Draft White Paper

COMMENTS ON THE NIOSH WHITE PAPER, "TBD 6000 REVIEW BY SC&A, DETERMINATION OF SETTLING TIME"

REVISION 0

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1.0 INTRODUCTION

SC&A has been tasked on numerous recent occasions with reviewing dose reconstructions, site profiles, and a petition evaluation report that relied on Battelle-TBD-6000 (Battelle 2011) to provide the bases for completed dose reconstructions or possible future dose reconstructions. These reviews provided additional insight into how TBD-6000 is used in practice and revealed some potential issues associated with using that document that were not apparent when the document was originally reviewed and proposed changes were discussed. Based on this recent experience, SC&A provided supplementary comments on TBD-6000 (SC&A 2013). One of the areas discussed in SC&A 2013 was the appropriateness of using a terminal settling velocity of 0.00075 m/s for small diameter particles and assuming that equilibrium between particle settling and removal was achieved in 30 days or less.

SC&A concluded that:

> *The assumption that equilibrium between deposition and removal processes is reached in 30 days as specified in TBD-6000 should be re-examined. The analyses presented here based on average settling rates in Main Bay of the Hanford Melt Plant Building indicate that 33–37 days are required to reach equilibrium based on 24 hr/day of settling and 40–44 days based on 12.4 hr/day of settling. The 95th percentile of the 15 Main Bay samples is 69 days to reach equilibrium. Based on these calculations, the claimant-favorable approach would be to use a value of 70 days to achieve an equilibrium surface concentration where the rate of deposition equals the rate of removal. However, if the settling time for dust is 12.4 hr, the time to reach equilibrium would increase by 20% suggesting an upper bound of 84 days.*

2.0 NIOSH RESPONSE

In August 2013, NIOSH issued a response in which they questioned the calculational approach taken by SC&A to estimate equilibrium settling times for airborne particles (NIOSH 2013). NIOSH recalculated equilibrium settling times for both Simonds Saw and Steel and the Hanford Melt Plant Building (Adley 1952). We will focus here on the Adley data, since they represent a more comprehensive dataset.[1]

In the August 2013 White Paper, NIOSH used the following equation to calculate the equilibrium settling time:

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[1] We have some questions about the appropriateness of using data from Simonds Saw and Steel. As described in SRBD 023579 – *Summary Report of Three Surveys* – air samples taken before and after the floor was washed with a high pressure hose showed little difference. This suggests that much of the contamination was embedded in the surface rather than simply deposited on the surface.

Settling time = Surface contamination ÷ airborne concentration ÷ 0.00075 m/s

In this equation, 0.00075 m/s is the theoretical terminal settling velocity for 5-µ AMAD spherical particles. For the Hanford Melt Plant, "surface contamination" was based on plate settling data from Table XIII of Adley. The settling data, listed in units of mg/ft^2/day, were multiplied by the applicable number of days the plate was exposed and converted to µg/m^2. From the 20 plate samples (office samples omitted), NIOSH developed statistics for the geometric mean, the average, and the 95th percentile assuming a lognormal distribution. It should be noted that this procedure combines plate settling results from the shop, the furnace room, the burnout room, and the main bay area, even though each of these areas were structurally separate and experienced different ventilation conditions. NIOSH results are included in Table 1 (extracted from Table 1 of NIOSH 2013).

Table 1. Equilibrium Settling Time – Hanford Melt Plant

Distribution Parameter	Surface Contamination (µg/m^2)	Airborne Concentration (µg/m^3)	Settling Days
Geometric Mean	1,839,873	534	53.1
Average	2,350,865	8,436	4.3
95th Percentile	5,645,961	26,757	3.3

Source: NIOSH 2013, Table 1

NIOSH calculated the "airborne concentration" using air sampling data included in Tables II through VII of Adley. We have several concerns about this calculation of the "airborne concentration:"

- Adley Table V includes air samples from outdoor burning of uranium, which do not appear relevant to the calculation of settling time based on indoor plate samples
- As with the surface contamination, all air samples are lumped together, even though they were taken in physically separated areas
- Some high concentration air samples do not contribute significantly to surface deposition

We have two additional concerns about the calculation of equilibrium settling times as summarized in Table 1 of the NIOSH White Paper:

- We believe that the airborne value should be adjusted to a time-integrated value, since the deposition on the plates occurred for only a portion of each operating day
- We question the use of 0.00075 m/s in calculating the settling time

Each of these points is discussed in the ensuing paragraphs.

