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USE OF PROBABILITY ANALYSIS TO ESTABLISH ROUTINE BIOASSAY SCREENING LEVELS

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Probability analysis was used by the Hanford Internal Dosimetry Program to establish bioassay screening levels for tritium and uranium in urine. Background environmental levels of these two radionuclides are generally detectable by the highly sensitive urine analysis procedures routinely used at Hanford. Establishing screening levels requires balancing the impact of false detection with the consequence of potentially undetected occupational dose; the former causes unwarranted worker concern and programmatic effort, and the latter results in a decreased level of radiation protection.

To establish the screening levels, tritium and uranium analyses were performed on urine samples collected from workers exposed only to environmental sources. All samples were collected at home using a simulated 12-hour protocol for tritium and a simulated 24-hour collection protocol for uranium. Results of the analyses of these samples were ranked according to tritium concentration or total sample uranium. The cumulative percentile was calculated and plotted using log-probability coordinates as shown in Figures 1 and 2. The data exhibited a lognormal probability distribution, as is commonly observed in many environmental media. Geometric means and screening levels corresponding to various percentiles were estimated by graphical interpolation and standard calculations.

The potentially undetected annual internal dose associated with a screening level was calculated using the methods described by Sula et.al. (1989). Screening levels were selected corresponding to the 99.9 percentile, implying that, on the average, 1 out of 1000 samples collected from an unexposed worker population would be expected to exceed the screening level.

APPLICATION TO TRITIUM BIOASSAY

The Fast Flux Test Facility (FFTF), located in the 400 Area of the Hanford Reservation, obtains its drinking water from groundwater wells. These wells contain low-levels of tritium (below the Environmental Protection Agency drinking water standards) originating from aquifer contamination by the past operation of 200 Area fuel processing and waste management facilities (Jaquish and Bryce 1989). Planned operations supporting fusion materials research were expected to produce large quantities of tritium, resulting in the need for a routine tritium bioassay program. The existence of potentially detectable tritium in FFTF workers, which could be attributable to environmental sources rather than occupational exposure, warranted establishing a screening level to use as a basis for initiating investigations and dose assessments of potential occupational exposure.

A baseline bioassay monitoring program was undertaken for FFTF workers prior to the commencement of the tritium operations. Forty-seven urine samples were collected from FFTF operations personnel over a five-month period in early 1989. These data are shown in Figure 1. Based on the curve fit, it was estimated that the geometric mean was 3 dpm/mL and the tritium concentration corresponding to the 99.9 percentile for environmental exposure at FFTF was 40 dpm/mL. This concentration is similar to the present 20,000 pCi/L (44 dpm/mL) EPA Drinking Water Standard for tritium (EPA 1976).

The potentially undetected annual (or 50-year committed) effective dose equivalent associated with a 40-dpm/mL tritium screening level was estimated to be 1.2 mrem for chronic equilibrium exposure conditions, 5 mrem for acute intakes with weekly to monthly sample intervals (the anticipated range of sampling intervals), and 100 mrem for quarterly intervals.

Because of the low dose potentially associated with chronic exposure or anticipated sampling intervals, use of the 99.9 percentile is justifiable on a cost-benefit basis. Thus, 40 dpm/mL was selected as a screening level for tritium bioassay of FFTF workers. Results below 40 dpm/mL are considered normal, nonoccupational exposure and do not require any dose assessment or follow-up investigation. Results in excess of 40 dpm/mL are considered as indicating exposure above the normal environmental level, and might be indicative of occupational exposure.

APPLICATION TO URANIUM BIOASSAY

Uranium work at Hanford can involve potential exposure to all three inhalation classes. The sensitivity of urine sampling as a uranium bioassay tool is limited by the presence of environmental levels of uranium. For class D forms of uranium, the dose (or fraction of the threshhold for chemical toxicity) associated with background levels is small, and the follow-up effort and worker concern resulting from erroneously interpreting the environmental background in urine as an occupational exposure is slight. For class Y forms of uranium, potential doses associated with misinterpreting background levels are more significant. Two studies were undertaken (in 1985 and 1990) to estimate the level and distribution of uranium in urine samples from occupationally unexposed Hanford workers.

