Health Administration
pCi/ µg	picocurie per microgram
POC	probability of causation
rem/hr	roentgen equivalent man per hour
SEC	Special Exposure Cohort
SRDB	Site Research Database
TRU	transuranics
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
$U_3 O_8$	triuranium oxide

1.0 INTRODUCTION

On February 1, 2006, the National Institute for Occupational Safety and Health (NIOSH) issued ORAUT-TKBS-0044 (ORAUT 2006a), which provides data and guidance for dose reconstruction of workers at the Allied Chemical Corporation Plant (ACCP), in Metropolis, Illinois. The facility was also known as the "General Chemical Division," "Allied Chemical and Dye," and the "Allied Signal Metropolis Plant." The facility was later purchased by Honeywell. Subsequent to authorization to proceed with the review of that document, the NIOSH Division of Compensation Analysis and Support (DCAS) issued a revised site profile on October 1, 2007 (ORAUT 2007). This report presents a review of the revised site profile.

The U.S. Atomic Energy Commission (AEC) stated the following in one of its 1957 reports (AEC 1957, p. 9):

> *On February 4, 1957, the Allied Chemical and Dye Corp. announced selection of Metropolis Ill., as the site of its plant to process 5,000 tons of U_3O_8 a year under contract with the Commission. The plant will produce uranium-hexafluoride feed for the nearby Paducah, Ky., gaseous diffusion plant.*

The period of AEC operations at ACCP in Metropolis, Illinois, from January 1, 1959, to December 31, 1976, involved AEC-contracted conversion of uranium ore concentrates (primarily U_3O_8) to uranium hexafluoride (UF_6). Commercial uranium conversion operations continued after the completion of the AEC contract. However, it is assumed that there was some residual contamination at the facility after 1959 remaining from Atomic Weapons Employer (AWE) operations, contamination that was difficult to distinguish from contamination resulting from commercial activities. Hence, the site profile is concerned with radiation exposures experienced by workers during AWE operation, and also from residual radioactivity following the termination of AWE operations and the commencement of commercial operations, which continue to the present.

As will be discussed in greater detail below, the uranium ore concentrates that were received at ACCP for processing contained variable amounts of residual Ra-226 and Th-230, which were not entirely removed from the original ore in the process of separating out the uranium from the ore. Because of the variable concentration of these radionuclides in different batches of concentrates (also referred to as yellowcake or U_3O_8) delivered to the facility, and the finding that the Ra-226 and Th-230 are separated and concentrated in various uranium chemical conversion and purifications steps associated with converting U_3O_8 to UF_6, there were sources of residue that contained elevated concentrations of Ra-226 and Th-230, similar to raffinates that are produced at facilities that process ore, but at a much reduced level. Nevertheless, the presence of the reconcentrated Ra-226 and Th-230 in residue makes it difficult to reconstruct worker doses, because bioassay and air sampling programs at that time emphasized uranium and not Ra-226 and Th-230. Because of these challenges to dose reconstruction, NIOSH determined that **internal dose from non-uranium radionuclides cannot be reconstructed with sufficient accuracy** for ACCP employees who worked at the facility from 1959 through 1976, and a Special Exposure Cohort (SEC) for ACCP employees was designated by the Secretary of Health and Human Services (HHS) in February 2007 (Leavitt 2007). As such, the site profile and this review of the site profile is concerned primarily with reconstructing the external and internal radiation doses to workers during the AWE operations period from uranium compounds, and also the doses to workers during the residual period from all radionuclides. As will be discussed, the site profile provides methods for bounding the doses not only from uranium, but also from Ra-226 and Th-230 during the residual period.

The method used to organize our review is in accordance with the way in which the site profile is organized, namely site description and operational history, internal exposure, external exposure, and residual radioactivity. The report concludes with a section on overall data adequacy that has applicability to all sections of the report.

2.0 SITE DESCRIPTION AND OPERATIONAL HISTORY

The site description and operational history is extremely thorough, well researched and documented, and well written. However, SC&A has a few observations that are worth mentioning.

2.1 Source Term Description

The fifth paragraph in Section 2.3 of the ACCP site profile, "Source Term," states the following:

> *The reported concentrate ratio was based on an average of yellowcake feed ratios from 33 mills (Perkins 1982, Table II-8).*

However, the statement made in the footnote to Table II-8, "Summary of Environmental Air Monitoring Results in 1979," is as follows (Perkins 1982, p. 24):

> *The licensee analyzed only the air samples at stations No. 6, 8, and 11 for ^{226}Ra and ^{230}Th. Analysis of air samples showed the ratio of ^{230}Th to natural uranium to be much higher than the yellowcake feed average over 33 mills (^{230}Th/U-natural = 0.0052).*

Thus, the Perkins report does not state that the feed into the ACCP facility is from 33 mills, but rather that the effluent ratios are higher than the average of 33 mills.

Observation 1: The statement that the concentrate ratio is based on the average of the output from 33 mills is unsubstantiated by the reference (Perkins 1982).

Notwithstanding the above misstatement, the source term for the ACCP site profile is exclusively based on the data presented in the Perkins document. In this document, the data presented are from the 1970s and the "Report Objectives" (Perkins 1982, p. 2), which states the following:

> *As part of the evaluation of effluents/wastes relating to the commercial nuclear fuel cycle, the objectives of this report were to determine the process discharge streams produced by the UF_6 conversion facilities, to determine how these streams are presently treated, to collect any publically* [sic] *available emission and monitoring data, to identify the final fate of these wastes, and to assess the adequacy of present waste treatment/disposal techniques and available data.*

Thus, the data presented in the report have been processed and summarized for discussing environmental control of emissions, not for dose assessment/dose reconstruction. In addition, the data are just from the 1970s and may not accurately reflect the ACCP operations in the 1950s and 1960s.

