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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
04/26/2005	00-A	New technical information bulletin for assignment of Portsmouth Gaseous Diffusion Plant internal doses based on coworker bioassay data. Initiated by Tracy A. Ikenberry.
05/27/2005	00-B	Incorporates internal review comments. Initiated by Tracy A. Ikenberry.
07/15/2005	00-C	Incorporates NIOSH review comments. Initiated by Tracy A. Ikenberry.
07/29/2005	00	First approved issue. Training required: As determined by the Task Manager. Initiated by Tracy A. Ikenberry.

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1.0 PURPOSE

Technical Information Bulletins (TIBs) are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained. TIBs may be used to assist the National Institute for Occupational Safety and Health in the completion of individual dose reconstructions.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 (42 U.S.C. § 7384l(5) and (12)).

There are instances of energy employees who, for a variety of reasons, were not monitored for internal exposure during the course of their employment at a U.S. Department of Energy (DOE) facility, or whose records of such monitoring are incomplete or unavailable. In such cases, dose reconstructors can use data from coworkers to approximate an individual's possible exposure. The purpose of this document is to provide the details of the calculation and assignment of intakes based on coworker data from the Portsmouth (Ohio) Gaseous Diffusion Plant (PORTS) for the purpose of estimating unmonitored exposures or where records of monitoring are incomplete or unavailable.

2.0 OVERVIEW

Analysis of Coworker Bioassay Data for Internal Dose Assignment (ORAU 2004a) describes the general process used to analyze bioassay data for assigning doses to individuals based on coworker results.

Bioassay results from 1955 to 1988 were obtained from the Health Physics Department at PORTS. The urinalysis data were derived from an Oracle 7.1 database (DEC/VMS operating system) that had been maintained by health physics personnel at the site for several years. Database information was reviewed for extraneous data and cleared by an authorized derivative classifier.

There were nearly a quarter million data records provided, which included gross alpha measurements with units of *gross alpha* disintegrations per minute per 100 milliliters (dpm/100 mL) and total uranium measurements with units of milligrams per liter (mg/L). Fewer than 4% of the data records included a nonzero uranium entry, while approximately 30% of the gross alpha records were nonzero. The gross alpha records provide a more robust data set for statistical analysis; therefore the gross alpha measurements were used as the indicator for uranium rather than the relatively few nonzero uranium-specific measurements in the database. A statistical analysis of these data was performed in accordance with ORAU (2004a). The resultant values were input to the Integrated Modules for Bioassay Analysis (IMBA) Expert OCAS-Edition computer program. It was assumed the data represented excretion of ^{234}U and a data fit was performed to obtain intake rates for assigning dose distributions.

3.0 DATA

3.1 SELECTED BIOASSAY DATA

Data were extracted from the urinalysis table in "HR_prior_1993," a Microsoft® Access version of the PORTS database. Sample dates were taken from the *Sample Date* field. Gross alpha urinalysis

results were taken from the *RES_Alpha* field in the database, which contains gross alpha bioassay results in units of dpm/100 mL.

3.2 ANALYSIS

Because of the number of sample results, data were analyzed by quarter, with the exception of 1955, when the analysis was for the entire year. The effective bioassay date was set equal to the midpoint of the analysis period. A lognormal distribution was assumed, and the 50th and 84th percentiles were calculated for each quarter (year for 1955), using the method described in ORAU (2004a). Table A-1 in Attachment A lists the statistical analysis results.

4.0 INTAKE MODELING

4.1 ASSUMPTIONS

The IMBA Expert OCAS-Edition computer program requires urine results to be in units of activity per day. The gross alpha results are in units of dpm/100 mL; therefore, the results were multiplied by 14 in order to normalize them to the Reference Man excretion rate of 1400 mL per day.

Each result used in the intake calculation was assumed to be normally distributed, and a uniform absolute error of 1 was applied to all results, thereby weighting all results equally. A chronic exposure pattern was assumed; while this is unlikely for workers at PORTS it approximates a series of acute intakes with unknown intake dates. Intakes were assumed to be by inhalation using a default breathing rate of 1.2 m^3/hr and a 5-µm activity median aerodynamic diameter (AMAD) particle size distribution.

The database reported all modeled results as "gross alpha," which this analysis conservatively assumed to be all uranium. Because a variety of enrichments occurred at PORTS, ^{234}U was assumed for the IMBA intake modeling. This assumption does not affect the fitting of the data for intake determination (i.e., the same total intakes would be obtained for any enrichment that was assumed) because all uranium isotopes behave the same biokinetically and the isotopes considered in this analysis have long half-lives in relation to the assumed intake period. The International Commission on Radiological Protection (ICRP) Publication 68 dose coefficients (also referred to as dose conversion factors) for ^{234}U are 7% to 31% larger than those for ^{235}U, ^{236}U, and ^{238}U (ICRP 1995). Because of the isotopic compositions of the source terms, the ^{234}U dose conversion factor will yield claimant-favorable doses.

Although PORTS began enrichment operations in September 1954, there are no gross alpha bioassay results before 1955 in the database. Intake modeling was based on the 1955 and later data; however uranium intakes should be considered possible as early as September 1, 1954.

4.2 BIOASSAY FITTING

The IMBA Expert OCAS-Edition computer program was used to fit the bioassay results to a series of inhalation intakes. Quarterly data from 1955 through 1988 were fit as a series of chronic intakes.

The intake assumptions were based on patterns observed in the bioassay data. Periods with constant chronic intake rates were chosen by selecting time spans for which the bioassay results are of similar magnitudes. A new chronic intake period was started if the data indicated a significant sustained change in the bioassay results. By this method, the period from 1955 through 1988 was divided into four chronic intake periods.