3.0 SELECTION OF THE APPROPRIATE AIRBORNE CONCENTRATION

As described above, the air samples from Adley Tables II through VII were used by NIOSH to calculate the airborne concentration. During the period of the air sampling (September 1949 through October 1951), the Melt Plant was operating on a single shift basis and the measured concentrations are spot values taken during single shift operation. In order to obtain a time-integrated value, these spot values must be adjusted. To accomplish this, we assumed that the plant was on a 5-day schedule for 52 weeks per year. We further assumed that, on a daily basis, settling occurred over a 10.7-hour period. This implies that at the start of each shift, the air concentration instantaneously ramps up to the measured value and that it takes about 5 hours after the end of the shift for the concentration to fall to zero (i.e., a particle falling from a height of 10 m at a settling velocity of 0.00052 m/s requires 5.3 hours to reach the surface). Using these assumptions, the measured air concentration multiplier is 0.32 (10.7/24 × 260/365 = 0.32).

4.0 SELECTION OF THE APPROPRIATE TERMINAL VELOCITY

NIOSH assumed that the terminal settling velocity to use in calculating the equilibrium settling time was 0.00075 m/s, the terminal settling velocity for spherical 5-µ AMAD particles. As described in Adley (1952, page 48), the particles were clearly not spherical. Since the goal is to calculate settling times from measured surface concentrations, it is more appropriate to use a settling velocity that takes into account the fact that the actual particles are non-spherical. In its *Supplementary Comments on Revision 01 of Battelle TBD-6000* (SC&A 2013), SC&A provided the basis for adjusting the terminal settling velocity to account for slip between air molecules and for lack of sphericity of the particles. The adjusted settling velocity was 0.00052 m/s.

5.0 CALCULATION OF EQUILIBRIUM SETTLING TIMES

SC&A has taken essentially the same data as used by NIOSH to develop Table 1 in their August white paper, but modified it based on the foregoing discussion. Rather than lumping all the surface contamination values together and all the airborne values together, as was done by NIOSH, we used disaggregated data based on the rooms or areas where the measurements were made. We also eliminated a few of the airborne values based on descriptions in Adley (1952) as to the relevance of particular values. For example, data for Operation E in the furnace room were eliminated based on a statement in Adley (1952, page 22):

> *Thus Operation E is an example of a process that is an exposure to the operator, but is not a contributor to general atmospheric dustiness.*

The average air concentrations calculated by SC&A are summarized in Table 2. Office data were excluded from this analysis.

All of the measured air concentrations in Table 2 were multiplied by a factor of 0.32 to account for the fact that the Melt Plant was operating and generating dust on a single shift basis. The terminal settling velocity was adjusted to 0.00052 m/s to account for slip and particle shape. Based on the available information, it was not possible to calculate separate air concentrations for winter and spring samples. Calculated equilibrium settling times are summarized in Table 3.

Table 2. Average Air Concentrations

Adley Source	Location	Average Air Concentration (dpm/m^3)
Table II	Furnace Room	723*
Table III	Saw Room	1,752*
Table IV	Burnout Room	11,849
Table VI	Oxide Burning	28,631
Table VII – Operation B	Storage Bay Activities	1,291
Table VII – Operation C	Rod Straightening Activities	5,358*
Table VII – Operation D	General Air Samples[a]	1,569
Table VII – Operation E	Autoclave Platform	440

a – Used only in calculating Main Bay Average
* – Adjusted based on comments in Adley 1952

Table 3. Recalculation of Equilibrium Settling Times Based on Average Adjusted Air Concentrations

Location	Settling Rate mg U/ft^2/day	Settling Rate µg/m^2/day	Measured Surf Conc. µg/m^2	Adjusted Air Concentration µg/m^3	Days to Equilibrium
Furnace Room – Winter	0.22	2,376	375,408	151	55.4
Furnace Room – Spring	0.89	9,612	1,124,604	151	166.1
Burnout Room – Winter	5.72	61,776	9,760,608	2,469	88.0
Saw Room – Winter	1.14	12,312	1,945,296	365	118.6
Saw Room – Spring	0.88	9,504	1,111,968	365	67.8
Main Bay – Winter	1.23	13,296	2,100,768	2,980	15.7
Main Bay – Spring	1.84	19,872	2,325,024	2,980	17.4

From this table, it can be seen that the time to reach equilibrium appears to be strongly dependent on whether one is dealing with a large open area (i.e., the Main Bay) subject to a variety of air currents or smaller enclosed rooms where shifting air currents are less likely. The NIOSH-proposed use of 30 days to reach equilibrium appears appropriate for large open areas at the Hanford Melt Plant, but understates by a factor of 2 to 5 the time to reach equilibrium in more enclosed settings. For perspective, the Melt Plant was about 200 ft long and 90 ft wide (Gerber 1996), and the Main Bay area occupies about 11,000 to 12,000 square feet of the plant. The smaller enclosed rooms are estimated to be 500 to 1,500 square feet in area.

6.0 REFERENCES

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