Finally, the Perkins document repeatedly refers back to documents in the Nuclear Regulatory Commission (NRC) archives; however, the ACCP site profile does not appear to have reviewed these documents from the NRC.

Finding 1: The source term is based primarily, if not exclusively, on the reference document (Perkins 1982), with little justification why these effluent data are acceptable for use in dose reconstruction, and why these data can be extrapolated to reflect operations during the 1950s and 1960s.

2.1 SAFETY

In the fourth paragraph in Section 2.4 of the ACCP site profile, "Safety," the following statement is made:

> *Protective clothing and shoes or shoe covers were provided to employees and visitors to ACCP to ensure that personnel were not inadvertently contaminated with uranium compounds as of 1982 (Perkins 1982), and probably from the earliest days of operations.*

SC&A can find no statement in the Perkins document about protective gear, and it is not clear that Perkins ever visited either site discussed in the report. In addition, the above statement contains the phrase, "…and probably from the earliest days of operations." The ACCP site profile provides no justification for the assumption of protective clothing availability in the 1950s through the 1970s. Therefore, this is a back-extrapolation of present-day policies and methodologies to those that were in place during the operational period. Thus, this extrapolation needs to be better supported.

Finding 2: The statement with regards to protective clothing is unsubstantiated by the reference (Perkins 1982), and neither substantiation nor justification is given for the assumption of protective clothing availability in the 1950s through the 1970s.

Section 2.4.1, "Visual Observation of Contamination;" Section 2.4.2, "Air Activity of Contamination;" Section 2.4.3, "Surface Contamination Measurements;" and Section 2.4.4, "Decontamination," discuss procedures and data that are from 1985 or later. While the ACCP site profile does not specifically state that these references from 1985 and later are to be used for the operating period from the 1950s through the 1970s, it implies that that is the assumption to be made.

Of special note is the third paragraph in Section 2.4.3, "Surface Contamination Measurements," which contains the following statement (Wilkins 1992, p. 3 of 6 and p. 4 of 6):

> *One summary of Health Physics data for the last half of 1991 (Wilkins 1992) noted that 1.7% of the 2,002 weekly smears exceeded the weekly limit of 200 dpm/100 cm^2 and that the highest result was 923 dpm/100 cm^2 in the lunchroom on a table. One of the 570 monthly smears and none of the 163 quarterly smears exceeded the limit.*

This again gives the impression that the levels of surface contamination were at reasonable levels from the 1950s through the 1970s. However, SC&A reviewed the CATI reports for ACCP claimants and the following are some of the conditions that the claimants said existed at ACCP (these statements have been paraphrased to assure claimant confidentiality):

- Yellow dust covered equipment and personnel in sampling lab.
- Plant was dusty, paint chips everywhere.
- Majority of the time, you brushed off the ore or green salt and went about your business.
- Protection wasn't stressed in the 1950s and 1960s.
- Contamination levels higher in 1950s and 1960s.
- Worked around green powdery material (green salt), very dusty.
- Very dusty all over facility except powerhouse.
- Feed Building where U was processed was filthy.
- In early days, plant was notified about NRC (AEC?) inspections, big cleanup effort before the visits.
- No safety procedures in 1950s and 1960s. Safety measures improved in the 1970s.
- Before OSHA (NRC?) safety wasn't always a concern.

Finally, the ACCP site profile made no attempt to access documents from the NRC archives that may provide additional information on contamination conditions at the facility.

Finding 3: Statements of contamination/decontamination are based on procedures and surveys that are from 1985 or later. Neither substantiation nor justification is given for the assumption that these procedures and surveys are applicable to the facility in the 1950s through the 1970s. No references were presented for the contamination condition of the ACCP during the 1950s through the 1970s. ACCP claimant statements were not included in the site profile. Therefore, the statements in the site profile on contamination/ decontamination are questionable.

In Section 2.5, "Incidents," the ACCP site profile makes the following statement:

> *The claims include some information about incidents, but details are few and there are no dates or references to particular incident reports. Occasional leaking valves or inadequate packing resulted in material releases.*

However, SC&A reviewed the CATI reports for ACCP claimants, and the following are some of the incidents that the claimants said happened at ACCP (these statements have been paraphrased to assure claimant confidentiality):

- 1960s: bought a cornfield and an orchard due to contamination.
- New process (learning curve) in the 1950s and 1960s equipment malfunctions caused frequent releases.
- Spills/releases occurred frequently in 1950s and 1960s (sometimes up to once a month).

- Spills/releases would cause evacuation of buildings.
- Spill shut down traffic in a 5-mile radius.
- Spill contaminated car windshields. Allied replaced the windshields of several cars.
- UF_6 releases were quite often.
- UF_6 releases minor, 10–12 per year; major, once every 2–3 years.
- UF_6 release like a thick fog, workers trapped in basement.
- UF_4 (green salt) releases.
- Drums stacked outdoors. Some drums would burst open and material would leak into the ground.
- At home—saw yellow cloud coming from the plant.
- Loud boom, became covered in green salt (UF_4), washed off UF_4 from body and washed out UF_4 from mouth.
- U ore dust so thick you could barely see the lights.
- If release was bad enough (i.e., major), the siren was turned on to warn Metropolis.
- When building was evacuated, the NRC would come to investigate.
- NRC would not come for a "puff" release (assumed to mean when detaching a filled UF_6 cylinder – some UF_6 remained in the line, and although vacuum hoses were used, some UF_6 would escape when the cylinder is disconnected); they would only come for an actual release.
- Nearly all areas had leaks (UF_6, UF_4) except powerhouse.
- UF_6, UF_4, U ore, yellowcake spills/releases.
- UF_6 fogs so thick, could barely see the UF_6 building.

