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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
10/15/2009	00	New technical information bulletin for internal dosimetry coworker data for Los Alamos National Laboratory. Incorporates formal internal and NIOSH review comments. Analysis of plutonium-239 and cesium-137 lung counts updated and new guidance added for Type Super S plutonium-239. Training required: As determined by the Objective Manager. Initiated by Matthew Arno.

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ACRONYMS AND ABBREVIATIONS

d	day
DOE	U.S. Department of Energy
GI	gastrointestinal
GM	geometric mean
GSD	geometric standard deviation
hr	hour
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
L	liter
LANL	Los Alamos National Laboratory
m	meter
MDA	minimum detectable activity
mL	milliliter
nCi	nanocurie
NIOSH	National Institute for Occupational Safety and Health
pCi	picocurie
POC	probability of causation
TIB	technical information bulletin
U.S.C.	United States Code
µCi	microcurie
µg	microgram
µm	micrometer
§	section or sections

1.0 INTRODUCTION

Technical information bulletins (TIBs) are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historic background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). TIBs may be used to assist NIOSH staff 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 (DOE) facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [42 U.S.C. § 7384l(5) and (12)].

Analysis of Coworker Bioassay Data for Internal Dose Assignment (ORAUT 2005) describes the general process used to analyze bioassay data for the assignment of doses to individuals based on coworker results. *Coworker Data Exposure Profile Development* (ORAUT 2004a) describes the approach and processes to develop reasonable exposure profiles based on available dosimetric information for workers at DOE sites.

Bioassay results were obtained directly from the Los Alamos National Laboratory (LANL) In-Vivo Measurements Laboratory and from the LANL Bioassay Repository for *in vitro* bioassay results. The combined databases used here contain more than half a million bioassay records from LANL and include measurements for ^{238}Pu, plutonium, tritium, polonium, and cesium for the years 1945 to 2008.

The database results were labeled with units that varied among the radionuclides, analysis techniques, and measurement periods. These units usually were disintegrations per minute, counts per minute, or picocuries per 24 hr or per liter. The specific units for each radionuclide are provided in the appropriate sections of this document.

A statistical analysis of the data was performed according to ORAUT (2005) and its implementing procedure ORAUT (2006). The results were entered in the Integrated Modules for Bioassay Analysis (IMBA) Expert^{TM} Oak Ridge Associated Universities (ORAU)-Edition computer software to obtain intake rates for the assignment of dose distributions.

2.0 PURPOSE

Some employees at DOE sites were not monitored for potential intakes of radioactive material, or the records of such monitoring are incomplete or unavailable. In such cases, data from monitored coworkers can be used to assign an internal dose to address potential intakes of radioactive material. The purpose of this TIB is to provide monitored coworker information for calculating and assigning occupational internal doses to employees at LANL for whom no or insufficient monitoring records exist.

3.0 DATA OVERVIEW

This section provides information on the general selection characteristics of the data and the methods of analysis. More detailed radionuclide-specific information is provided in Section 4.0.

3.1 BIOASSAY DATA SELECTION

Urinalysis data for ^{238}Pu, plutonium, polonium, uranium, and tritium from 1945 to 2004 were extracted from a Microsoft® Access® database named "LANL CO-Worker Data – Rev 1.mdb." There were more than 400,000 records in the urinalysis database. There were also six measurements for ^{239}Pu in 1944 that were not used because the low number of measurements does not permit reliable statistical analysis. The same data for 2005 through 2008 was extracted from a Microsoft® Access® database named "LANL_invitro_dataset_feb2009.mdb," which contains an additional 55,000+ urinalysis results. The units used are dependent on both the analyte and the era. The specific units used are discussed in more detail below in the discussion of each radionuclide.

In vivo data from 1965 to 2004 were extracted from a Microsoft® Access® database named "2007_10_08-LANL_IN_VIVO_DATA-Access2003.mdb." There are approximately 100,000 records in this database. Most of the records are for chest or whole-body counts, although a few counts of specific organs or body regions (hand, skull, etc.) are included. Only the chest and whole-body counts were used. Bioassay data were available for *in vivo* measurements of ^{238}Pu, ^{239}Pu, ^{241}Am, and ^{137}Cs. Beyond these four nuclides, very limited data were available, primarily for the late 1980s when the use of high-resolution germanium detectors became more widespread, which allowed identification of a wide selection of other radionuclides. However, insufficient data were available to perform any analysis for these other radionuclides. Even for the four primary radionuclides, sufficient non-zero data for analysis were available only for ^{239}Pu and ^{137}Cs.

3.2 ANALYSIS

Bioassay data were analyzed by quarter, year, or multiyear span dependent on the amount of data available for each radionuclide during a given period and the expected biokinetics of each radionuclide. A lognormal distribution was assumed. After log-transforming the data, the 50th and 84th percentiles were determined for each period through the use of the method described in ORAUT (2005). A large fraction of the data for every radionuclide was entered as zero bioassay results. These zeros were retained in the analysis to rank the results. The acute intake of polonium in 1955 was addressed differently as discussed below in the sections regarding polonium.

3.3 TRITIUM

Tritium urine bioassay data were extracted from the "LANL CO-Worker Data – Rev 1.mdb" database. The "co_worker_data" table in this database was queried to identify all records with a nuclide type of "H-3" and collection dates ranging from the earliest recorded through the end of 2004. The "coll_date," "z_number," and "activity" fields were extracted and exported to a spreadsheet. All activity results are in microcuries per liter. No other codes or fields with useful information were identified.

For the period from the start of data (June 23, 1950) through approximately 1991, no records had fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1989 data were identified as historical spot samples. All data were used. A total of 72,153 distinct records were identified.

Visual examination of the data indicates that almost all of the high bioassay values are clearly the result of acute intakes. Involved employees were regularly monitored while the tritium was excreted, which resulted in well-defined decaying exponential excretion curves. No attempt was made to exclude the bioassay data resulting from these acute intakes.

The minimum detectable activity (MDA) for the entire period was 1 µCi/L until late 1987, when the MDA decreased to 0.1 µCi/L. Prior to 1991, MDAs are reported in the database separately from the analytical result. Analytical results <MDA were recorded as zero, except for December 1968 through January 1971, when the actual result was recorded. Starting in 1991, the actual result, regardless of whether it was above or below the MDA, was reported and the MDA was not reported separately. Activities recorded in site records as less than the MDA were input as one-half of the MDA for this analysis.

For 2005 through 2008, tritium urine bioassay data were extracted from the "LANL IN VITRO DATA FEB 2009" table in the "LANL_invitro_dataset_feb2009.mdb" database. All records with a nuclide type of "H-3" and collection dates ranging from 2005 through 2008 inclusive were identified. The "ZNO," "COLLECTED_DATE," and "ACTIVITY" fields were extracted and exported to a spreadsheet. All activity results are in microcuries per liter. No other codes or fields with useful information were identified. A total of 5,186 distinct records were identified. The actual result, regardless of whether it was above or below the MDA was reported. In addition, the MDA was reported.

3.4 PLUTONIUM-238

The "co_worker_data" table in the "LANL CO-Worker Data – Rev 1.mdb" database was queried to identify all records with a nuclide type of "PU-238" and collection dates that ranged from the beginning of 1968 through the end of 2004. Predominantly pure ^{238}Pu was not encountered at LANL prior to 1968 (ORAUT 2004c). The "coll_date," "z_number," and "activity" fields were extracted and exported to a spreadsheet. All activity results were in units of picocuries per 24 hr. For the period from the start of data (1968) through the end of 1990, all the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1991 data were identified as simply historical samples. All data were used.

It appears that values less than the MDA were reported beginning in 1971 with negative results reported as zero. Negative results were reported beginning in 1973 except for two results in 1971. All activity values, including zero, less than zero, and less-than MDA, were used without modification for all years.

The statistical analysis was performed on an annual basis. A total of 77,739 distinct records were used for the statistical analysis. Table A-1 in Attachment A lists the statistical analysis results for ^{238}Pu.

Examination of the reported activities revealed that a relatively small number of individuals accounted for the majority of the highest bioassay results. These results tended to skew the curve fit. The bioassay results for these individuals were filtered out for the years indicated to eliminate this skew of the curve fit. Table 3-1 lists the individuals whose results were filtered out and for which years. Additional detail, with personally identifiable information removed, for filtering out these individuals is provided below.

Table 3-1. High bioassay readings for ^{238}Pu.

Individual	Years filtered out
1	1972 through 1988
2	1972 through 1988
3	1972 through 1988
4	1977 through 1988
5	1981 through 1988

Individuals 1 through 3: These individuals were involved in the Wing-9 incident in 1971, which has been the subject of multiple studies (Hickman et al 1995, James et al 2003). Their bioassay data is well-studied and associated with a known incident. Their data was removed for 1972 through 1988.

Individual 4: In 1977, this individual had an acute intake on February 10, 1977 and was bioassayed a total of 96 times during 1977 and was treated with DTPA (ORISE 2009). The bioassay measurements exhibit a clear exponential decay and the initial data were extreme outliers and skewed the fit. All data for this individual for 1977 through 1988 were removed. The same pattern was seen in this individual's ^{239}Pu bioassay measurements.

Individual 5: This individual had an acute intake in mid April 1981 (Inkret and Miller 1995). He was sampled numerous times and the bioassay data exhibits an exponential decay trend. All data for this individual for 1981 through 1988 were removed. This individual also had high ^{239}Pu bioassay measurements starting at same time.

For 2005 through 2008, the "LANL IN VITRO DATA FEB 2009" table in the "LANL_invitro_dataset_feb2009.mdb" database was queried to identify all records with a nuclide type of "PU-238" and collection dates that ranged from the beginning of 2005 through the end of 2008. The "ZNO," "COLLECTED_DATE," "SAMPLE_ID," "ACTIVITY_PS" and "ACTIVITY" fields were extracted and exported to a spreadsheet. For a given "SAMPLE_ID," the "ACTIVITY_PS" field was used as the sample activity unless it was blank, in which case the value in the "ACTIVITY" field was used as the result. All samples are 24-hour or simulated 24-hour samples and were in units of pCi per sample or pCi per 24-hours. Thus all results were treated as pCi/day. All data were used.

3.5 PLUTONIUM-239

3.5.1 Pu-239 In-Vitro Data

The "co_worker_data" table in the "LANL CO-Worker Data – Rev 1.mdb" database was queried to identify all urinalysis records with a nuclide type of "PU-239" and collection dates that ranged from the beginning of 1945 through the end of 2004. The "coll_date," "z_number," and "activity" fields were extracted and exported to a spreadsheet. All activity results were in units of picocuries per 24 hr. For the period from the start of data (1944) through approximately 1991, all the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1989 data were identified as simply historical samples. All data were used.

Values less than the MDA and negative results were reported as such from 1945 through 1957 and from 1971 onward. For 1958 through 1970, values less than zero were reported as zero. All activity values, including zero, less than zero, and above-MDA, were used without modification for all years. Prior to 1967, plutonium urinalysis measured gross plutonium alpha activity rather than $^{239/240}$Pu activity. However, the pre-1967 data has been treated as measuring the $^{239/240}$Pu count rate, which overestimates the actual $^{239/240}$Pu activity by 10 to 12% for weapons-grade plutonium depending on the fuel age. The statistical analysis was performed on an annual basis. A total of 85,752 distinct records were used for the statistical analysis. Table A-2 in Attachment A lists the statistical analysis results for *in vitro* ^{239}Pu.

Examination of the reported activities revealed that, for a few years, a few individuals were responsible for the vast majority of the highest bioassay results. These results tended to skew the curve fit. The bioassay results for these individuals were filtered out for the specific year listed to eliminate this skew of the curve fit. Table 3-2 lists the individuals whose results were filtered out and

for which years. The justification for filtering out these individuals is the same as given for Pu-238 above.

Table 3-2. High bioassay readings for ^{239}Pu.

Individual	Years filtered out
4	1977 through 1988
5	1981 through 1988

For 2005 through 2008, the "LANL IN VITRO DATA FEB 2009" table in the "LANL_invitro_dataset_feb2009.mdb" database was queried to identify all records with a nuclide type of "PU-239," "PU-240," or "PU-239+PU-240" and collection dates that ranged from the beginning of 2005 through the end of 2008. The "ZNO," "COLLECTED_DATE," "SAMPLE_ID," "ANALYSIS_TYPE," "ACTIVITY_PS" and "ACTIVITY" fields were extracted and exported to a spreadsheet. All samples are 24-hour or simulated 24-hour samples and were in units of pCi per sample or pCi per 24-hours. Thus all results were treated as pCi/day.

Pu-239/240 results were obtained by both alpha spectrometry, "RAS," and by mass spectrometry, "TIMS." The TIMS results report a concentration separately for Pu-239 and for Pu-240. RAS results do not distinguish between Pu-239 and Pu-240 since the alpha particle energies for these two radionuclides are very similar and report the combined activity as "PU-239." The TIMS results have a lower limit of detection and are generally more reliable. For this study, the combined Pu-239/240 activity is the desired quantity. A single sample ID in the database may have as many as 8 records associated with it. To determine the single quantity to use for this study, the following priority order was used:

For a given "sample_ID" #, use the record(s) highest in the following priority list:

1 "NUCLIDE" field = "PU-239+PU-240", "ANALYSIS_TYPE" = "TIMS", recorded value in the "ACTIVITY_PS" field
2 "NUCLIDE" field = "PU-239+PU-240", "ANALYSIS_TYPE" = "TIMS", "ACTIVITY_PS" field blank, with a recorded value in the "ACTIVITY" field
3 Sum the "ACTIVITY_PS" fields of:
   a. "NUCLIDE" field = "PU-239", "ANALYSIS_TYPE" = "TIMS", recorded value in the "ACTIVITY_PS" field plus
   b. "NUCLIDE" field = "PU-240", "ANALYSIS_TYPE" = "TIMS", recorded value in the "ACTIVITY_PS" field.
4 Sum the "ACTIVITY" fields of:
   a. "NUCLIDE" field = "PU-239", "ANALYSIS_TYPE" = "TIMS", "ACTIVITY_PS" field blank, recorded value in the "ACTIVITY" field plus
   b. "NUCLIDE" field = "PU-240", "ANALYSIS_TYPE" = "TIMS", "ACTIVITY_PS" field blank, recorded value in the "ACTIVITY" field
5 "NUCLIDE" field = "PU-239", "ANALYSIS_TYPE" = "RAS", recorded value in the "ACTIVITY_PS" field.
6 "NUCLIDE" field = "PU-239", "ANALYSIS_TYPE" = "RAS", "ACTIVITY_PS" field blank, recorded value in the "ACTIVITY" field

A single value for each sample ID was used. All sample IDs with reported Pu-239 and/or Pu-240 results were used. In 2007, one individual had the 67 largest results. All of this person's bioassay data in 2007 was excluded from the analysis.

3.5.2 Pu-239 In-Vivo Data

The "TBL_NIOSH_REPORT_2007_V2" table in the "2007_10_08-LANL_IN_VIVO_DATA-Access2003.mdb" database was queried to identify all lung count records with a nuclide type of "Pu-239," organ type of "Chest," count reason other than "new hire," "rehire," or "baseline," and collection dates ranging from the beginning of 1969 through the end of 2004. The "count_date," "zno" and "abundance_nCi" fields were extracted and exported to Excel. The "zno" field was used as the employee identifier and the "abundance_nCi" field was used as the value of the chest count.

Records with no abundance value given were entered with an abundance of "0," based on the assumption that the result was less than the MDA and the fact that the recorded MDAs were much higher than the typical recorded positive values. Only 1969 through 1979 were analyzed since there were few positive results after 1979. Table A-3 in Attachment A lists the statistical analysis results for *in-vivo* ^{239}Pu.

3.6 POLONIUM-210

The "co_worker_data" table in the "LANL CO-Worker Data – Rev 1.mdb" database was queried to identify all records with a nuclide type of "Po" and collection dates that ranged from the beginning of 1947 through the end of 2004. The "coll_date," "z_number," and "activity" fields were extracted and exported to Excel®. The activity results are reported in units of picocuries per liter or counts per minute per liter. Results reported in counts per minute were converted to disintegrations per minute using a detector efficiency of 50% based on the assumption that a 2-π detector was used in the absence of any other information and a recovery fraction of 10%. The results in disintegrations per minute were then converted to picocuries for consistency with the other data. Results reported in picocuries per liter were adjusted assuming a recovery fraction of 10% rather than 100% (ORAUT 2009). All the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Therefore, all data were used.

Examination of the data indicated several anomalies. Several individuals had acute intakes in January 1953. Because more than one individual was involved (even though a limited number), these data were left in the data set for the entire year. In August 1954, one employee had an acute intake that resulted in all of the highest 20% of bioassay results for the year. All bioassay results for this employee for the third and fourth quarters of 1954 were excluded from the analysis.

Another acute intake involving a large number of individuals occurred in late July or early August 1955. To separate the urinalysis results due to this acute intake, urinalysis results for seven employees were excluded from the fits performed for the last two quarters of 1955. Although these seven individuals were not the only ones involved in the incident, these seven had the majority of the highest readings. The bioassay data for these seven individuals as a result of this incident have been analyzed separately as an acute intake. Dose reconstruction for individuals who were involved in this incident and who do not have relevant bioassay data should also be assigned this intake. This applies only to individuals for whom there is evidence or reason to believe that they were involved in this incident. An incident date of August 1, 1955 was chosen as the best fit to the available data.

All activity values, including zero, less than zero, and less-than MDA, were used without modification for all years. The normal statistical analysis was performed on a quarterly basis. For the seven identified individuals involved in the incident, the bioassay data for each individual was fit separately

to determine the intake of material that occurred in the incident. Table A-4 in Attachment A lists the statistical analysis results for ^{210}Po. A total of 5,121 distinct records were used for the quarterly and incident analyses.

3.7 URANIUM

The "co_worker_data" table in the "LANL CO-Worker Data – Rev 1.mdb" database was queried to identify all records with a nuclide type of "U-234," "U-235" or "U-238" and collection dates ranging from 1950 through the end of 2004. The "coll_date," "z_number," "activity," and "MDA" fields were extracted and exported to a spreadsheet. All activity results are in units of picocuries per 24 hr. For the period from the start of data (1950) through approximately 1991, all the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1989 data were identified as historical spot samples. All data were used.

Prior to July, 1991, the bioassay records identified the results as being specific for either ^{238}U or ^{235}U. However, both techniques truly measured the same quantity but reported the results in different units. A single measurement technique was used during any given time frame (See Table 5-13 in ORAUT 2004c) for analysis of uranium in urine prior to 1991. The analytical results were interpreted based on the materials to which an individual was presumed to have been exposed. Therefore, the two data sets were merged to create an overall uranium data set. The ^{238}U data were converted to activity units assuming an activity of 0.4673 pCi/µg based on the specific activity of D-38 uranium (ORAUT 2004c) and merged with the ^{235}U data. All activity values, including zero, less than zero, and less-than MDA, were used without modification for all years.

Beginning in July, 1991, alpha spectrometry was used to analyze the urine samples for uranium, at which time results for U-234, U-235, and U238 were reported. Since all uranium activity is assumed to be U-234 for the purposes of calculating dose, the activities of all three isotopes were summed and used as the total uranium activity.

The statistical analysis was performed on an annual basis. A total of 126,523 records were used for the statistical analysis. Table A-5 in Attachment A lists the statistical analysis results for uranium.

For 2005 through 2008, the "LANL IN VITRO DATA FEB 2009" table in the "LANL_invitro_dataset_feb2009.mdb" database was queried to identify all records with a nuclide type of "U-234," "U-235," or "U-238" and collection dates that ranged from the beginning of 2005 through the end of 2008. The "ZNO," "COLLECTED_DATE," "SAMPLE_ID," "ACTIVITY_PS" and "ACTIVITY" fields were extracted and exported to a spreadsheet. For a given "SAMPLE_ID," the "ACTIVITY_PS" field was used as the sample activity unless it was blank, in which case the value in the "ACTIVITY" field was used as the result. All samples are 24-hour or simulated 24-hour samples and were in units of pCi per sample or pCi per 24-hours. Thus all results were treated as pCi/day. The U-234, U-235, and U238 activities for a given sample ID were summed and used as the total uranium activity. All data were used.

3.8 CESIUM-137

The "TBL_NIOSH_REPORT_2007_V2" table in the "2007_10_08-LANL_IN_VIVO_DATA-Access2003.mdb" database was queried to identify all records with a nuclide type of "Cs-137," organ type of "Whole Body," collection dates that ranged from the beginning of 1970 through the end of 2004, and count reason other than "new hire." The "count_date," "zno," and "abundance_nCi" fields

were extracted and exported to a spreadsheet. The "zno" field was used as the employee identifier and the "abundance_nCi" field was used as the value of the whole-body count.

Records with no abundance value were entered with an abundance equal to the MDA based on the assumption that the result was less than the MDA and since the MDA was typically less than the positive values recorded.

Due to the small number of records (301 distinct records), the statistical analysis was performed in 5- or 4-yr blocks: 1970 to 1974, 1975 to 1979, 1980 to 1984, 1985 to 1989, and 1990 to 1993. Table A-6 in Attachment A lists the statistical analysis results for ^{137}Cs. Insufficient data is available after 1993 to permit analysis.

4.0 INTAKE MODELING

This section discusses intake modeling assumptions, intake fitting, and intake materials.

4.1 ASSUMPTIONS

Each result used in the intake calculations was assumed to have a normal distribution. A uniform absolute error of 1 was applied to all results, thus assigning the same weight to each result. IMBA requires results to be in units of activity per day; therefore, all urinalysis results were normalized as needed to 24-hr samples using 1,400 mL (the volume of urine excreted by Reference Man in a 24-hr period).

Because of the nature of work at LANL, intakes could have been either chronic or acute. However, a series of acute intakes can be approximated as a chronic intake. Therefore, intakes were assumed to be chronic and were assumed to occur through inhalation with a default breathing rate of 1.2 m^3/hr and a 5-µm activity median aerodynamic diameter particle size distribution.

For intake modeling purposes, all uranium activity was assumed to be ^{234}U. This assumption does not affect the fitting of the data for intake determination because all uranium isotopes have the same biokinetic behavior and the isotopes considered in this analysis all have long half-lives in relation to the assumed intake period. 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 the dose coefficients for ^{235}U, ^{236}U, and ^{238}U (ICRP 1995). Therefore, the assumption that the intake is 100% ^{234}U provides a result that is favorable to claimants.

4.2 BIOASSAY FITTING

The IMBA Expert™ ORAU-Edition computer program was used to fit the bioassay results to a series of inhalation intakes. Data from 1945 through 2008 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 the selection of periods in which the bioassay results were similar. A new chronic intake period was started if the data indicated a significant sustained change in the bioassay results. By this method, the years from 1945 through 2008 were divided independently into multiple chronic intake periods for each radionuclide.

4.3 MATERIAL TYPES

ORAUT (2004c) discussed LANL internal dosimetry data for the dose reconstructor and included guidance for the appropriate use of that information. Workers at LANL had the potential to receive intakes of ^{238}Pu, ^{239}Pu, uranium, polonium, tritium, and cesium. Site-specific internal dosimetry information for other radionuclides is rare or not available (ORAUT 2004c).

4.3.1 Tritium

The data set discussed in the previous section for tritium was condensed into a file for the period from January 1, 1950, to December 31, 2008, with the following columns:

Z Number	ID Number	Name	Days Post 1/1/1950	Conc uCi/L	MDA uCi/L

Duplicate records (i.e., lines that had all six fields the same as another line) were deleted to leave unique records. The doses were calculated by individual for each calendar year from 1950 to 2008.

Any person who had only a single urine result of <MDA µCi/L for a given period was not included in the calculations of the dose distribution for that period because they were not considered part of the routine monitoring program. All remaining concentrations of <MDA µCi/L were replaced with one-half of the appropriate MDA. Any person with a single measurement in a period was assigned a second measurement 40 days later of one-half of the MDA of the first measurement.

The protocol given in *Technical Information Bulletin: Tritium Calculated and Missed Dose Estimates* (ORAUT 2004b) was used to calculate the dose for each individual with the following rules concerning the elapsed time between consecutive samples:

- Type 1 calculations were performed for samples separated by 40 or fewer days.
- Type 3 calculations were performed if there were no other samples within 90 days of a sample.
- Type 2 calculations were performed in all other situations.

The doses for a period are plotted on a lognormal probability plot and the typical parameters [geometric mean (GM), geometric standard deviation (GSD), and R^2] are determined from a linear regression. The plotting positions were calculated with $i/n - 1/(2n)$ convention specified in ORAUT-PROC-0095 (ORAUT 2006).

4.3.2 Plutonium-238

Plutonium-238 urinalysis results were analyzed with IMBA using type M and S materials to derive intake rates for 1968 to 2008. Note that solubility Type Super S is not applicable to ^{238}Pu (ORAUT 2008).

Plutonium-238 Type M: The solid lines in Figures B-1 to B-8 and B-9 to B-15 in Attachment B show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Figures B-16 and B-17 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type M intakes. Table B-1 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from ^{238}Pu urinalysis.

Plutonium-238 Type S: The solid lines in Figures B-18 to B-24 and B-25 to B-31 in Attachment B show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type S materials. The same intake periods were applied for both percentiles because the values followed a similar pattern. Figures B-32 and B-33 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table B-2 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from ^{238}Pu urinalysis.

4.3.3 Plutonium-239

Plutonium-239 urinalysis results were analyzed with IMBA using type M and S materials to derive intake rates for 1944 to 2008.

Plutonium-239 Type M Urinalysis: The solid lines in Figures B-34 to B-42 and B-43 to B-51 in Attachment B show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. The same intake periods were applied for both percentiles because the values followed a similar pattern. Figures B-52 and B-53 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type M intakes. Table B-3 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from ^{239}Pu urinalysis.

Plutonium-239 Type S Urinalysis: The solid lines in Figures B-54 to B-62 and B-63 to B-71 in Attachment B show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type S materials. Figures B-72 and B-73 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table B-4 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from ^{239}Pu urinalysis.

Plutonium-239 Type S Lung Counts: The solid lines in Figures B-74 to B-78 and B-79 to B-83 in Attachment B show the individual fits to the 50th- and 84th-percentile lung burdens, respectively, for type S materials. The same intake periods were applied for both percentiles as the values followed a similar pattern. Table B-5 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from ^{239}Pu lung burdens.

4.3.4 Polonium

Polonium urinalysis results were analyzed with IMBA using type F and M materials to derive intake rates for 1947 to 1956.

Polonium Type F: The solid lines in Figures B-84 and B-85 in Attachment B show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table B-6 lists the 50th- and 84th percentile intake rates along with the associated GSD determined from the polonium urinalysis.

Polonium Type M: The solid lines in Figures B-86 and B-87 in Attachment B show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Table B-7 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from the polonium urinalysis.

August 1, 1955 Incident: The bioassay data for the seven individuals positively identified as having been involved in this incident were analyzed separately using standard dose reconstruction bioassay fitting methods assuming both Type F and Type M material types. Figures B-88 through B-94 and B-95 through B-101 show the fits for each individual for Type F and M material types respectively. Table B-8 lists the calculated intakes from these fits.

1944 to 1946: Polonium bioassay data to evaluate coworker intakes is not available for this time period. To approximate intakes during this time period, which falls within a SEC definition, the intake rate for each solubility class for 1947 to 1949 was applied.

4.3.5 Uranium

Because the uranium isotopes present at LANL have very long radiological half-lives, and because the material is retained in the body for long periods, excretion results are not independent. 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 LLNL for relatively short periods, each chronic intake was fit independently using only the bioassay results from the single intake period for type S solubility. This method results in an overestimate of intakes for exposures that extended through multiple assumed intake periods. Only the results in the intake period were selected for use in the fitting of each period. Excluded results are shown in light gray in the figures in Attachment B. For type M and F solubility, this approach was not used.

Uranium Type F: The solid lines in Figures B-102 and B-103 in Attachment B show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table B-9 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from the uranium urinalysis.

Uranium Type M: The solid lines in Figures B-104 and B-105 in Attachment B show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Table B-10 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from the uranium urinalysis.

Uranium Type S: The solid lines in Figures B-106 to B-112 and B-113 to B-119 in Attachment B show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type S materials. The same intake periods were applied for both percentiles because the values followed a similar pattern. Figures B-120 and B-121 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table B-11 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from the uranium urinalysis.

1947 to 1949: Uranium bioassay data to evaluate coworker intakes is not available for this time period. To approximate intakes during this time period, which falls within a SEC definition, the intake rate for each solubility class for 1950 to 1955 was applied

4.3.6 Cesium-137

Cesium whole-body count results were analyzed with IMBA using type F materials to derive intake rates for 1970 through 1993. The solid lines in Figures B-122 and B-123 in Attachment B show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table B-12 lists the 50th- and 84th-percentile intake rates along with the associated GSD determined from the cesium whole-body counts.

5.0 ASSIGNING INTAKES AND DOSES

This section describes the derived intake rates and provides guidance for assigning doses.

5.1 INTAKE RATE SUMMARY

For the calculation of doses to individuals from bioassay data, a GSD of 3 has been used to account for biological variation and uncertainty in the models. It was considered inappropriate to assign a value less than 3 for the coworker data. Therefore, a GSD of at least 3 was assigned for each of the intake periods. The GSDs for different intake periods have been conservatively adjusted for consistency between intake periods for calculational efficiency.

The following subsections list the intake rates that should be used for each radionuclide and the period of applicability of each intake rate except that for tritium. For tritium, the actual dose that should be used is provided.

5.2 TRITIUM

Table 5-1 lists the tritium doses and GSDs to be used for each year of potential tritium exposure.

Table 5-1. Tritium annual doses (mrem) and GSDs.

Year	Dose	GSD		Year	Dose	GSD
1950	33	7.2		1980	15	4.1
1951	36	5.9		1981	17	4.1
1952	25	4.2		1982	21	4.5
1953	26	6.7		1983	18	4.8
1954	16	6.2		1984	16	3.4
1955	43	6.5		1985	18	3.3
1956	33	6.9		1986	21	3.8
1957	35	6.9		1987	17	4.3
1958	26	5.7		1988	7	4.4
1959	22	5.5		1989	7	3.5
1960	27	5.2		1990	6	3.2
1961	20	4.7		1991	2	3.0
1962	17	4.7		1992	5	3.5
1963	18	3.7		1993	6	3.4
1964	17	3.5		1994	3	3.0
1965	18	3.5		1995	5	3.0
1966	19	4.2		1996	5	3.0
1967	23	6.0		1997	4	3.0
1968	16	4.6		1998	7	3.0
1969	21	5.0		1999	4	3.0
1970	25	7.0		2000	9	4.1
1971	16	4.9		2001	6	3.0
1972	14	5.4		2002	6	3.5
1973	16	5.3		2003	5	3.3
1974	25	6.7		2004	3	3.0
1975	19	6.2		2005	3	3.0
1976	13	4.1		2006	4	3.0
1977	20	5.5		2007	4	3.0
1978	20	5.2		2008	6	3.3
1979	12	4.9				

5.3 PLUTONIUM-238

Intakes of ^{238}Pu should be assigned if the energy employee is known or believed to have been exposed to heat source plutonium. For heat source plutonium, solubility Type Super S is not

applicable. If the energy employee was only exposed to weapons-grade plutonium (^{239}Pu), then the intake of ^{238}Pu should be based on the isotope mixture for weapons-grade ^{239}Pu and the ^{239}Pu intakes given in Section 5.4 and not on the intakes in this section. Table 5-2 lists the ^{238}Pu intakes and associated GSDs to be used for each year of potential ^{238}Pu exposure for both Type M and Type S material. Solubility Type Super S is not applicable to plutonium-238 (ORAUT 2008).

