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PUBLICATION RECORD

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05/12/2005	00-A	New technical information bulletin for assignment of Paducah Gaseous Diffusion Plant internal doses based on coworker bioassay data. Initiated by Tracy A. Ikenberry.
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09/20/2005	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 Paducah (Kentucky) Gaseous Diffusion Plant (PGDP) 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.

Uranium urine bioassay results from 1952 through 1988 were obtained from the PGDP Dosimetry Section. The data were copied from working files that are the basis for the PGDP annual dose reports and dose histories. Some of the bioassay data were taken from handwritten logs and then added to the electronic data base.

The database results are in units of micrograms or milligrams of total uranium per liter (µg/L or mg/L, respectively). All results were converted to µg/L for data analysis. There were a limited number of "beta" results in one of the files used (about 11%) which likely reflects measurement for technitium-99 (^{99}Tc). The decision was made not to use these data, because most of the results (> 97%) were reported as zero. The uranium records provide a more robust data set for statistical analysis.

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 Office of Compensation Analysis and Support (OCAS)-Edition computer program. The bioassay data were assumed to represent excretion of ^{234}U which is biokinetically identical to other uranium isotopes and would result in the highest dose; a data fit was performed to obtain intake rates for assigning dose distributions. Bioassay results were converted from mass to activity before fitting.

3.0 DATA

3.1 SELECTED BIOASSAY DATA

PGDP urinalysis data were extracted from two separate Microsoft® Access files provided by the PGDP Dosimetry Section. File "PGDP_Historical_Urine" was the source of urinalysis data from 1977

through 1988. Sample dates were taken from the *Sample_Date* field. Total uranium urinalysis results were taken from the *Result* field in the database; the *Units* field identified result units as micrograms per liter.

File "Historical_Urinalysis_Data_(unverified)" was the source of urinalysis data from October 1952 to mid-1977. Sample dates were taken from the *Date_Sample* field. Total uranium urinalysis results were taken from the *Urinalysis_Result* field in the database; there were no units associated with urinalysis results in this file. Comparison to results with identified units in file "PGDP_Historical_Urine" and with information presented in *Technical Basis Document for Paducah Gaseous Diffusion Plant – Occupational Internal Dose* (ORAU 2004b) determined the results in this file were in units of milligrams per liter. Results in this file were converted to micrograms per liter for analysis.

Because both of the above files included PGDP uranium urinalysis data from 1977, the data were evaluated to identify and eliminate duplicate entries.

3.2 ANALYSIS

Because of the number of sample results, data were analyzed by quarter from the final quarter of 1952 through 1988. 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, 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 total uranium results are in units of µg/L; therefore the results were multiplied by 1.4 in order to normalize them to the Reference Man excretion rate of 1400 mL per day. Bioassay results were converted from mass to activity before fitting assuming 0.0389 Bq/µg, characteristic of low-enrichment (2 percent) uranium. Low-enrichment uranium feed is the default value in ORAU (2004b) when the specific location where a claimant worked is not available.

The uncertainty for each result in the intake calculation was assumed to be normally distributed. All results were equally weighted by applying a uniform absolute error of 1, indicating to IMBA that all results are (assumed to be) equally precise. A chronic exposure pattern was assumed for PGDP workers; this pattern also 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 results as "uranium." The bioassay data were assumed to represent excretion of ^{234}U. All uranium isotopes considered have long half-lives in relation to the assumed intake period so radioactive decay is not a consideration. Also, all uranium isotopes are biokinetically identical so there is no effect on the fitting of the data for intake determination. ^{234}U was the isotope selected because it would result in the highest internal dose; 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 assumption of ^{234}U will yield claimant-favorable doses.

PGDP received uranium and began enrichment operations during June 1952 and first withdrew enriched uranium during November 1952. The November 1952 period is consistent with uranium urinalysis data; however, the first intake period was conservatively assumed to begin on June 1, 1952.

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 1952 through 1988 were fit as a series of chronic intakes.

The intake assumptions were based on patterns observed in the bioassay data. The analysis for this TIB used periods with constant chronic intake rates by selecting time spans for which the bioassay results are of similar magnitudes. The analysis started a new chronic intake period if the data indicated a significant sustained change in the bioassay results. By this method, the period from 1952 through 1988 was divided into two chronic intake periods.