4.3 URANIUM MATERIAL TYPES

Section 5.1.2.6 of the Portsmouth Technical Basis Document on Occupational Internal Dose (ORAU 2004b) indicates uranium could be present in material with all three (F, M, and S) lung clearance rates. Therefore, all three material types were evaluated. The bioassay results were entered into IMBA and the assumed 50th-percentile intakes that resulted are shown in the figures in Attachment A. In these figures, quarterly bioassay data used in the fits are shown as blue dots (●), and data that are not used in the fits are shown as red dots (●).

The Type S uranium compounds present at PORTS have very long radiological half-lives, and the body retains the material for long periods. Therefore, the excretion results for different chronic intake periods are not independent for Type S materials. For example, an intake in the 1950s could contribute to urinary excretion in the 1980s and later. To avoid potential underestimation of intakes for people who worked at PORTS for relatively short periods, each chronic intake of Type S material was fit independently, using only the bioassay results from the single intake period. This will result in an overestimate of intakes for assumed Type S exposures extending through multiple assumed intake periods.

4.3.1 Type F

Uranium urine results were fit using a Type F material. Figure A-1 in Attachment A shows the fits to the 50th-percentile values from all intakes. The same intake periods were applied to the 84th-percentile values because the values followed a similar pattern, as shown in Figure A-2. These depict the expected excretion rates from an individual exposed for all the periods at the 50th- and 84th-percentile intake rates, respectively. Table 4-1 summarizes the intake periods and corresponding intake rates for the 50th and 84th percentiles. The geometric standard deviations (GSDs) were determined by dividing the 84th-percentile intake rates by the 50th-percentile intake rates.

Table 4-1. Type F uranium intake periods and rates.

		Uranium intake rate (dpm/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
1/1/1955	12/31/1956	115.6	504.8	4.37
1/1/1957	12/31/1958	73.75	239.6	3.25
1/1/1959	6/30/1961	155.4	565.8	3.64
7/1/1961	12/31/1988	33.37	111	3.33

4.3.2 Type M

The intake periods used in the Type F fits were applied to the Type M material fits. Figures A-3 and A-4 show the fits to the 50th- and 84th-percentile values from all intakes. Table 4-2 summarizes the intake periods and corresponding intake rates for the 50th and 84th percentiles. The GSDs were determined as described for the Type F intake rates.

Table 4-2. Type M uranium intake periods and rates.

		Uranium intake rate (dpm/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
1/1/1955	12/31/1956	497.4	2161	4.34
1/1/1957	12/31/1958	275.7	809.1	2.93
1/1/1959	6/30/1961	664.9	2,449	3.68
7/1/1961	12/31/1988	132.8	440.9	3.32

4.3.3 Type S

The intake periods used in the Type F and M fits were applied to the Type S material fits. As discussed above, each chronic intake period for Type S material was fit independently. Figures A-5 to A-8 show the individual fits for the 50th-percentile values. The 84th-percentile values are not shown but were fit similarly. Table 4-3 summarizes the intake rates for the 50th- and 84th-percentile values. The GSDs were determined as described for the Type F intake rates.

Table 4-3. Type S uranium intake periods and rates.

		Uranium intake rate (dpm/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
1/1/1955	12/31/1956	11,990	51,429	4.29
1/1/1957	12/31/1958	8,344	27,002	3.24
1/1/1959	6/30/1961	16,423	61,616	3.75
7/1/1961	12/31/1988	1,644	5,233	3.18

Figures A-9 and A-10 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all Type S intakes.

5.0 ASSIGNMENT OF INTAKES AND DOSES

5.1 INTAKE RATE SUMMARY

A summary of uranium intake rates and GSDs for different time periods from 1954 to 1988 is presented in Tables 5.1, 5.2, and 5.3 for Type F, M, and S material, respectively. These tables include potential intakes that may have occurred as early as September 1, 1954. Type F material during the period from 1957 through 1988 had intake rate GSDs within 10% of each other; for simplicity the largest intake rate GSD was assigned to all three intake rates during the period, as listed in Table 5-1. Similarly, with Type M material, the largest GSD for the period from 1959 through 1988 was assigned to both of the intake rates during the period, as indicated in Table 5-2. Table 5-2 also has one GSD value adjusted from 2.93 to 3. When calculating doses to individuals from their own bioassay data, a GSD of 3 is assigned to account for biological variation and uncertainty in the models. A GSD of at least 3 is assigned for intake rates based on coworker data. No changes were made for the Type S material listed in Table 5-3; it is identical to Table 4-3 but presented here for completeness.

Table 5-1. Type F uranium intake periods and rates.

		Uranium intake rate (dpm/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
9/1/1954	12/31/1956	115.6	504.8	4.4
1/1/1957	12/31/1958	73.75	239.6	3.6
1/1/1959	6/30/1961	155.4	565.8	3.6
7/1/1961	12/31/1988	33.37	111	3.6

Table 5-2. Type M uranium intake periods and rates.

		Uranium intake rate (dpm/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
9/1/1954	12/31/1956	497.4	2161	4.3
1/1/1957	12/31/1958	275.7	809.1	3
1/1/1959	6/30/1961	664.9	2,449	3.7
7/1/1961	12/31/1988	132.8	440.9	3.7

Table 5-3. Type S uranium intake periods and rates.

Start date	Stop date	Uranium intake rate (dpm/day)		GSD
		50th percentile	84th percentile	
9/1/1954	12/31/1956	11,990	51,429	4.3
1/1/1957	12/31/1958	8,344	27,002	3.2
1/1/1959	6/30/1961	16,423	61,616	3.8
7/1/1961	12/31/1988	1,644	5,233	3.2

5.2 CONTRIBUTION FROM CONTAMINANTS IN RECYCLED URANIUM

Throughout the DOE complex, spent fuel from fission reactors has been processed to recover uranium for recycling. Because the uranium streams at PORTS could have contained recycled uranium, the dose from the added constituents, including plutonium, ^{237}Np, and ^{99}Tc, must be included. See ORAU (2004b) for information about intake values in relation to the uranium intake amounts.