The site profile needs to explore these incidents and conditions and determine if the internal and external dosimetry data can be used to reconstruct exposures associated with these incidents and conditions.

As pointed out in Section 3.2 of the site profile, "Notations on Bioassay Records," some bioassay samples are labeled "S," which the site profile assumes means special. According to the CATI reports, additional urine samples were taken after exposure incidents and if a routine bioassay was high. It is likely that such urine samples were labeled "S," and as a result, information about incidents might exist in the bioassay records and should be investigated.

In addition, the site profile does not access files at the state/local government level. This source of information might be useful, because if releases could be seen from outside the facility, the plant siren was activated, and/or roads had to be closed, the state and local governments may have some records of the incidents. Also, such incidents may be documented in the local newspapers.

Finally, the ACCP site profile made no attempt to access documents from the NRC archives that may provide additional information on events/incidents at the facility.

Finding 4: Based on the CATI reports and the "S" bioassay samples, documentation searches of the NRC archive, state/local government records, and local newspaper records need to be undertaken to assess the incidents that have taken place at the ACCP facility.

With respect to Section 2.6, "Physical Examinations—X-Rays," SC&A concurs with the site profile that the assumption that x-ray examinations happened annually is claimant favorable.

In Section 2.7 of the site profile, "Summary Operational Period Assumptions, Workdays, Work Hours, Work Categories," it was decided that determining workdays, work hours, and work categories was unnecessary because of the availability of bioassay and film badge data. While SC&A finds this acceptable for photon and U uptake, it is not apparent that such an approach is acceptable for neutron exposures, which need to be estimated from workdays, work hours, and work categories.

SC&A reviewed the CATI reports for ACCP claimants and the following are some of the information that claimants provided with respect to work hours at ACCP (these statements have been paraphrased to assure claimant confidentiality):

- 40+ hours per week were routine, with some workers working up to 80 hours per week.
- Since operation was 24/7, during strikes, non-union personnel would live on-site and run the plant.

Work hours will be further discussed in Section 5.0 of this review with respect to neutron exposure.

3.0 INTERNAL EXPOSURE

In Section 3.0, "Estimating Internal Exposure," the ACCP site profile reiterates the information from Section 1.0 with regards to the SEC and thus states that only uranium will be evaluated with respect to internal exposure. SC&A concurs with this assessment.

Section 3.1, "Uranium," discusses isotopic fractions and lung absorption types. SC&A concurs with this discussion.

The site profile also explains that virtually all workers during the covered period were under a bioassay program that included periodic urine analyses of all workers using fluorometric analyses, including some chest count data that can be used to verify the results of the urine analyses. Because of the comprehensive nature of the bioassay program, the site profile states that it was not necessary to develop a coworker model. In order to confirm this statement, we tried to access the data in the Site Research Database (SRDB); however, we were unable to find an electronic database for Allied Chemical. As a result, we reviewed the statements made by NIOSH by performing a semi-random sample of claimant hardcopy records (see Appendix A). Overall, SC&A examined the records of 62 claims (60 completely random, and 2 extra to assure that the major job types were covered). The results are quite favorable, as follows:

(1) Only one worker had no uranium analyses; however, this worker was only on site for 6 months at the very beginning of the operational period.

(2) The sampling schedule appears to be monthly for most years and workers; however, if there was a generally high result (arbitrarily chosen by SC&A as greater than 40 µg/l), the sampling schedule was shortened to around 2 weeks. If the sample was exceptionally high, re-sampling often occurred within a few days.

(3) Over 95% of the worker-years examined had uranium analyses; over 77% of the claimants examined had uranium monitoring in every single year they were employed during the operational period.

SC&A concludes that the uranium bioassay monitoring was comprehensive and had a focus on workers with higher exposure potential.

The site profile also states that only natural and perhaps depleted recycled uranium was received and processed at the facility during the covered period. As a result, the specific activity of 0.683 pCi/µg of uranium was employed. We concur with this value, which applies to natural uranium. However, the site profile mentions the possibility that a small amount of recycled uranium might have been shipped to ACCP from Rocky Flats. Given the potential for high levels of contamination with transuranics (TRU), with very high dose conversion factors (DCFs), at least a semi-quantitative assessment of the possible impact of such contamination should have been performed.

Finding 5. The site profile should include a discussion of the impact of any recycled uranium that may have been processed at the facility.

The site profile goes on to state that, since the facility worked with U_3O_8, UF_4, and UF_6, it is possible the chemical form of the uranium intake could have been Type *S*, *M*, or *S*, and, as a result, the dose reconstructor is to assume the form that is limiting for the organ of concern. We concur with this claimant-favorable strategy.

4.0 EXTERNAL EXPOSURE

Section 4.0 of the ACCP site profile, "Estimating External Exposure," discusses penetrating exposure (photon energies of 30 keV or greater), non-penetrating exposure (photon energies of less than 30 keV or electrons), and neutron exposure (neutron energies of 0.1 to 2 MeV).