4.3 URANIUM MATERIAL TYPES

Section 5.1.2.6 of the PGDP Technical Basis Document on Occupational Internal Dose (ORAU 2004b) indicates uranium could be present in material with all three lung clearance rates (F, M, and S). Therefore, all three material types were evaluated. The bioassay results were entered into IMBA and the 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 PGDP have very long radiological half-lives, and the body retains the compounds 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 PGDP 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 both 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.

Start date	Stop date	Uranium intake rate (Bq/day)		GSD
		50th percentile	84th percentile	
6/1/1952	3/31/1980	1.11	3.05	2.75
4/1/1980	12/31/1988	0.279	0.862	3.09

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, respectively, 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 (Bq/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
6/1/1952	3/31/1980	4.53	12.42	2.74
4/1/1980	12/31/1988	1.07	3.35	3.13

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 and A-6 show the individual fits for the 50th-percentile values. The 84th-percentile values 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 (Bq/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
6/1/1952	3/31/1980	51.45	138.3	2.69
4/1/1980	12/31/1988	18.91	59.11	3.13

Figures A-7 and A-8 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 time periods from 1952 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 June 1, 1952. Each of these tables has one GSD value adjusted from approximately 2.7 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.

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

		Uranium intake rate (Bq/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
6/1/1952	3/31/1980	1.11	3.05	3
4/1/1980	12/31/1988	0.279	0.862	3.1

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

		Uranium intake rate (Bq/day)		
Start date	Stop date	50th percentile	84th percentile	GSD
6/1/1952	3/31/1980	4.53	12.42	3
4/1/1980	12/31/1988	1.07	3.35	3.1

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

Start date	Stop date	Uranium intake rate (Bq/day)		GSD
		50th percentile	84th percentile	
6/1/1952	3/31/1980	51.45	138.3	3
4/1/1980	12/31/1988	18.91	59.11	3.1

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 PGDP 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 Paducah Gaseous Diffusion Plant – Occupational Internal Dose*, ORAUT-TKBS-0019-5, Oak Ridge, Tennessee.

ATTACHMENT A

Table A-1. Summary of quarterly uranium 24-hr urinary excretion rate analyses, 1952-1988.