5.3 DOSE ASSIGNMENT

Doses to be assigned to individuals are calculated from the 50th-percentile intake rates; the material type resulting in the largest probability of causation, which is determined by the Department of Labor, is selected. A comparison of the intake rates shows that the intake rate substantially increases as the material solubility decreases. However, because lower solubility materials remain in the lungs for longer periods, while higher solubility materials are transferred to the systemic organs, it is necessary to compare the annual doses on a case-by-case basis to determine which will deliver the larger dose to the organ of interest. Recycled uranium contaminants, when appropriate for the period, are a factor in this comparison.

The lognormal distribution is selected in the Interactive RadioEpidemiological Program (IREP), with the calculated dose entered as Parameter 1 and the associated GSD as Parameter 2. The GSD is associated with the intake, so it is applied to all annual doses determined from the intake period.

REFERENCES

ICRP (International Commission on Radiological Protection), 1995, *Dose Coefficients for Intakes by Workers*, Publication 68, Pergamon Press, Oxford, England.

ORAU (Oak Ridge Associated Universities), 2004a, *Analysis of Coworker Bioassay Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Oak Ridge, Tennessee.

ORAU (Oak Ridge Associated Universities), 2004b, *Technical Basis Document for Portsmouth Gaseous Diffusion Plant – Occupational Internal Dose*, ORAUT-TKBS-0015-5, Oak Ridge, Tennessee.

ATTACHMENT A

Table A-1. Summary of quarterly uranium 24-hour urinary excretion rate analyses, 1955-1988.

Effective sample date	50th percentile (dpm/d)	84th percentile (dpm/d)	Effective sample date	50th percentile (dpm/d)	84th percentile (dpm/d)	Effective sample date	50th percentile (dpm/d)	84th percentile (dpm/d)
7/1/1955*	**28.95**	**150.76**	8/15/1966	2.36	12.36	11/15/1977	13.75	36.39
2/15/1956	28.42	128.17	11/15/1966	3.03	13.65	2/15/1978	14.76	38.34
5/15/1956	36.58	152.73	2/15/1967	3.91	25.02	5/15/1978	3.58	15.68
8/15/1956	36.09	143.76	5/15/1967	6.07	23.81	2/15/1979	2.18	10.12
11/15/1956	26.66	107.93	2/15/1968	3.13	15.49	5/15/1979	11.86	28.42
2/15/1957	24.96	93.31	5/15/1968	3.44	14.25	8/15/1979	11.04	34.86
5/15/1957	22.03	83.84	8/15/1968	3.54	15.65	11/15/1979	9.68	21.07
8/15/1957	22.33	60.55	11/15/1968	3.91	18.95	2/15/1980	11.25	22.64
11/15/1957	19.39	62.82	2/15/1969	14.06	103.20	5/15/1980	12.70	22.87
2/15/1958	18.60	55.84	5/15/1969	5.50	29.89	8/15/1980	12.86	24.34
5/15/1958	21.89	70.35	8/15/1969	4.74	21.70	11/15/1980	13.43	23.67
8/15/1958	13.74	48.28	11/15/1969	7.50	33.38	2/15/1981	13.17	25.28
11/15/1958	21.07	64.17	2/15/1970	6.58	51.85	5/15/1981	12.65	24.97
2/15/1959	29.45	91.09	5/15/1970	8.67	37.69	8/15/1981	10.78	22.94
5/15/1959	44.64	139.88	8/15/1970	4.87	18.97	11/15/1981	10.58	22.79
8/15/1959	26.51	89.44	11/15/1970	5.22	20.81	2/15/1982	6.07	19.98
11/15/1959	31.04	111.51	2/15/1971	6.86	36.73	5/15/1982	9.11	18.76
2/15/1960	58.01	175.95	5/15/1971	9.89	41.37	8/15/1982	8.68	25.29
5/15/1960	55.25	192.36	8/15/1971	8.68	32.76	11/15/1982	8.76	22.90
8/15/1960	53.58	174.45	11/15/1971	8.51	28.29	2/15/1983	6.25	19.42
11/15/1960	48.61	197.29	2/15/1972	5.39	22.11	5/15/1983	9.11	23.11
2/15/1961	38.73	175.27	5/15/1972	8.46	25.16	8/15/1983	9.47	23.21
5/15/1961	36.27	187.36	8/15/1972	5.13	18.02	11/15/1983	9.84	27.32
8/15/1961	21.39	59.48	11/15/1972	7.18	30.52	2/15/1984	7.85	21.06
11/15/1961	14.43	42.94	2/15/1973	8.09	37.98	5/15/1984	10.50	21.44
2/15/1962	7.39	32.13	5/15/1973	4.22	22.53	8/15/1984	12.07	25.75
5/15/1962	7.68	34.96	8/15/1973	4.22	21.70	11/15/1984	7.84	27.94
8/15/1962	14.81	43.17	11/15/1973	6.79	76.22	2/15/1985	7.26	20.19
11/15/1962	9.47	44.79	2/15/1974	4.26	27.83	5/15/1985	10.36	23.48
2/15/1963	4.07	31.74	5/15/1974	6.79	22.55	8/15/1985	13.33	30.05
5/15/1963	6.49	17.55	8/15/1974	6.08	19.07	11/15/1985	8.43	17.77
8/15/1963	6.70	25.84	11/15/1974	8.89	22.37	2/15/1986	8.09	14.61
11/15/1963	11.68	62.28	2/15/1975	10.51	30.95	5/15/1986	11.92	18.22
2/15/1964	9.45	45.78	5/15/1975	11.72	30.17	8/15/1986	13.31	23.32
5/15/1964	10.19	23.24	8/15/1975	13.54	60.73	11/15/1986	13.38	25.30
8/15/1964	8.14	30.99	11/15/1975	10.15	40.65	2/15/1987	12.29	25.60
11/15/1964	13.04	49.30	2/15/1976	11.36	29.62	5/15/1987	13.85	31.03
2/15/1965	23.92	176.43	5/15/1976	13.86	26.81	8/15/1987	9.15	25.24
5/15/1965	13.88	88.81	8/15/1976	16.72	40.62	11/15/1987	7.04	21.65
8/15/1965	10.92	58.95	11/15/1976	19.89	62.78	2/15/1988	5.06	18.42
11/15/1965	8.21	38.71	2/15/1977	17.04	37.21	5/15/1988	11.93	29.26
2/15/1966	7.02	25.13	5/15/1977	16.79	36.86	8/15/1988	14.59	29.91
5/15/1966	3.35	23.23	8/15/1977	17.44	40.72	11/15/1988	7.13	18.78

