TO: Advisory Board on Radiation and Worker Health Work Group on TBD-6000
FROM: Robert Anigstein and John Mauro, SC&A
SUBJECT: Review of NIOSH Estimates of Internal Exposures at GSI
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Review of NIOSH Estimates of Internal Exposures at GSI

On April 1, 2013, David Allen (2013) transmitted a White Paper on GSI providing details on (1) how NIOSH intends to estimate doses from external radiation to nonradiographers prior to 1963; (2) how individual cases will be assigned to different job categories; and (3) how internal doses will be estimated. The same day, Ted Katz, Designated Federal Official to the Advisory Board, sent an e-mail message asking SC&A review this report. In our previous memo (Anigstein and Mauro 2013), we addressed the NIOSH estimates of external exposures and the assignment of doses to different workers. This memo is our response to the discussion of internal exposure in Allen's White Paper.

In a table at the end of the White Paper, Allen (2013) lists the inhaled and ingested activities during various periods of the operational and residual periods. The inhaled activity is greater than the ingested activity during most of the period of AEC operations at GSI. Furthermore, the effective dose coefficients for inhalation are one to two orders of magnitude greater than the corresponding coefficients for ingestion. We will therefore address intakes of uranium via inhalation, which constitute the major source of internal exposure for the reasons stated above.

According to Allen (2013), the inhaled activity has two sources: exposure to dust generated during the handling of uranium while setting up the radiographic exposures, and resuspension of the airborne dust that had settled on the floor of the facility. The work group, NIOSH, and SC&A have all agreed that the uranium aerosol concentrations generated by the handling of uranium metal can be represented by a lognormal distribution with a geometric mean or median (M) of 17.54 dpm/m^3 and a geometric standard deviation (GSD) of 2.29, which yields a 95th percentile value of 68.7 dpm/m^3. Allen assumed that the workers were exposed to the uranium dust at the 95th %ile concentration only during the 15 minutes they spent setting up a betatron shot, and spent the next 60 minutes in the control room, where they were protected from the uranium aerosols. Thus, they inhaled an aerosol concentration of 68.7 dpm/m^3 during 20% of the time allotted to uranium radiography by the purchase orders GSI received from the Mallinckrodt Chemical Works (MCW) over various time periods.

Allen (2013) next derived a surface contamination level by assuming that this airborne activity settled over a period of 30 days, with a settling velocity of 7.5×10^{-4} m/s. He thus derived a surface activity concentration of 1.34×10^5 dpm/m^2. He calculated the airborne activity concentration by applying a resuspension factor (RF) of 10^{-5} m^{-1}, obtaining a concentration of 1.34 dpm/m^3.

We disagree with this approach for several reasons. Our main problem is with the method of calculating the surficial activity by deposition of uranium aerosols. The assumptions about the

deposition velocity and settling time are based on TBD-6000 (Allen 2011). However, these parameters and methods apply to a steady-state situation in which the aerosol generation is continuous and equilibrium between airborne and surficial activity concentrations is achieved over 30 days. In the case of GSI, the aerosol generation was highly intermittent and took place at unknown intervals. According to the MCW purchase orders, the uranium radiography was to be performed during the day shift on weekdays (presumably to avoid paying premium rates for night or weekend shifts). Assuming, as Allen does, 337.5 h/y of uranium radiography from 1/1/1953 until 6/30/1961, this work would take ~8.4 weeks if performed continuously, or an average of 6.75 h/week if performed intermittently, as is more likely. If, as Allen postulates, the uranium was handled for only 15 min per shot, then the generation was even more intermittent.

A 30-d settling period has two implications. If the dust were to settle for even one week (assuming weekly uranium radiography), the column of contaminated air would have to extend ~454 m above the floor, which is not possible, given that the betatron shooting room is ~10 m high. More important, workers would be exposed to the inhalation of this dust during the entire settling period. That is, they would be inhaling it for 65 h, the length of the average work week, following each uranium radiography campaign. If the campaigns took place weekly, or even monthly, the workers would be exposed to this concentration for the entire year. To put it succinctly, one cannot postulate a 30-d settling period without anyone breathing the initial dust concentration during this time.

We would like to propose an alternate approach which is consistent with the agreed-upon surrogate data and which avoids the problem discussed above. We assume that the upper bound to the uranium aerosol concentration during the operational period is given by the lognormal distribution discussed previously. This assumption does not require us to specify the mechanism by which this concentration is achieved and maintained. However, it is unrealistic to assume that workers would be exposed to the 95th percentile concentration during their entire work year. It would be more appropriate to utilize the entire distribution during dose reconstruction to all workers. This also avoids postulating the detailed duration of exposure of the betatron teams to handled uranium, since it is likely they would have spent some time in the betatron shooting room while the uranium was brought into and removed from the room, released from the crane, etc. This intake would be applicable to both betatron operators and other workers. The exposure of operators performing uranium radiography would actually be slightly less, since they would have some measure of protection in the control room. However, since the control room was not airtight, and since the workers would have tracked the uranium dust into the room while walking in and out, the degree of protection cannot be ascertained.

Although there is no simple method for calculating the inhaled activities from the entire lognormal distribution, an approximate value can be obtained from the arithmetic mean. Using this value, the inhaled intake during the operational period is estimated to be ~264 dpm/cal. day. In comparison, Allen (2013) estimates a range of 15.01–34.37 dpm/cal. day,[1] while Allen and Glover (2007) assigned inhaled intakes of 5.2–128 dpm/cal. day.

[1] He lists the values as dpm/d; based on earlier DCAS reports, we assume this refers to dpm/ cal. day—we did not verify his calculations.

To calculate the doses during the residual period, we first calculate the areal activity concentration. The arithmetic mean (μ) of the airborne concentration is 24.72 dpm/m^3. If we divide this by an RF of 10^{-5} m^{-1}, we obtain an areal activity concentration of 2.47×10^6 dpm/m^2. This surficial concentration is assumed to decrease at the rate of 6.7×10^{-4} d^{-1} (Sharfi 2012). The airborne concentration during the residual period can be calculated by applying this RF to the decreasing surficial activity. Thus, the inhaled intakes would be 264 dpm/cal. day at the end of AEC operations (June 30, 1966), decreasing exponentially with time after that date. Allen estimated an inhalation of 1.44 dpm/cal. day at the start of the residual period, using an RF of 10^{-6} m^{-1} and the previously cited surficial contamination level. He stated that the exponential removal rate cited by Sharfi would be applied to subsequent times.

We do not agree with Allen (2013) that an RF of 10^{-6} m^{-1} is applicable to the residual period. As Allen correctly points out, this RF value is applicable to *aged* activity in a *quiescent* setting. Although the contamination gradually aged, the setting—the betatron shooting room and other areas of GSI—was hardly quiescent.

References

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