Table 5-2. Plutonium-238 intake rates (pCi/d).

		Type M		Type S	
Start	End	50th percentile	GSD	50th percentile	GSD
1/1/1968	12/31/1971	1.8	5.63	43	5.74
1/1/1972	12/31/1972	14.	3.13	765	3.13
1/1/1973	12/31/1974	2.0	4.31	72	4.17
1/1/1975	12/31/1977	0.67	3.59	5.2	8.47
1/1/1978	12/31/1981	0.32	7.56	5.2	8.47
1/1/1982	12/31/1988	0.084	8.73	1.8	8.47
1/1/1989	12/31/1993	0.44	4.31	9.7	4.17
1/1/1994	12/31/2008	0.048	6.82	0.72	6.58

5.4 PLUTONIUM-239

Intakes of ^{239}Pu should be assigned if the energy employee is known or believed to have been exposed to weapons-grade plutonium. For weapons-grade plutonium, solubility Type Super S must be considered. If the energy employee was only exposed to heat source plutonium (^{238}Pu), then the plutonium intake should be based on the ^{238}Pu intakes in Section 5.3 and not on the intakes in this section. Table 5-3 lists the ^{239}Pu urine-based intakes and associated GSDs to be used for each year of potential ^{239}Pu exposure for Type M material. Intakes of the associated isotopes as given in Table 5-9 of the LANL internal TBD (ORAUT 2009) must also be assigned.

Table 5-3. Plutonium-239 Type M intake rates (pCi/d).

		Type M	
Start	End	50th percentile	GSD
1/1/1944	12/31/1945	248	5.05
1/1/1946	12/31/1946	95	6.24
1/1/1947	12/31/1953	10	5.16
1/1/1954	12/31/1954	3.1	17.2
1/1/1955	12/31/1956	3.1	12.4
1/1/1957	12/31/1966	0.38	12.4
1/1/1967	12/31/1972	3.3	4.81
1/1/1973	12/31/1975	1.5	6.21
1/1/1976	12/31/1993	0.16	6.83
1/1/1994	12/31/2008	0.013	12.2

Table 5-4 lists the ^{239}Pu urinalysis and lung burden-based intakes and associated GSDs to be used for each year of potential ^{239}Pu exposure for Type S and Super S material. Intakes of the associated isotopes as given in Table 5-9 of the LANL internal TBD (ORAUT 2009) must also be assigned.

Table 5-4. Plutonium-239 Type S and Super S intake rates (pCi/d).

Systemic intake rates				Non-systemic intake rates			
Start	**End**	**50th percentile**	**GSD**	**Start**	**End**	**50th percentile**	**GSD**
1/1/1944	12/31/1945	8,651 [a]	5.05	1/1/1944	12/31/1945	8,651 [a]	5.05
1/1/1946	12/31/1946	5,125 [a]	6.24	1/1/1946	12/31/1946	5,125 [a]	6.24
1/1/1947	12/31/1953	200 [a]	4.87	1/1/1947	12/31/1953	200 [a]	4.87
1/1/1954	12/31/1954	88[a]	11.12	1/1/1954	12/31/1954	88[a]	11.12
1/1/1955	12/31/1956	88[a]	15.3	1/1/1955	12/31/1956	88[a]	15.3
1/1/1957	12/31/1966	6.3[a]	11.91	1/1/1957	12/31/1966	6.3[a]	11.91
1/1/1967	12/31/1972	73[a]	4.62	1/1/1967	12/31/1968	73[a]	4.62
				1/1/1969	12/31/1971	27.66[b]	4.50
1/1/1973	12/31/1975	41 [a]	6.34	1/1/1972	12/31/1974	29.43[b]	4.50
				1/1/1975	12/31/1975	505.4[b]	3.00
1/1/1976	12/31/1993	2.3 [a]	6.34	1/1/1976	12/31/1977	96.07[b]	3.90
				1/1/1978	12/31/1979	19.55[b]	6.24
				1/1/1980	12/31/1993	2.3 [a]	6.34
1/1/1994	12/31/2008	0.14 [a]	12.8	1/1/1994	12/31/2008	0.14 [a]	12.8

a. Urinalysis-based intake rates.
b. Lung count-based intake rates.

The Table 5-4 intake rates should be used as follows:

- For doses to systemic organs, only the urinalysis-based intakes should be used in accordance with the guidance in ORAUT-OTIB-0049 (ORAUT 2008).

- Doses to the lungs and thoracic lymph nodes, gastrointestinal tract, and extrathoracic regions (non-systemic organs) should be based on the lung counts when available in accordance with the guidance in ORAUT-OTIB-0049 (ORAUT 2008).

    - Type S doses should be calculated using the lung count-based intakes for 1969 through 1974 and urinalysis-based intakes for all other time periods.

    - Type Super S doses should be calculated using the lung count-based intakes for 1969 through 1979 and urinalysis-based intakes for all other time periods.

5.5 POLONIUM

Table 5-5 lists the polonium intakes and associated GSDs to be used for each year of potential polonium exposure.

Table 5-5. Polonium intake rates (pCi/d).

		Type F		Type M	
Start	**End**	**50th percentile**	**GSD**	**50th percentile**	**GSD**
1/1/1944	12/31/1946	592.8[a]	6.96	2013[a]	7.01
1/1/1947	03/31/1949	592.8	6.96	2013	7.01
4/1/1949	12/31/1956	592.8	3.00	2013	3.00

a. Intakes for 1944 through 1946 are based on the 1947 to March 31, 1949 intakes.

Dose reconstruction for individuals who were involved in the polonium incident that occurred at or near the beginning of August 1955 and who do not have relevant bioassay data should be assigned the intakes in Table 5-6. The most favorable to claimant material type should be used. This intake should be applied only to individuals for whom there is evidence or reason to believe that they were involved in this incident.

Table 5-6. August 1, 1955 incident polonium intakes (pCi).

Date	Type F		Type M	
	50th percentile	GSD	50th percentile	GSD
8/1/1955	2.8E6	3.00	1.2E7	3.00

5.6 URANIUM

Table 5-7 lists the uranium intakes and associated GSDs to be used for each year of potential uranium exposure.

Table 5-7. Uranium intake rates (pCi/d).

Start	End	Type F		Type M		Type S	
		50th percentile	GSD	50th percentile	GSD	50th percentile	GSD
1/1/1947	12/31/1949	21.3[a]	3.36	88.7[a]	3.36	1,520[a]	3.24
1/1/1950	12/31/1955	21.3	3.36	88.7	3.36	1,520	3.24
1/1/1956	12/31/1957	5.36	3.36	16.0	3.36	656	3.24
1/1/1958	12/31/1965	1.98	4.81	7.95	4.90	141	4.71
1/1/1966	12/31/1973	0.909	6.84	3.53	7.03	59.3	6.59
1/1/1974	12/31/1982	0.227	11.31	1.03	10.6	19.7	9.27
1/1/1983	12/31/1989	1.53	4.81	6.29	4.90	105	4.44
1/1/1990	12/31/2000	0.201	4.03	0.756	4.06	11.0	4.57
1/1/2001	12/31/2001	1.019	3.00	4.70	3.00	92.0	3.00
1/1/2002	12/31/2008	0.201	4.03	0.756	4.06	11.0	4.57

a. Intakes for 1947 through 1949 are based on the 1950 through 1955 intakes.

5.7 CESIUM-137

Table 5-8 lists the cesium intakes and associated GSDs to be used for each year of potential cesium exposure.

Table 5-8. Type F ^{137}Cs intake rates (pCi/d).

Start	End	50th percentile	GSD
1/1/1970	12/31/1974	185.5	3.00
1/1/1975	12/31/1979	130.7	3.28
1/1/1980	12/31/1984	69.47	3.00
1/1/1985	12/31/1989	47.36	3.00
1/1/1990	12/31/1993	30.16	3.00

6.0 ATTRIBUTIONS AND ANNOTATIONS

All information requiring identification was addressed via references integrated into the reference section of this document.

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Table A-1. Statistical summary of ^{238}Pu urinary excretion rates (pCi/d), 1968 to 2008.

Effective bioassay date	GM (50th)	GM*GSD (84th)
7/1/1968	0.00823	0.0339
7/1/1969	0.00486	0.0332
7/1/1970	0.00147	0.0062
7/1/1971	0.00815	0.0466
7/1/1972	0.02683	0.0840
7/1/1973	0.00581	0.0308
7/1/1974	0.00571	0.0214
7/1/1975	0.00261	0.0154
7/1/1976	0.00224	0.0164
7/1/1977	0.00232	0.0182
7/1/1978	0.00101	0.0143
7/1/1979	0.00162	0.0118
7/1/1980	0.00126	0.0091
7/1/1981	0.00124	0.0118
7/1/1982	0.00010	0.0027
7/1/1983	0.00010	0.0019
7/1/1984	0.00011	0.0026
7/1/1985	0.00028	0.0038
7/1/1986	0.00079	0.0053
7/1/1987	0.00056	0.0047
7/1/1988	0.00072	0.0048
7/1/1989	0.0017	0.0079
7/1/1990	0.0021	0.0081
7/1/1991	0.0025	0.0091
7/1/1992	0.0022	0.0079
7/1/1993	0.0016	0.0078
7/1/1994	0.0006	0.0046
7/1/1995	0.0003	0.0049
7/1/1996	0.0006	0.0035
7/1/1997	0.0004	0.0035
7/1/1998	0.0004	0.0029
7/1/1999	0.0002	0.0013
7/1/2000	0.0002	0.0028
7/1/2001	0.0002	0.0017
7/1/2002	0.0002	0.0012
7/1/2003	0.0002	0.0011
7/1/2004	0.0003	0.0016
7/1/2005	0.0005	0.0022
7/1/2006	0.0007	0.0031
7/1/2007	0.0004	0.0042
7/1/2008	0.0005	0.0029

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Table A-2. Statistical summary of ^{239}Pu urinary excretion rates (µCi/L), 1945 to 2008.

Effective bioassay date	GM (50th)	GM*GSD (84th)		Effective bioassay date	GM (50th)	GM*GSD (84th)
7/1/1945	0.8332	4.2106		7/1/1980	0.0018	0.0154
7/1/1946	0.1793	1.1191		7/1/1981	0.0014	0.0137
7/1/1947	0.1065	0.4876		7/1/1982	0.0003	0.0057
7/1/1948	0.0571	0.4084		7/1/1983	0.0006	0.0093
7/1/1949	0.0301	0.2028		7/1/1984	0.0003	0.0053
7/1/1950	0.0434	0.2118		7/1/1985	0.0017	0.0111
7/1/1951	0.0574	0.2595		7/1/1986	0.0013	0.0108
7/1/1952	0.0628	0.4073		7/1/1987	0.0013	0.0084
7/1/1953	0.0703	0.4009		7/1/1988	0.0012	0.0071
7/1/1954	0.0153	0.1779		7/1/1989	0.0017	0.0077
7/1/1955	0.0119	0.0978		7/1/1990	0.0021	0.0083
7/1/1956	0.0115	0.0979		7/1/1991	0.0023	0.0084
7/1/1957	0.0042	0.052		7/1/1992	0.0017	0.0076
7/1/1958	0.0040	0.0537		7/1/1993	0.0015	0.0083
7/1/1959	0.0020	0.0322		7/1/1994	0.0004	0.0045
7/1/1960	0.0022	0.0306		7/1/1995	0.0003	0.0043
7/1/1961	0.0019	0.0201		7/1/1996	0.0007	0.0040
7/1/1962	0.0016	0.0232		7/1/1997	0.0002	0.0038
7/1/1963	0.002	0.0306		7/1/1998	0.0002	0.0026
7/1/1964	0.0026	0.0265		7/1/1999	0.00010	0.00120
7/1/1965	0.0023	0.0253		7/1/2000	0.00009	0.00136
7/1/1966	0.0037	0.0380		7/1/2001	0.00004	0.00094
7/1/1967	0.0066	0.0471		7/1/2002	0.00003	0.00064
7/1/1968	0.0093	0.0584		7/1/2003	0.00002	0.00034
7/1/1969	0.0145	0.0814		7/1/2004	0.00002	0.00041
7/1/1970	0.0066	0.0422		7/1/2005	0.00004	0.00049
7/1/1971	0.0157	0.1008		7/1/2006	0.00002	0.00035
7/1/1972	0.0341	0.1136		7/1/2007	0.00004	0.00051
7/1/1973	0.0083	0.0446		7/1/2008	0.00006	0.00068
7/1/1974	0.0061	0.0350				
7/1/1975	0.0037	0.0265				
7/1/1976	0.0022	0.0201				
7/1/1977	0.0023	0.0292				
7/1/1978	0.0012	0.0157				
7/1/1979	0.0011	0.0116				

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Table A-3. Statistical summary of ^{239}Pu lung burdens (pCi), 1969 to 1979.

Measurement data date range	Effective bioassay date	GM (50th)	GM*GSD (84th)
1969-1970	7/1/1970	473	2033
1971-1974	7/1/1973	504	2268
1975	7/1/1975	3712	6922
1976-1977	1/1/1977	1221	4319
1978-1979	1/1/1979	248	1290

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Table A-4. Statistical summary of polonium urinary excretion rates (pCi/d), 1947 to 1956.

Effective bioassay date	GM (50th)	GM*GSD (84th)
2/15/1947	54.51	219.82
5/15/1947	76.59	343.47
8/15/1947	25.15	240.80
11/15/1947	50.89	200.17
2/15/1948	48.88	252.94
5/15/1948	52.76	294.13
8/15/1948	98.45	507.63
11/15/1948	53.79	189.88
2/15/1949	79.84	364.04
5/15/1949	49.10	148.29
8/15/1949	32.53	86.43
11/15/1949	29.78	120.96
2/15/1950	20.90	63.53
5/15/1950	41.23	90.29
8/15/1950	25.93	79.71
11/15/1950	31.89	119.93
2/15/1951	42.18	115.02
5/15/1951	33.14	111.07
8/15/1951	41.25	144.68
11/15/1951	36.96	125.69
2/15/1952	45.76	142.02
5/15/1952	32.36	157.48
8/15/1952	27.83	105.86
11/15/1952	27.15	84.03
2/15/1953	76.61	299.93
5/15/1953	33.87	127.48
8/15/1953	51.79	138.64
11/15/1953	65.50	225.54
2/15/1954	43.99	122.20
5/15/1954	46.75	120.15
8/15/1954	39.35	89.36
11/15/1954	34.75	76.77
2/15/1955	33.08	77.69
5/15/1955	16.99	52.10
8/15/1955	55.54	200.24
11/15/1955	30.19	54.61
7/1/1956	14.44	52.33

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Table A-5. Statistical summary of uranium urinary excretion rates (pCi/d) from 1950 to 2008.

Effective bioassay date	GM (50th)	GM*GSD (84th)		Effective bioassay date	GM (50th)	GM*GSD (84th)
7/1/1950	6.941	24.394		7/1/1980	0.002	0.054
7/1/1951	5.035	15.898		7/1/1981	0.003	0.060
7/1/1952	6.764	19.354		7/1/1982	0.016	0.274
7/1/1953	3.979	11.575		7/1/1983	0.438	2.136
7/1/1954	5.656	20.846		7/1/1984	0.410	1.788
7/1/1955	6.536	18.864		7/1/1985	0.215	1.045
7/1/1956	1.447	5.702		7/1/1986	0.482	1.723
7/1/1957	1.518	4.324		7/1/1987	0.286	1.893
7/1/1958	0.410	2.087		7/1/1988	0.348	1.543
7/1/1959	0.090	1.110		7/1/1989	0.317	1.351
7/1/1960	0.083	0.660		7/1/1990	0.030	0.240
7/1/1961	0.206	1.498		10/1/1991	0.058	0.231
7/1/1962	0.723	4.006		7/1/1992	0.024	0.168
7/1/1963	0.471	2.691		7/1/1993	0.033	0.223
7/1/1964	1.009	3.153		7/1/1994	0.074	0.346
7/1/1965	0.722	3.779		7/1/1995	0.084	0.399
7/1/1966	0.467	2.249		7/1/1996	0.088	0.366
7/1/1967	0.356	3.554		7/1/1997	0.072	0.292
7/1/1968	0.065	0.919		7/1/1998	0.070	0.291
7/1/1969	0.204	1.287		7/1/1999	0.064	0.307
7/1/1970	0.224	1.370		7/1/2000	0.066	0.383
7/1/1971	0.001	0.044		7/1/2001	0.285	0.746
7/1/1972	0.150	1.046		7/1/2002	0.070	0.231
7/1/1973	0.233	1.501		7/1/2003	0.053	0.164
7/1/1974	0.070	0.876		7/1/2004	0.059	0.197
7/1/1975	0.080	0.784		7/1/2005	0.114	0.312
7/1/1976	0.040	0.529		7/1/2006	0.078	0.230
7/1/1977	0.023	0.391		7/1/2007	0.103	0.288
7/1/1978	0.034	0.513		7/1/2008	0.074	0.216
7/1/1979	0.055	0.590				

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Table A-6. Statistical summary of cesium whole-body counts (pCi), 1970 to 1993.

Measurement data date range	Effective bioassay date	GM (50th)	GM*GSD (84th)
1970–1974	7/1/1972	12740	37156
1975–1979	7/1/1977	9013	29573
1980–1984	7/1/1982	4799	9442
1985–1989	1/1/1987	3277	6896
1990-1993	1/1/1992	2089	4354

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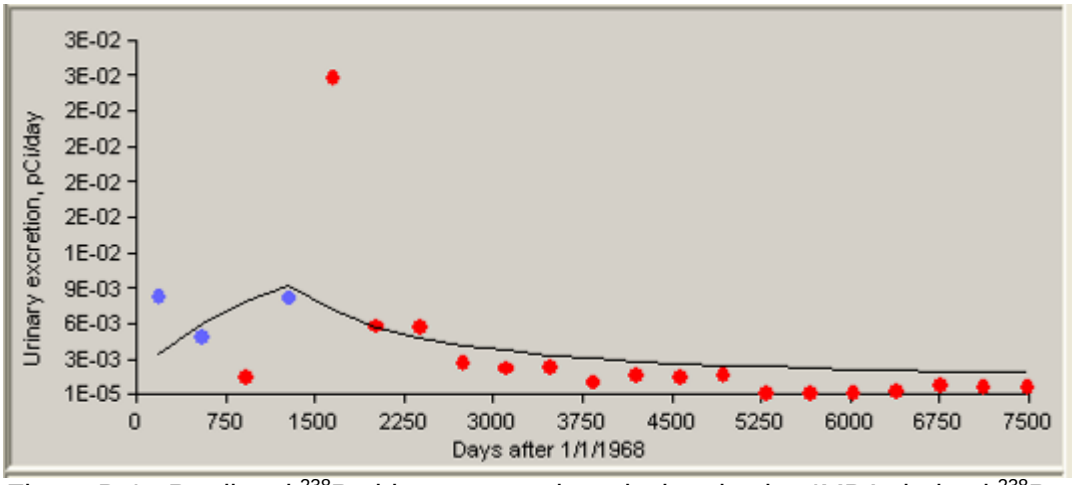

Figure B-1. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 50th percentile, type M.

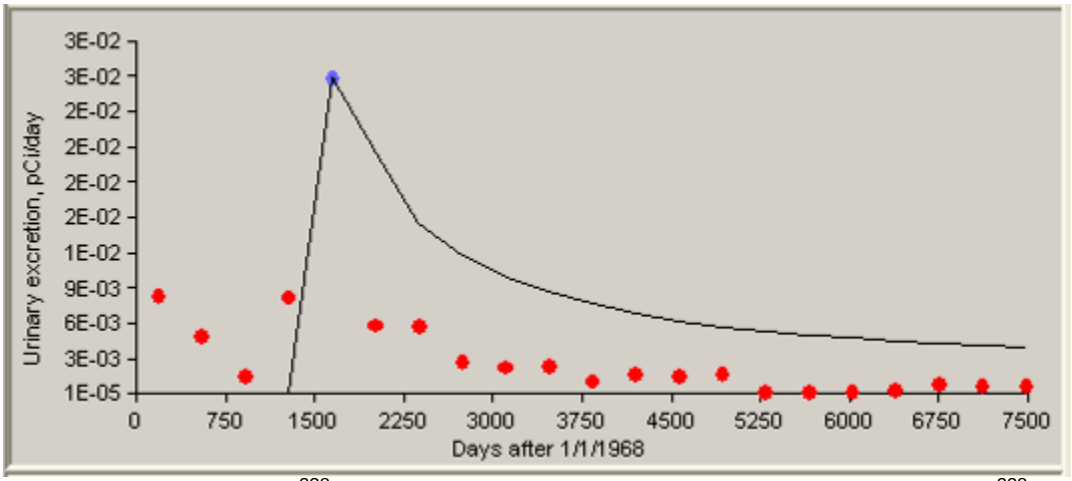

Figure B-2. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 50th percentile, type M.

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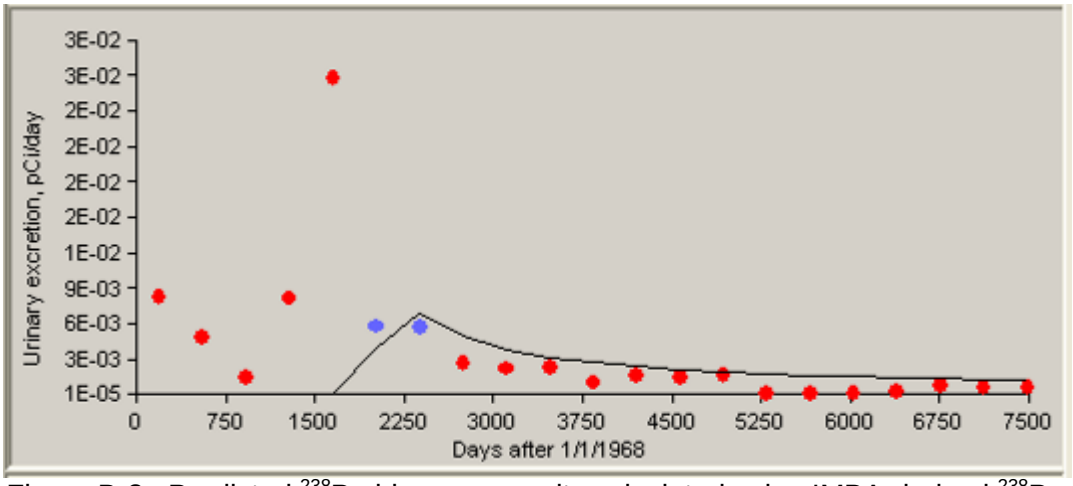

Figure B-3. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1974, 50th percentile, type M.

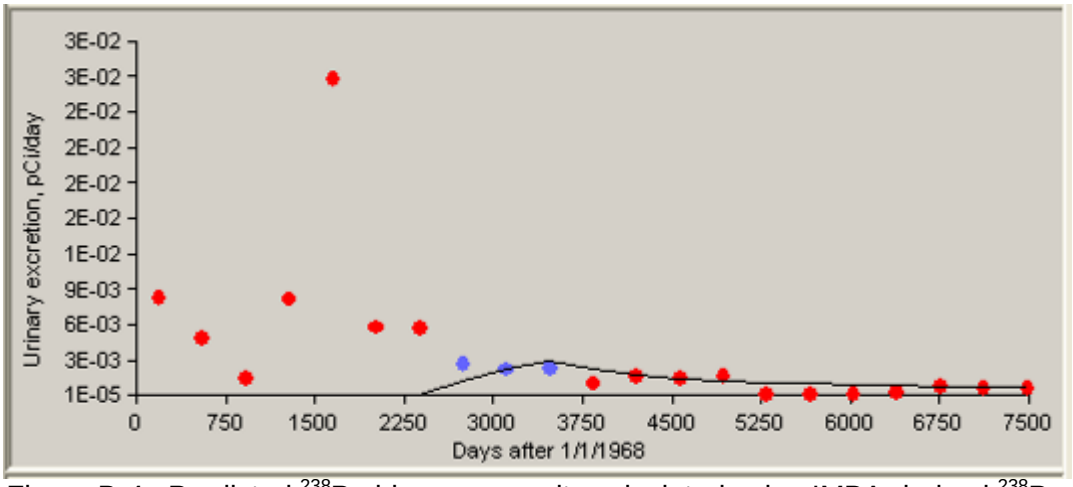

Figure B-4. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1977, 50th percentile, type M.

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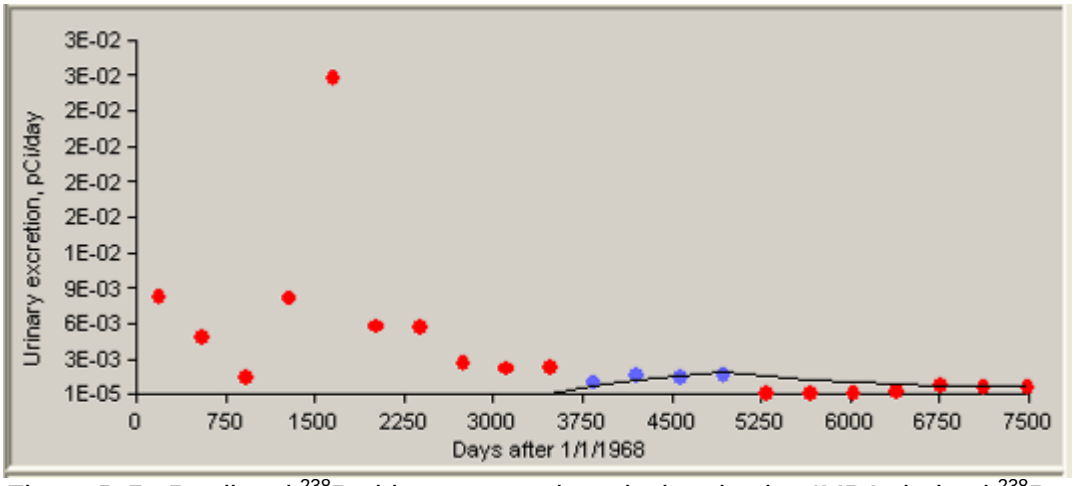

Figure B-5. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1981, 50th percentile, type M.

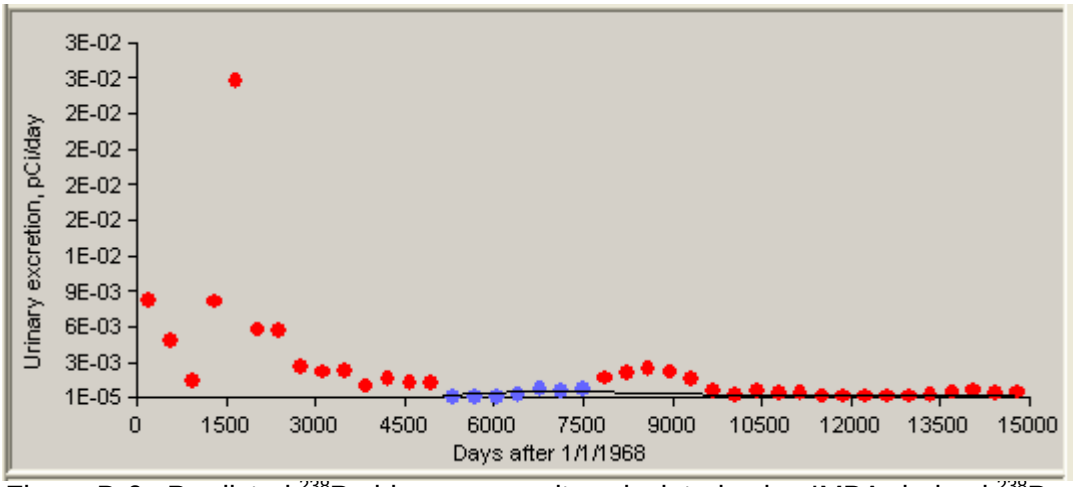

Figure B-6. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 50th percentile, type M.

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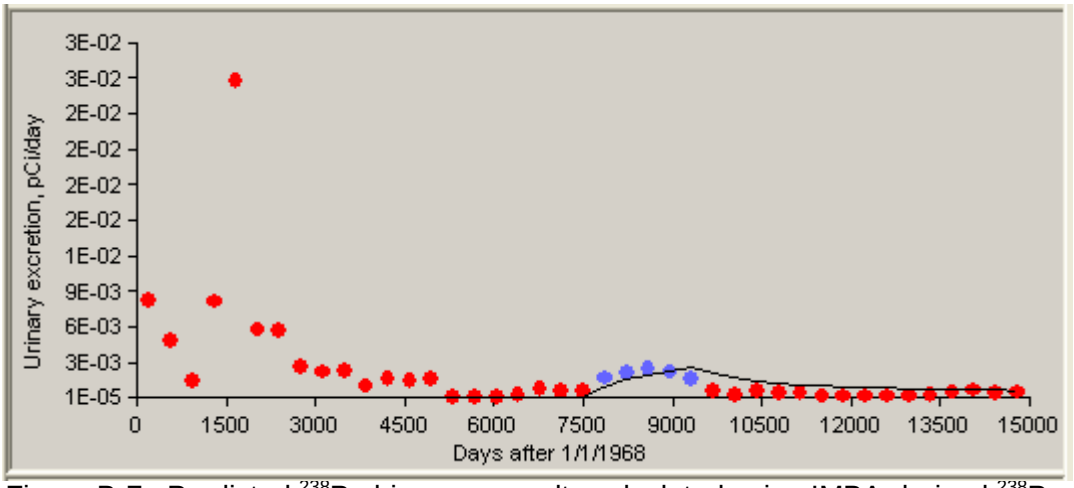

Figure B-7. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 50th percentile, type M.