Effective sample date	50th percentile (Bq/d)	84th percentile (Bq/d)	Effective sample date	50th percentile (Bq/d)	84th percentile (Bq/d)	Effective sample date	50th percentile (Bq/d)	84th percentile (Bq/d)
11/14/1952	0.599	3.246	5/15/1965	0.196	0.441	5/15/1977	0.334	0.972
8/15/1953	0.205	0.980	8/15/1965	0.242	0.467	8/15/1977	0.321	0.964
11/15/1953	0.362	1.373	11/15/1965	0.279	0.520	11/15/1977	0.432	1.189
2/15/1954	0.578	2.023	2/15/1966	0.326	0.672	2/15/1978	0.418	1.037
5/15/1954	0.466	1.643	5/15/1966	0.336	0.683	5/15/1978	0.330	0.862
8/15/1954	0.383	0.951	8/15/1966	0.293	0.598	8/15/1978	0.245	0.603
11/15/1954	0.330	1.010	11/15/1966	0.318	0.558	11/15/1978	0.209	0.621
2/15/1955	0.331	1.327	2/15/1967	0.305	0.612	2/15/1979	0.071	0.376
5/15/1955	0.471	1.419	5/15/1967	0.289	0.689	5/15/1979	0.159	0.577
8/15/1955	0.411	1.185	8/15/1967	0.275	0.503	8/15/1979	0.170	0.447
11/15/1955	0.468	1.465	11/15/1967	0.224	0.561	11/15/1979	0.258	0.658
2/15/1956	0.466	1.454	2/15/1968	0.241	0.523	2/15/1980	0.229	0.674
5/15/1956	0.407	0.800	5/15/1968	0.241	0.449	5/15/1980	0.117	0.330
8/15/1956	0.323	0.739	8/15/1968	0.293	0.647	8/15/1980	0.120	0.318
11/15/1956	0.328	0.930	11/15/1968	0.421	0.981	11/15/1980	0.109	0.232
2/15/1957	0.377	0.866	2/15/1969	0.529	1.165	2/15/1981	0.100	0.297
5/15/1957	0.453	1.063	5/15/1969	0.394	0.840	5/15/1981	0.081	0.243
8/15/1957	0.316	0.886	8/15/1969	0.278	0.677	8/15/1981	0.097	0.236
11/15/1957	0.351	0.900	11/15/1969	0.344	0.847	11/15/1981	0.083	0.207
2/15/1958	0.415	1.028	2/15/1970	0.218	0.661	2/15/1982	0.106	0.279
5/15/1958	0.353	0.859	5/15/1970	0.228	0.636	5/15/1982	0.061	0.199
8/15/1958	0.425	1.040	8/15/1970	0.223	0.764	8/15/1982	0.086	0.267
11/15/1958	0.365	0.857	11/15/1970	0.254	0.912	11/15/1982	0.081	0.250
2/15/1959	0.380	1.046	2/15/1971	0.260	0.797	2/15/1983	0.107	0.291
5/15/1959	0.277	0.770	5/15/1971	0.208	0.634	5/15/1983	0.116	0.307
8/15/1959	0.243	0.655	8/15/1971	0.253	0.746	8/15/1983	0.060	0.214
11/15/1959	0.311	0.930	11/15/1971	0.341	0.947	11/15/1983	0.098	0.276
2/15/1960	0.260	0.737	2/15/1972	0.298	0.875	2/15/1984	0.088	0.275
5/15/1960	0.197	0.581	5/15/1972	0.163	0.570	5/15/1984	0.069	0.245
8/15/1960	0.195	0.558	8/15/1972	0.176	0.548	8/15/1984	0.051	0.193
11/15/1960	0.287	1.119	11/15/1972	0.216	0.736	11/15/1984	0.062	0.222
2/15/1961	0.297	1.083	2/15/1973	0.175	0.632	2/15/1985	0.086	0.384
5/15/1961	0.190	0.551	5/15/1973	0.248	0.624	5/15/1985	0.055	0.249
8/15/1961	0.176	0.529	8/15/1973	0.212	0.630	8/15/1985	0.052	0.157
11/15/1961	0.340	0.977	11/15/1973	0.275	0.735	11/15/1985	0.053	0.156
2/15/1962	0.447	1.284	2/15/1974	0.221	0.665	2/15/1986	0.054	0.250
5/15/1962	0.412	0.950	5/15/1974	0.177	0.546	5/15/1986	0.039	0.106
8/15/1962	0.302	0.797	8/15/1974	0.232	0.695	8/15/1986	0.072	0.240
11/15/1962	0.369	0.911	11/15/1974	0.354	0.980	11/15/1986	0.055	0.185
2/15/1963	0.343	0.929	2/15/1975	0.422	1.185	2/15/1987	0.088	0.259
5/15/1963	0.327	0.807	5/15/1975	0.347	0.818	5/15/1987	0.061	0.213
8/15/1963	0.228	0.597	8/15/1975	0.307	0.698	8/15/1987	0.107	0.282
11/15/1963	0.274	0.678	11/15/1975	0.362	0.890	11/15/1987	0.091	0.229
2/15/1964	0.316	0.720	2/15/1976	0.401	0.869	2/15/1988	0.114	0.425
5/15/1964	0.305	0.917	5/15/1976	0.321	0.876	5/15/1988	0.119	0.341
8/15/1964	0.286	0.616	8/15/1976	0.329	0.906	8/15/1988	0.089	0.257
11/15/1964	0.233	0.540	11/15/1976	0.384	0.965	11/15/1988	0.110	0.358
2/15/1965	0.213	0.461	2/15/1977	0.260	0.879			

