Draft White Paper

REVIEW OF THE USE OF SURROGATE DATA FOR ESTIMATING INTAKES OF URANIUM AT GENERAL STEEL INDUSTRIES

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Prepared by

Robert Anigstein
S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, Virginia 22182

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REVIEW OF THE USE OF SURROGATE DATA FOR ESTIMATING INTAKES OF URANIUM AT GENERAL STEEL INDUSTRIES	Page 2 of 22
Task Manager: ______________________________ Date:__________ Robert Anigstein, PhD	Supersedes: Revision 0
Project Manager: ______________________________ Date:__________ John Stiver, MS, CHP	Reviewers: John Mauro, PhD William C. Thurber, MS

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Review of the Use of Surrogate Data for Estimating Intakes of Uranium at General Steel Industries

1 Background

During Meeting 84 of the Advisory Board on Radiation and Worker Health, the Board tasked SC&A with reviewing NIOSH's use of surrogate data for estimating intakes of uranium at General Steel Industries (GSI). In Appendix BB to TBD-6000, Allen and Glover (2007) based the activity concentrations of airborne uranium during uranium handling operations on that of a uranium slug production operator listed in the parent document (Allen 2011, Table 7.6).[1] That table lists measured airborne uranium activity concentrations reported by Harris and Kingsley (1959). The measurements were taken at an unnamed plant or plants in the breathing zone of the die-processing technician who was involved in the fabrication of finished uranium shapes for reactor fuel elements, known as "slugs."[2] These measurements were performed during the processing of slugs produced by powder metallurgy, a process in which heated uranium powder is placed in a die and hot pressed into the desired shape. Harris and Kingsley list five operations performed by the die-processing technician, in order of decreasing breathing zone uranium concentrations—the highest concentration was measured during the stamping of the slug, which apparently refers to numbering the slug in a pneumatic numbering machine.

2 Evaluation of the Use of Surrogate Data

The ABRWH Work Group on Use of Surrogate Data (2010) issued five "criteria that need to be considered in determining whether the specific use of surrogate data for individual dose reconstruction is scientifically sound and appropriate for that particular application." We have reviewed the use of the slug stamping operation as a surrogate for the uranium handling operations at GSI against these five criteria. Following the statement of each criterion is an evaluation of how well the use of these surrogate data conforms to that criterion.

2.1 Criterion 1: Hierarchy of Data

> It should be assumed that the usual hierarchy of data would apply to dose reconstructions for that site (individual worker monitoring data followed by co-worker data followed by workplace monitoring data such as area sampling followed by process and source term data). This hierarchy should be considered when evaluating the potential use of surrogate data. Surrogate data should only be used to replace data if the surrogate data have some distinct advantages over the available data and then only after the *appropriate adjustments have been made* to reflect the uncertainty inherent in this substitution [italics added for emphasis].

[1] The original reference was to the 2006 version of this document—the relevant values are unchanged. The cited value is listed in Table 7.6, not 7.8, as incorrectly cited by Allen and Glover (2007).

[2] Harris and Kingsley (1959) acknowledge the cooperation of several individuals and five government-owned or private facilities involved in uranium fabrication. However, the authors do not indicate which facilities were the source of which data, or whether other, unnamed facilities were also involved.

2.1.1 Evaluation of Hierarchy of Data

There are no monitoring data relating to uranium intakes at GSI. However, some process and source term data are available, namely information on the duration of uranium handling operations and some limited information on the nature of the uranium metal handled at GSI. Only the duration of the handling operations, based on the available MCW purchase orders, was utilized by Allen and Glover (2007) in their analysis. Murray and Brown (1994, Table 4) present surface contamination measurements at 32 random locations in the Old Betatron Building at GSI, performed in June 1993, prior to remediation under FUSRAP. These data could have been utilized in modeling surface contamination, as discussed in section 4 of the present report. Instead, Allen and Glover cite only the maximum measured contamination level reported in an earlier FUSRAP survey (Cottrell and Carrier 1990) and observe it is "reasonably close" to the value derived by their model. Thus, we conclude that the use of surrogate data does not strictly conform to the hierarchy of data.