*Due to the low number of urinalysis samples in 1955, only the annual summary was analyzed.

Type F Uranium

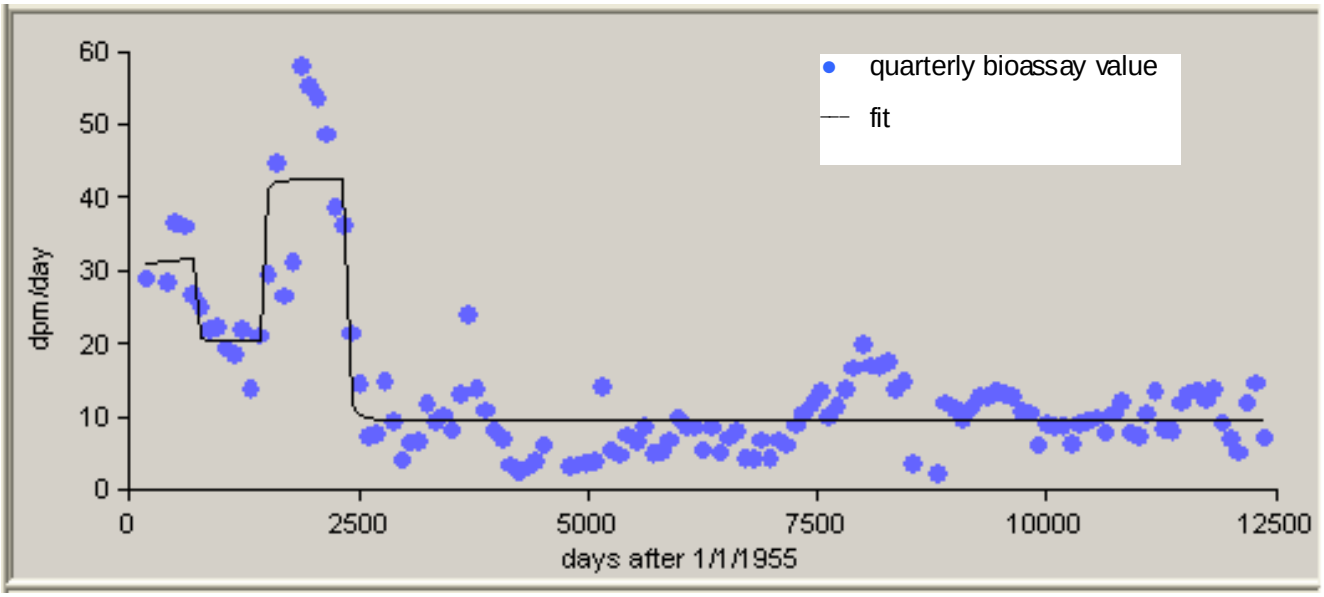

Figure A-1. 50th-percentile uranium urinalysis data used to estimate intakes of Type F uranium occurring 1/1/55 to 12/31/88.

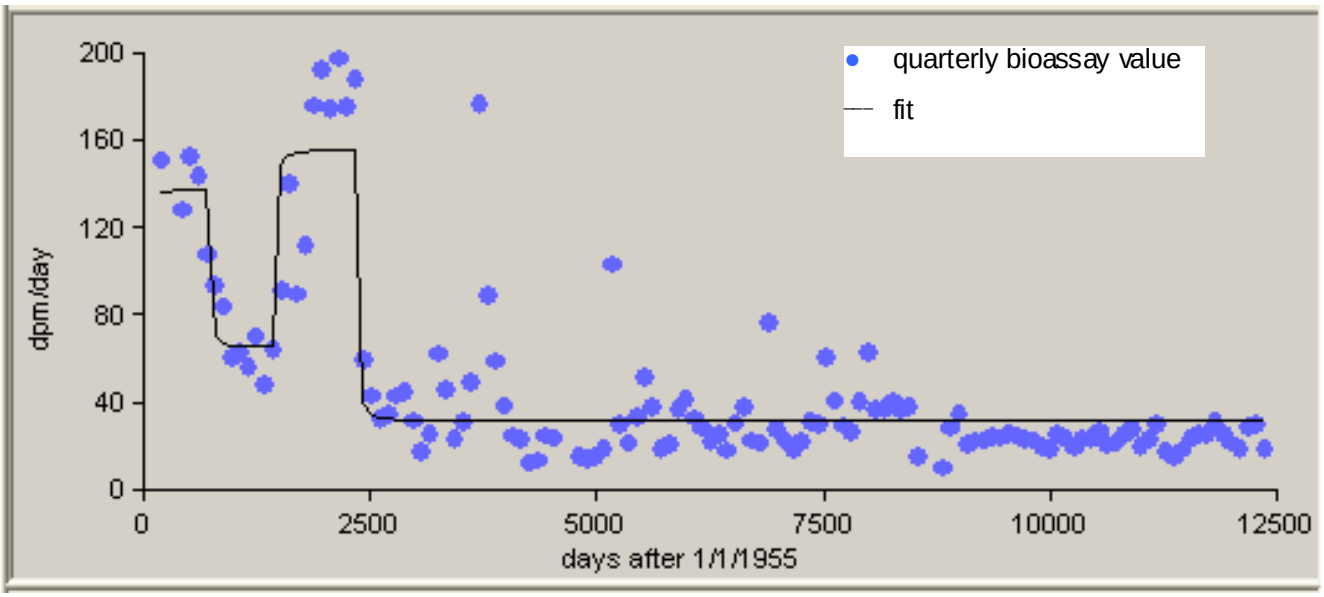

Figure A-2. 84th-percentile uranium urinalysis data used to estimate intakes of Type F uranium occurring 1/1/55 to 12/31/88.