The site profile explains that, during the AWE period, all workers were badged for photon exposures and non-penetrating exposures using film badge dosimeters. SC&A reviewed the film badge data and concurs that most if not all workers were badged, and that the assumed energy ranges of exposure and the badge limits of detection are reasonable. However, SC&A has some concerns with the neutron exposure discussion.

With respect to neutron exposures, the site profile explains that the doses are based on calculations of the alpha,n reaction associated with UF_4 and UF_6, which, in principle, is a scientifically valid strategy for estimating potential neutron exposures. In the last paragraph of Section 4.0, the site profile explains and makes the following statement about the derived neutron doses:

> *A reasonable neutron dose estimation which is favorable to the claimant is based on a 500-pound drum that contains 75% by mass of natural uranium. It is assumed that the alpha particles collide with a fluorine target. Using the method described in* [ORAUT 2005a]*, the neutron dose is 3.28E-04 rem/hr, calculated at 1 foot from a drum. A worker who is 1 foot from such a drum for 2,000 hr/yr would be exposed to a dose rate of 6.56E-01 rem/yr. This document considers this estimated neutron dose rate to be an upper bound (maximum estimate) of the ACCP neutron dose rate. The mode neutron dose rate is estimated as 5.47E-03 rem/yr, which is the result of applying an occupancy of 3 hours/week over 50 weeks to the estimated dose rate at 3 feet from a drum [5]. The minimum neutron dose rate is estimated as 0 rem/yr. These estimated minimum, mode and maximum neutron dose rates are to be used only for reconstructing doses during the listed operational period, and applied in IREP as a triangular distribution. During the residual period, the weapons-related source materials (uranium, fluorine targets) needed to produce neutrons are not presumed to be present in amounts significant enough to warrant the estimation of neutrons.*

This exposure rationale is based on ORAUT-OTIB-0024 (ORAUT 2005a) (see Appendix B for a summary of SC&A's findings associated with the review of this procedure) and on callout [5], which refers to the following statement that is provided in Section 6.0 of the site profile, "Attributions and Annotations:"

> *Olsen, Bernard M. MJW Corporation. Senior Health Physicist. August 2007. Surveys of UF_6 storage cylinders more enriched than those at Allied Chemical, and studies of work practices in moving those cylinders, have been made at the Portsmouth Gaseous Diffusion Plant, as described in ORAUT-2006d* [ORAUT-TKBS-0015-6 (ORAUT 2006b)]. *It was estimated in ORAUT-2006d that a worker would take on average 3 hours/week, for 50 weeks in a year, to*

transport these cylinders, and that the average neutron dose rate to the worker would be that at approximately 1 meter from the cylinder surface. The upper bound neutron dose rate developed in Section 4.0 is 3.28E-04 rem/hr at 1 foot from the cylinder. At 3 feet from the cylinder, the neutron dose rate would be estimated at 3.28E-04 rem/hr [(1 ft)^2/(3 ft)^2], or 3.64E-05 rem/hr. The average neutron dose rate, applying the 150 hr/year occupancy methodology of ORAUT-2006d (3 hr/wk for 50 wk/yr), is 5.47E-03 rem/yr.

The neutron dose rates cited above are not scientifically correct, for the following reasons:.

- In an earlier report, SC&A (2007) calculated the dose rate at a distance of 1 m from a 55-gal drum filled with UF_4 to be 0.015 mrem/h. We wish to compare this calculated dose rate to the dose rate of *3.64E-05 rem/h* (0.036 mrem/h) at 3 ft, listed in the site profile. If we were to employ the inverse-square law, the methodology in the site profile, the value of 0.036 mrem/h at 3 ft extrapolates to 0.030 mrem/h at 1 m. Hence, the value reported in the site profile is twice the value calculated by SC&A (2007) (i.e., 0.030 mrem/h vs. 0.015 mrem/h at 1 meter). We note that SC&A (2007) employed the SOURCES-4C code developed by Los Alamos National Laboratory to estimate the neutron spectrum, and the MCNP code to calculate the dose rate based on that spectrum, both state-of-the-art physics-based computer codes. Furthermore, we note that the inverse-square law applies only to point sources in a vacuum; the dose rate near a large object, such as the drum, decreases more slowly with distance. Thus, the discrepancy between the SC&A calculation and the site profile is even greater. The SC&A (2007) calculation was based on a drum containing ~1,500 lb UF_4, rather than 500 lbs that was cited by NIOSH, indicating an even greater overestimate in the site profile.

- Using the inverse-square to extrapolate the dose rate at 1 ft to 3 ft is incorrect for a drum at such close distances, and would lead to a gross underestimate at the greater distance, assuming that the dose rate at 1 ft was correct.

The site profile makes the assumption that the work practices at Portsmouth (ORAUT 2006b) are equivalent to the work practices at Allied Chemical (ORAUT 2007). There are reasons to believe that the practices differed, as follows. Essentially, Portsmouth receives UF_6, enriches UF_6, ships enriched UF_6, and ships/stores depleted UF_6. Portsmouth does not do any chemical processing of UF_6, while Allied Chemical was responsible for turning U_3O_8 into UF_6. Therefore, while it is probably acceptable to just consider the neutron doses emanating from the UF_6 cylinders for Portsmouth workers, it may not be appropriately applied to Allied Chemical, where UF_4 (green salt) was first manufactured in vessels, then the green salt was converted to UF_6 in other vessels, and then transferred to the UF_6 cylinders. That said, the neutron flux from UF_6 is ~2.5% higher than from UF_4, per unit mass of the compound, which is not a significant difference.