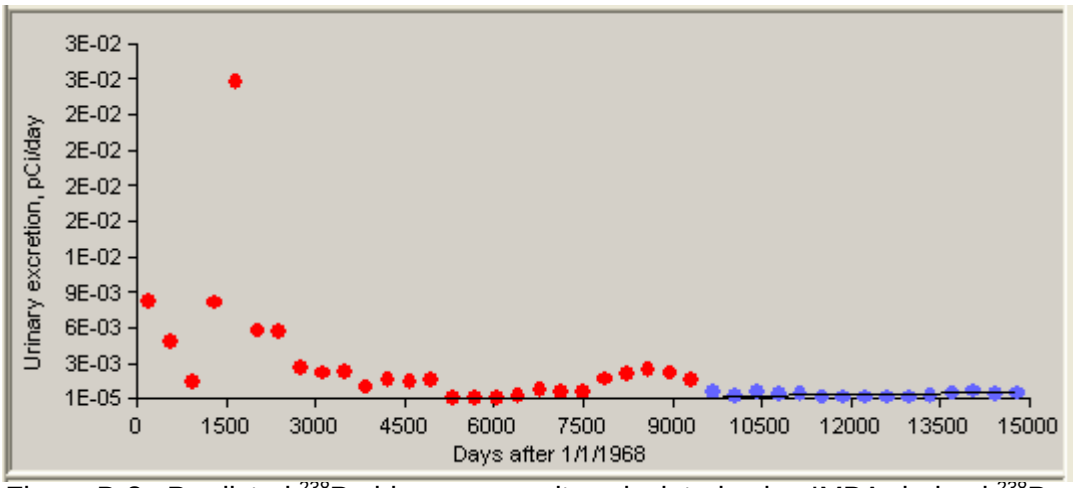

Figure B-8. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type M.

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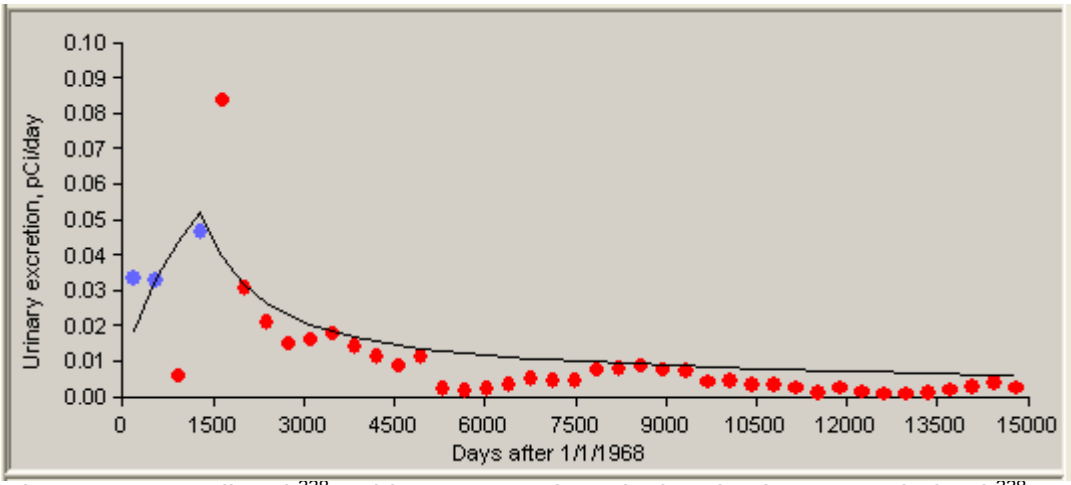

Figure B-9. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 84th percentile, type M.

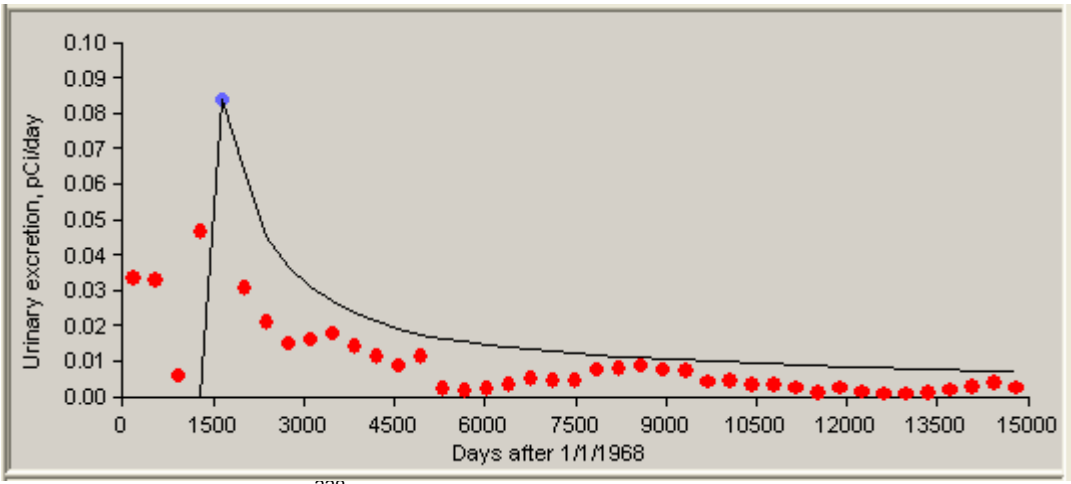

Figure B-10. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 84th percentile, type M.

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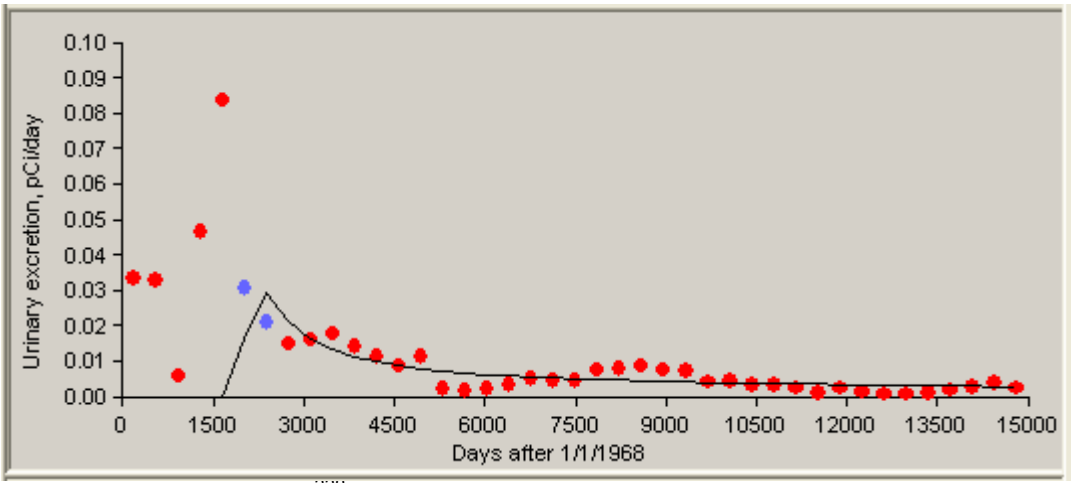

Figure B-11. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973-1974, 84th percentile, type M.

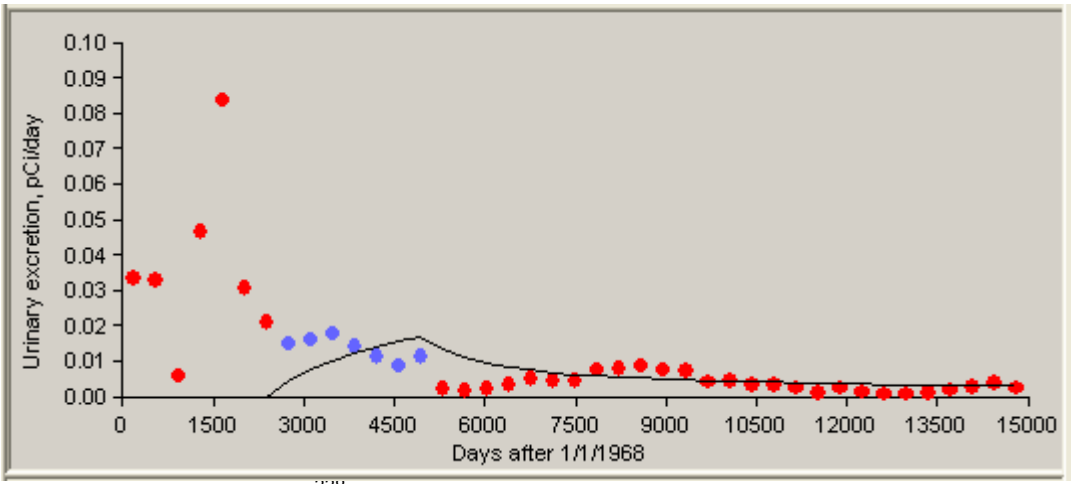

Figure B-12. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1981, 84th percentile, type M.

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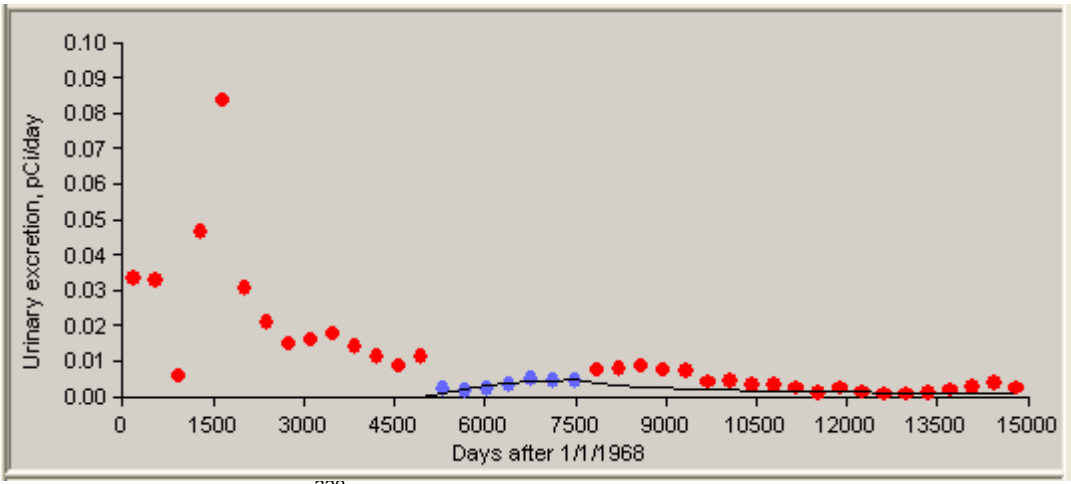

Figure B-13. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 84th percentile, type M.

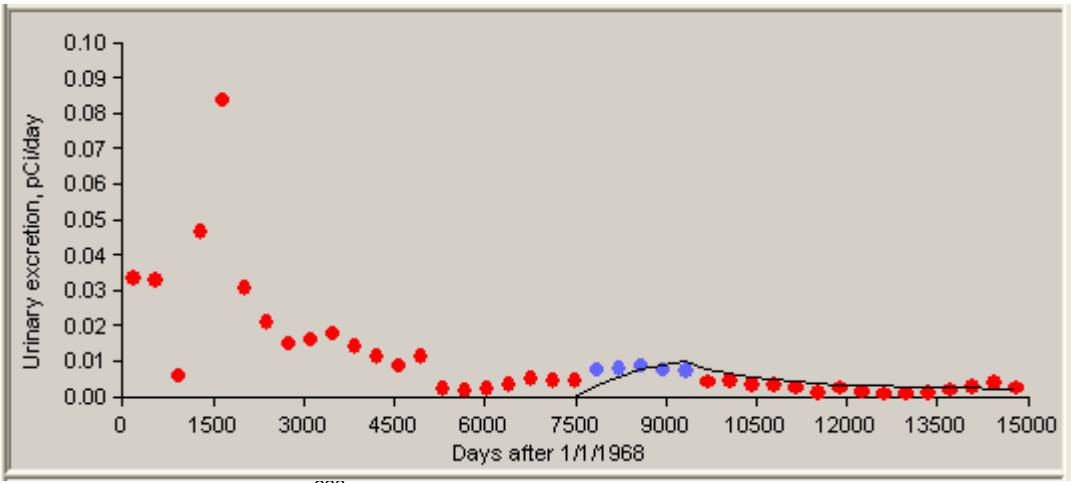

Figure B-14. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 84th percentile, type M.

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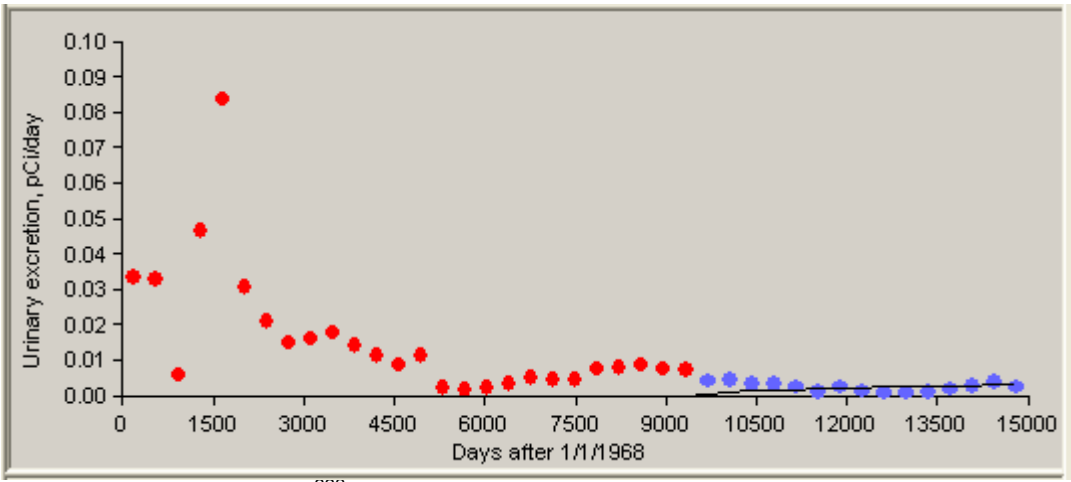

Figure B-15. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type M.

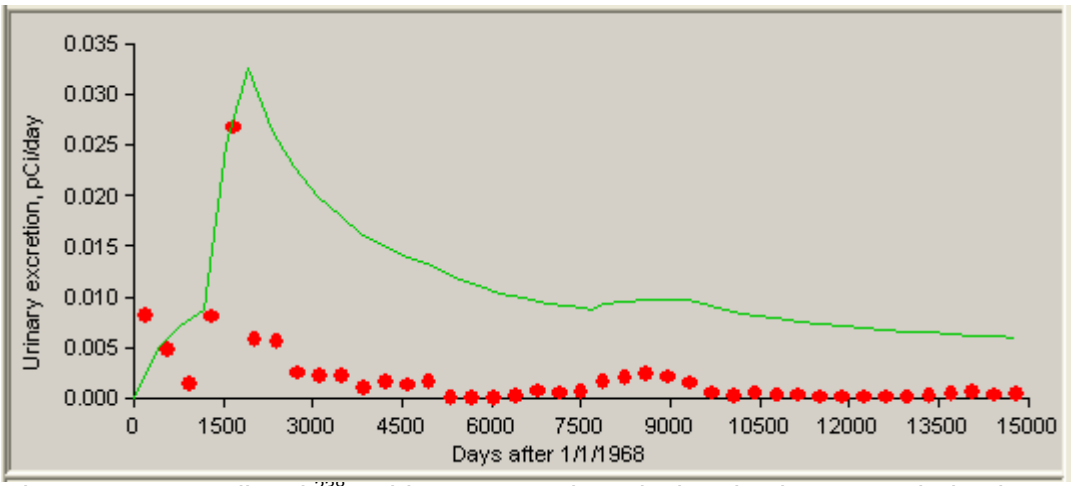

Figure B-16. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

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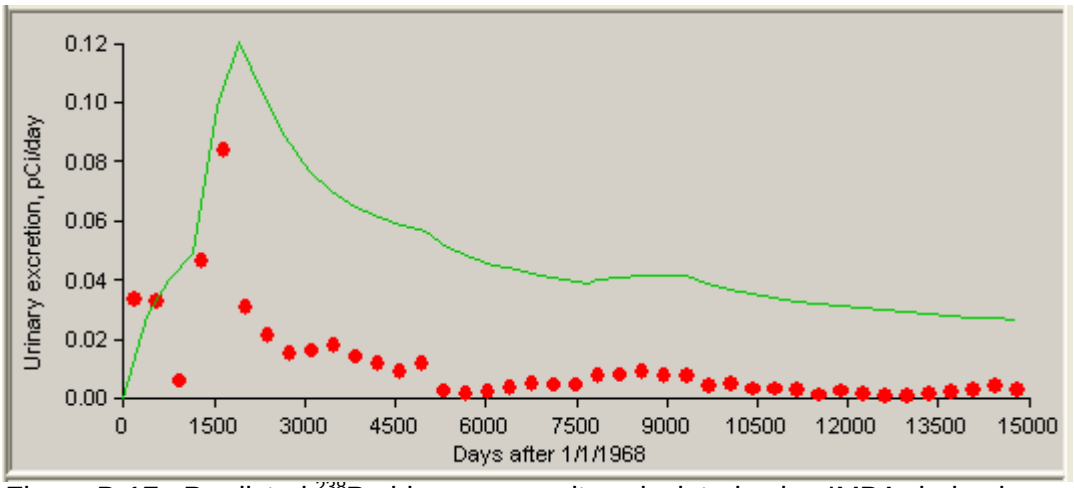

Figure B-17. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-1. Summary of ^{238}Pu type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1968	12/31/1971	1.774	9.981	5.63
1/1/1972	12/31/1972	14.12	44.22	3.13
1/1/1973	12/31/1974	2.038	8.793	4.31
1/1/1975	12/31/1977	0.666	2.394	3.59
1/1/1978	12/31/1981	0.317	2.394	7.56
1/1/1982	12/31/1988	0.084	0.737	8.74
1/1/1989	12/31/1993	0.439	1.764	4.02
1/1/1994	12/31/2008	0.048	0.326	6.82

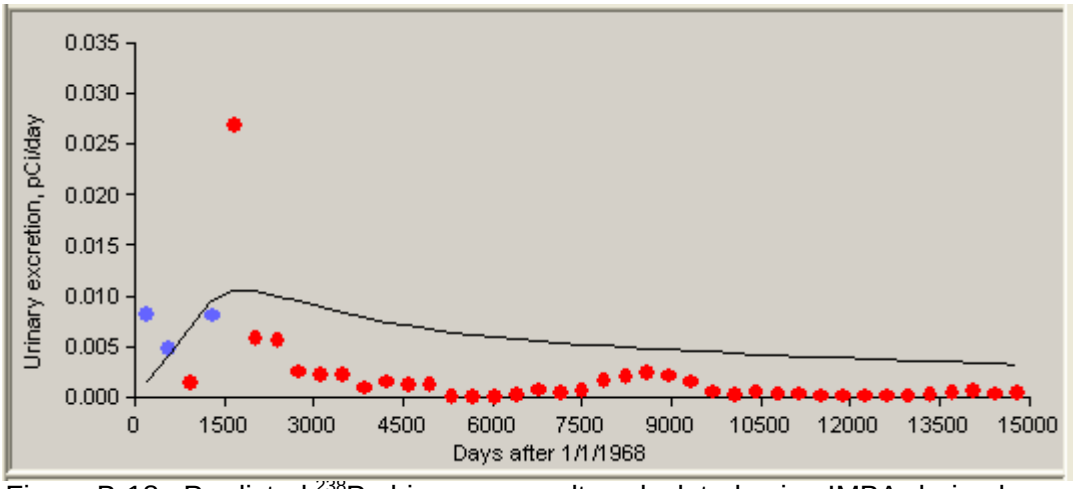

Figure B-18. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 50th percentile, type S.

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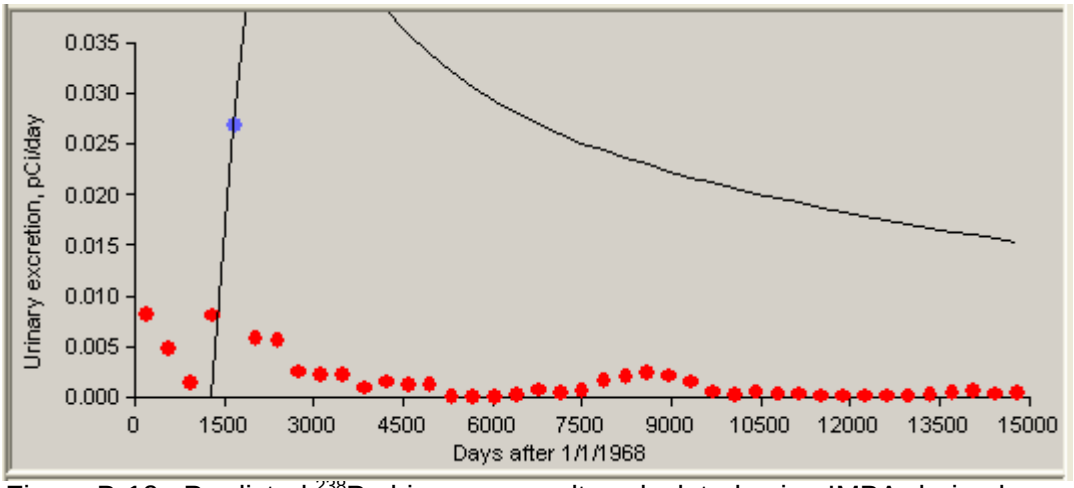

Figure B-19. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 50th percentile, type S.

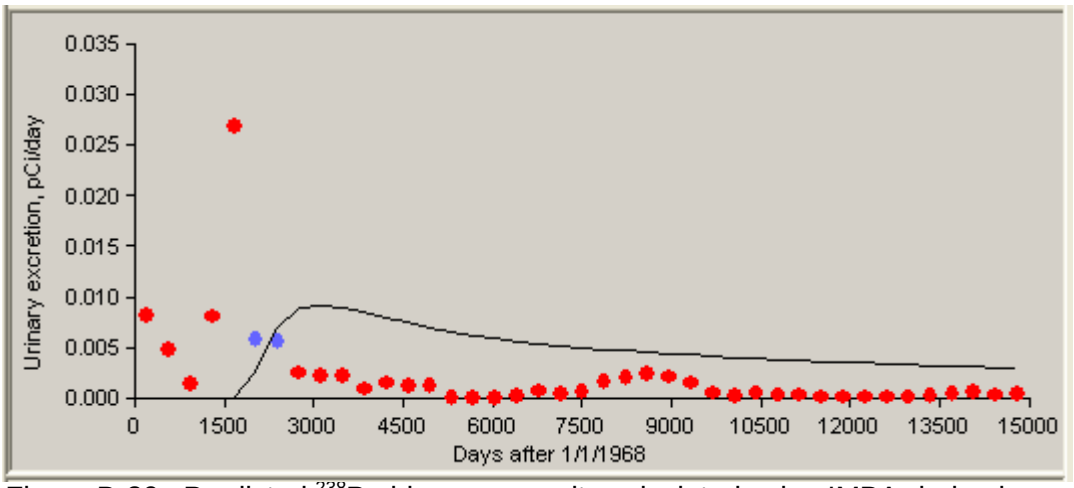

Figure B-20. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1974, 50th percentile, type S.

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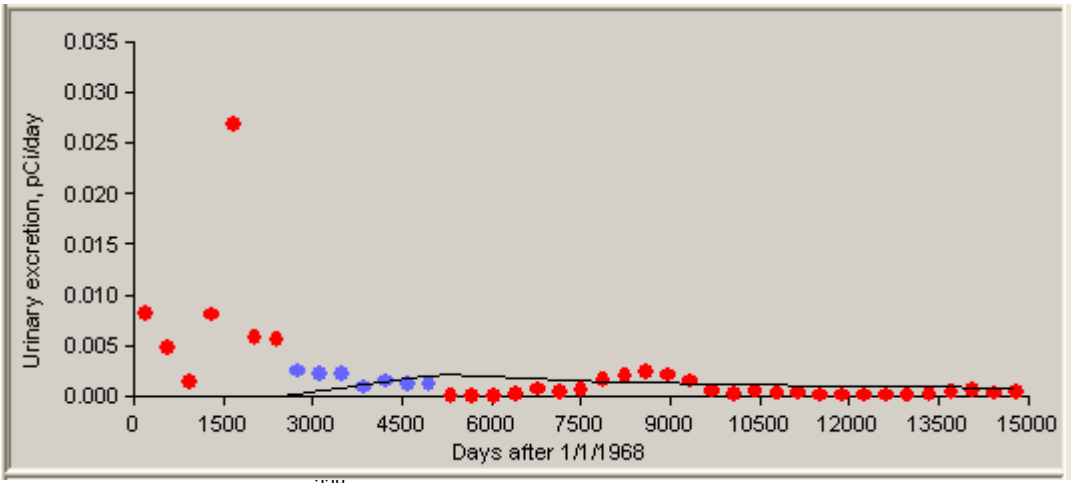

Figure B-21. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1981, 50th percentile, type S.

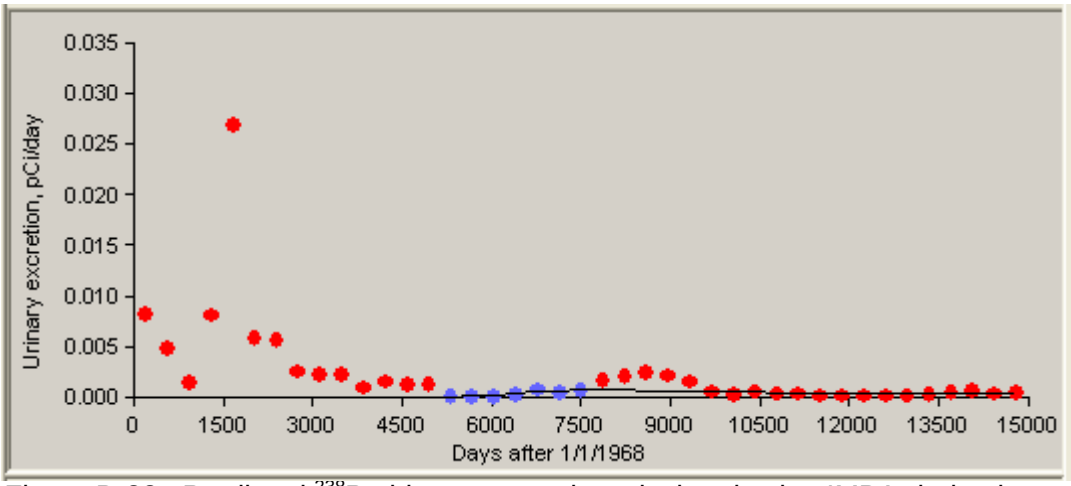

Figure B-22. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 50th percentile, type S.

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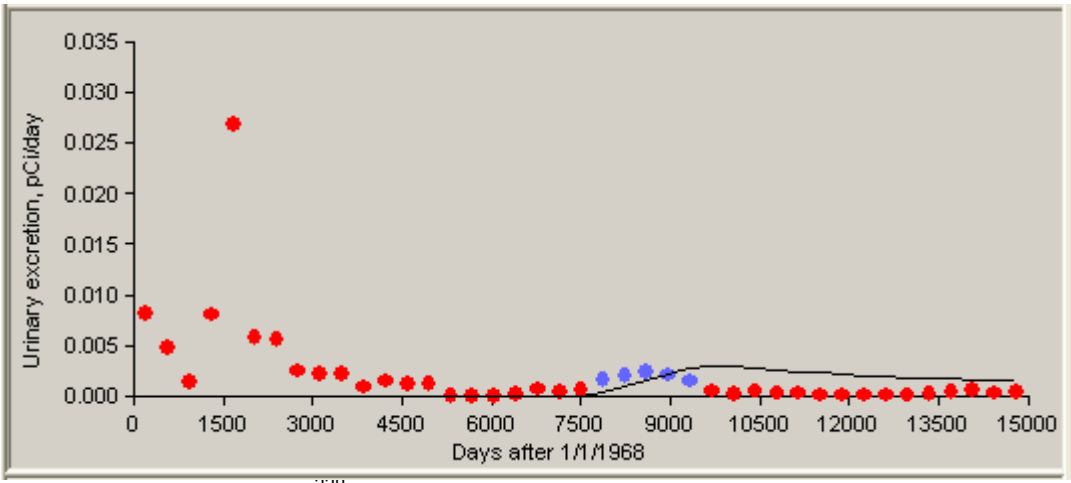

Figure B-23. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 50th percentile, type S.

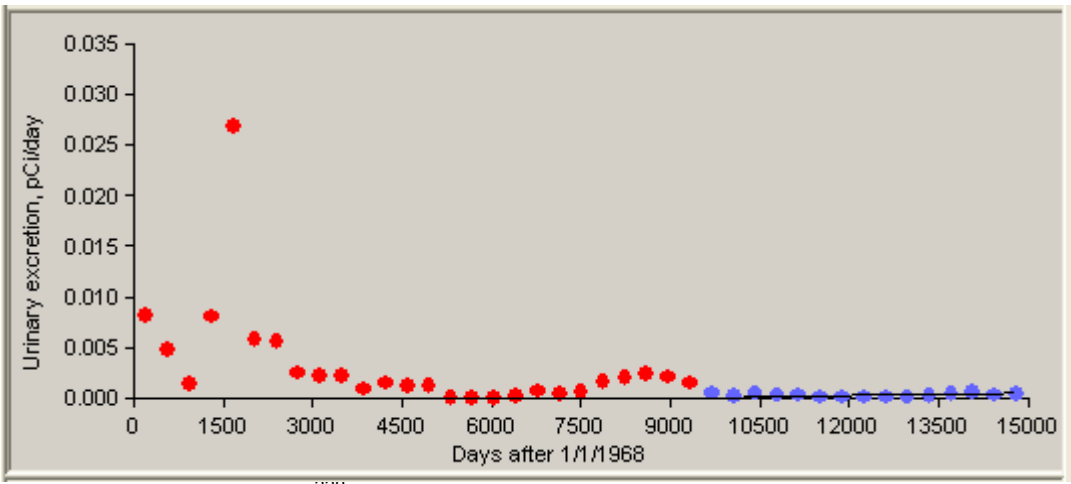

Figure B-24. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type S.

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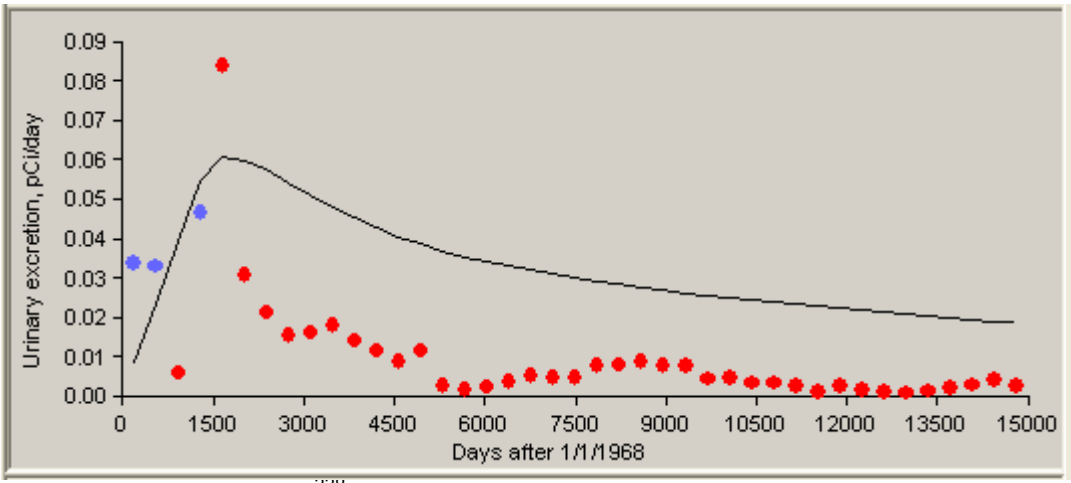

Figure B-25. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 84th percentile, type S.