2.1.2 Evaluation of Appropriate Adjustments to Surrogate Data

We next need to determine if appropriate adjustments have been made to the surrogate data as it was applied to GSI. The measured air concentrations corresponding to the five operations presented by Harris and Kingsley (1959) are listed in the first column of numerical values (Allen 2011, Table 7.6), followed by the corresponding geometric means. According to Allen (2011): "If the air concentration was presented [by Harris and Kingsley (1959)] as a single value, this value was assumed to be the arithmetic mean, with an assumed geometric standard deviation (GSD) of 5." The ratio $\mu:\mu_g$ can be calculated using the following formula:[3]

$$\frac{\mu}{\mu_g} = e^{\frac{(\ln \sigma_g)^2}{2}}$$

μ = arithmetic mean

μ_g = geometric mean

σ_g = geometric standard deviation
= 5 (Allen 2011)

According to the above formula, $\frac{\mu}{\mu_g} = 3.65$; however, the values of μ and μ_g listed by Allen (2011, Tables 7.2–7.7) yield $\frac{\mu}{\mu_g} \approx 2.23$. The values of μ_g listed by Allen are thus about 60% higher than the values calculated on the basis of the stated assumptions. Although this higher value is claimant favorable, it is not scientifically correct.

Allen (2011, Table 7.6) listed the geometric mean of the operator's daily weighted average (DWA) air concentration, which was calculated as 75% of the μ_g listed for the slug stamping operation. The factor of 75% was based on the assumption that the 25% of the operator's time

[3] Derived from Gilbert 1987.

was spent away from the area of high uranium concentrations. Allen and Glover (2007) adopted this value as the uranium airborne activity concentration at GSI during the time the workers were handling uranium before and after betatron radiography.

Aside from the error in calculation, we question the use by Allen and Glover (2007) of an airborne uranium concentration derived by adjusting the Harris and Kingsley (1959) data. First, since the derived concentration was used as a fixed value that represented the average air concentrations during the relatively brief handling operations (assumed by Allen and Glover to last one hour at a time), it would be more appropriate to use the measured concentration presented by Harris and Kingsley and listed by Allen (2011, Table 7.6), rather than a derived geometric mean, which is appropriate for a lognormal distribution, but not for a fixed value. Second, the factor 75% may be appropriate for estimating the DWA exposure, averaged over an 8-h workday, since the worker would occasionally be away from his work station. It should not be applied to the short-term exposures, since these exposure times are based on the time actually spent handling the uranium metal at GSI. Using the actual measured air concentration reported by Harris and Kingsley would lead to an increase of X2.9 over the value employed by Allen and Glover.

We conclude that "appropriate adjustments" were not made to these surrogate data. We find that Criterion 1 is not fully satisfied by the use of the slug stamping scenario presented by Allen (2011).

2.2 Criterion 2: Exclusivity Constraints

> [In situations where] there are no or very little monitoring data available . . . the use of the surrogate data as the basis for individual dose reconstruction would need to be *stringently justified* [italics added for emphasis]. This judgment needs to take into account not only the amount of surrogate data being relied on relative to data from the site but also the quality and completeness of that surrogate data.[4]

As stated previously, there are no monitoring data on uranium intakes at GSI. Allen and Glover (2007) selected the scenario presented by Allen (2011) that listed the lowest uranium aerosol concentrations. The basis for the selection was their observation that the GSI uranium handling operations resulting in less disturbance of the metal than the other scenarios listed by Allen. We do not agree that the use of the surrogate data was stringently justified. We find that Criterion 2 is not satisfied.