The site profile assumes 3 hours per week neutron exposure, which is inadequate for Allied Chemical workers. A review of the CATI documents shows that Allied Chemical workers routinely worked 40+ hours per week in the manufacture of UF_4 and UF_6, with some working as much as 80 hours per week. Many ACCP workers could have been exposed to neutrons for their entire shift, depending on their work assignments and/or locations. Also, in the event of a strike (and there were several at the facility), salaried workers stayed on site at the facility 24/7 in order to maintain UF_6 production. Thus, during a strike, these workers received a larger neutron dose.

Finding 6: The assumptions for neutron exposure do not appear to be claimant favorable. The assumptions are based on ORAUT-OTIB-0024 (ORAUT 2005a), which NIOSH has determined needs to be revised to reflect a work-hour exposure rate that, at a minimum, is an order of magnitude too low, and workplace conditions that do not match the conditions/ configurations/processes of the ACCP workplace. Since this plant produces UF_4 and UF_6, and these materials are in significant quantities throughout the facility, the validity of any dose reconstruction that results in a POC that is under 50% is questionable until an acceptable neutron dose can be incorporated into the ACCP site profile and into any affected dose reconstruction.

SC&A concurs with the discussion in Section 4.1, "Occupationally Required Medical X-Ray." SC&A's review of the CATI reports provides sufficient evidence that it is reasonable to assume that workers received annual required medical x-ray exams. SC&A further agrees that the use of ORAUT-TIB-0006 (ORAUT 2005b) is claimant favorable.

In Section 4.2, "Miscellaneous Information about External Dose," the site profile discusses the possibility that those workers who handled fluorination bed ash could receive significantly higher doses on their extremities than measured by the dosimeters carried on the trunk of their bodies. However, the site profile provides no guidance on how the dose reconstructor is to calculate this exposure. Without guidance, inconsistent methodologies could be used that could result in dose reconstructions that are not claimant favorable.

Finding 7: No guidance is provided for the dose reconstructor to calculate extremity exposure for those workers who handled fluorination bed ash. Without guidance, inconsistent methodologies could be used that could result in dose reconstructions that are not claimant favorable.

With the exception of the neutron exposure, which has been previously discussed, SC&A concurs with the summary presented in Section 4.3 of the site profile, "Occupational External Dose Reconstruction Assumptions and Summary."

5.0 REVIEW OF EXPOSURES DURING RESIDUAL PERIOD

The residual period extended from January 1, 1997, to the present, a time period when workers experienced exposures associated with commercial uranium processing and exposures associated with residual radioactivity from AWE operations. It is noteworthy that Section 5 of the site profile states that exposures to residual uranium, Ra-226, and Th-230 from AWE operations can be reconstructed during the residual period based on (1) personnel monitoring during the residual period, (2) knowledge of the radionuclide activity ratios in relation to uranium based on reported activities in ACCP concentrates, wastes, air, and effluents, as provided in Table 2-1 of the site profile and in Attachment A, "Application Of Residual Dose Factors," of the site profile, and (3) assumptions regarding the rate at which AWE residual contamination declined during the residual period.

5.1 INTERNAL EXPOSURES

Since uranium bioassay data are available for all workers in 1977, it appears that the site profile assumes that the intake of uranium for 1977, as derived using the bioassay data for individual workers in 1977, is all due to the inhalation of resuspended uranium that was residual from the AWE period. The intake rate of all other radionuclides is based on the ratios in Table 1.

Table 1. Source Term Activity Ratios Relative to Uranium

U-Natural	1
Th-232	0.076
Th-230	0.167
Th-228	0.076
Ra-226	0.00846
Pb-210	0.00846
Po-210	0.00846

Note: Based on the largest reported ratio in relation to uranium in Table 2-1 of the site profile, excerpted directly from Table 5-1 of the site profile

Table 5-1 of the site profile omits Ra-228, the first daughter of Th-232. Since Th-228 is assumed to be in equilibrium with Th-232, Ra-228 should be included as well. Otherwise, SC&A has determined that this basic strategy for deriving the intake rates of radionuclides for 1977, the first year of the residual radioactivity period, is scientifically sound and claimant favorable. We recognize that one could reasonably question whether the intake rate of non-uranium radionuclides can be derived in this manner. However, it would seem that the ratios of these radionuclides as observed in various waste streams is a reasonable approximation of what one would expect in the residue during the residual period. SC&A acknowledges that this is very much a judgment call, but since the site profile elected to use the highest of these observed ratios, we find this strategy appropriately claimant favorable. Notwithstanding this conclusion, we refer the reader to Section 6 of this report, where we discuss the fact that extensive data are available from the Atomic Energy Commission (AEC) docket that might provide additional useful information on the mix of radionuclides and should be consulted.

SC&A does have concerns with respect to the rate at which these intake rates are assumed to decline with time during the residual period. Specifically, as indicated in Table 5-2 of the site profile, in 1978, the intake rates of these radionuclides are assumed to decline by a factor of 0.03 compared to 1977, and for all subsequent years, the intake rates for these radionuclides are 0.0007 the 1977 intake rate. The site profile cites a number of papers that describe the rate at which resuspension factors have been observed to decline and concludes that, for indoor environments, the guidance adopted in ORAUT-OTIB-0004 (ORAUT 2006c)is applicable here; specifically, it is assumed that the rate at which the resuspension factor declines is 1% per day. This issue, i.e., the rate at which exposures associated with the residual period decline, has been discussed extensively by the Subcommittee on Procedures Review as part of SC&A's review of ORAUT-OTIB-0070 (ORAUT 2008) and the Norton site profile. Agreement has been achieved, in principle, with NIOSH, the Subcommittee on Procedures Review, and SC&A that the 1% per day assumption needs to be revised, since there is empirical evidence that the rate of decline of residual radioactivity is much slower and may get progressively slower with time.