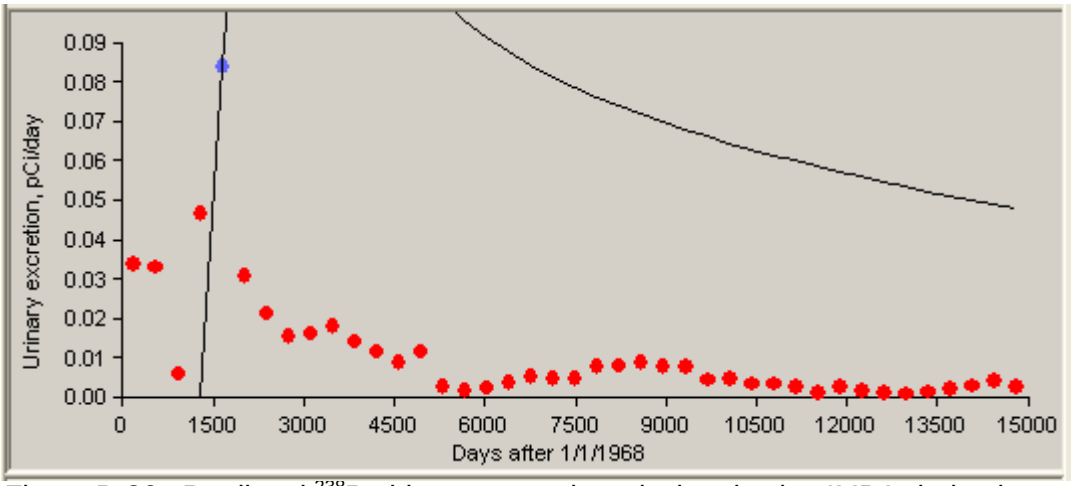

Figure B-26. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 84th percentile, type S.

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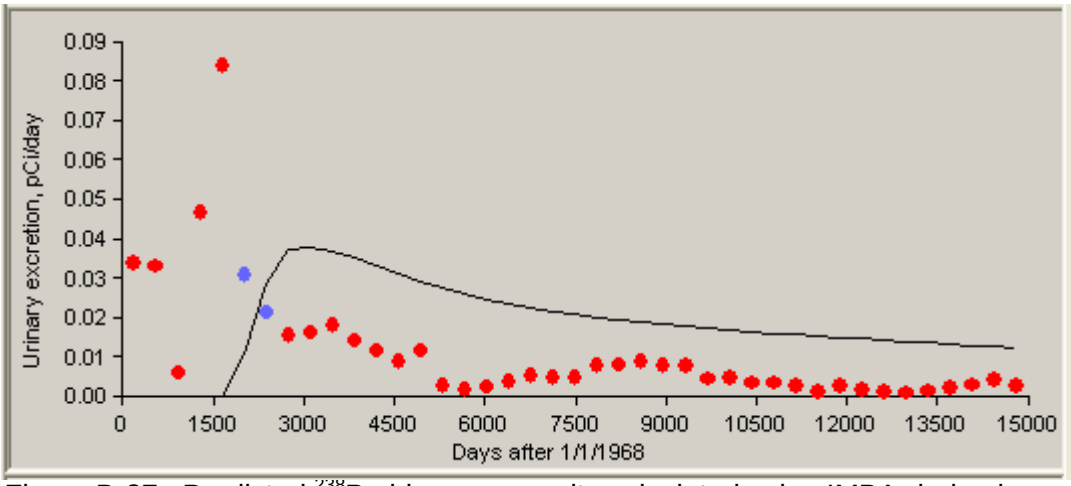

Figure B-27. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1974, 84th percentile, type S.

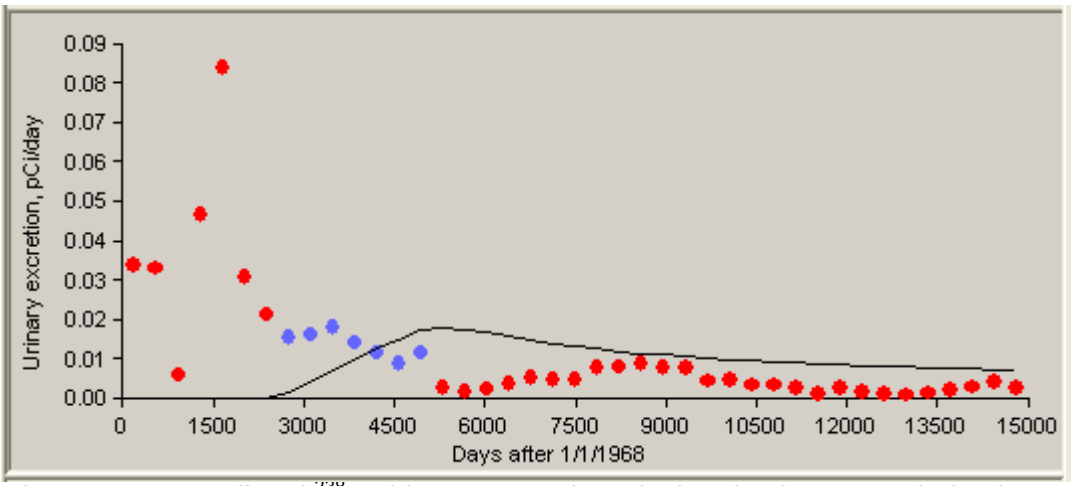

Figure B-28. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1981, 84th percentile, type S.

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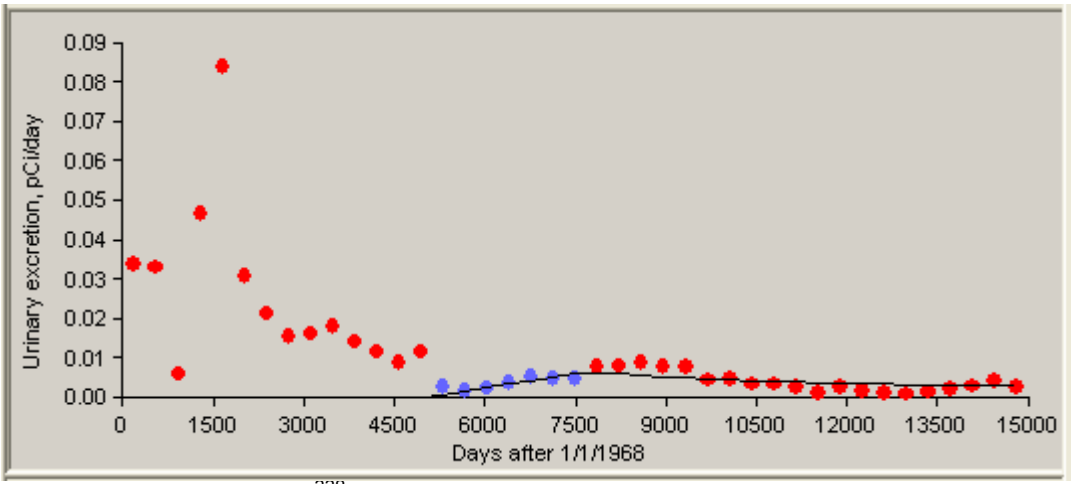

Figure B-29. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 84th percentile, type S.

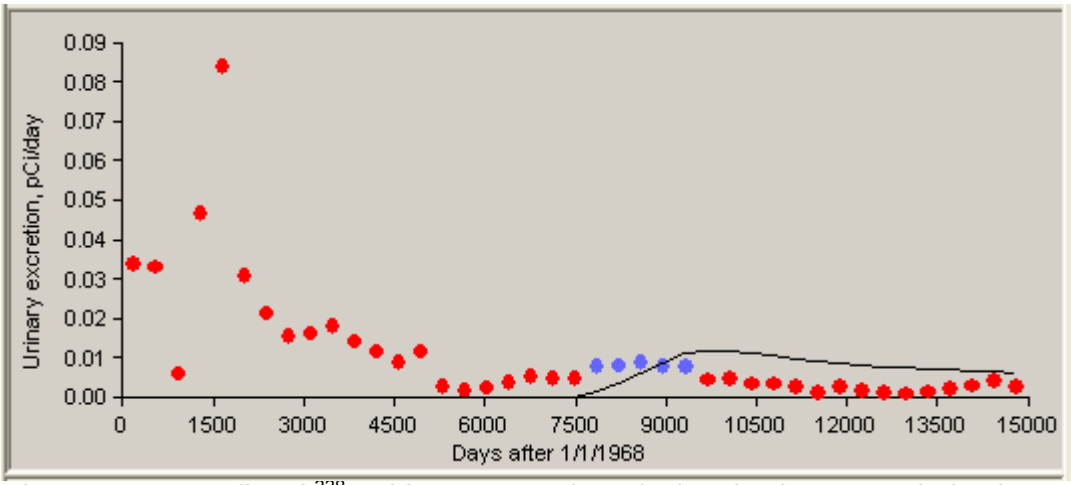

Figure B-30. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 84th percentile, type S.

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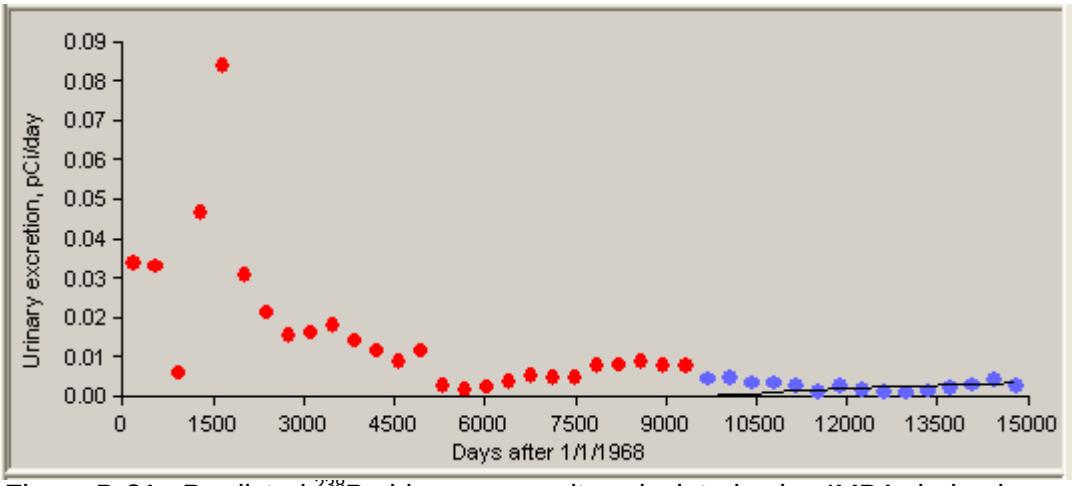

Figure B-31. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type S.

Figure B-32. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type S.

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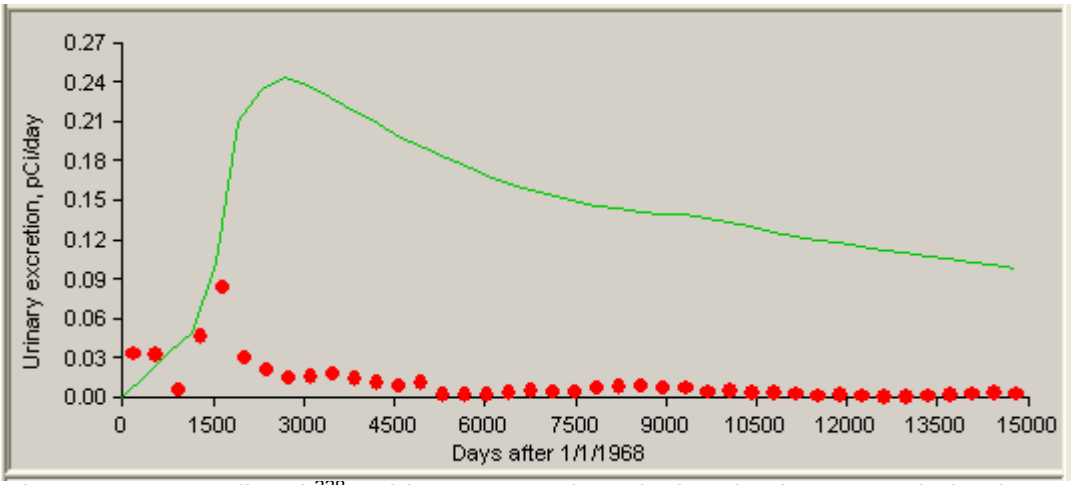

Figure B-33. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type S.

Table B-2. Summary of ^{238}Pu type S intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1968	12/31/1971	42.95	246.5	5.74
1/1/1972	12/31/1972	764.7	2394	3.13
1/1/1973	12/31/1974	72.28	301.3	4.17
1/1/1975	12/31/1981	5.235	44.34	8.47
1/1/1982	12/31/1988	1.818	15.02	8.26
1/1/1989	12/31/1993	9.708	39.21	4.04
1/1/1994	12/31/2008	0.717	4.72	6.58

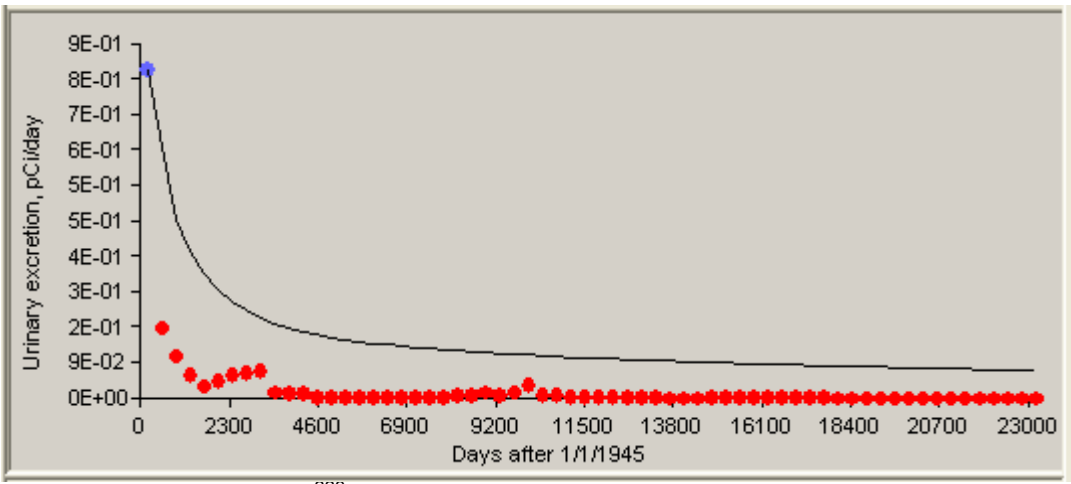

Figure B-34. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 50th percentile, type M.

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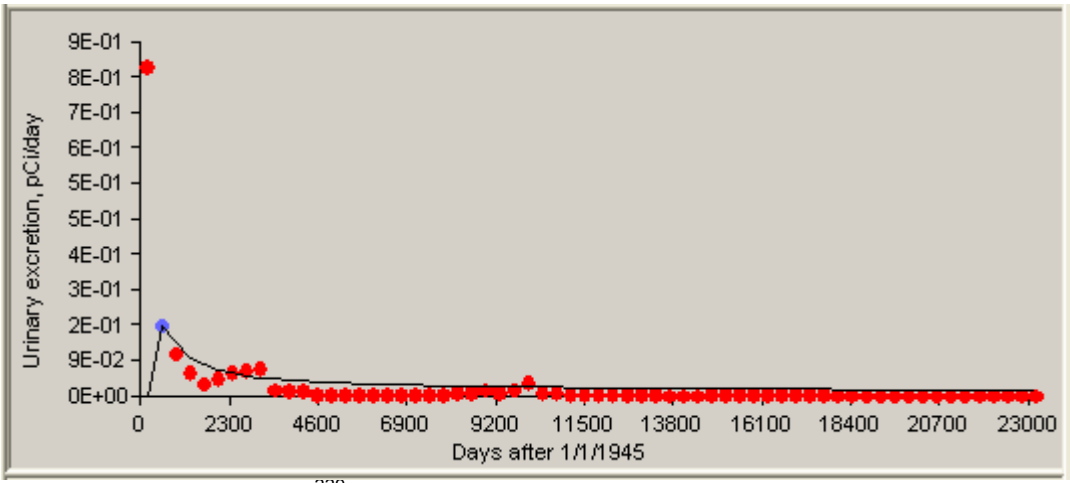

Figure B-35. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 50th percentile, type M.

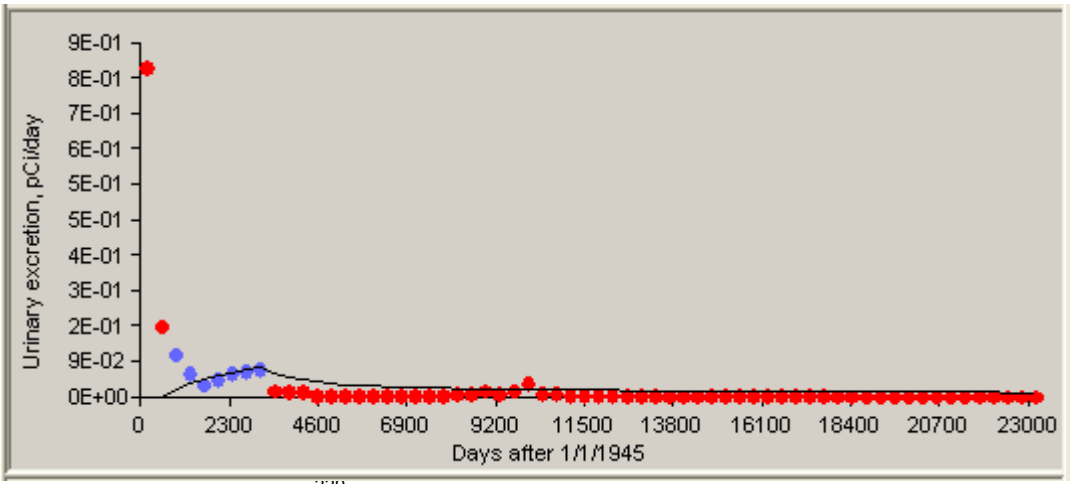

Figure B-36. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947-1953, 50th percentile, type M.

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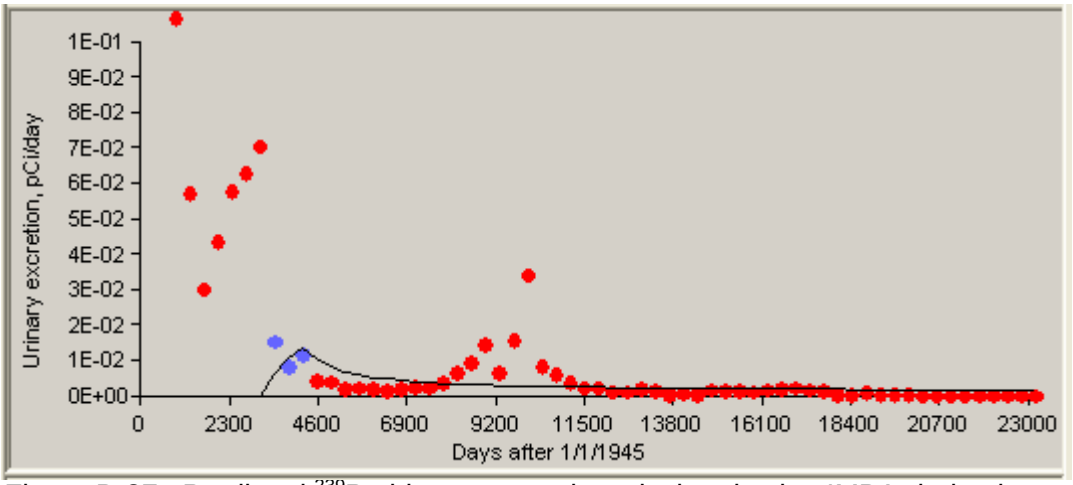

Figure B-37. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1954 to 1956, 50th percentile, type M.

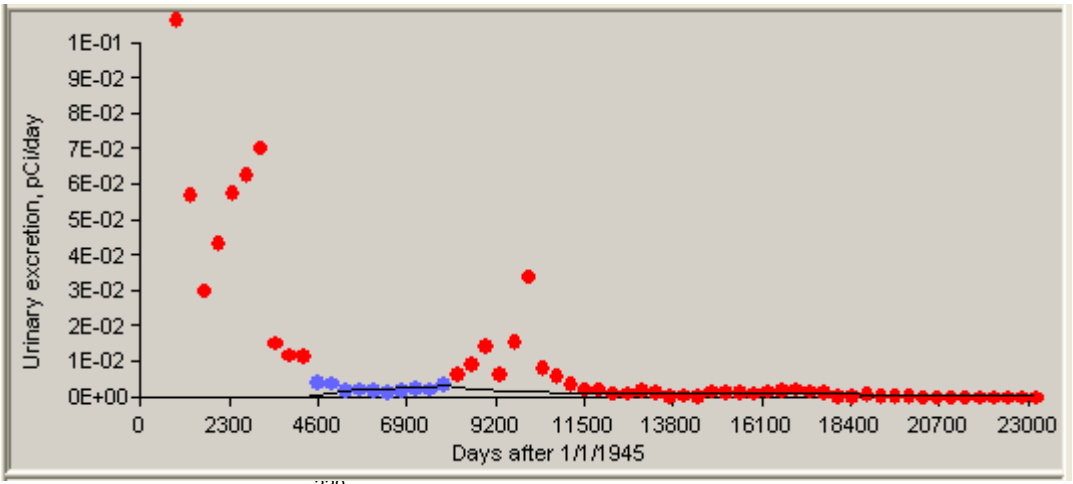

Figure B-38. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 50th percentile, Type M.

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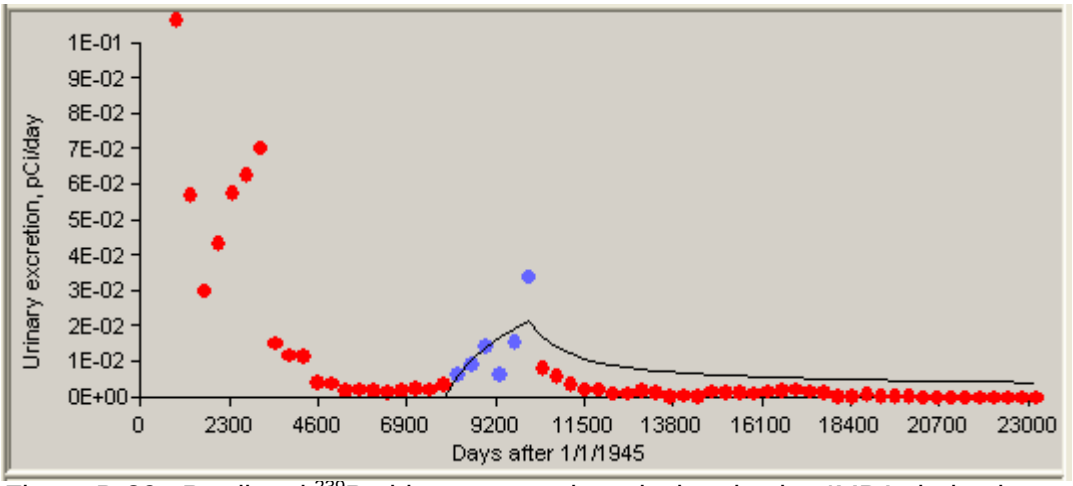

Figure B-39. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 50th percentile, Type M.

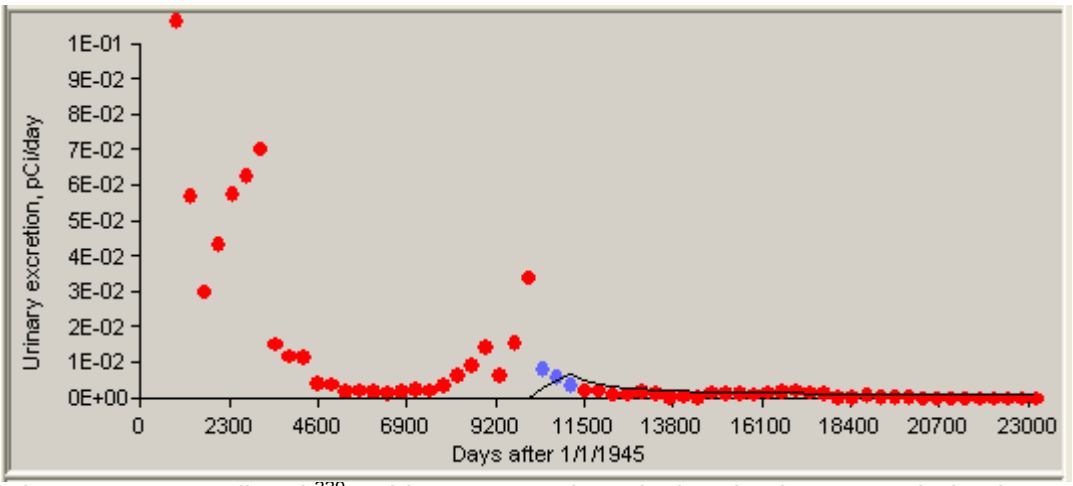

Figure B-40. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 50th percentile, type M.

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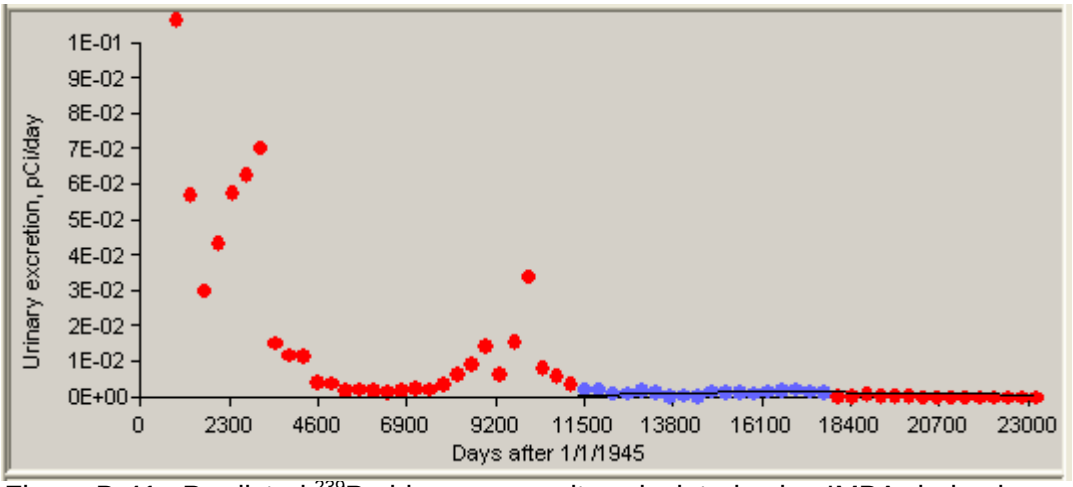

Figure B-41. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 50th percentile, type M.

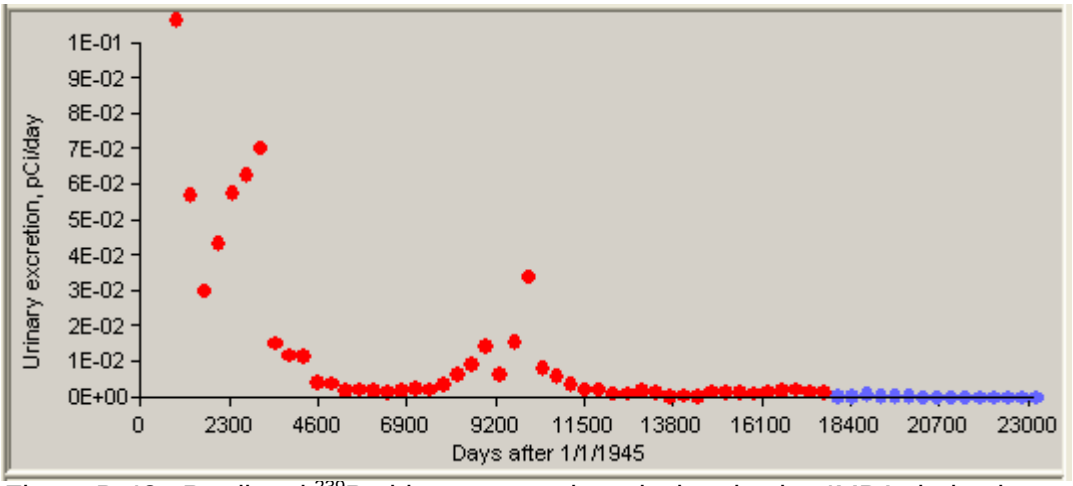

Figure B-42. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type M.

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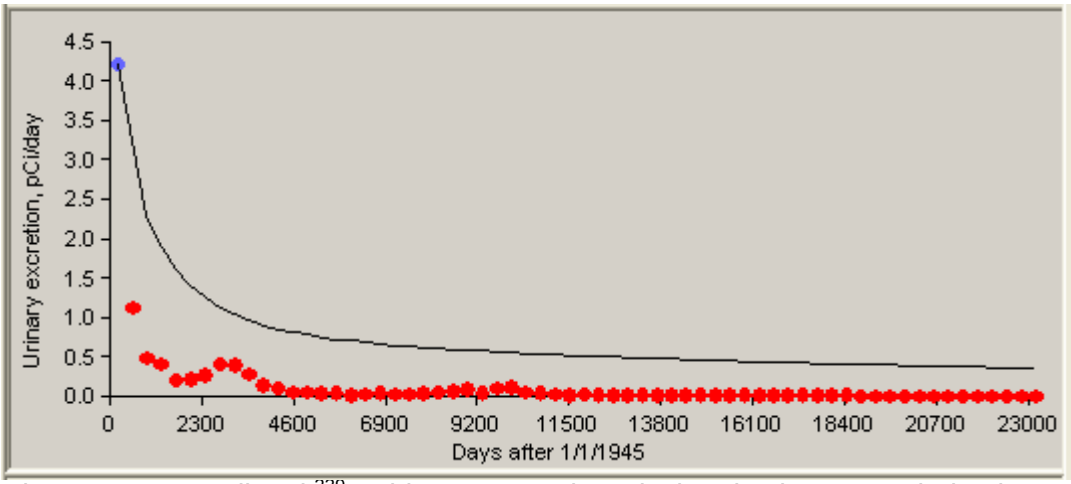

Figure B-43. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 84th percentile, type M.