Type M Uranium

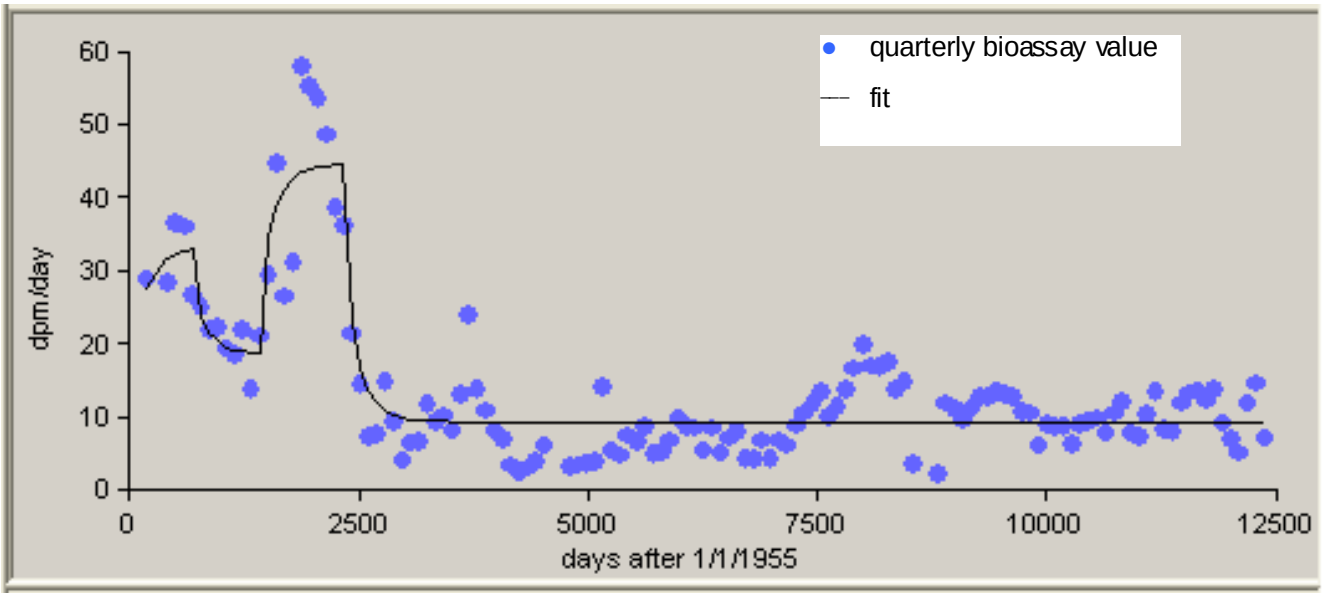

Figure A-3. 50th-percentile uranium urinalysis data used to estimate intakes of Type M uranium occurring 1/1/55 to 12/31/88.

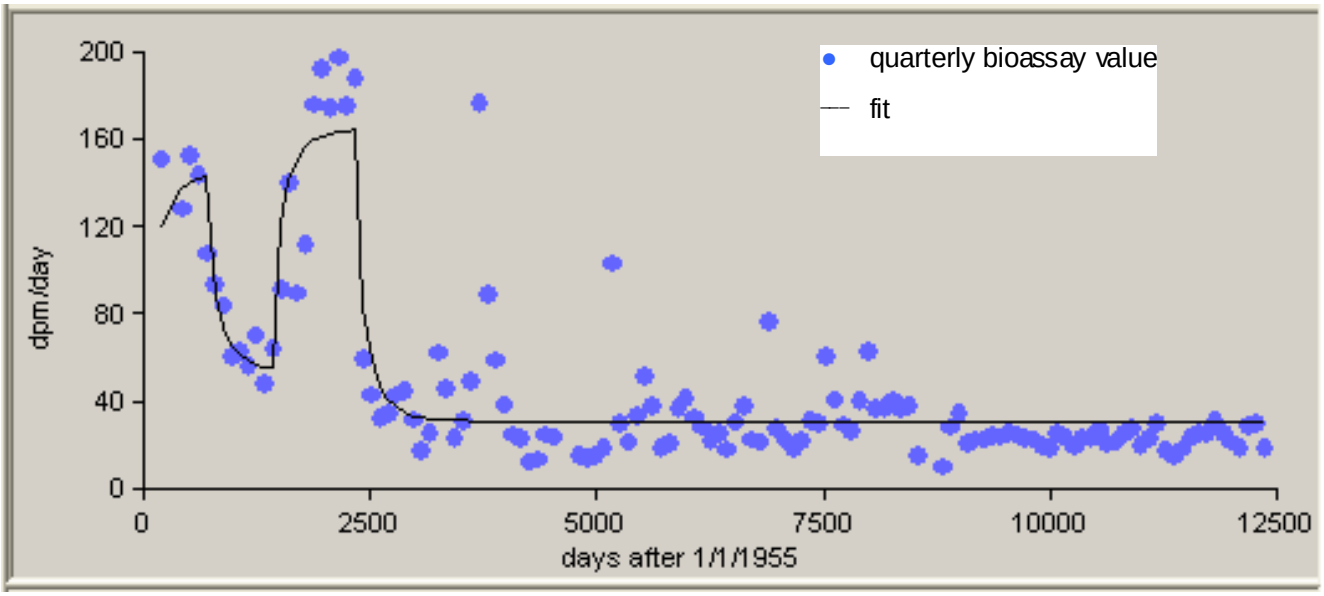

Figure A-4. 84th-percentile uranium urinalysis data used to estimate intakes of Type M uranium occurring 1/1/55 to 12/31/88.