Finding 8: NIOSH should revisit the rate of decline factors provided in Table 5-1 of the site profile in light of the new information under development by NIOSH regarding the 1% per day issue.

5.2 EXTERNAL EXPOSURES

The site profile explains that external exposures during the residual period are based on the results of external dosimetry performed on all workers during that time period. This is an extremely claimant-favorable (to the extent that it might not be plausible) assumption, because it includes exposures from residual contamination plus exposures from ongoing commercial operations. A more plausible approach would be to assume that the external exposures associated with 1976 dosimetry decline at a realistic rate for normal depletion of deposited radioactivity. One could argue that the current approach is certainly claimant favorable, but it also could be argued that such claimant favorability should also be granted for the residual period at other sites.

Finding 9: The external exposures assigned to workers during the residual period appear to be implausibly high.

6.0 REVIEW OF DOCUMENT ADEQUACY

In reviewing the ACCP site profile, SC&A has determined that the document has several general deficiencies, which are discussed in this section.

6.1 INADEQUATE DOCUMENT RESEARCH

From its inception, ACCP was a commercial facility licensed by the AEC (later the NRC). Thus, ACCP was required to apply for a materials license. Submittals and correspondence to/from ACCP to the AEC/NRC are part of the public record; this record resides in the NRC archives and is accessible. The documents for any licensed facility are filed by Docket Number, which for ACCP is 40-3392. Even though this docket number appeared in several references of the Perkins report (Perkins 1982, p. 30); in NRC License SUB-526, Amendment 10 (NRC 1993); and in NRC License SUB-526, Amendment 15 (NRC 2003), there is no apparent attempt to obtain additional information from the NRC.

In addition, based on many incidents outlined in the ACCP CATI reports, not only should the NRC archives have been accessed, but also state and local government files and the local newspaper archives for additional information.

Finding 10: The document research for the ACCP site profile is inadequate and needs to be reinstituted to provide additional documentation and data for the site profile, including data available from the AEC docket for this facility.

Observation 2: In the references for the ACCP site profile (ORAUT 2007), the reference "NRC 1993" erroneously labeled as "Amendment 15," is actually Amendment No. 10.

Finding 11: The site profile needs to be revised to provide a more thorough exploration of incidents cited in the CATI reports.

The figures provided are of poor quality. Figure 2-1 from the Perkins report (Perkins 1982, p. 3) is partially illegible and a half page in the site profile (it's a full page in the Perkins report). In addition, the copy in the SRDB is of poor quality. SC&A went to the Department of Energy (DOE) Information Bridge (http://www.osti.gov/bridge/), typed in the Los Alamos document number LA-9397-MS (Perkins 1982, Cover Page) and a much more legible copy of the Perkins report was available for download. Finally, Perkins most likely obtained this plot plan from one of the NRC documents referenced in the report. Thus, an even better quality figure is available. When the site profile is revised, a much cleaner plot plan should be provided and it should take an entire page.

Figure 2-2 is from the NRC license (NRC 2003, p. 9-18), and since this is a simple diagram, it could have been redrawn for better clarity; and again, in the revised site profile, it should take an entire page.

Observation 3: Any revision of the site profile should contain more legible figures.

7.0 REFERENCES

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ORAUT 2007. *Site Profile for Allied Chemical Corporation Plant*, ORAUT-TKBS-0044, Rev. 01, Oak Ridge Associated Universities Team (ORAUT), Cincinnati, Ohio. October 1, 2007. [SRDB Ref ID: 35196]

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SC&A 2007. "Review of the Feed Materials Production Center (FMPC) Special Exposure Cohort (SEC) Petition-00046 and the NIOSH SEC Petition Evaluation Report," SCA-SEC-TASK5-0056, SC&A, Inc., Vienna, Virginia, and Saliant, Inc., Jefferson, Maryland. May 31, 2007.

Wilkins, C.W., 1992. "Semiannual Health Physics Data Review (July 1991–December 1991)." Allied Chemical Corp. March 30, 1992. [SRDB Ref ID: 12374, p. 58]

APPENDIX A: ANALYSIS OF URANIUM URINALYSIS RECORDS FOR THE OPERATIONAL PERIOD (1959–1976)

In order to determine the scope of uranium monitoring at the Allied Chemical Corporation Plant, SC&A compiled uranium urinalysis data for 62 claimants who were employed during the operational period (1959–1976). This represents over one-third of the total number of claimants contained in the NIOSH OCAS Claims Tracking System (NOCTS) for the site. Of the 62 claimants, 60 were chosen purely at random; the additional 2 claimants were chosen to assure that all major job classifications were captured in the sample set. The breakdown by job classification for the group of 62 claimants is shown in Table A-1, along with the total number of workers in each category contained in NOCTS. As seen in Table 1, the job classifications of 'Operator,' 'Chemist/Lab Tech,' and 'Maintenance/Mechanic' made up the majority of claimants surveyed, so the analysis likely covers the workers with the highest exposure potential.