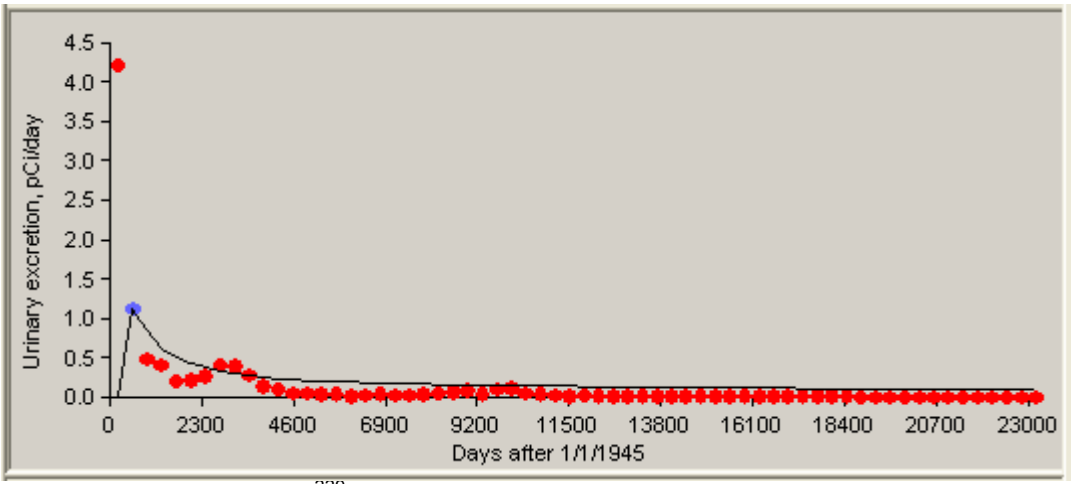

Figure B-44. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 84th percentile, type M.

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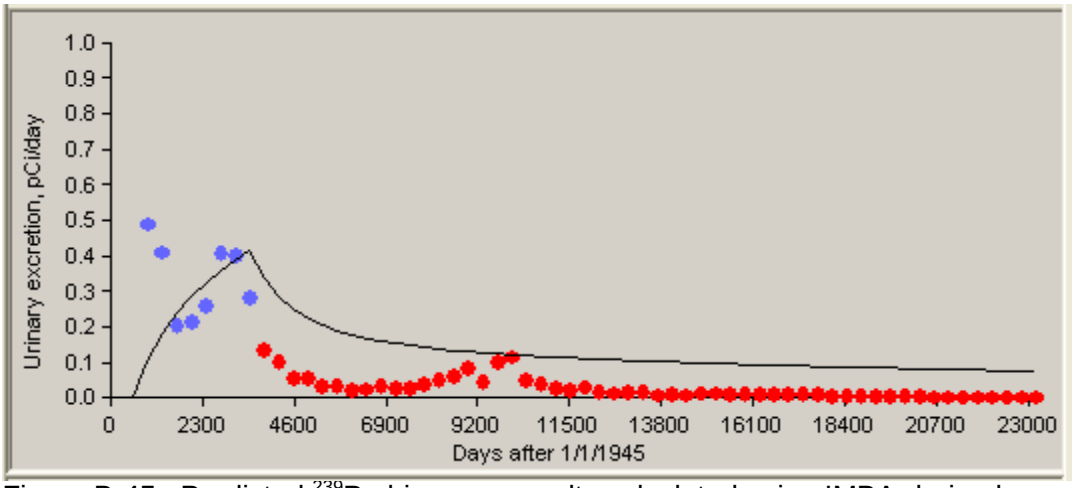

Figure B-45. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1954, 84th percentile, type M.

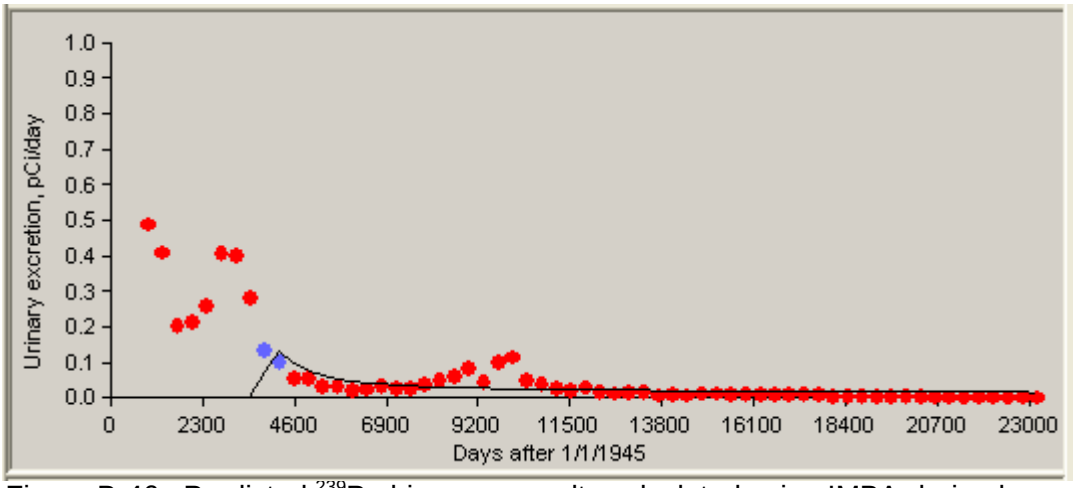

Figure B-46. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1955 to 1956, 84th percentile, type M.

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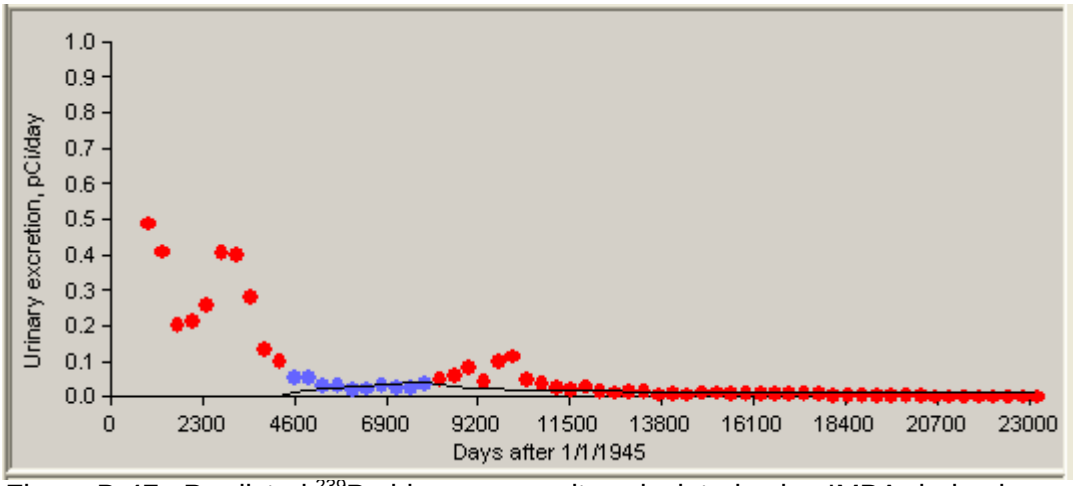

Figure B-47. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 84th percentile, type M.

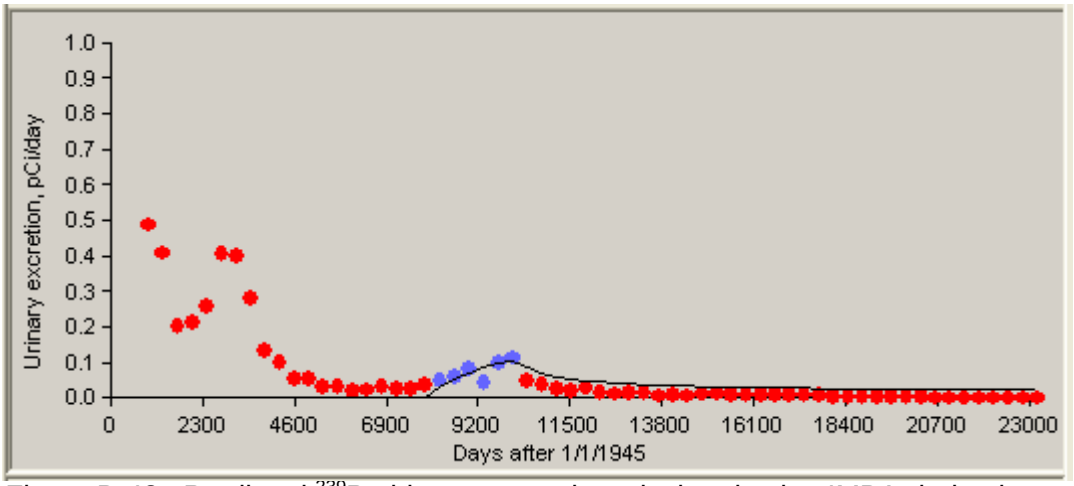

Figure B-48. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 84th percentile, type M.

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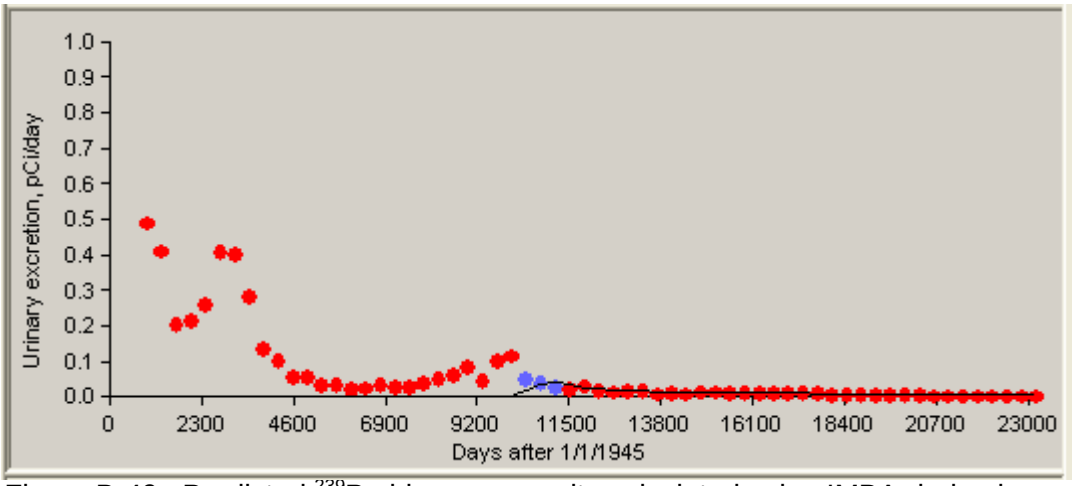

Figure B-49. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 84th percentile, type M.

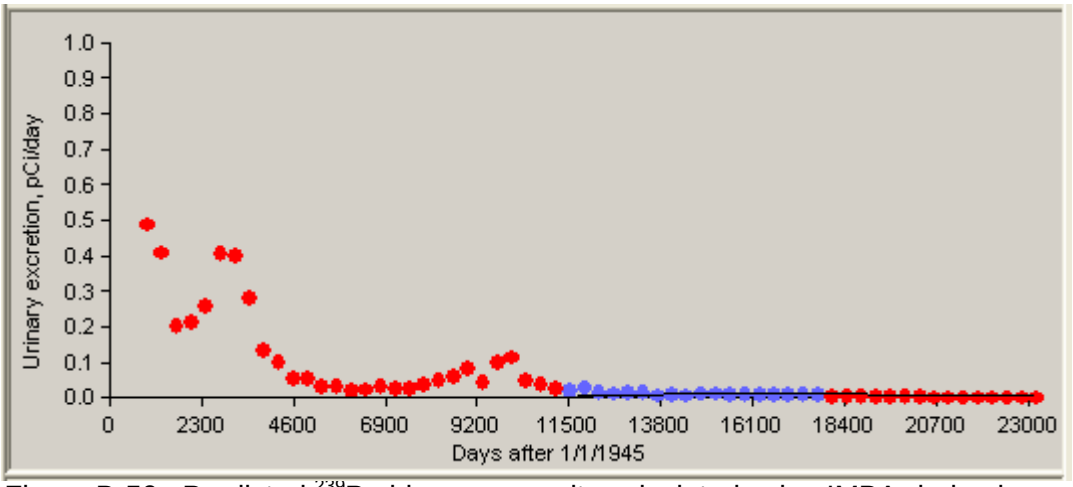

Figure B-50. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 84th percentile, type M.

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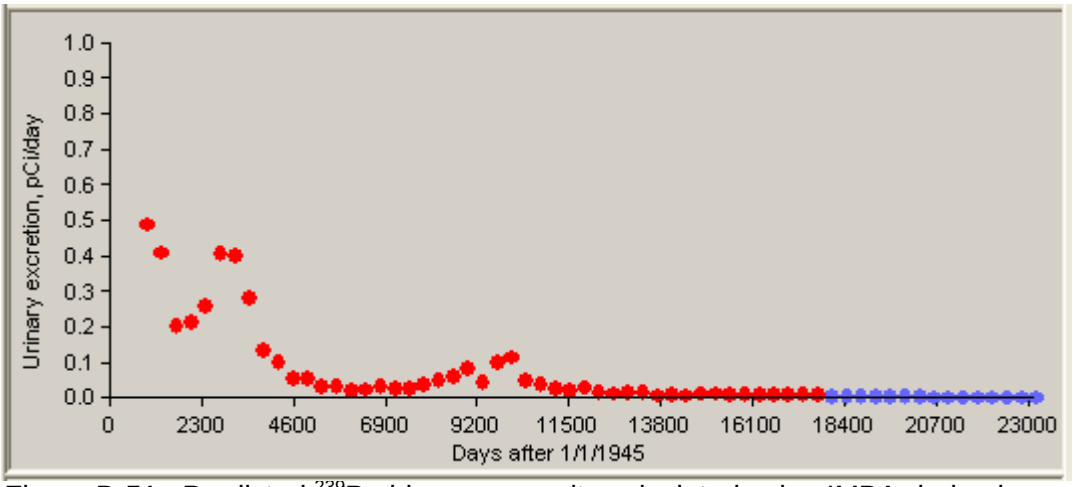

Figure B-51. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type M.

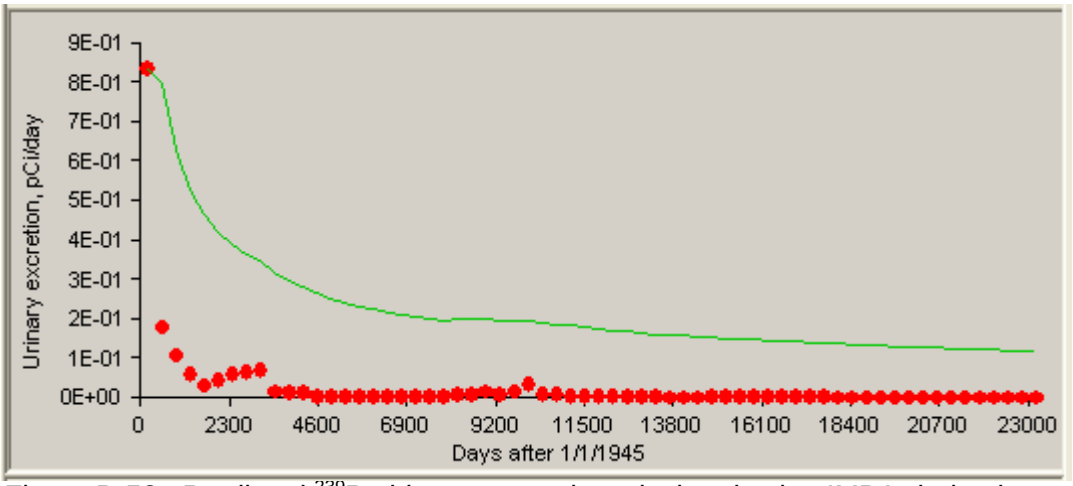

Figure B-52. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

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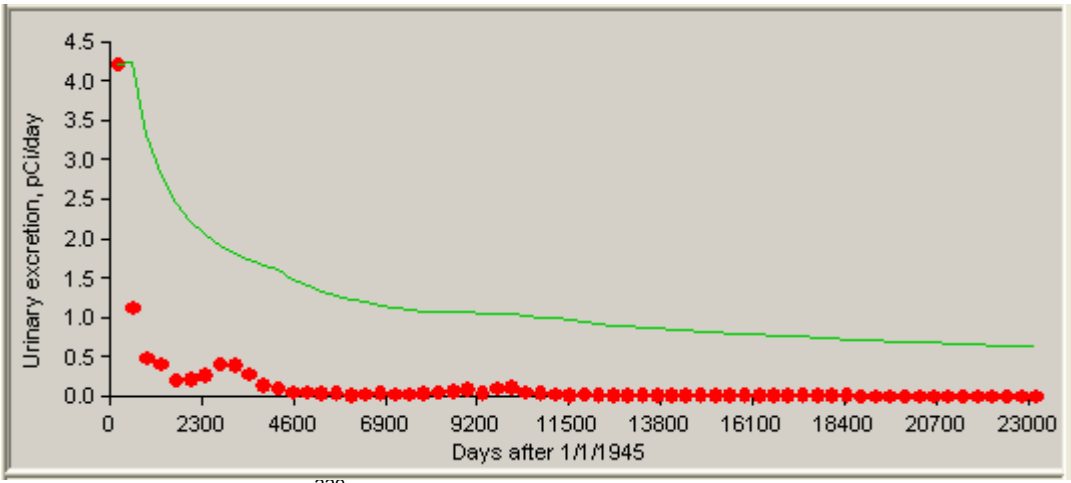

Figure B-53. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-3. Summary of ^{239}Pu type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1944	12/31/1945	247.9	1253	5.05
1/1/1946	12/31/1946	94.53	590	6.24
1/1/1947	12/31/1953	10.46	53.96	5.16
1/1/1954	12/31/1954	3.146	53.96	17.15
1/1/1955	12/31/1956	3.146	39.05	12.41
1/1/1957	12/31/1966	0.379	4.62	12.19
1/1/1967	12/31/1972	3.267	15.71	4.81
1/1/1973	12/31/1975	1.535	9.54	6.21
1/1/1976	12/31/1993	0.164	1.12	6.83
1/1/1994	12/31/2008	0.013	0.15	12.20

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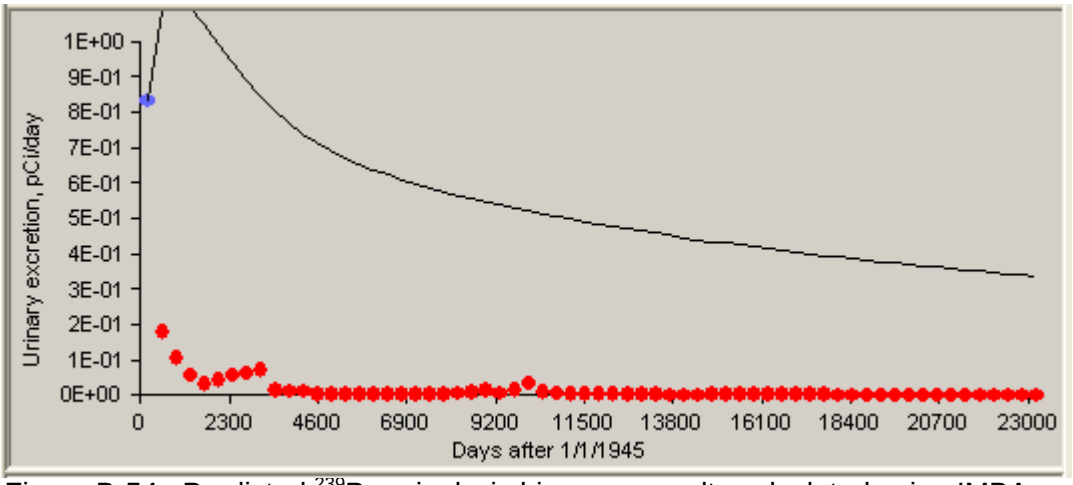

Figure B-54. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 50th percentile, type S.

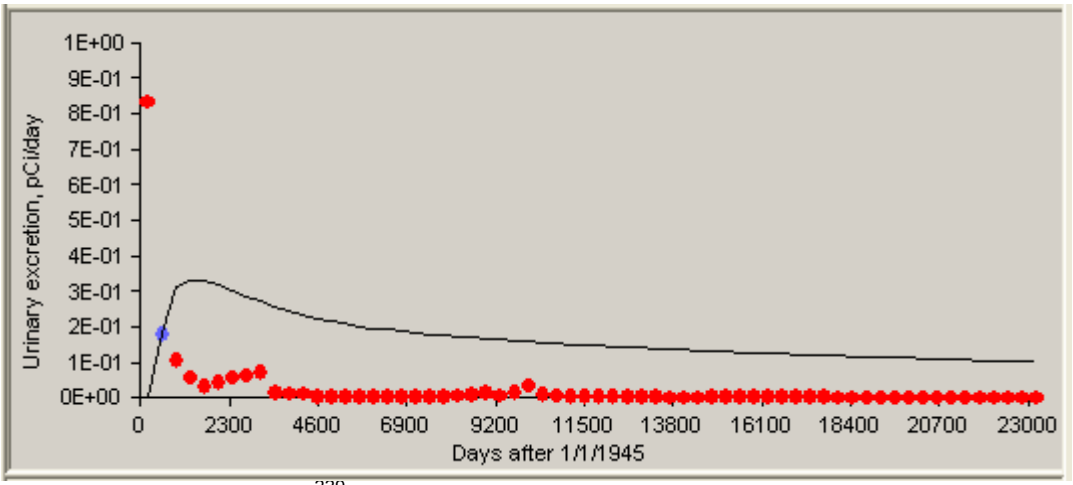

Figure B-55. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 50th percentile, type S.

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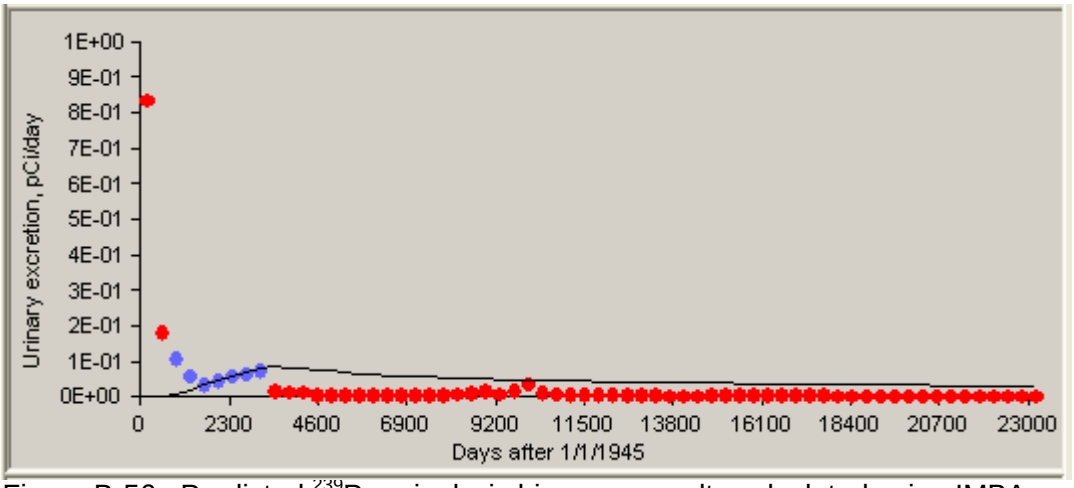

Figure B-56. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1953, 50th percentile, type S.

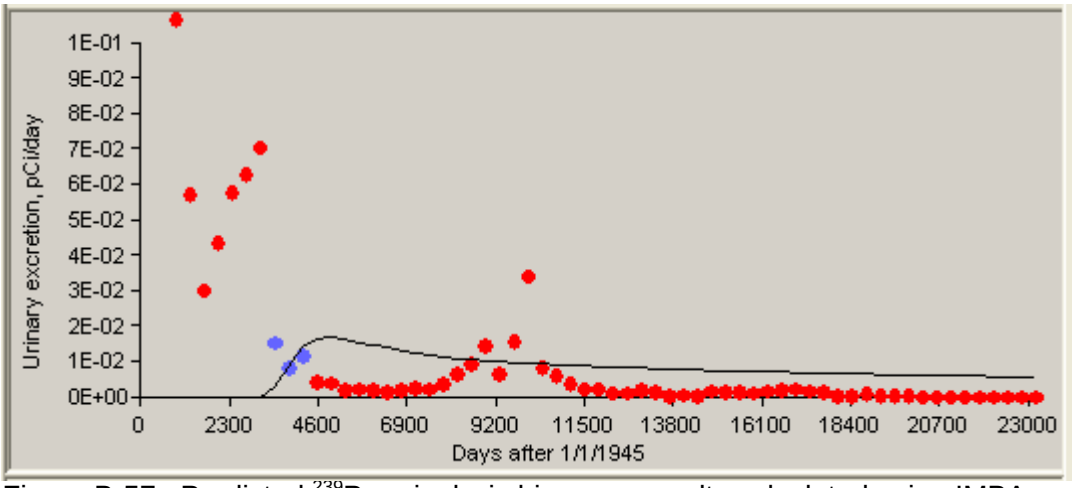

Figure B-57. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1954 to 1956, 50th percentile, type S.

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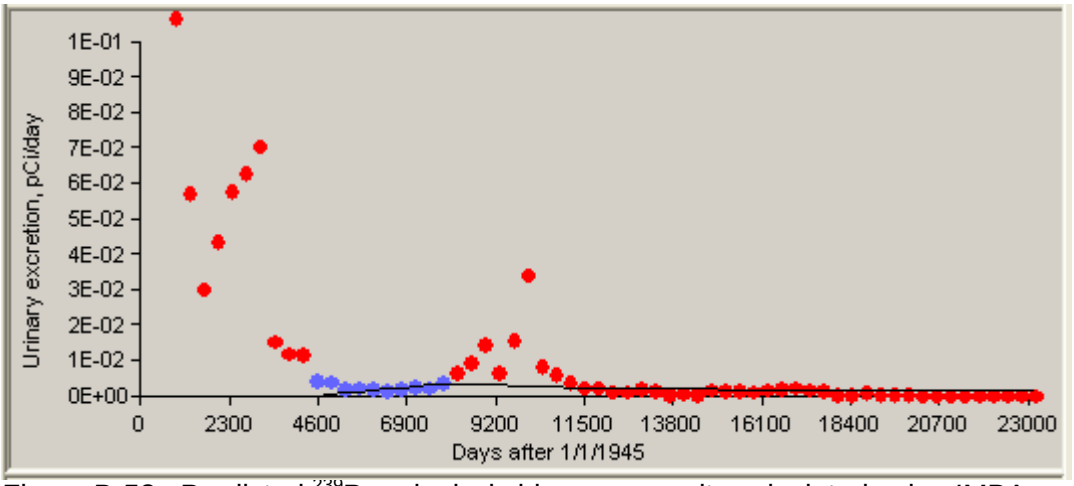

Figure B-58. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 50th percentile, type S.

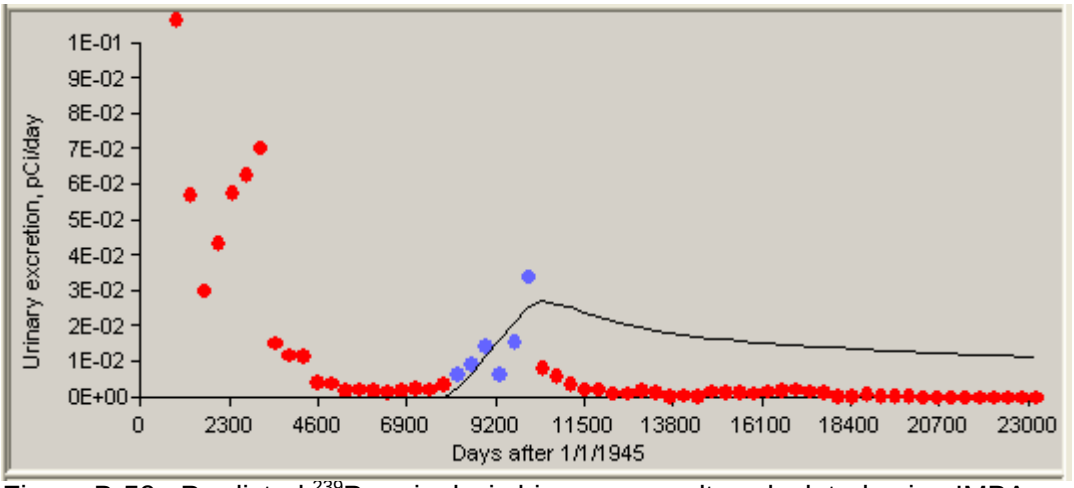

Figure B-59. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 50th percentile, type S.

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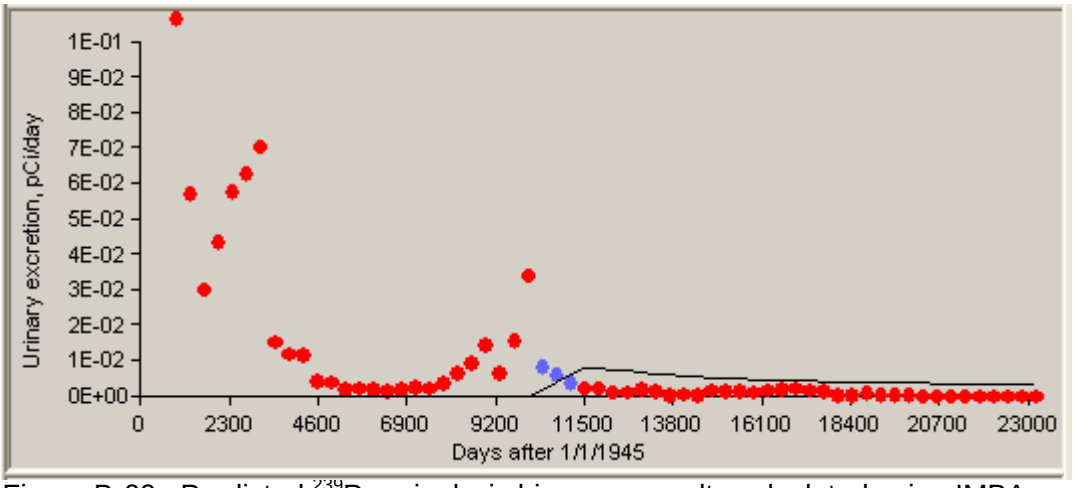

Figure B-60. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 50th percentile, type S.