Type F Uranium

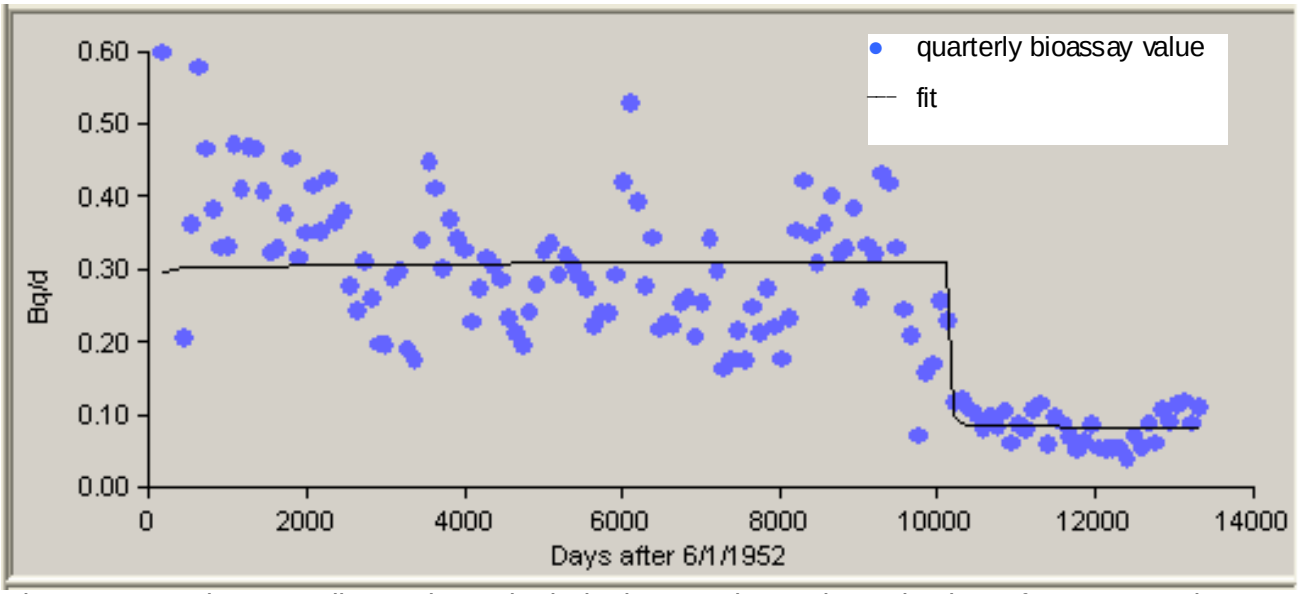

Figure A-1. 50th-percentile uranium urinalysis data used to estimate intakes of Type F uranium occurring 6/1/52 to 12/31/88.

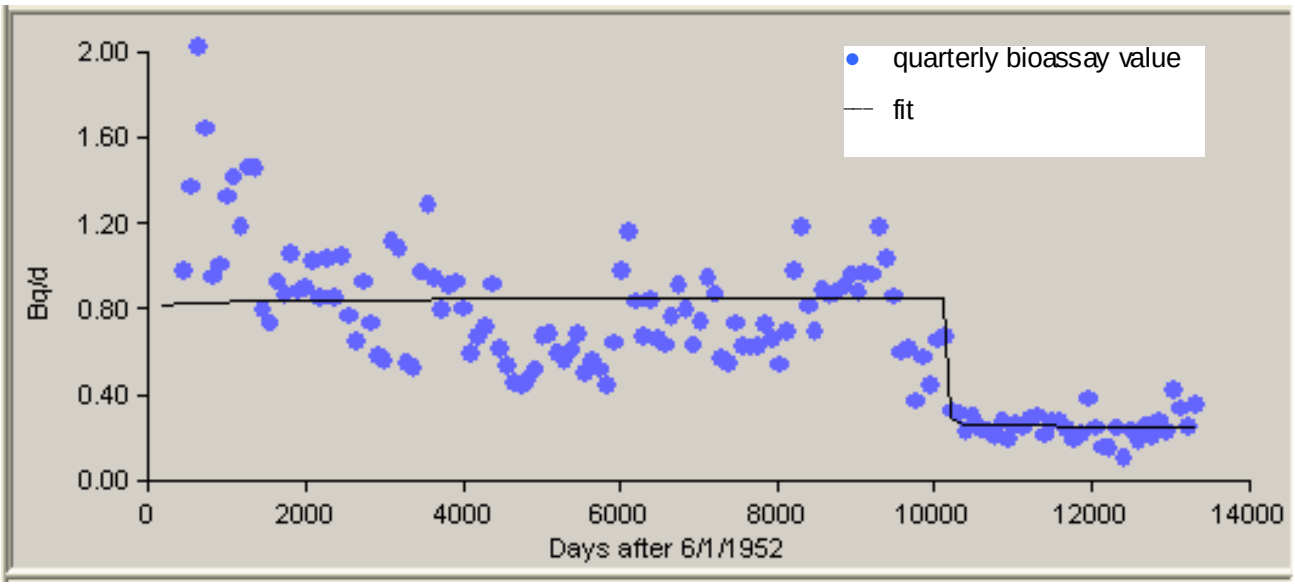

Figure A-2. 84th-percentile uranium urinalysis data used to estimate intakes of Type F uranium occurring 6/1/52 to 12/31/88.