Urine samples were collected in mid-1985 from 21 occupationally unexposed Hanford workers who resided in various locations around Hanford and used both municipal drinking water and individual well-water systems. The results ranged from below detectable levels (0.03 ug/day) to 0.12 ug/day. For seven of the individuals, three samples were collected over a 2-week period, and the daily excretion remained fairly constant for each individual over the period. Data for this group are shown as the 1985 curve in Figure 2.

The median daily uranium output for the 1985 study group was 0.06 ug, and the screening level was established at 0.2 ug/day (99.9 percentile). Samples containing less than 0.2 ug/day of uranium are considered to be within the expected environmental range, and results above 0.2 ug/day are considered to contain occupationally derived uranium. The net amount attributed to occupational sources is calculated as the total observed amount minus the average expected environmental level of 0.06 ug/day. The potentially undetected effective dose equivalent associated with the screening level varies with the solubility and sampling interval. Selected combinations for acute intakes of natural uranium are shown in Table 1.

A second study of background uranium levels in urine commenced in 1990. Urine samples were collected from 20 non-occupationally exposed workers in early 1990 with the intent of collecting quarterly samples from each worker throughout the year, as well as samples of their drinking water. The workers were selected to provide an indication of the possible correlation between drinking water sources and urinary excretion. Due to unrelated and unforeseen events, this study was terminated following collection of the first samples. However, the data are useful as a comparison with the 1985 data and, as can be seen in Figure 2, show some very interesting variations. The geometric mean of this sample group was 0.024 ug/day with a 99.9 percentile of 2.8 ug/day. There are at least two contributing factors to these apparent differences. First, the workers sampled were a substantially different subset than the first group; whereas the 1985 subjects were primarily from two large municipal water systems, the 1990 subjects were carefully selected to provide an indication of possible impact from water consumption in numerous outlying communities around Hanford. Second, a significant change in the analytical process occurred during the time elapsed between the two sets of samples - namely, the practice of subtracting reagent blanks from sample results was initiated. Interpretation of the 1990 data and implications for bioassay program screening levels and potentially undetected doses are still under review.

TABLE 1. Potentially Undetected Effective Dose Equivalent for a Natural Uranium Urine Bioassay Program Based on a Screening Level of 0.2 ug/day.

Inhalation Class	Sample Frequency	Effective Dose Equivalent (mrem) First-Year	50-Yr Committed
D	Quarterly	4	14
	Bimonthly	1	3
	Monthly	<1	1
	Biweekly	<1	<1
	Weekly	<1	<1
W	Annual	69	76
	Semiannual	7	8
	Quarterly	2	2
	Monthly	<1	<1
Y	Annual	125	600
	Semiannual	125	600
	Quarterly	125	600
	Monthly	70	340
	Biweekly	40	190

CONCLUSIONS

The use of the 99.9 percentile as a screening level for initiating the intake evaluation and dose assessment process has worked well for tritium and uranium because, for most applications, the potentially undetected annual effective dose equivalent is small. If the potentially undetected dose becomes a significant fraction of an annual limit, then setting a screening level at a lower percentile may be necessary. This can be expected to result in performing more evaluations for environmentally derived radioactivity, with the assessed doses falsely assumed to be from occupational activities.

The cost-benefit of screening levels based on various percentiles must be considered, given the unique characteristics of each application. This technique may have application to other air-sampling or bioassay monitoring programs where detectable environmental background can significantly impact the occupational dose assessment process (e.g., radon measurements).