Type S Uranium

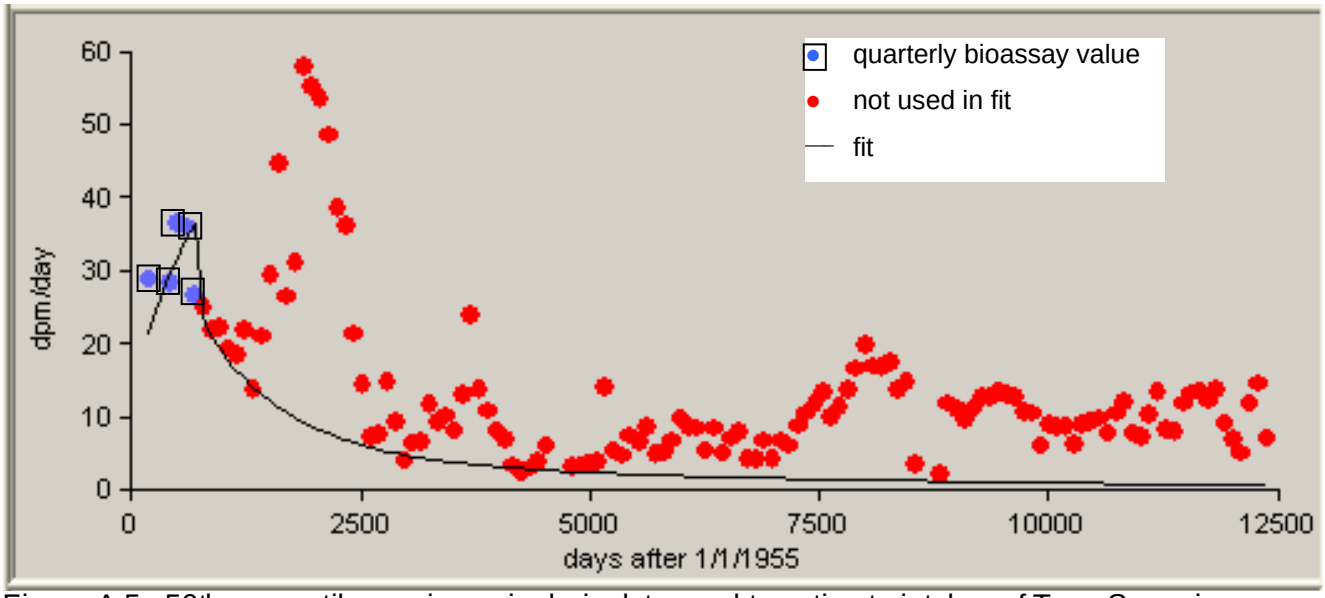

Figure A-5. 50th-percentile uranium urinalysis data used to estimate intakes of Type S uranium occurring 1/1/55 to 12/31/56.

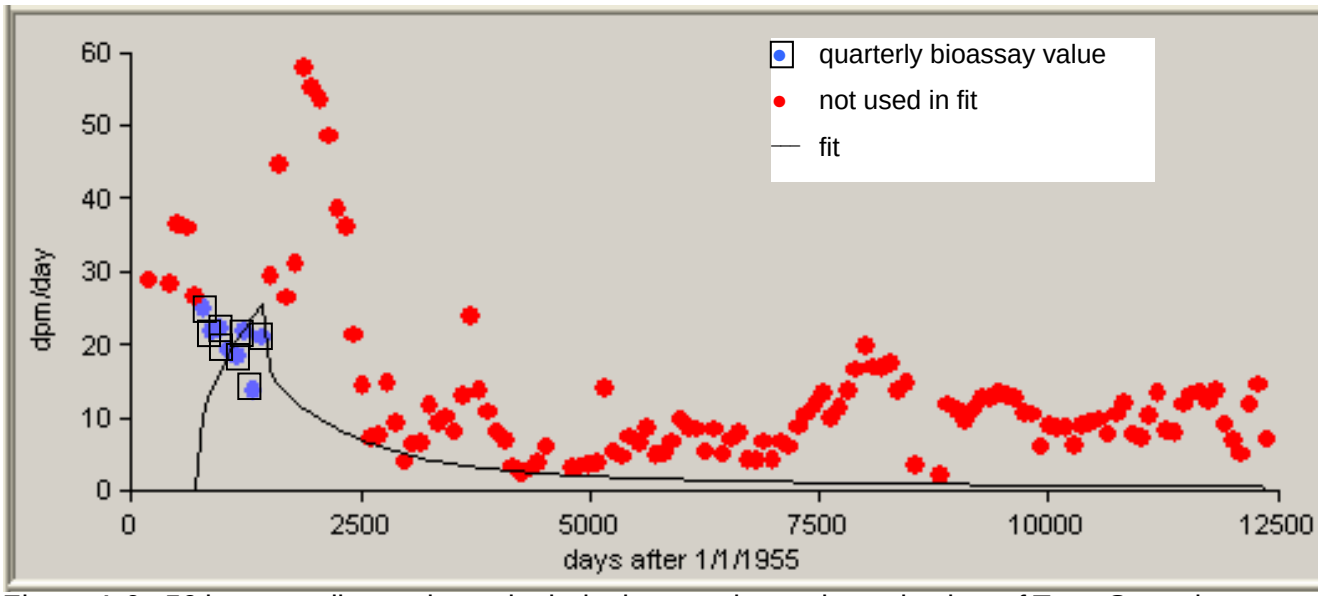

Figure A-6. 50th-percentile uranium urinalysis data used to estimate intakes of Type S uranium occurring 1/1/57 to 12/31/58.