Type M Uranium

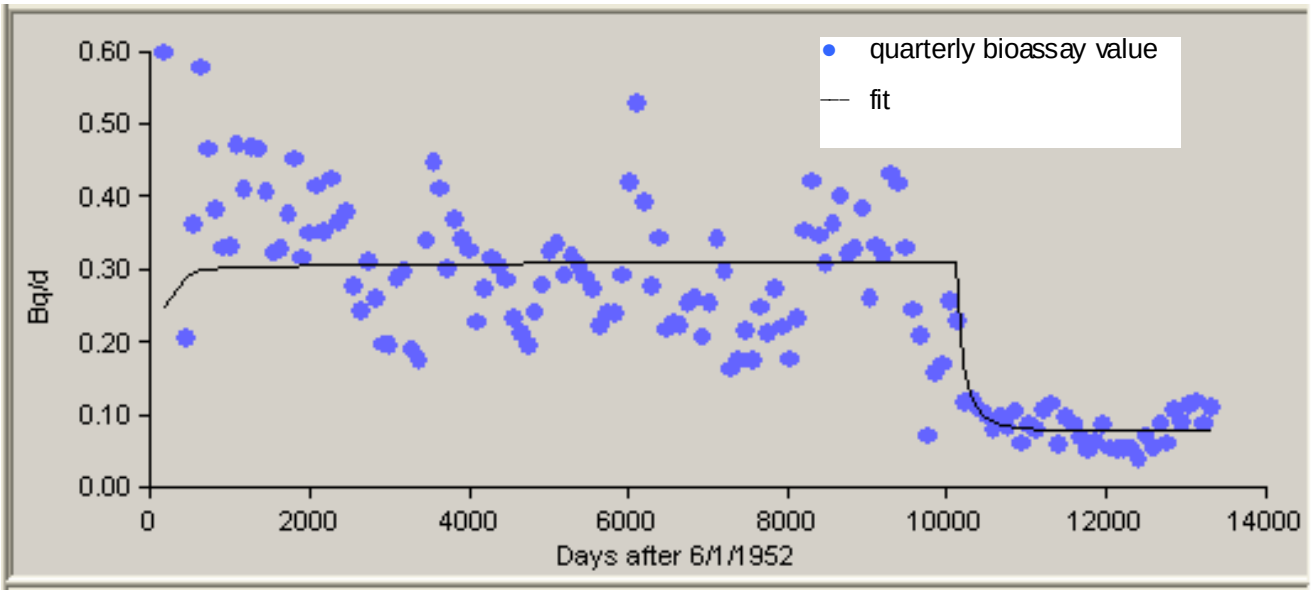

Figure A-3. 50th-percentile uranium urinalysis data used to estimate intakes of Type M uranium occurring 6/1/52 to 12/31/88.