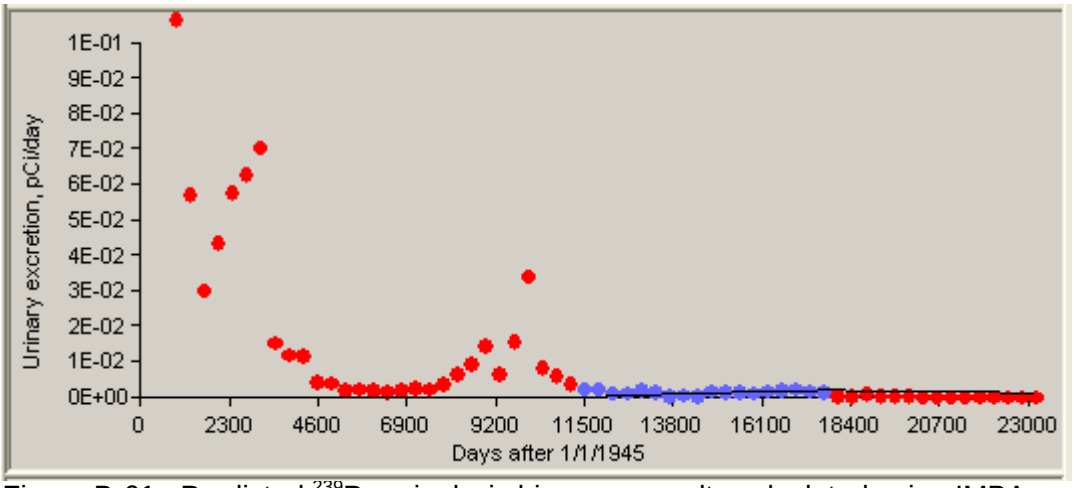

Figure B-61. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 50th percentile, type S.

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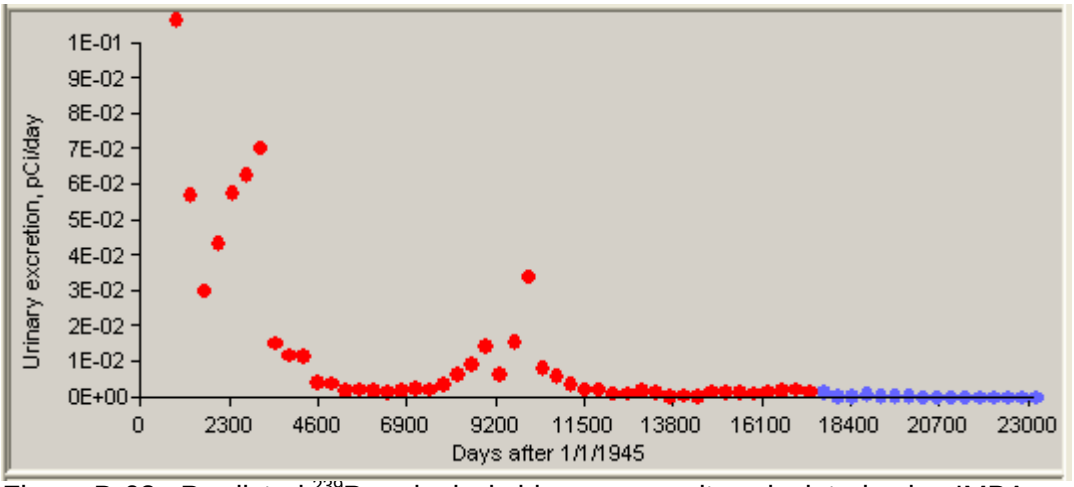

Figure B-62. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type S.

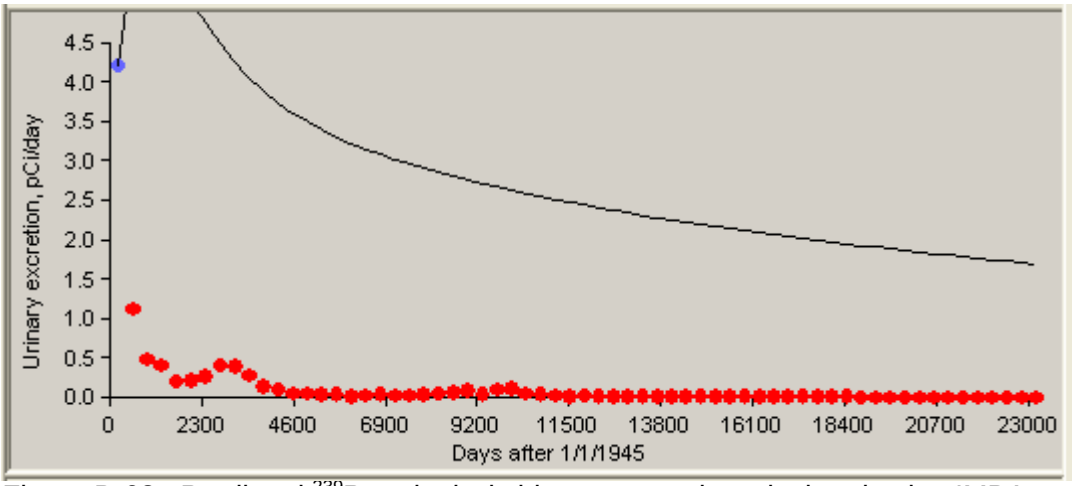

Figure B-63. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 84th percentile, type S.

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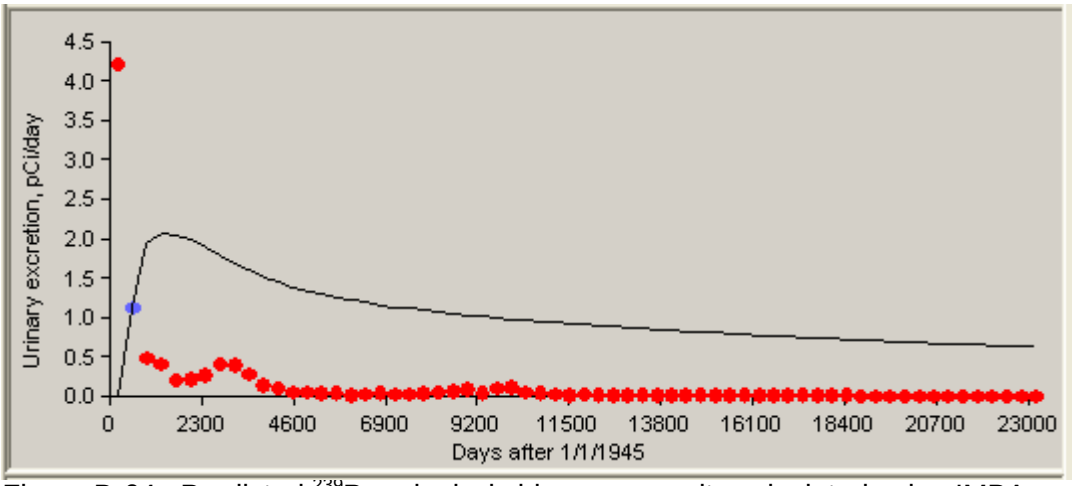

Figure B-64. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 84th percentile, type S.

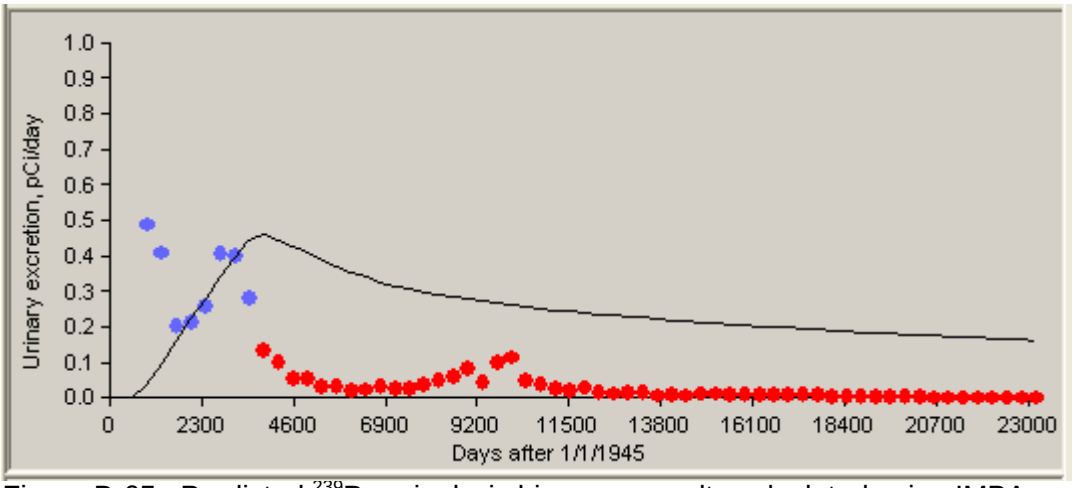

Figure B-65. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1954, 84th percentile, type S.

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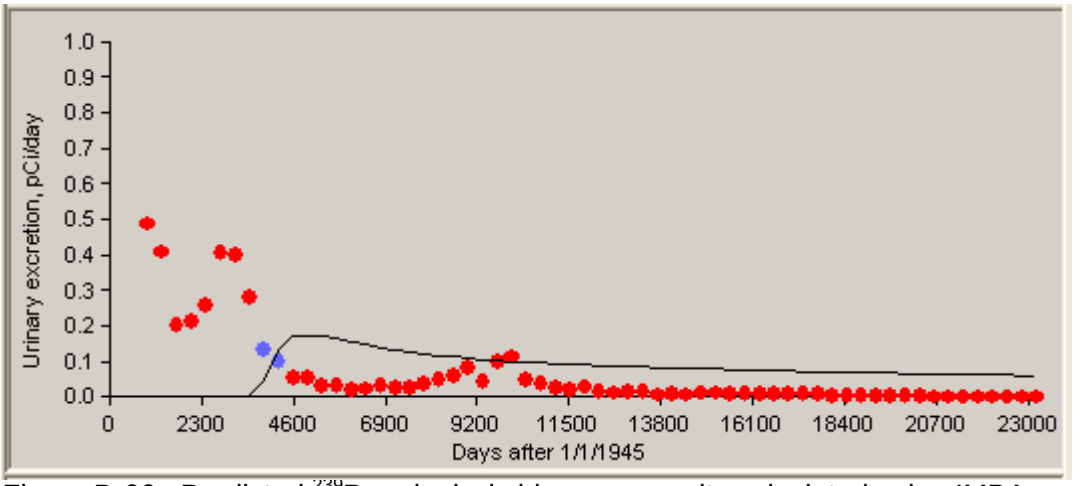

Figure B-66. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1955 to 1956, 84th percentile, type S.

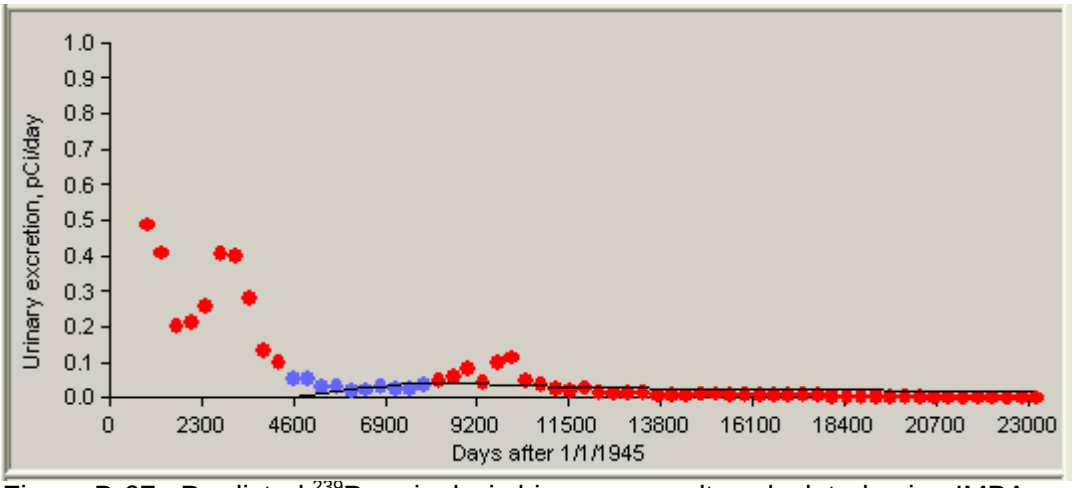

Figure B-67. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 84th percentile, type S.

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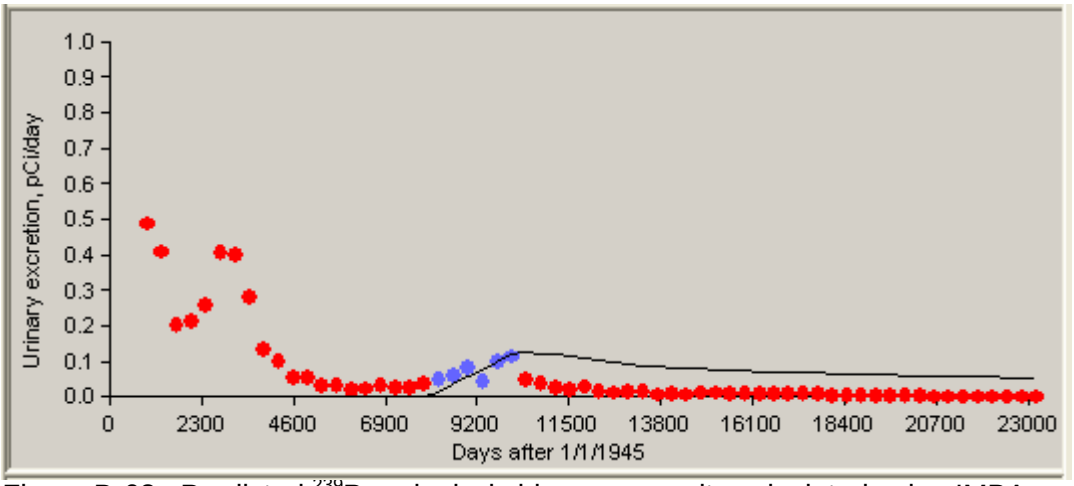

Figure B-68. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 84th percentile, type S.

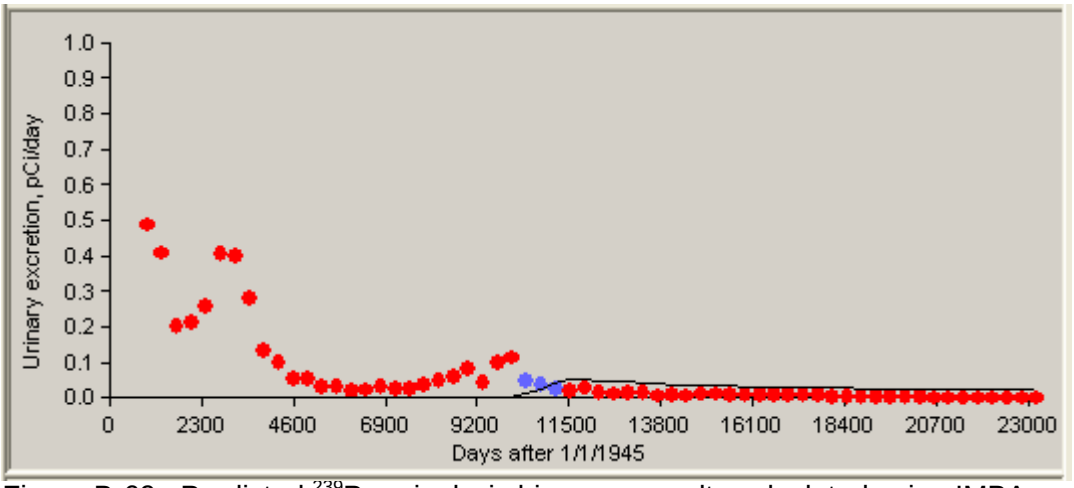

Figure B-69. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 84th percentile, type S.

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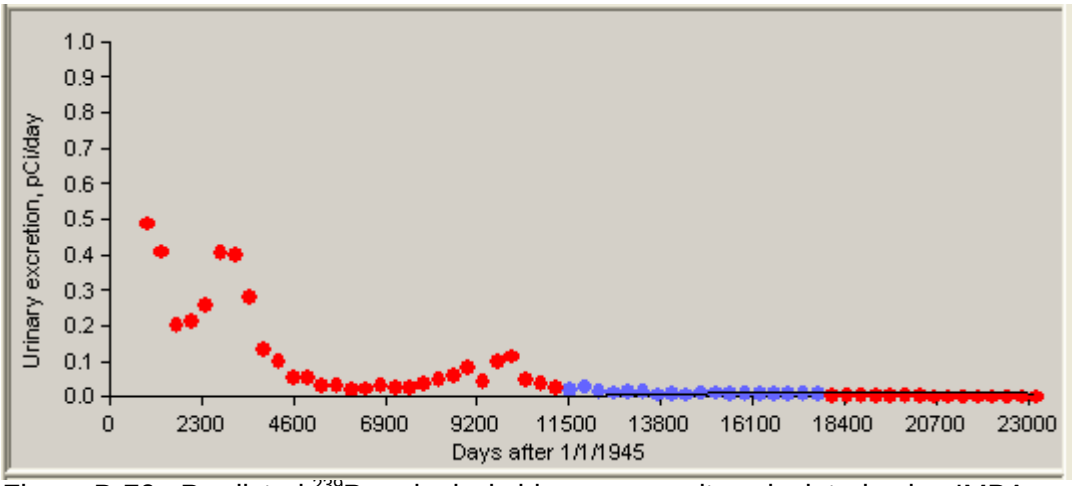

Figure B-70. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 84th percentile, type S.

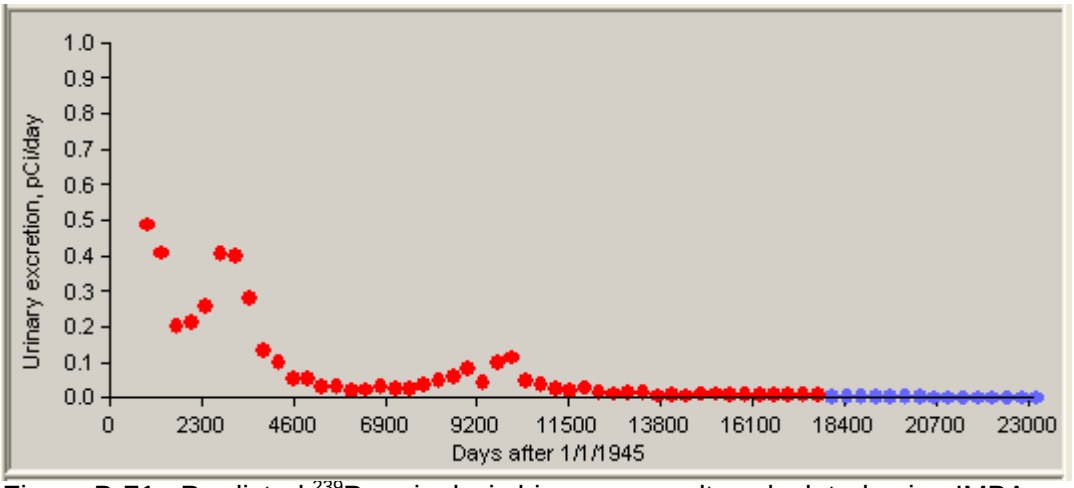

Figure B-71. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type S.

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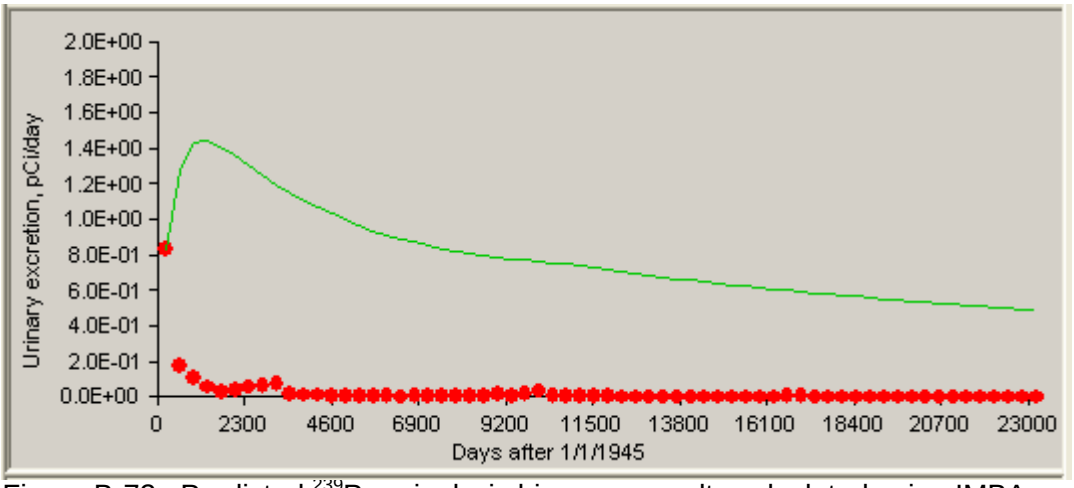

Figure B-72. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type S.

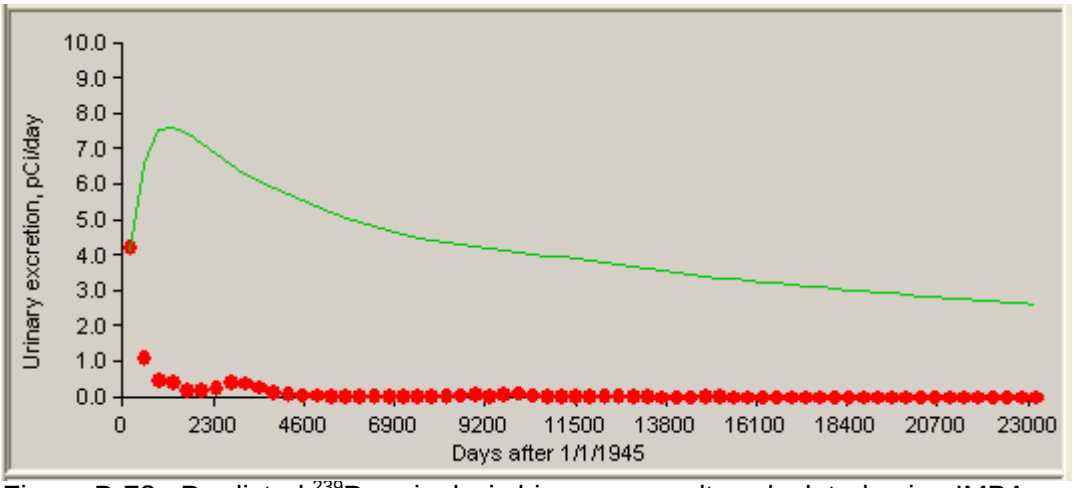

Figure B-73. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type S.

Table B-4. Summary of ^{239}Pu type S urinalysis-based intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1944	12/31/1945	8651	43270	5.05
1/1/1946	12/31/1946	5125	31990	6.24
1/1/1947	12/31/1953	200.2	975	4.87
1/1/1954	12/31/1954	87.71	975	11.12
1/1/1955	12/31/1956	87.71	1342	15.30
1/1/1957	12/31/1966	6.27	74.67	11.91
1/1/1967	12/31/1972	73.47	339.2	4.62
1/1/1973	12/31/1975	40.56	257	6.34

1/1/1976	12/31/1993	2.303	14.51	6.30
1/1/1994	12/31/2008	0.1402	1.798	12.82

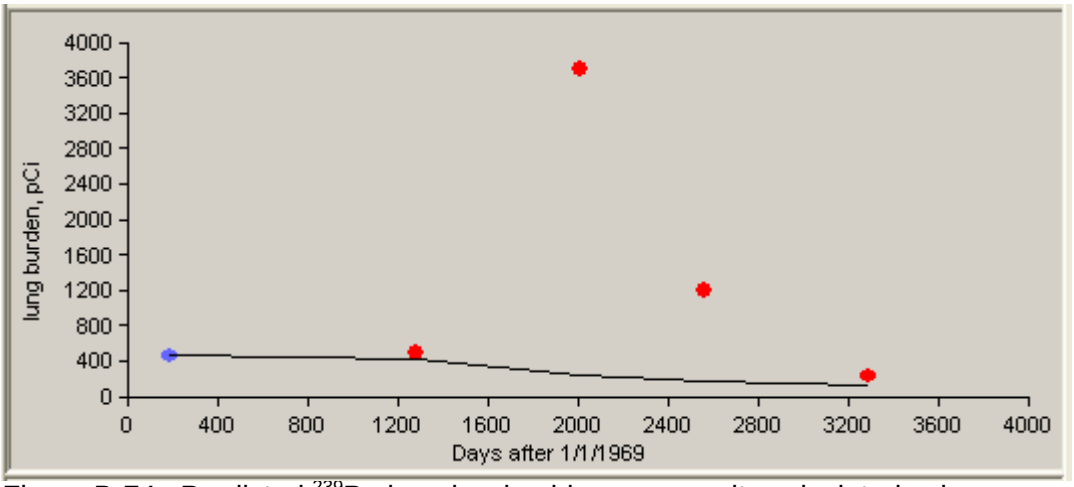

Figure B-74. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1969 to 1971, 50th percentile, type S.

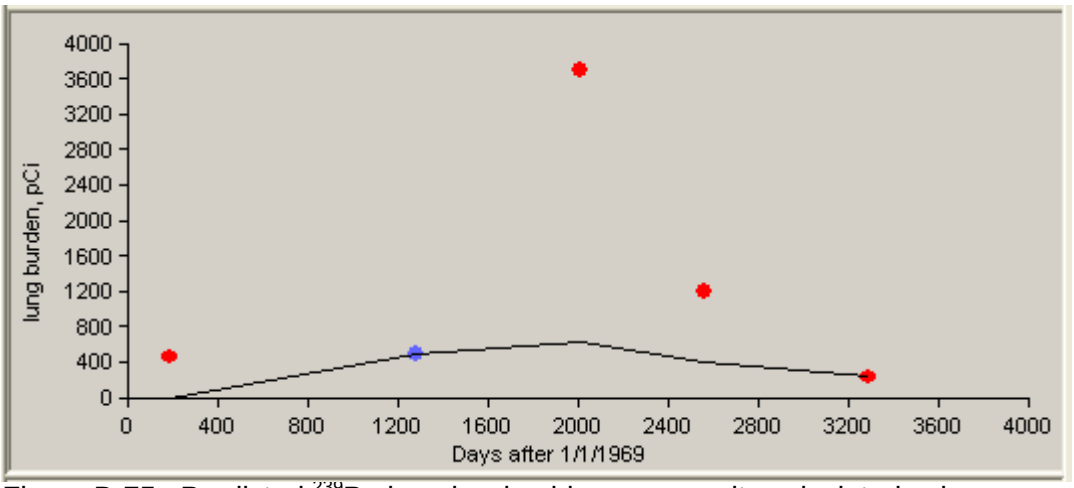

Figure B-75. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1972 to 1974, 50th percentile, type S.

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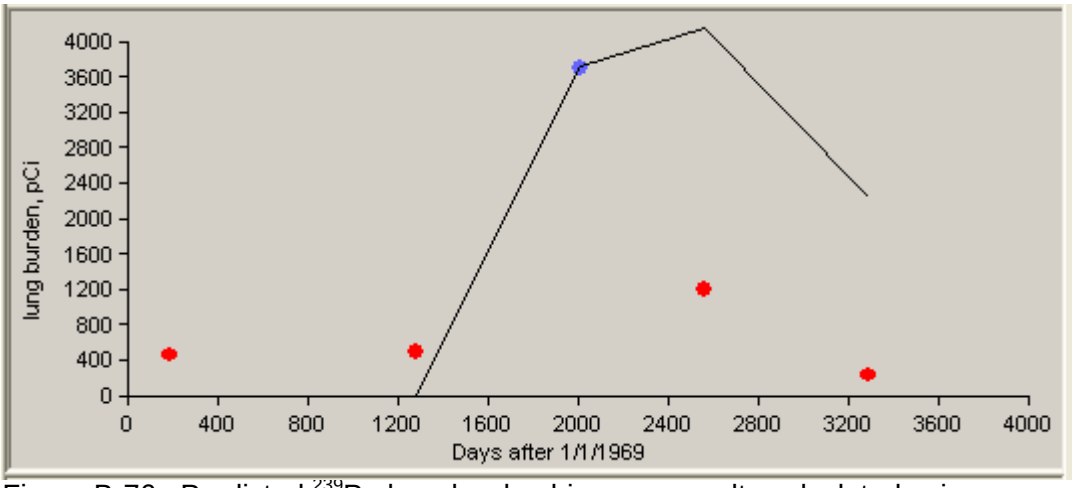

Figure B-76. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1975, 50th percentile, type S.

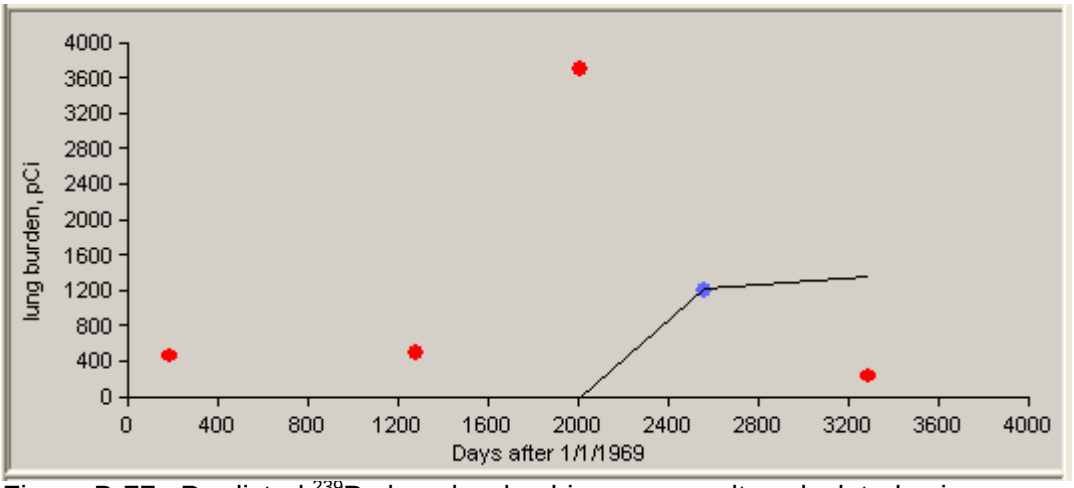

Figure B-77. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1977, 50th percentile, type S.