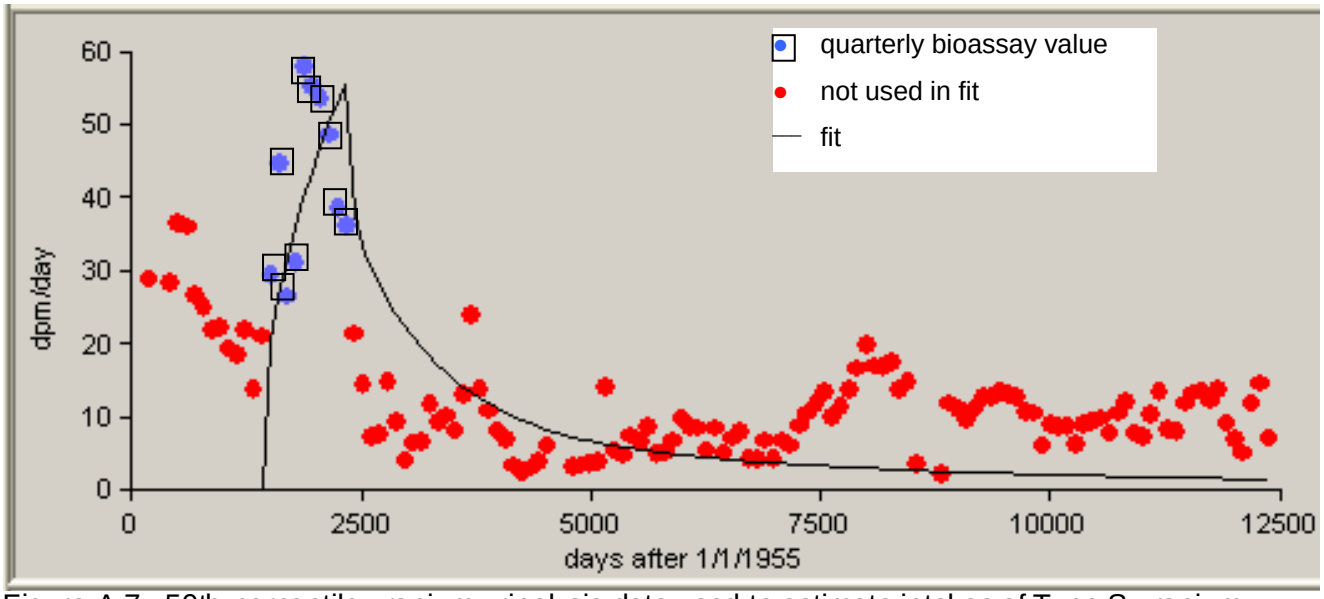

Figure A-7. 50th-percentile uranium urinalysis data used to estimate intakes of Type S uranium occurring 1/1/59 to 6/30/61.

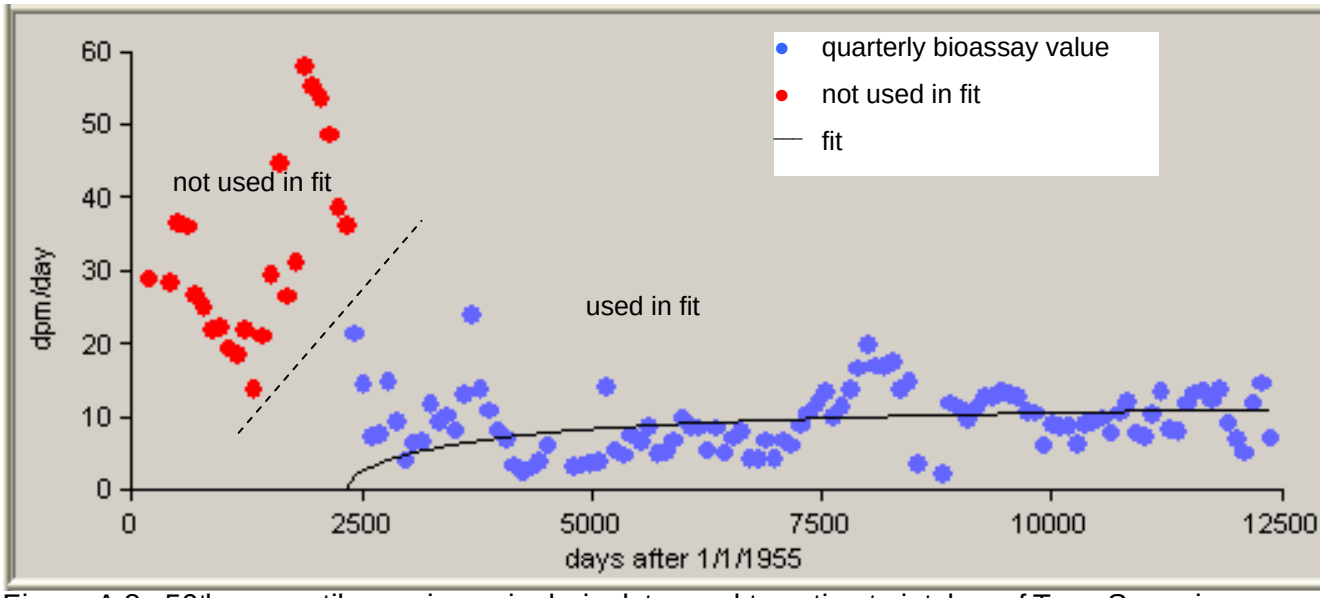

Figure A-8. 50th-percentile uranium urinalysis data used to estimate intakes of Type S uranium occurring 7/1/61 to 12/31/88.