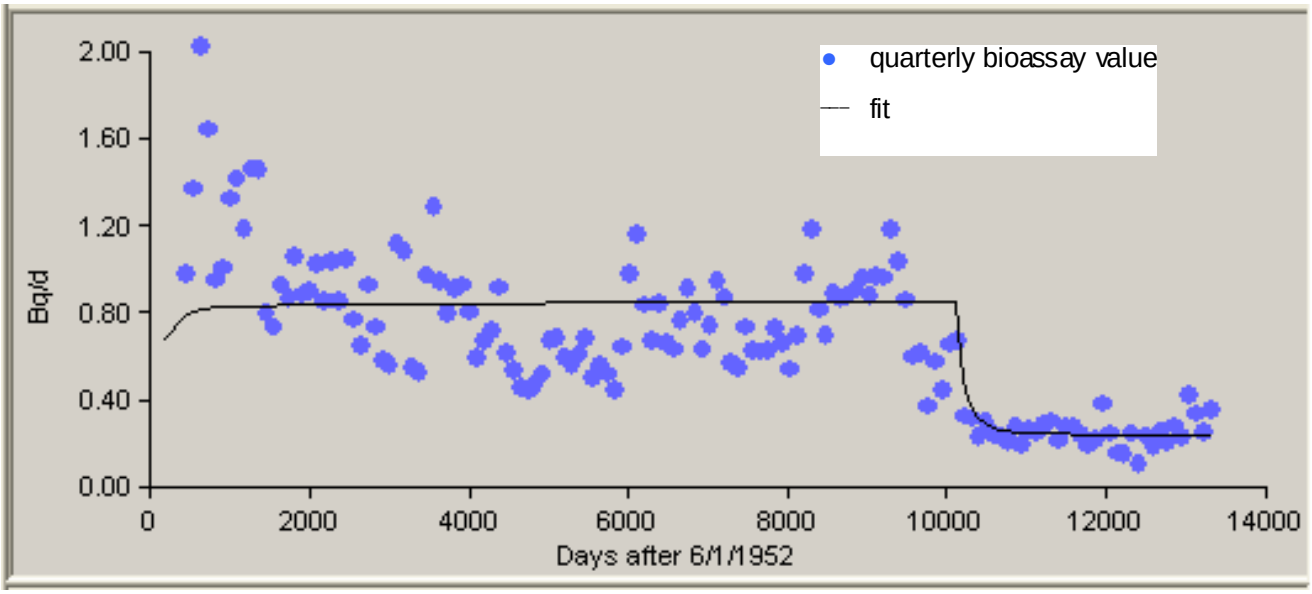

Figure A-4. 84th-percentile uranium urinalysis data used to estimate intakes of Type M uranium occurring 6/1/52 to 12/31/88.

Type S Uranium

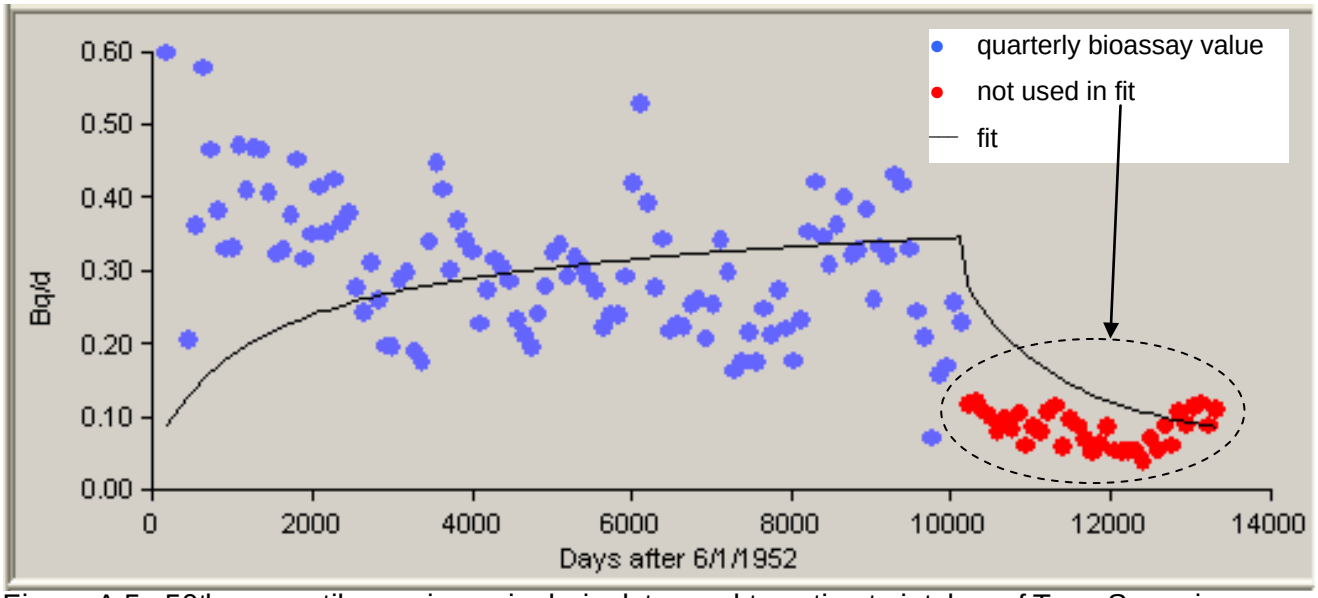

Figure A-5. 50th-percentile uranium urinalysis data used to estimate intakes of Type S uranium occurring 6/1/52 to 3/31/80.