2.3 Criterion 3: Site or Process Similarities

> One of the key criteria for judging the appropriateness of the use of surrogate data would be the similarities between the site (or sites) where the data were generated and the site where the surrogate data are being utilized. The application of any surrogate data to an individual dose reconstruction at a site should include a careful review of the rationale for utilizing that source of data. Factors that could

[4] Only the relevant text from Criterion 2 is quoted here.

be considered include, but are not limited to, similarity of the production processes, presence or absence of conditions that might affect exposure, and monitoring methods employed at the site(s). The potential availability of other sources of surrogate data needs to be considered and the selection of the surrogate data used for dose reconstruction justified. Some of the questions to be considered where appropriate are:

- Are there other sources of surrogate data that were not used?
- Do these other potential sources contradict or undermine the application of the data from the selected site?
- Are there adequate data characterizing the site being used that would help support its application to other sites?
- Do the surrogate data reflect the type of operations and work practices in use at the facilities in question?

Surrogate data should not be used if the equivalence of working conditions, source terms, and processes of the surrogate facility to the one for which dose reconstructions are being done cannot be established with reasonable scientific or technical certainty as outlined here.

Our first observation regarding Criterion 3 is the dissimilarity of uranium slugs produced by powder metallurgy and the recast uranium ingots or "dingots" (ingots produced by direct reduction of UF_4) at GSI. Not only were the uranium objects dissimilar, the stamping of numbers on the slugs bears no resemblance to setting up and transporting the uranium objects at GSI.

We note that the NIOSH/DCAS Web site lists approximately 124 work sites for which DCAS has developed information. We believe that NIOSH should have performed a systematic review of those sites that handled uranium metal and at which concentrations of airborne and/or surficial uranium levels were recorded. Such a review could answer the question: Are there other sources of surrogate data that were not used?

The third bullet under Criterion 3 asks: Are there adequate data characterizing the site being used that would help support its application to other sites? Although Harris and Kingsley (1959) describe the powder metallurgy operations involved in producing uranium slugs, the specific work site is not identified, and only sparse descriptions of the facilities at this site (or sites) are furnished. We conclude that there are not "adequate data characterizing the site." Finally, in answer to the fourth bullet, we conclude that the surrogate data do not reflect the types of operations and work practices used at GSI.

We find that the use of slug stamping as a surrogate for the handling of uranium at GSI does not fulfill Criterion 3.

2.4 Criterion 4: Temporal Considerations

> Consideration also needs to be given to the period in question, since working conditions and processes varied in different periods. Surrogate data should belong in the same general period as the period for which doses are sought to be reconstructed unless it can be demonstrated that the working conditions, procedures, monitoring methods, and (perhaps) legal requirements were comparable to the period in question.

According to Rolfes et al. (2008): "[I]t is likely that the data [presented by Harris and Kingsley (1959)] were collected before 1957 and perhaps as early as the late 1940s." We note that the report was submitted for publication on June 6, 1958. Thus, the measurement of uranium air concentration cited by Allen and Glover (2007) may have been made 10–20 years prior to the end of the period of AEC operations at GSI (1953 to mid-1966). Allen and Glover need to justify the application of this measurement to the entire period of operations at GSI.

2.5 Criterion 5: Plausibility

> The manner in which the surrogate data are to be used must be "plausible" with regard to the reasonableness of the assumptions made. The plausibility determination should address issues of:
>
> - Scientific plausibility. Are the assumed models (e.g., bioassay, concentration gradients) scientifically appropriate? Have the models been validated (where feasible) using actual monitoring data collected in a similar situation?
> - Workplace plausibility. Are the assumed processes and procedures (including monitoring) plausible for the facility in question? Have all of the factors that could significantly impact exposure been taken into account? Is adequate information available about the facility in order to be able to make a fair assessment?