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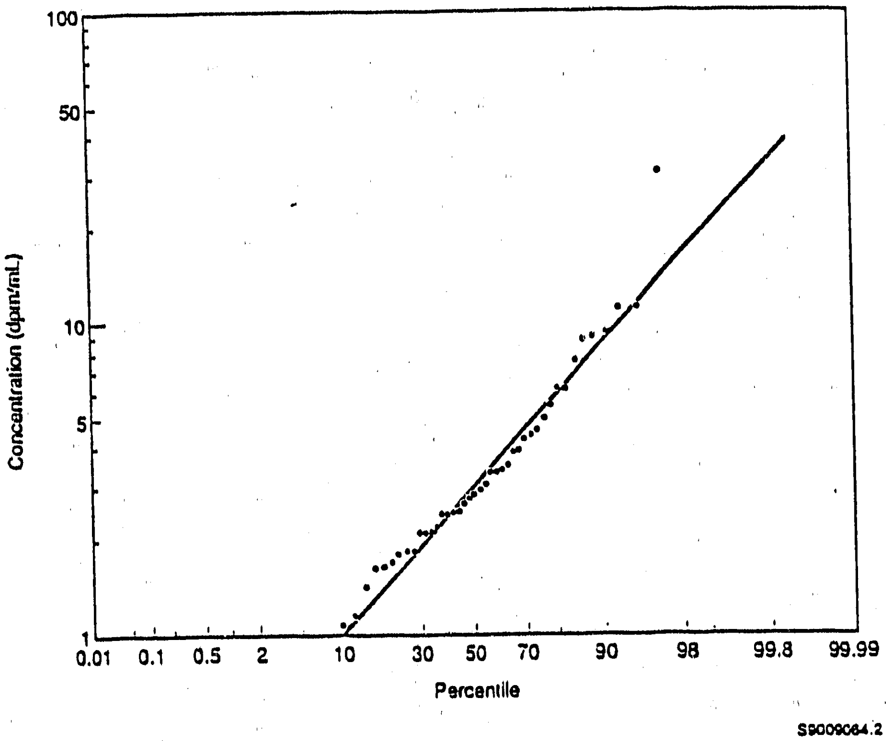

FIGURE 1. Tritium Concentration in Urine of Unexposed Workers

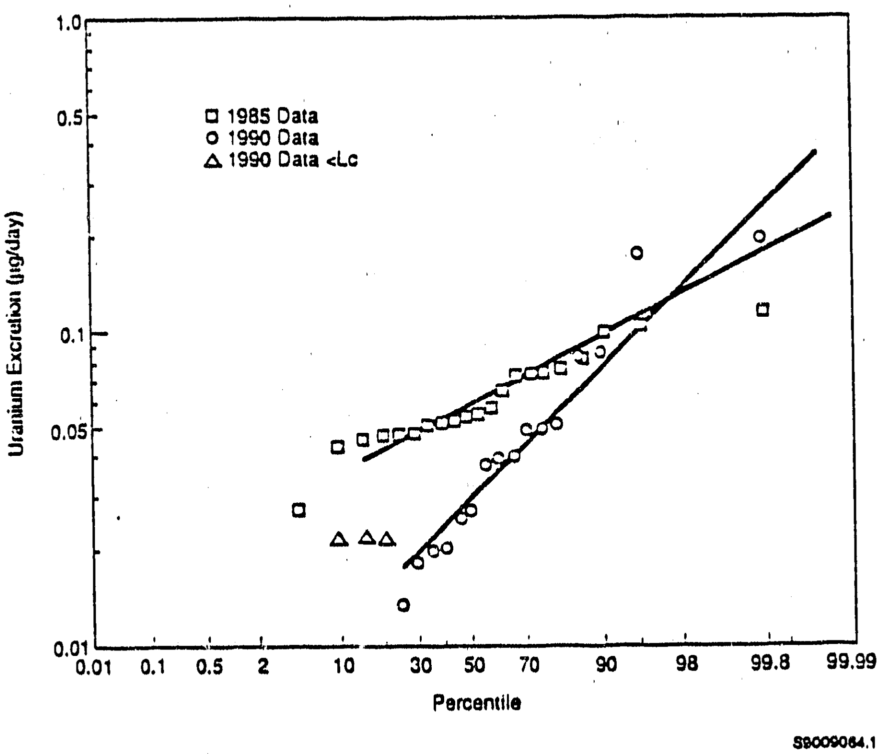

FIGURE 2. Urinary Excretion of Uranium in Unexposed Workers

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