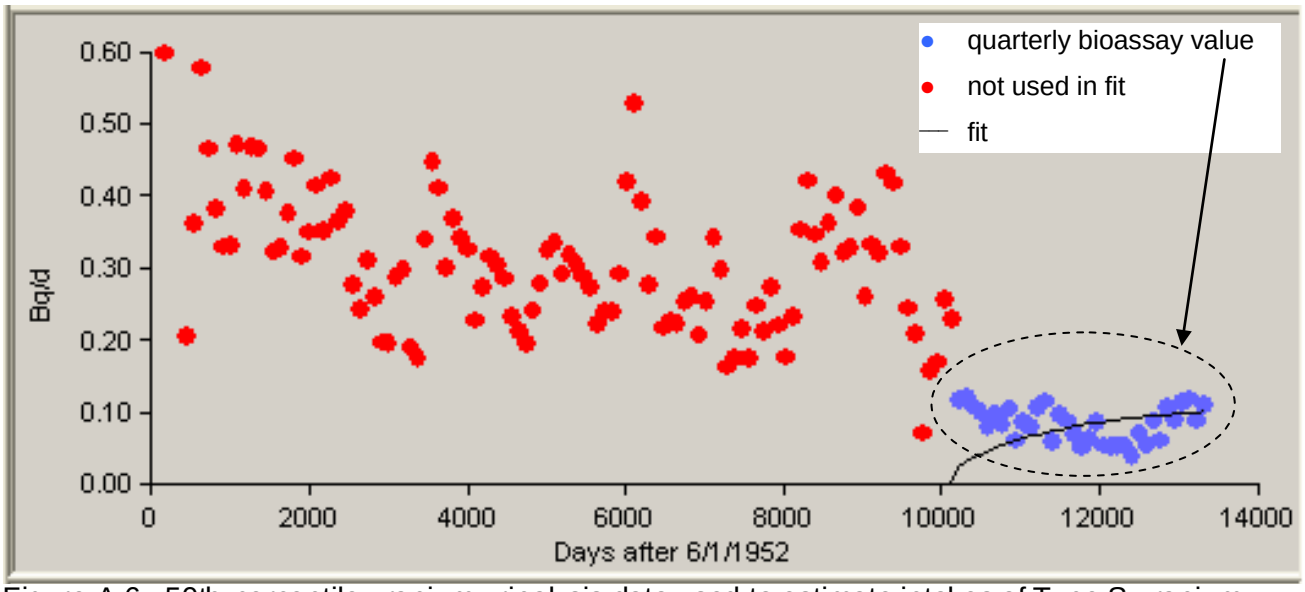

Figure A-6. 50th-percentile uranium urinalysis data used to estimate intakes of Type S uranium occurring 4/1/80 to 12/31/88.