2.5.1 Evaluation of Scientific Plausibility

According to Allen and Glover (2007), uranium handling operations, derived from purchase orders issued by Mallinckrodt Chemical Works (MCW), had a maximum total duration of ~218 h/y, out of an assumed work-year of 3,250 h. The remainder of the time, uranium intakes were based on resuspension of uranium from contaminated surfaces. (This was the sole source of internal exposure during the residual period.) Thus, the buildup of uranium on the floor is potentially significant in the assessment of uranium intakes by GSI workers. Allen and Glover assume that the uranium air concentration is achieved immediately at the beginning of the handling operation and disappears immediately after its end. The former might be a plausible and claimant-favorable bounding assumption, since it is difficult to estimate the time-dependence of the build-up of uranium dust in the vicinity of the uranium metal. However, the latter assumption, that the deposition abruptly stops at the end of the operation, is neither plausible nor claimant favorable. In reality, the dust would continue to be generated during the entire uranium handling period. It would settle to the floor during this period, and would continue to do so until the airborne concentration is depleted. The time required is determined by the elevation of the dust above the floor and the deposition velocity. As an extreme example, the dust concentration could be assumed to extend from the floor to the roof, a height of 35 ft (10.7 m). Assuming a settling velocity of 7.5×10^{-4} m/s (Allen 2011), it would take almost 4 h for all the dust to settle to the floor. Thus, the assumption that the deposition abruptly stops at the end of the handling operation could significantly understate the surficial concentration.

Aside from the question regarding the actual duration of deposition, and questions regarding the adjustments to the air concentration data reported by Harris and Kingsley (1959) that are discussed in section 2.1.2 of the present report, we question the plausibility of calculating the surficial concentration from deposition during the hours of uranium handling during one year—an arbitrarily chosen time period. The model assumes that the surficial contamination throughout a given calendar year has a constant value, derived from a steady deposition of uranium dust during the assumed hours of uranium handling during that year. There is no carryover of this accumulation from year to year—it is as if this contamination level existed at the beginning of the year (even before any uranium handling has taken place) and vanished at the end of the year, to be replaced by the accumulation from the next year's uranium handling. The maximum hours of uranium handling were during the period July 1, 1961 to June 30, 1962. Allen and Glover (2007) assumed that the surficial contamination level from July 1, 1961, until the end of the residual period was equal to the total uranium deposition during that 12-month period, with no removal but also no contribution from deposition that occurred before or after that period. A more realistic model would assume continuous buildup of the surficial contamination, based on the periods of uranium handling operations, together with continuous or intermittent removal. The authors need to demonstrate that the assumed one-year period of accumulation is scientifically plausible.

2.5.2 Evaluation of Workplace Plausibility

The assumption that handling of uranium ingots at GSI had a potential for generating aerosols that were comparable to the uranium slug stamping operation reported by Harris and Kingsley (1959) does not meet the criterion of workplace plausibility. The assumption that the surficial contamination levels can be calculated from the airborne concentrations reported by Harris and Kingsley is likewise inconsistent with this criterion. Uranium oxide could have been removed from the surfaces of ingots or dingots by mechanical abrasion during the transport and positioning of the metal objects. The particles could range in size from fine aerosols to flakes as big as ¼-inch in diameter.

In its response to Issue 5 of SC&A (2009) findings on TBD-6000, NIOSH stated: "Large flakes of uranium that are produced would fairly quickly be ground into dust under foot and forklift traffic typical of operating area. They would then be available for resuspension and contribute to the air concentrations." We agree that, over the long term, equilibrium would be achieved between the resuspendable surface layer and the uranium aerosols. According to Allen (2011), NIOSH assumed that 30 days were required to achieve such equilibrium, once fine particles were deposited on the floor. Assuming, for the sake of the present argument, the validity of the assumed equilibrium period, the settling velocity—based on an assumed AMAD (activity median aerodynamic diameter) of 5 μm—and some assumed persistent air concentration, it can be argued that the intermittent introduction of large flakes is reflected in the equilibrium air and surface concentrations. However, the assumed air concentrations, derived from the Harris and

Kingsley (1959) slug stamping scenario, do not correspond to equilibrium conditions, since such equilibria were not achieved during the intermittent uranium handling operations at GSI. We thus find that the calculation of surficial uranium concentrations described by Allen and Glover does not meet the criterion of workplace plausibility.