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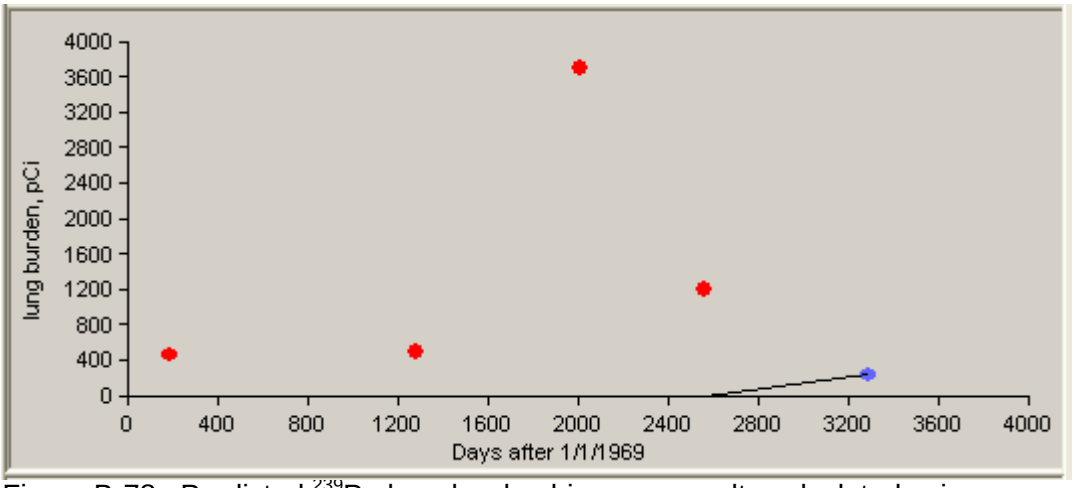

Figure B-78. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1979, 50th percentile, type S.

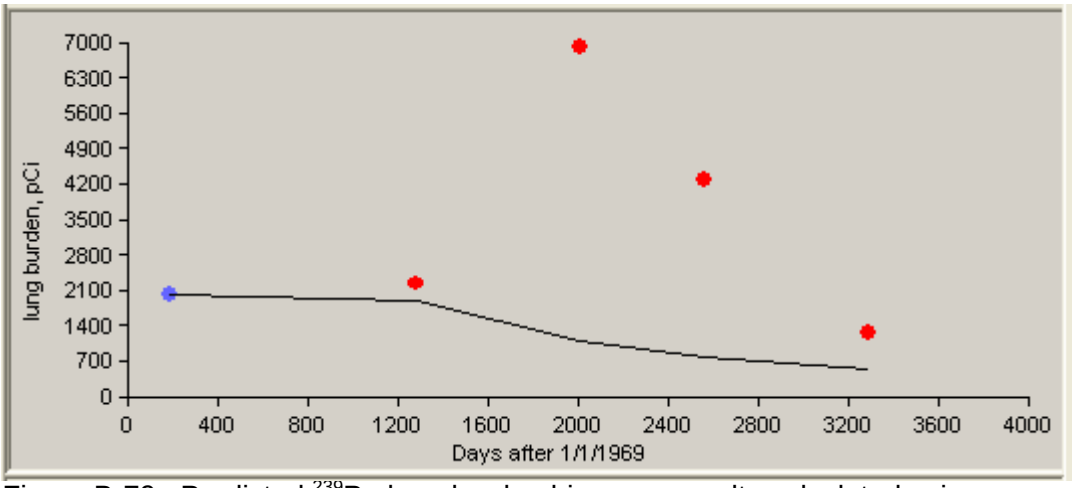

Figure B-79. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1969 to 1971, 84th percentile, type S.

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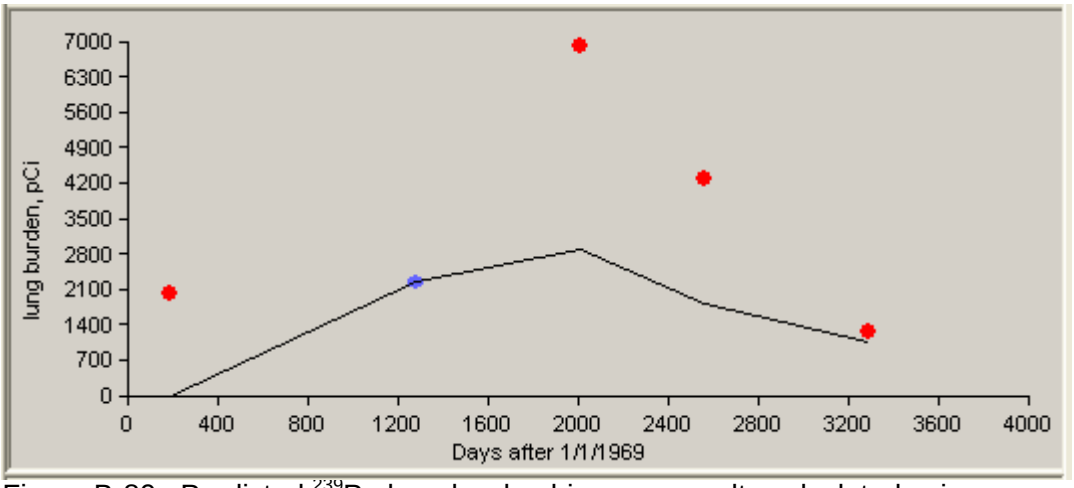

Figure B-80. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1972 to 1974, 84th percentile, type S.

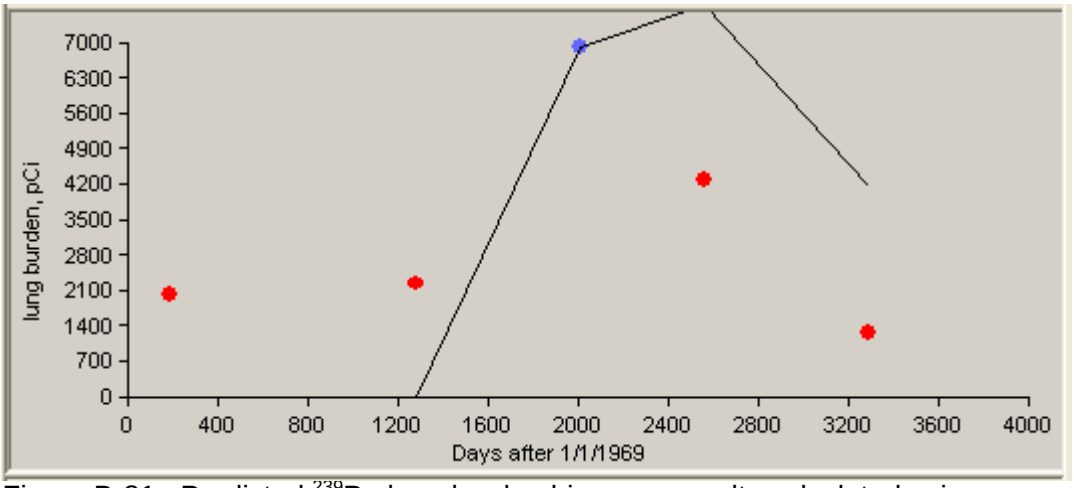

Figure B-81. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1975, 84th percentile, type S.

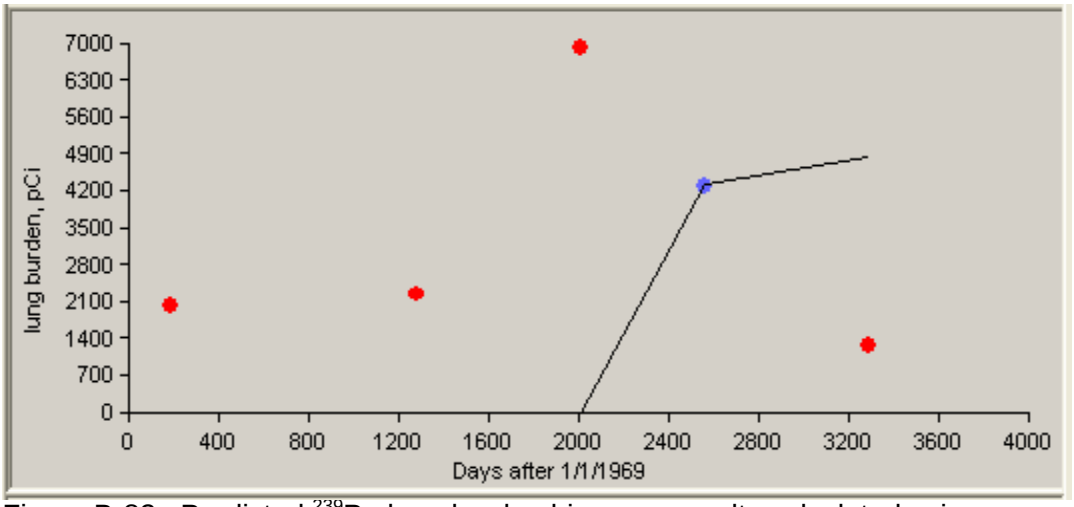

Figure B-82. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1977, 84th percentile, type S.

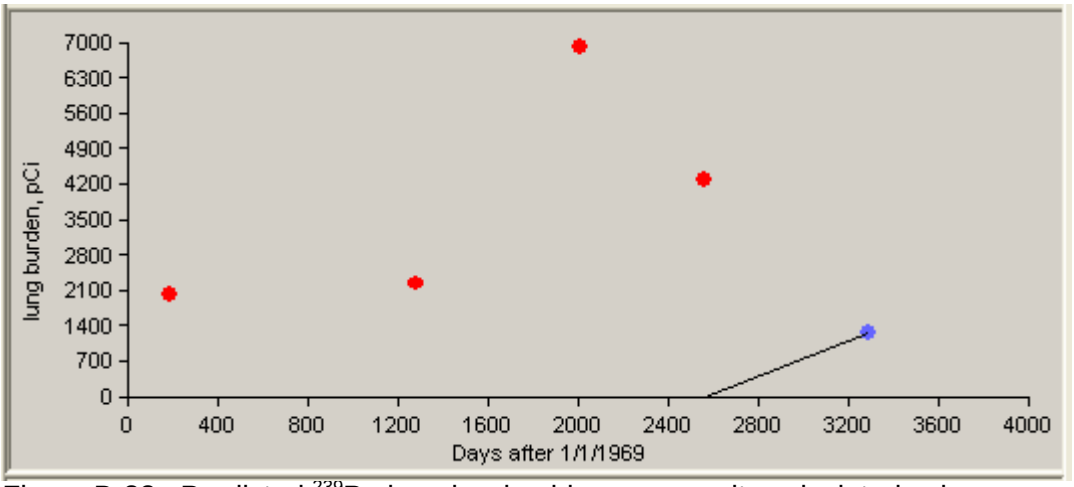

Figure B-83. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1979, 84th percentile, type S.

Table B-5. Summary of ^{239}Pu type S lung burden-based intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1969	12/31/1971	27.66	118.9	4.30
1/1/1972	12/31/1974	29.43	132.5	4.50
1/1/1975	12/31/1975	505.4	942.5	1.86
1/1/1976	12/31/1977	96.07	339.8	3.54
1/1/1978	12/31/1979	19.55	101.7	5.20

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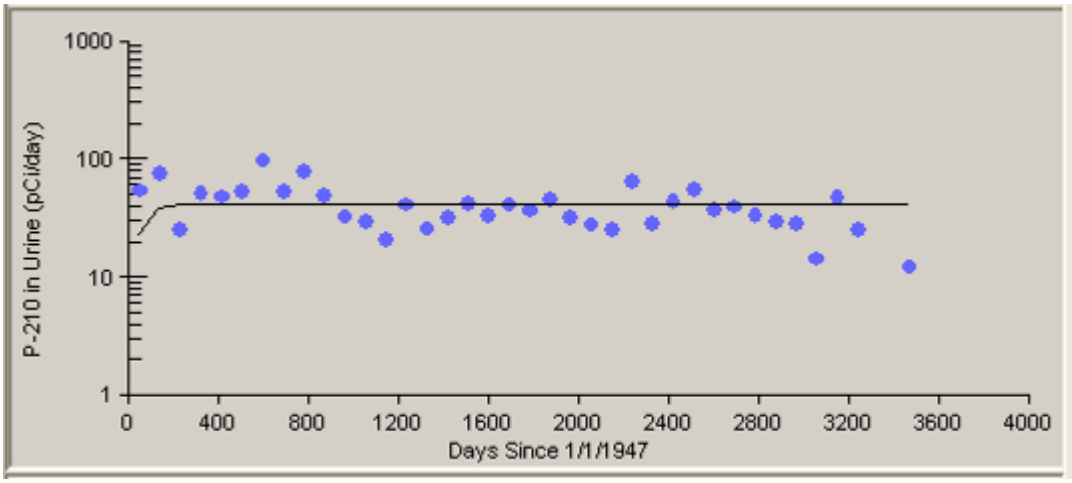

Figure B-84. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type F.

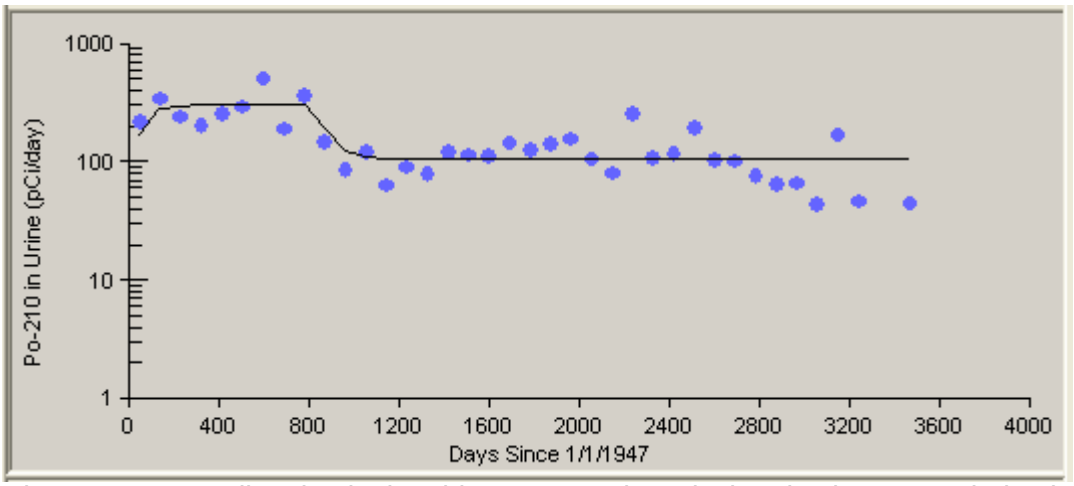

Figure B-85. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots), from all intakes, 84th percentile, type F.

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Table B-6. Summary of polonium type F intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1947	03/31/1949	592.8	4126	6.96
4/1/1949	12/31/1956	592.8	1587	2.68

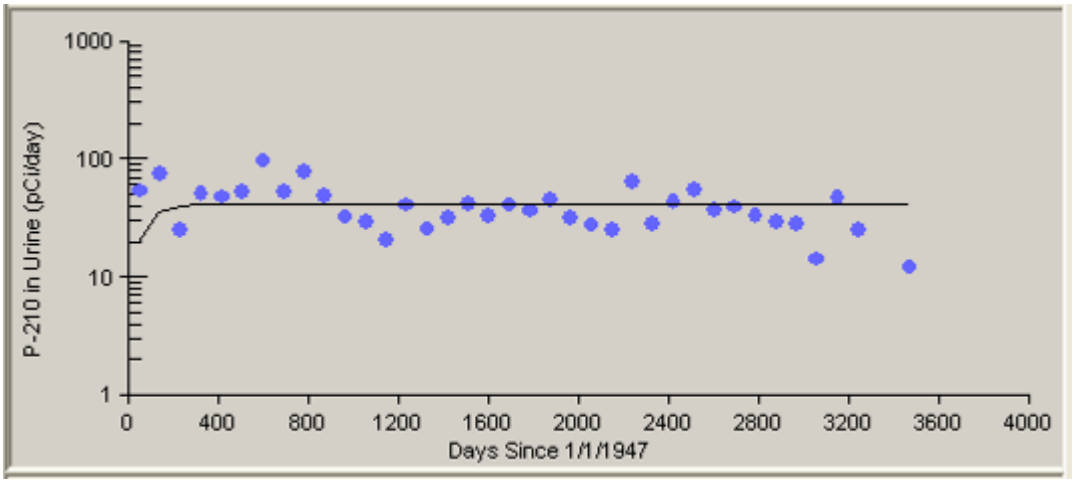

Figure B-86. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

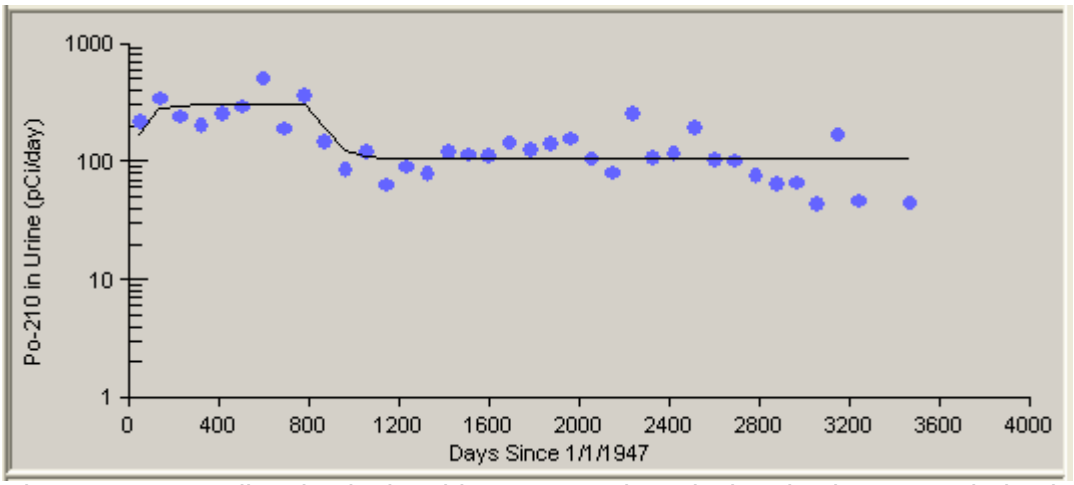

Figure B-87. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-7. Summary of polonium type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1947	3/31/1949	2013	14120	7.01
4/1/1949	12/31/1956	2013	5346	2.65

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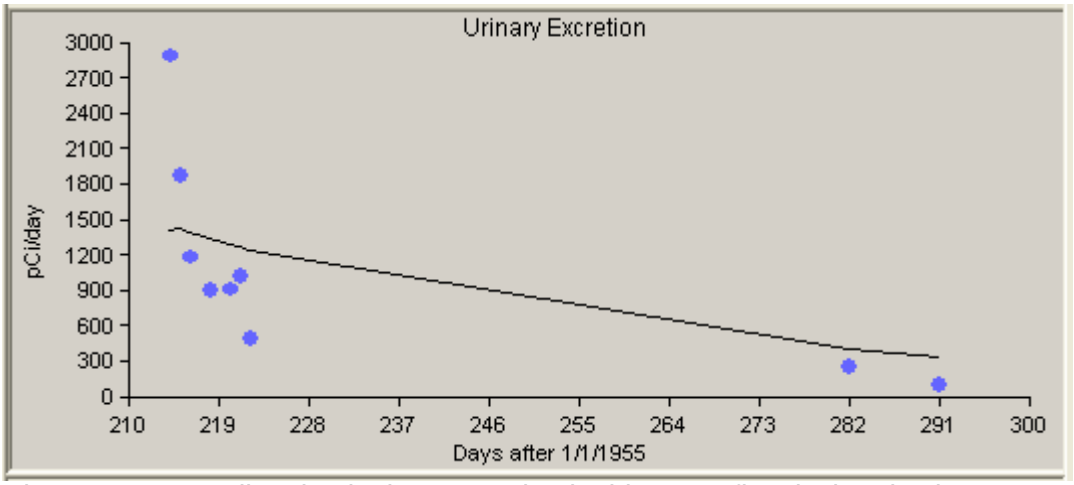

Figure B-88. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "A," type F.

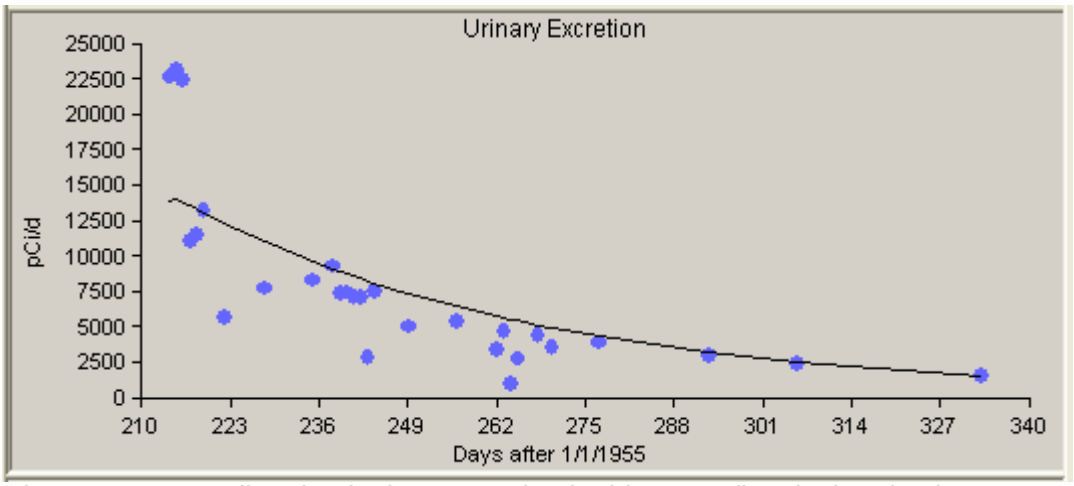

Figure B-89. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "B," type F.

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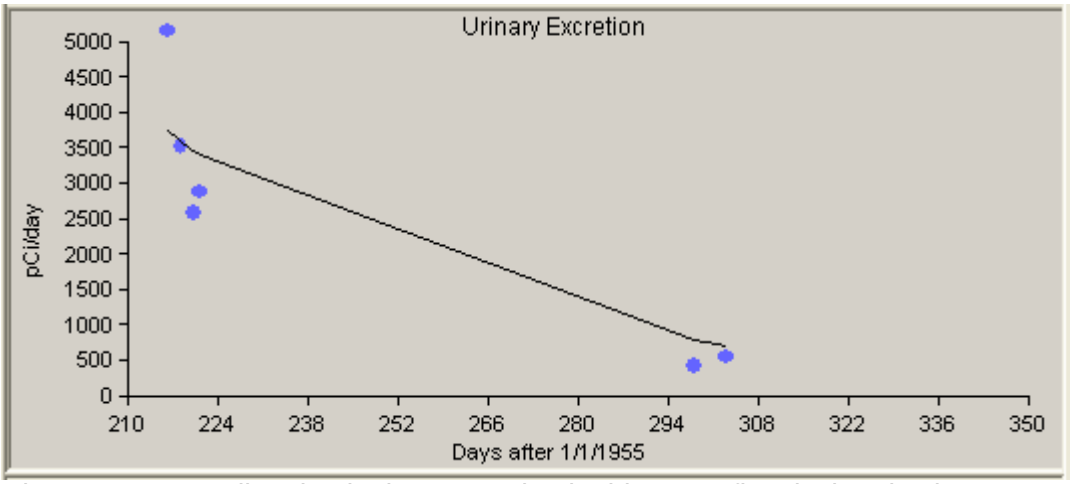

Figure B-90. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "C," type F.

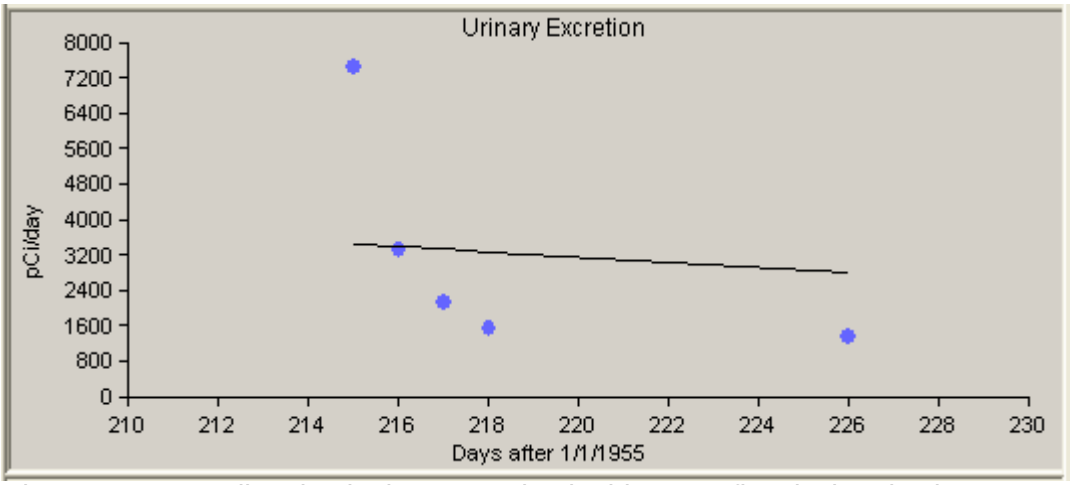

Figure B-91. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "D," type F.

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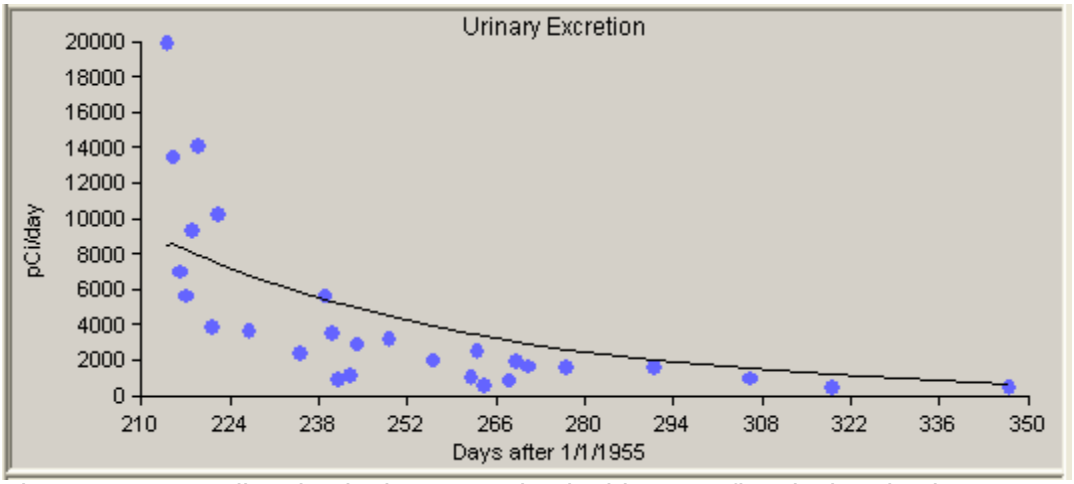

Figure B-92. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "E," type F.

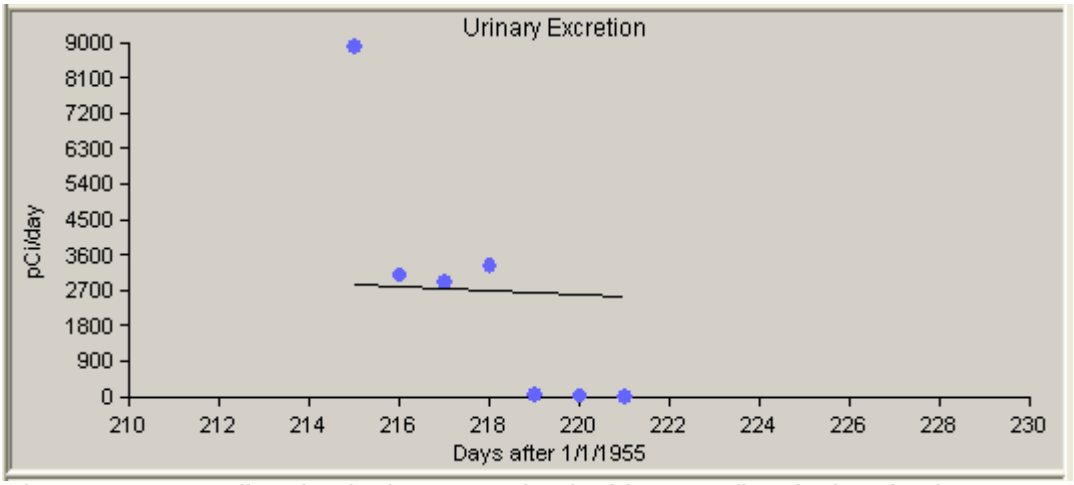

Figure B-93. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "F," type F.

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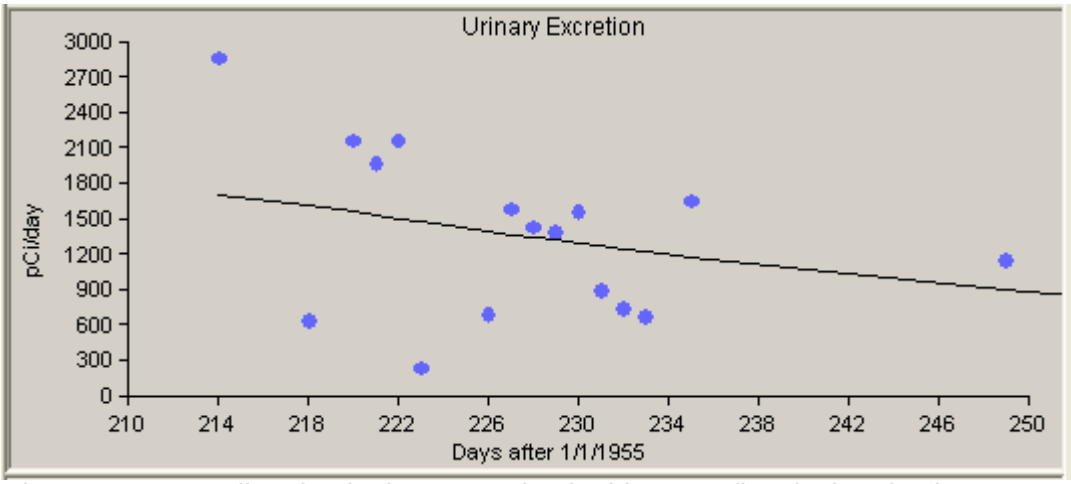

Figure B-94. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "G," type F.