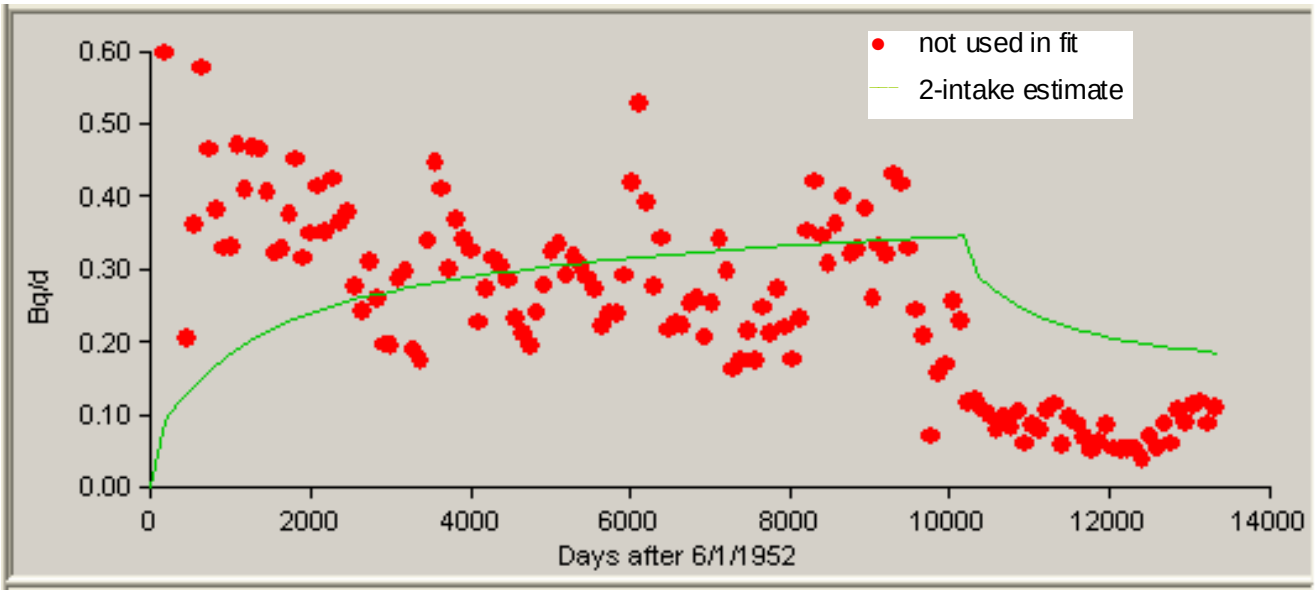

Figure A-7. Predicted 50th-percentile urinary excretion of Type S uranium from 1952 to 1988 based on two independent intakes, compared to bioassay data.

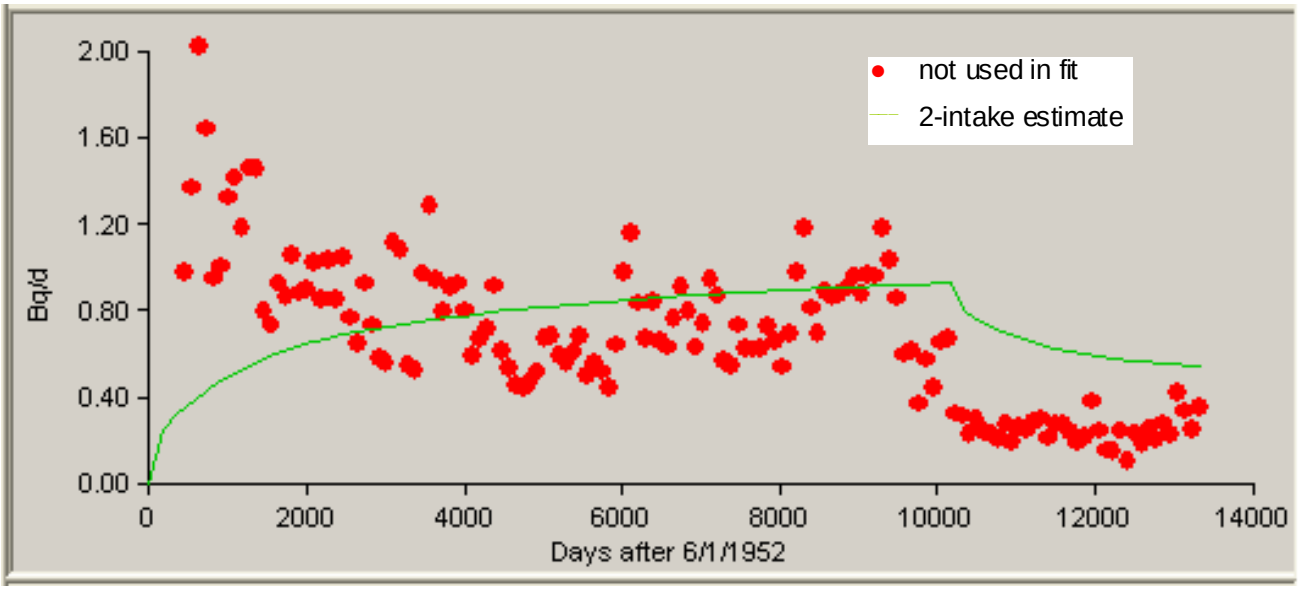

Figure A-8. Predicted 84th-percentile urinary excretion of Type S uranium from 1952 to 1988 based on two independent intakes, compared to bioassay data.