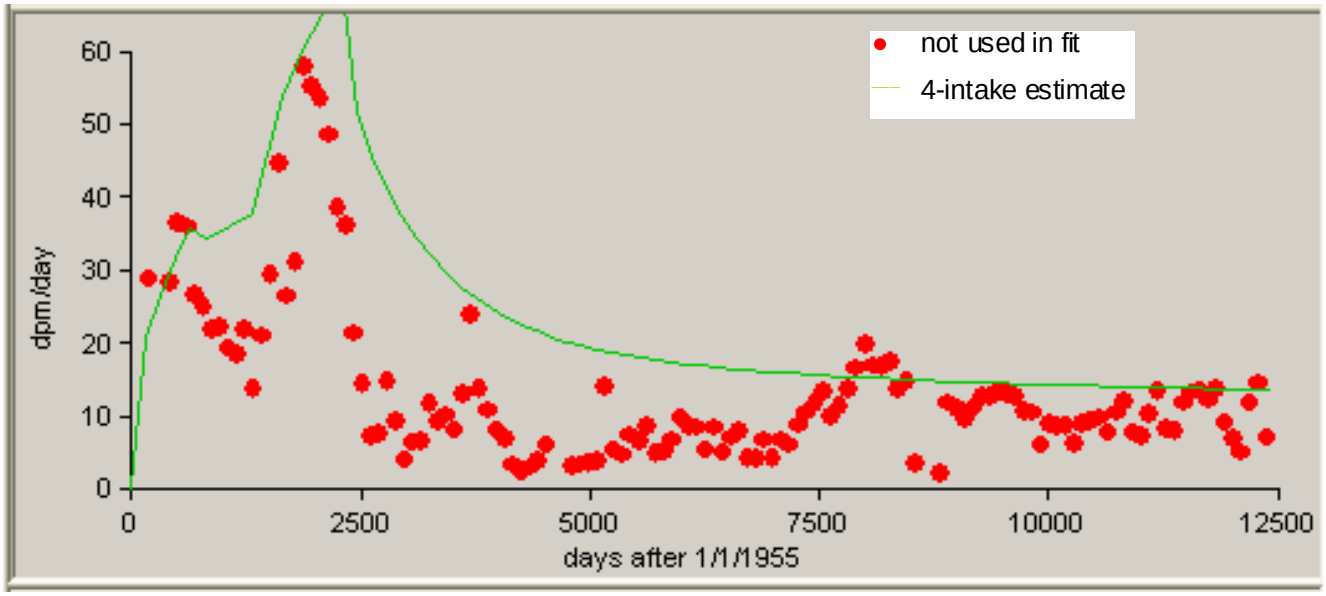

Figure A-9. Predicted 50th- percentile urinary excretion of Type S uranium from 1955 to 1988 based on four independent intakes, compared to bioassay data.

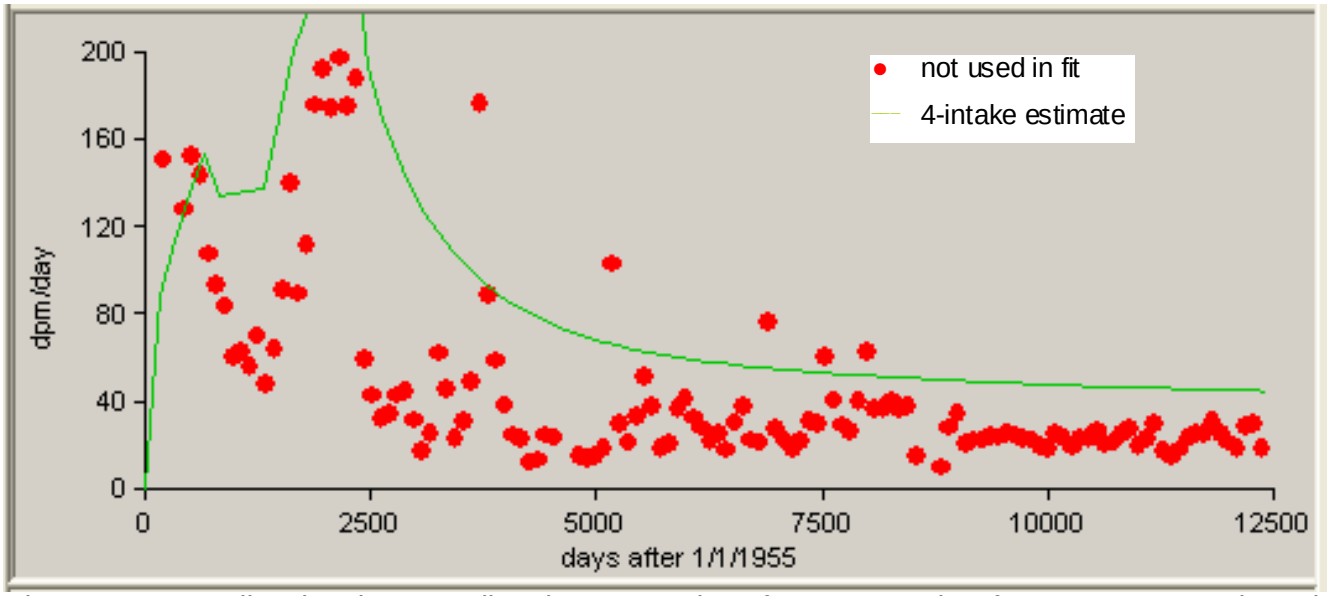

Figure A-10. Predicted 84th-percentile urinary excretion of Type S uranium from 1955 to 1988 based on four independent intakes, compared to bioassay data.