Table A-1. Overview of the Job Classification for Claimants Selected as Part of the Test Sample

Classification	# Claimants in NOCTS	# Claimants Compiled (% of Total)	% of the Total Number of Claimants in Category
Laborer	[redacted]	2	22%
Maintenance/Mechanic	58	23	40%
Operator	54	16	30%
Chemist/Lab Tech	23	10	43%
Foreman	[redacted]	2	33%
Miscellaneous or Unknown	[redacted]	1	17%
Administrative	11	6	55%
Health Physics	[redacted]	1*	50%
Instrument Tech	[redacted]	1*	33%
Total	**172**	**62**	**36%**

*Claimants specifically chosen to assure all job classifications were covered in the test sample

The 62 selected test cases were analyzed to determine how frequently workers were sampled during their employment; the results are presented by year in Table A-2. The table displays the number of test claimants that were employed in a given year, the % of those workers sampled, and the number of records per worker per year (presented as the arithmetic mean, median, and geometric mean). As shown, the percentage of workers sampled for uranium by year was generally greater than 95% and displayed 100% coverage. The exception to this is in 1965 and 1966, when the coverage dropped to around 50% of the employed claimant test population; this also coincided with a general decrease in the number of test claimants employed during these years. This coincides with the operational shutdown described in Section 2 of the site profile.

For most years, the number of records per worker was right around 12, which would indicate a monthly sampling schedule. In 1964 and 1967, uranium monitoring appears to have switched to a bimonthly schedule, though this might also be the result of the plant shutdown. There was a much lower number of records per worker in 1965 and 1966, but this is likely also the result of the operational shutdown previously mentioned.

Table A-2. Uranium Monitoring by Year for the Test Claimant Subpopulation

Year	# of 62 Sampled Claimants Employed in year	% of Workers Sampled for Uranium in Year	Number of Records per Worker per Year		
			Arithmetic Mean	Median	Geometric Mean
1959	23	95.7%	14.0	13	13.1
1960	26	96.2%	14.0	13	13.8
1961	25	96.0%	13.0	13	13.1
1962	25	100.0%	15.1	13	13.2
1963	25	100.0%	10.5	11	10.3
1964	24	95.8%	6.5	7	6.4
1965	17	52.9%	1.2	1	2.1
1966	17	41.2%	3.6	0	8.0
1967	24	100.0%	6.6	7.5	5.8
1968	40	100.0%	10.6	12	9.7
1969	35	97.1%	11.1	12	11.1
1970	34	97.1%	11.5	12	11.5
1971	33	97.0%	11.9	12	12.2
1972	33	97.0%	10.7	11	10.9
1973	36	100.0%	10.0	11	9.1
1974	37	100.0%	10.3	10	10.0
1975	42	100.0%	17.0	17.5	15.8
1976	43	100.0%	19.5	23	17.7

SC&A also analyzed the dosimetry records to determine the number of samples above an assumed threshold value of 40 µg/l.[1] The duration between the sample reported as above 40 µg/l and the next sample was compiled in order to characterize any special sampling practices. The overview for each test claimant is shown in Table A-3, which displays the following:

- A randomly generated reference number assigned to the test claimants
- Number of years employed during operational period
- Total number of records during employment
- Average number of records per year
- Percentage of employed years with no uranium monitoring records
- Number of records with results greater than 40 µg/l
- Average time between sample greater than 40 µg/l and the next sample

[1] 40 µg/l was chosen by SC&A, based on the sampled claimant records, as representing a significant positive value for the purposes of analyzing special monitoring practices such as re-sampling.

The claimants shown in Table A-3 are sorted by the number of results that were reported as greater than 40 µg/l. As shown in Table A-3, 42 of the 62 claimants tested (~77.4%) had uranium monitoring records for every year they were employed during the operational period. One worker had no uranium monitoring associated with Allied Chemical Corporation Plant; however, this worker was only employed for approximately 6 months at the very beginning of the operational period (1959). The final two columns of Table A-3 show the number of samples that were greater than 40 µg/l, and the average duration between these higher samples and the next uranium sample.

One general trend that can be noticed is that workers with a large number of samples above 40 µg/l were (on average) sampled approximately 2 weeks after the high sample was reported. This would likely represent a special sample, since the normal schedule was monthly for most years. Workers with five or fewer records above 40 µg/l often showed no change to their normal monthly monitoring schedule. These two observations would indicate that any special sampling was directed at the workers with the highest exposure potential (as evidenced by a greater number of samples above 40 µg/l).

Overall, the claimant test population was missing uranium monitoring records in less than 5% of the worker-years compiled. The population averaged ~12 records per year, and the average time between a high sample (above 40 µg/l) and the next sample was about 11 days. It can also be qualitatively stated that the very highest samples observed were often followed up within a few days of the high result.

Table 3. Overview of the 62 Test Claimants

Reference Number*	# Years of Employment During Operational Period	Total Number of Records	Average # Records per Year	Percentage of Employment Years with No Records	# Records Greater than 40 µg/l	Average Time Between Sample Greater than 40 µg/l and the Next Sample
1	18	286	15.9	0.0%	111	6.1
2	6	104	17.3	0.0%	52	11.4
3	12	151	12.6	0.0%	44	6.8
4	18	210	11.7	11.1%	33	15.2
5	18	207	11.5	0.0%	26	13.3
6	16	187	11.7	0.0%	22	11.0
7	17	197	11.6	11.8%	18	6.4
8	6	76	12.7	0.0%	18	17.3
9	18	227	12.6	5.6%	17	9.0
10	18	208	11.6	11.1%	17	14.9
11	17	199	11.7	11.8%	16	10.4
12	8	75	9.4	0.0%	12	17.3
13	18	211	11.7	5.6%	12	17.3
14	17	175	10.3	11.8%	7	10.6
15	15	195	13.0	0.0%	7	11.4