2.6 Summary of Findings

We find that the use of uranium air concentrations based on measured on measurements made during the stamping of uranium slugs as a surrogate for uranium air concentrations at GSI does not meet the five ABRWH criteria for the use of surrogate data. Our findings with respect to these criteria are summarized as follows:

Criterion 1. Hierarchy of Data

- Data from the 1993 FUSRAP survey (Murray and Brown 1994), that could help estimate levels of contamination on the floor of the Old Betatron Building, were not utilized by NIOSH.
- Adjustments to the measurement reported by Kingsley and Harris (1959), described by Allen (2011) and utilized by Allen and Glover (2007), are not appropriate to the uranium handling scenario at GSI.

Criterion 2. Exclusivity Constraints: The use of the surrogate data was not stringently justified.

Criterion 3. Site or Process Similarities

- Neither the form of the uranium metal (slugs produced by powder metallurgy vs. recast ingots or direct reduced dingots), nor the processes (stamping numbers on slugs vs. transporting uranium objects and positioning them for radiography) are sufficiently similar to justify the use of the surrogate data.
- Alternate sources of surrogate data (e.g., the 124 work sites for which NIOSH has collected information) were not evaluated.
- There are insufficient data regarding the characteristics of the surrogate site to support the use of the surrogate data for GSI.

Criterion 4. Temporal Considerations: The Kingsley and Harris (1959) data were most likely collected between the late 1940s and ca. 1957. The measurement used as a surrogate at GSI could thus precede the end of the covered the period by 10–20 years. The application of these data for the 1953-1966 period of AEC operations needs to be justified by Allen and Glover (2007).

Criterion 5. Plausibility

- The methodology of calculating surface contamination levels based on the assumed uranium aerosol concentration is not scientifically plausible.

- The assumption that the surface contamination levels result only from the deposition of aerosols during the uranium handling operations does not satisfy the criterion of workplace plausibility.

3. Use of Alternate Scenarios

We examined the possible use of surrogate data from five other uranium metal working scenarios described by Allen (2011). None of these operations satisfy the surrogate data criteria any better than the slug stamping scenario.

We also examined the data in the report on uranium aerosol concentrations in the melt plant building at Hanford (Adley et al. 1952). Several operations involving the handling of uranium rods resemble the handling uranium operations at GSI more closely than the slug stamping scenario described by Allen (2011). Three operations that involve storage bay activities are listed below.

Operation	U concentration	
	10^{-5} µg/cc*	dpm/m^3**
Unloading rods from truck with fork lift	258	3,926
Receiving rods: unloading truck and stacking rods; sample in breathing zone of man operating fork lift	34	517
Loading straightened rods directly from table onto truck; general atmosphere in storage bay	5.8	88

Source: Adley et al. 1952, Table VII

* Reported by Adley et al.

** Calculated total activity of uranium isotopes in ratios of natural abundance

To be consistent with the choice by Allen (2011, Table 7.6) of the maximum concentration produced by the uranium slug production, the first operation listed above should be selected to characterize this scenario. The corresponding activity concentration is more than 6 times higher than that reported for the slug stamping scenario by Harris and Kingsley (1959), and would consequently lead to dose assessments that are more claimant favorable. Although this operation better satisfies Criterion 3, Site or Process Similarities, and may satisfy Criterion 4, Temporal Considerations, additional study would be required to determine if other criteria are satisfied. In particular, we continue to have reservations about conformity with Criterion 5, Plausibility, which concern the model which NIOSH uses to calculate the surficial contamination levels, regardless of the choice of the aerosol concentration during the uranium handling operations.

4. Recommendation

SC&A recommends that NIOSH develop a methodology for estimating uranium intakes at GSI that does not rely on surrogate data. We suggest a model that uses the exponential source-term depletion rate recommended in OTIB-0070 (Sharfi 2012). The contamination levels on the floor of the Old Betatron Building at the time of the 1993 cleanup, reported by Murray and Brown (1994), together with the depletion rate and the varying hours of uranium handling operations at

GSI, could be used to calculate the average surficial uranium concentrations during each year of the operational and residual periods.

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