Table 3. Overview of the 62 Test Claimants

Reference Number*	# Years of Employment During Operational Period	Total Number of Records	Average # Records per Year	Percentage of Employment Years with No Records	# Records Greater than 40 μg/l	Average Time Between Sample Greater than 40 μg/l and the Next Sample
16	6	58	9.7	0.0%	7	14.7
17	2	60	30.0	0.0%	5	3.0
18	16	162	10.1	0.0%	5	20.6
19	6	66	11.0	0.0%	5	26.0
20	9	114	12.7	0.0%	4	4.3
21	4	38	9.5	0.0%	4	9.0
22	5	59	11.8	0.0%	4	21.3
23	18	177	9.8	11.1%	4	23.0
24	9	115	12.8	0.0%	4	34.0
25	4	74	18.5	0.0%	3	1.0
26	18	180	10.0	11.1%	3	29.0
27	2	21	10.5	0.0%	3	29.7
28	2	33	16.5	0.0%	2	1.5
29	18	185	10.3	0.0%	2	15.0
30	9	122	13.6	0.0%	2	15.0
31	6	66	11.0	0.0%	2	24.0
32	4	23	5.8	25.0%	1	1.0
33	9	91	10.1	0.0%	1	1.0
34	9	123	13.7	0.0%	1	5.0
35	3	55	18.3	0.0%	1	9.0
36	9	79	8.8	33.3%	0	NA
37	17	129	7.6	23.5%	0	NA
38	9	94	10.4	11.1%	0	NA
39	10	99	9.9	0.0%	0	NA
40	10	129	12.9	0.0%	0	NA
41	10	111	11.1	0.0%	0	NA
42	9	99	11.0	0.0%	0	NA
43	9	110	12.2	0.0%	0	NA
44	9	110	12.2	0.0%	0	NA
45	9	136	15.1	0.0%	0	NA
46	9	96	10.7	0.0%	0	NA
47	9	105	11.7	0.0%	0	NA
48	9	102	11.3	0.0%	0	NA
49	4	59	14.8	0.0%	0	NA
50	4	63	15.8	0.0%	0	NA
51	3	22	7.3	0.0%	0	NA

Table 3. Overview of the 62 Test Claimants

Reference Number*	# Years of Employment During Operational Period	Total Number of Records	Average # Records per Year	Percentage of Employment Years with No Records	# Records Greater than 40 μg/l	Average Time Between Sample Greater than 40 μg/l and the Next Sample
52	2	13	6.5	0.0%	0	NA
53	2	4	2.0	0.0%	0	NA
54	2	41	20.5	0.0%	0	NA
55	2	7	3.5	0.0%	0	NA
56	2	33	16.5	0.0%	0	NA
57	2	38	19.0	0.0%	0	NA
58	2	15	7.5	0.0%	0	NA
59	2	47	23.5	0.0%	0	NA
60	1	15	15.0	0.0%	0	NA
61	1	4	4.0	0.0%	0	NA
62	1	0	0.0	100.0%	0	NA
Average Value for All Test Claimants			12.2	4.8%	7.8	11.1

* All numbers are randomly assigned.

APPENDIX B: FINDINGS ON ORAUT-OTIB-0024

Procedure ORAUT-OTIB-0024 (ORAUT 2005a) was reviewed by SC&A for the Advisory Board on Radiation and Worker Health. The review produced seven findings. These findings and NIOSH's initial responses are provided below:

Item 1

Finding:
The dose rates are expressed as per gram of source isotopes, rather than per gram of compound.

Initial Response:
ORAUT-OTIB-0024 will be revised using a modern computer code and dose rates will be expressed appropriately.

Item 2

Finding:
The OTIB limits the neutron generation to the (α,n) reaction, and overlooks the contribution from spontaneous fission.

Initial Response:
ORAUT-OTIB-0024 will be revised using a modern computer code taking into account the neutron dose contribution from spontaneous fission.

Item 3

Finding:
The doses are truncated at ^{226}Ra for the ^{238}U decay series, and at ^{223}Ra for the ^{235}U decay series.

Initial Response:
ORAUT-OTIB-0024 will be revised using a modern computer code to calculate the neutron dose rate contribution from all of the alpha emitting progeny in the decay chains.

Item 4

Finding:
The overriding issue with the OTIB is its reliance on outdated experimental results collected from secondary or even tertiary sources; also, it overlooks a current computer code, SOURCES 4C.

Initial Response:
ORAUT-OTIB-0024 will be revised using a modern computer code.

Item 5

Finding:
The validity of portions of the calculation are questioned, e.g., extrapolating to higher alpha energies, use of 1971 NCRP rather than ICRP Publication 74 quality factors and fluence per unit dose equivalent, interpolation of interpolated data, etc.

Initial Response:
ORAUT-OTIB-0024 will be revised using a modern computer code and ICRP Publication 74 quality factors and fluence per unit dose equivalent data.

Item 6

Finding:
Presenting dose rates at 1 foot and 3 feet from a point source does not appear to be a realistic representation of actual working conditions.

Initial Response:
ORAUT-OTIB-0024 will be revised using a modern computer code and more realistic exposure scenarios.

Item 7

Finding:
The average dose per neutron was calculated from a neutron spectrum that does not embody source nuclides with $E\alpha$ greater than the maxima in the level branching data for the given target nuclide. The neutrons from the entire decay chain would have a somewhat different spectrum.

Initial Response:
ORAUT-OTIB-0024 will be revised using a modern computer code to accurately determine the neutron energy spectrum.

The status of all seven findings is “In Abeyance.” There is no schedule as to when these seven findings will be resolved.