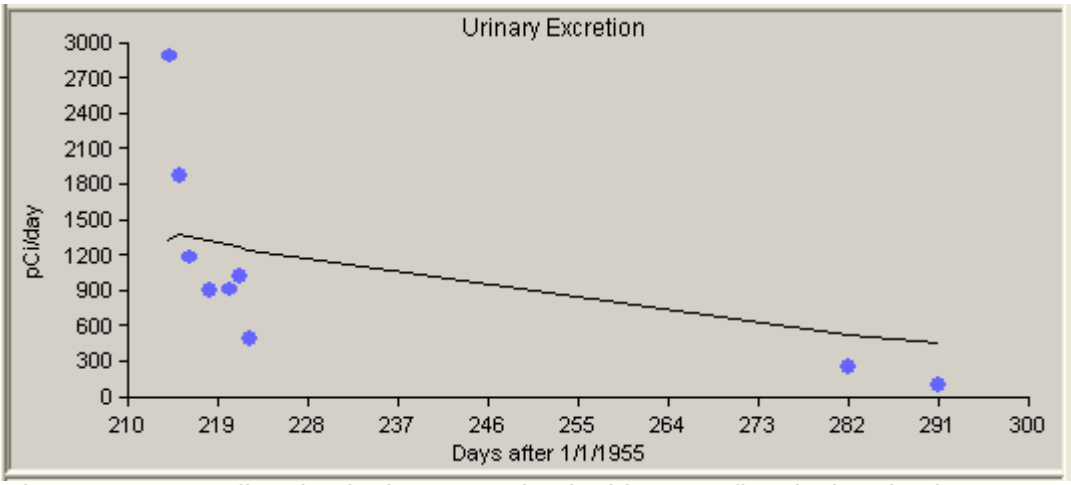

Figure B-95. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "A," type M.

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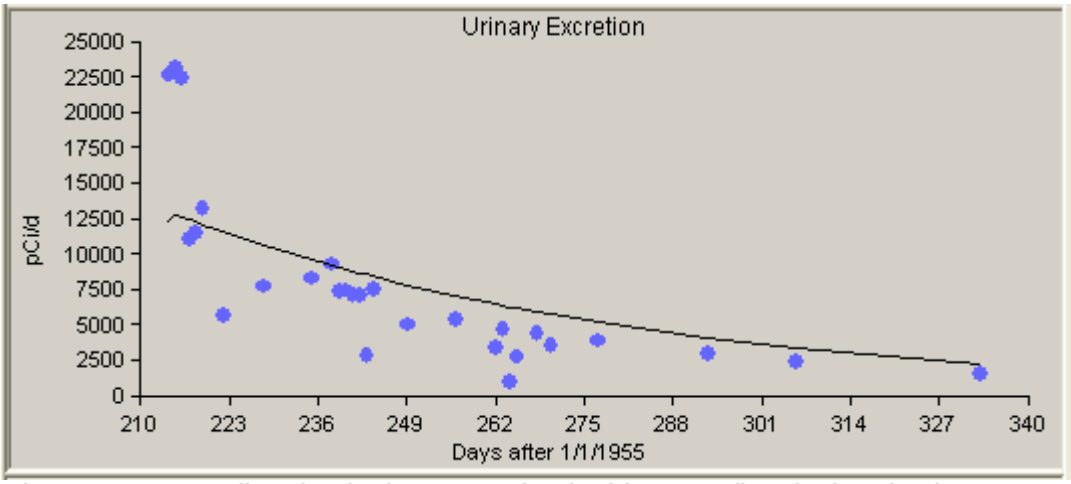

Figure B-96. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "B," type M.

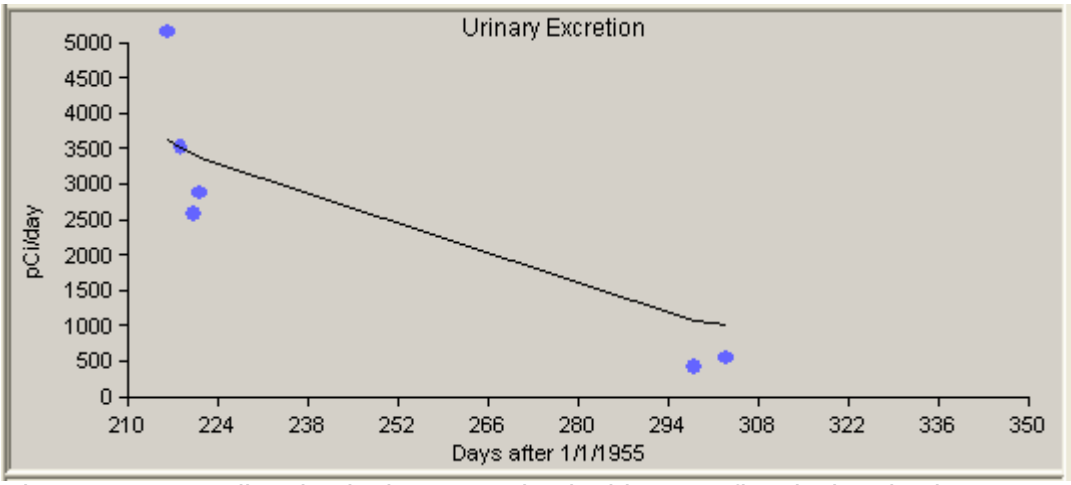

Figure B-97. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "C," type M.

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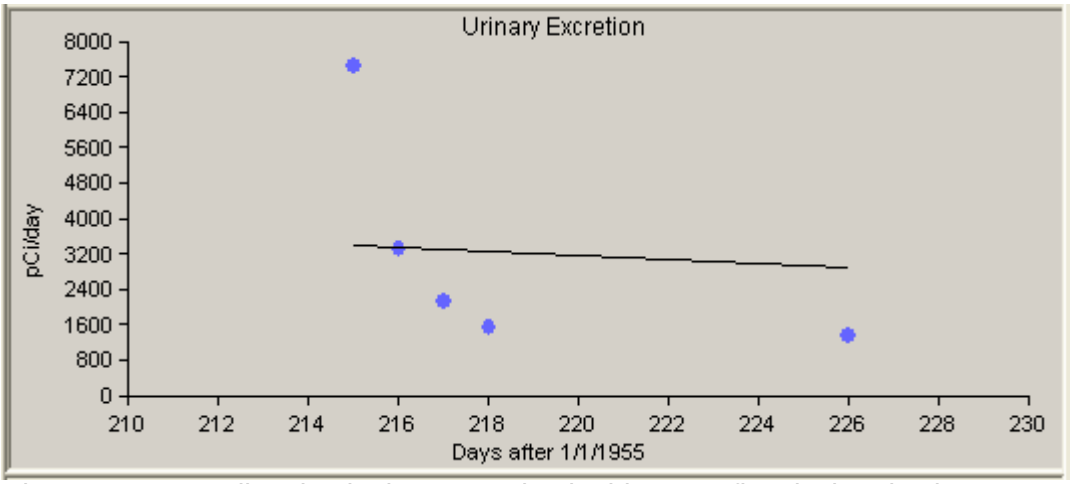

Figure B-98. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "D," type M.

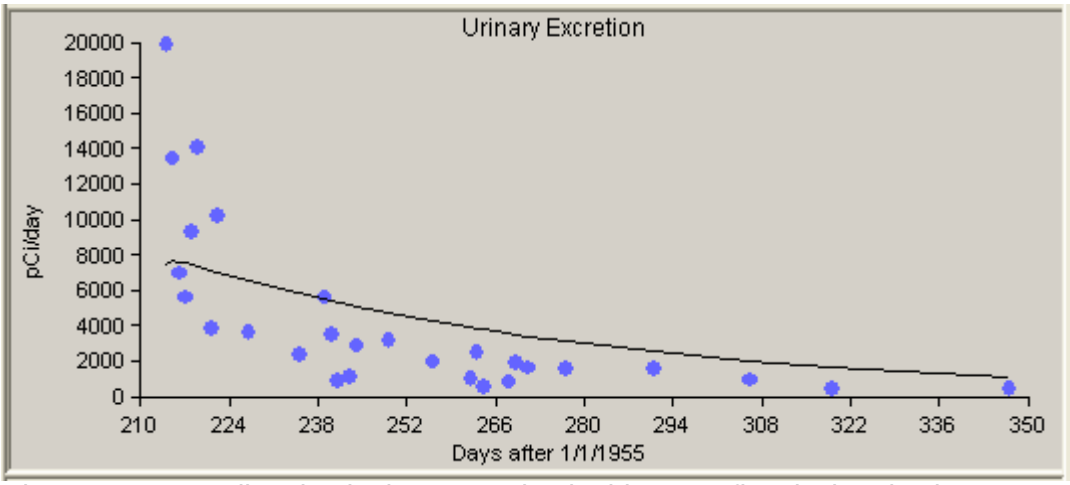

Figure B-99. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "E," type M.

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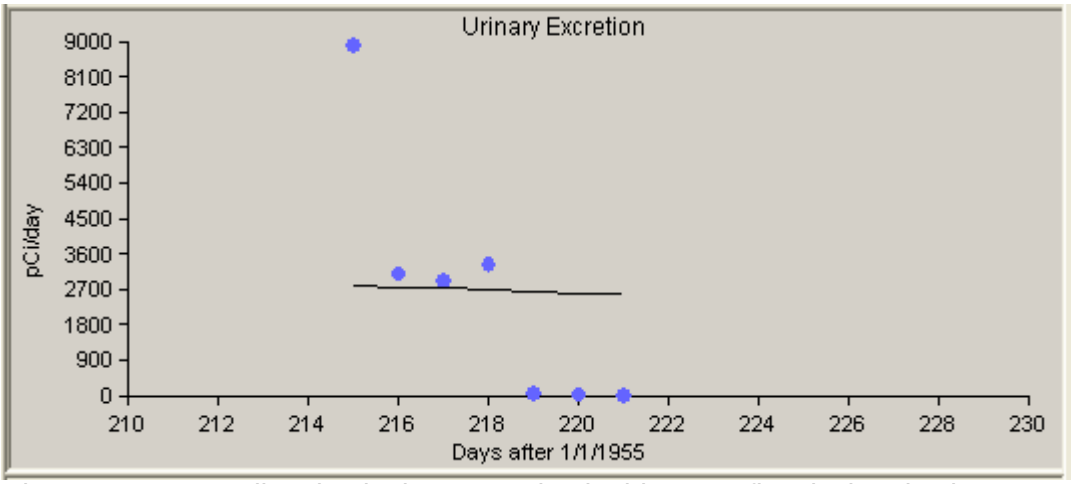

Figure B-100. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "F," type M.

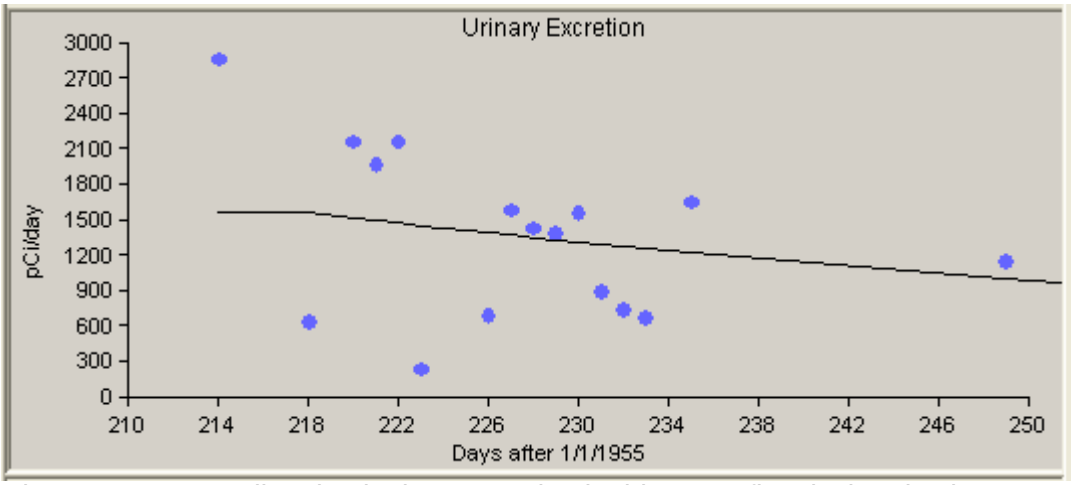

Figure B-101. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "G," type M.

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Table B-8. Summary of polonium acute intakes (pCi) type F and M.

Individual	Type F	Type M
A	1.07E+06	4.55E+06
B	1.06E+07	4.22E+07
C	2.85E+06	1.21E+07
D	2.61E+06	1.12E+07
E	6.44E+06	2.56E+07
F	2.16E+06	9.30E+06
G	1.29E+06	5.36E+06
Geometric mean	2.84E+06	1.19E+07

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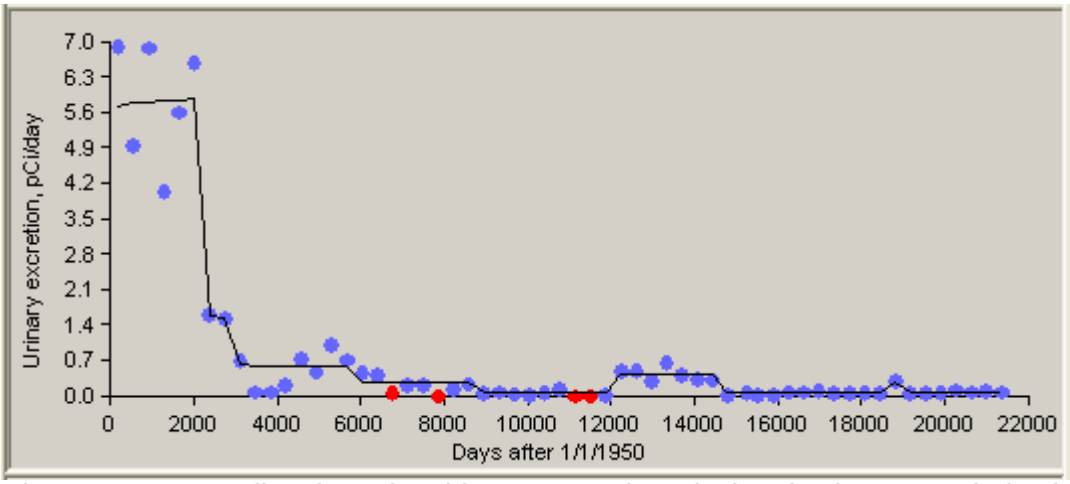

Figure B-102. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type F.

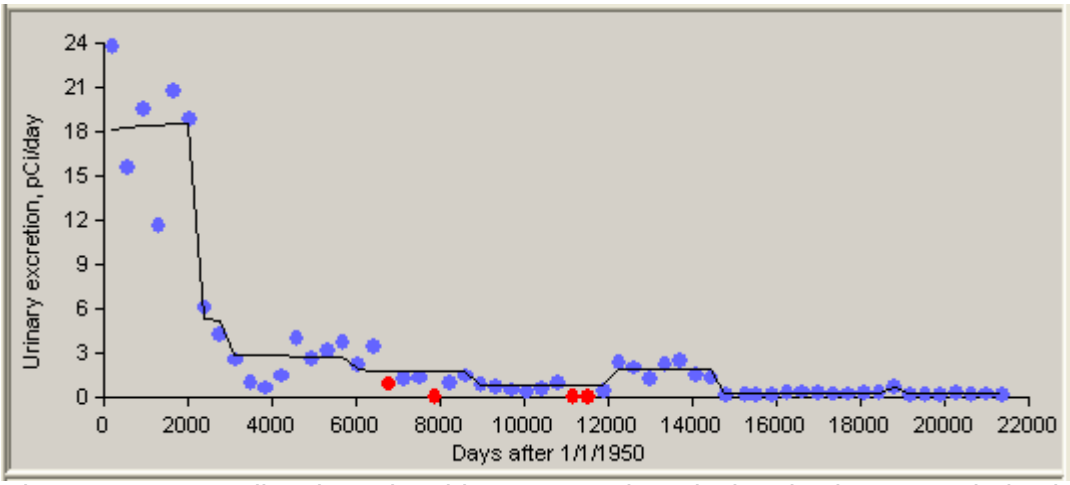

Figure B-103. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type F.

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Table B-9. Summary of uranium type F intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1950	12/31/1955	21.28	67.25	3.16
1/1/1956	12/31/1957	5.358	17.99	3.36
1/1/1958	12/31/1965	1.981	9.535	4.81
1/1/1966	12/31/1973	0.9086	6.218	6.84
1/1/1974	12/31/1982	0.2270	2.567	11.31
1/1/1983	12/31/1989	1.526	6.768	4.44
1/1/1990	12/31/2008	0.201	0.8091	4.03
1/1/2001	12/31/2001	0.818	1.794	2.19

Note: the 2001 intake is additive to the 1990-2008 intake.

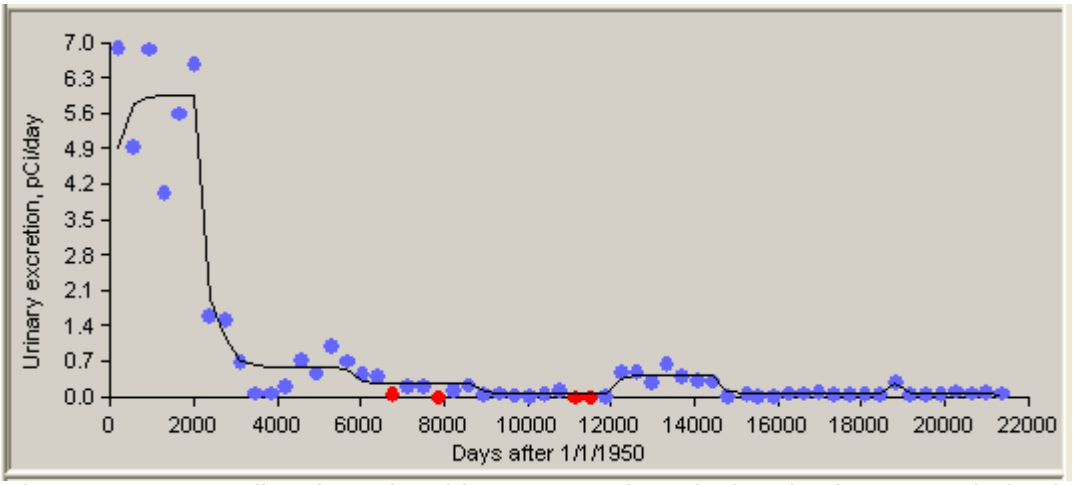

Figure B-104. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

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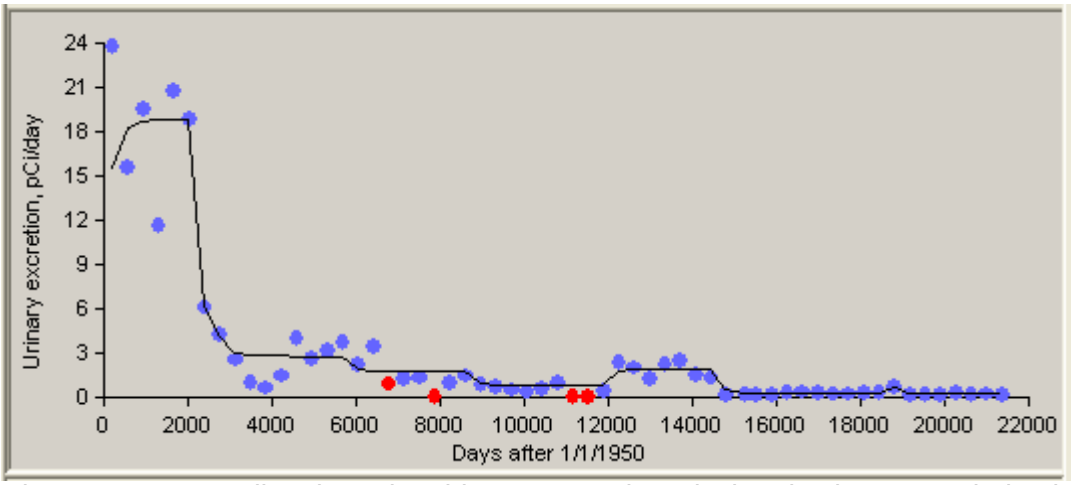

Figure B-105. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-10. Summary of uranium type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1950	12/31/1955	88.72	279.9	3.15
1/1/1956	12/31/1957	15.96	53.6	3.36
1/1/1958	12/31/1965	7.946	38.94	4.90
1/1/1966	12/31/1973	3.528	24.8	7.03
1/1/1974	12/31/1982	1.029	10.91	10.60
1/1/1983	12/31/1989	6.285	27.74	4.41
1/1/1990	12/31/2008	0.7555	3.065	4.06
1/1/2001	12/31/2001	3.944	8.644	2.19

Note: the 2001 intake is additive to the 1990-2008 intake.

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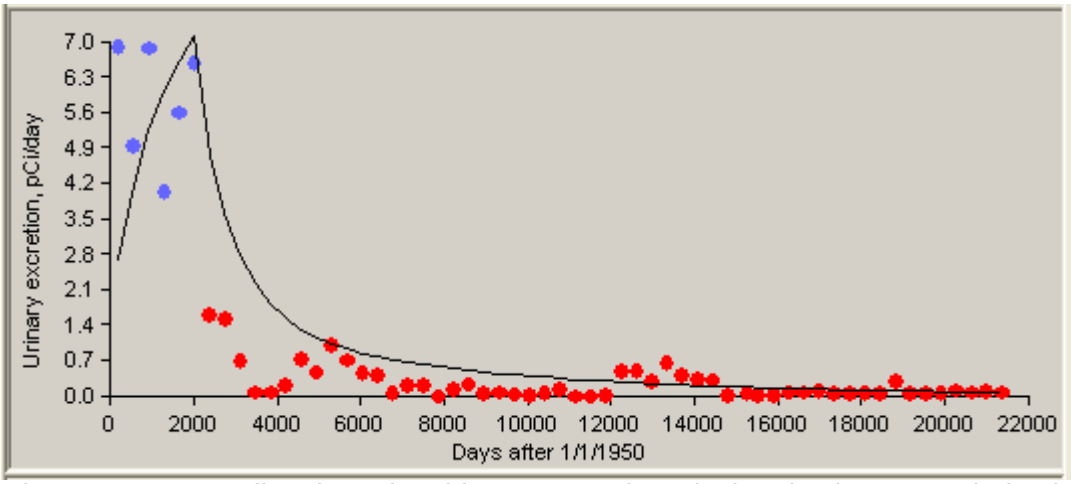

Figure B-106. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1950 to 1955, 50th percentile, type S.

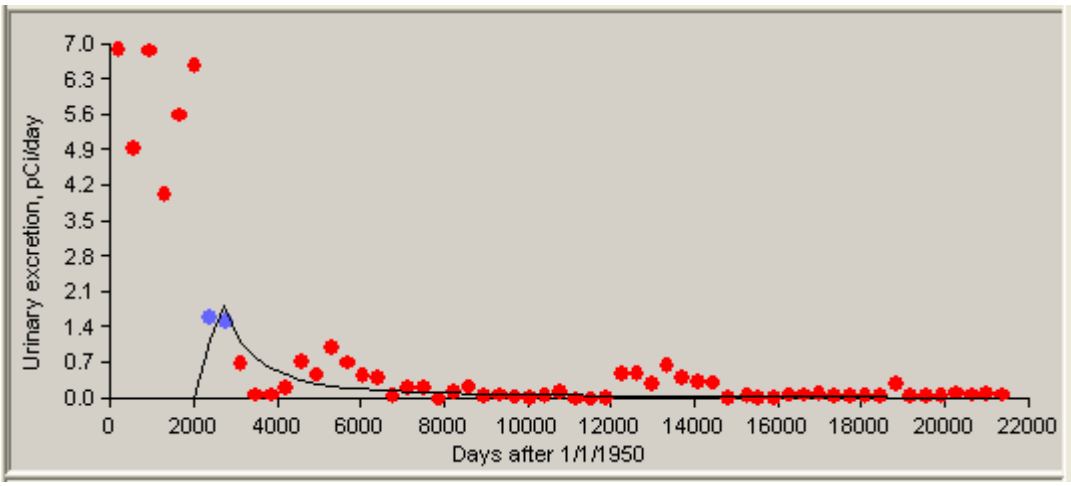

Figure B-107. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1956 to 1957, 50th-percentile, type S.

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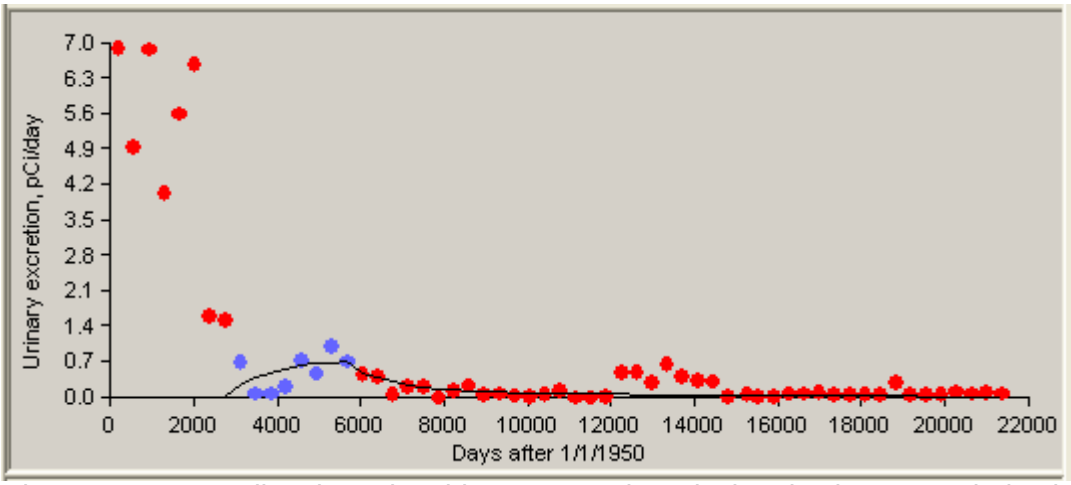

Figure B-108. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1958 to 1965, 50th percentile, type S.

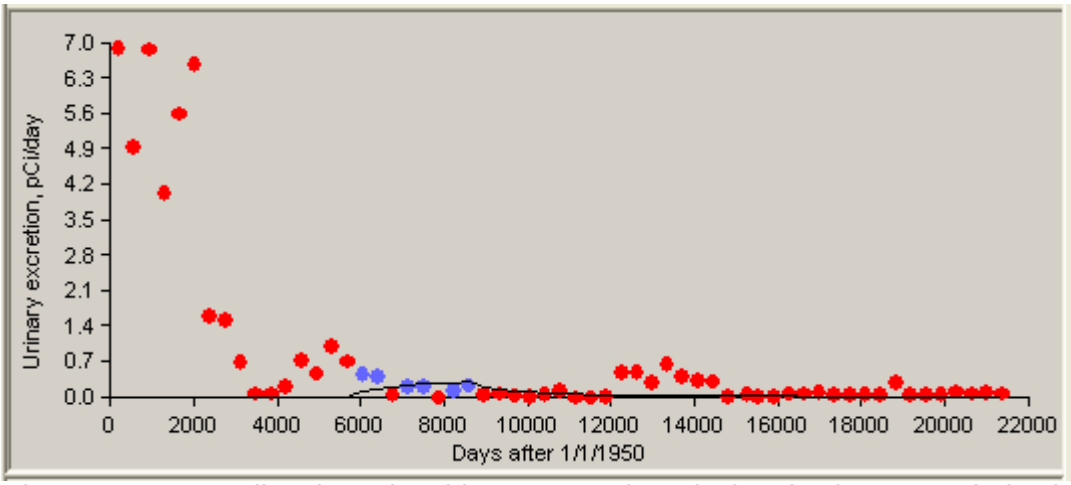

Figure B-109. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1966 to 1973, 50th percentile, type S.

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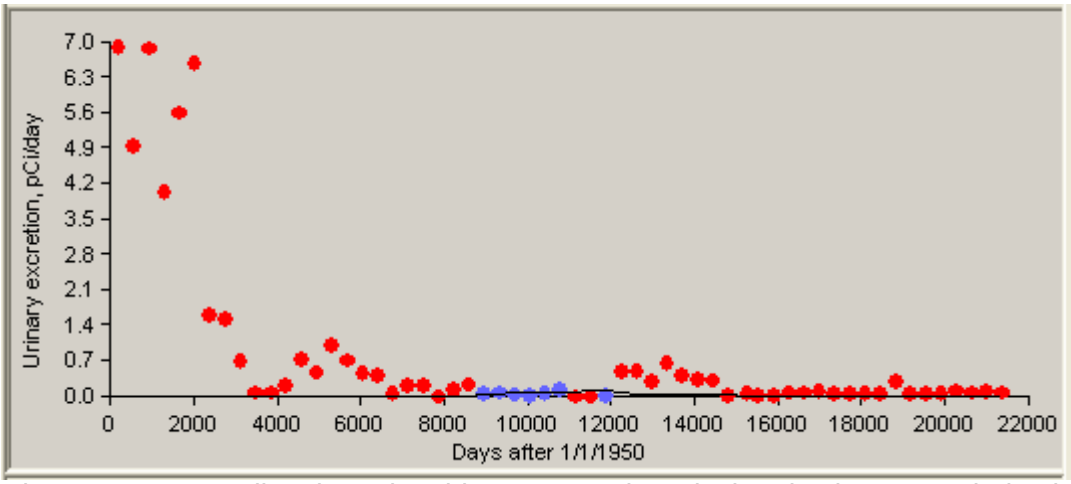

Figure B-110. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1974 to 1982, 50th percentile, type S.

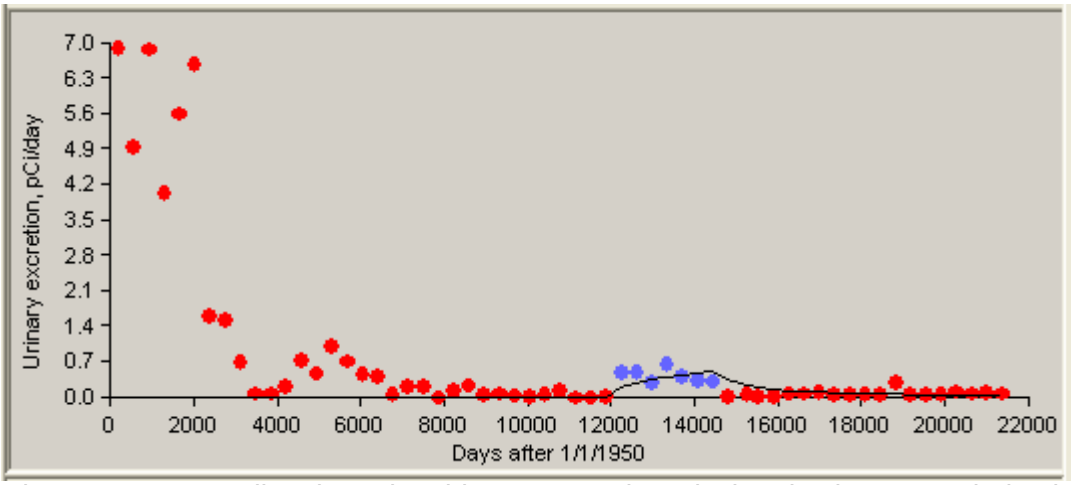

Figure B-111. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1983 to 1989, 50th percentile, type S.

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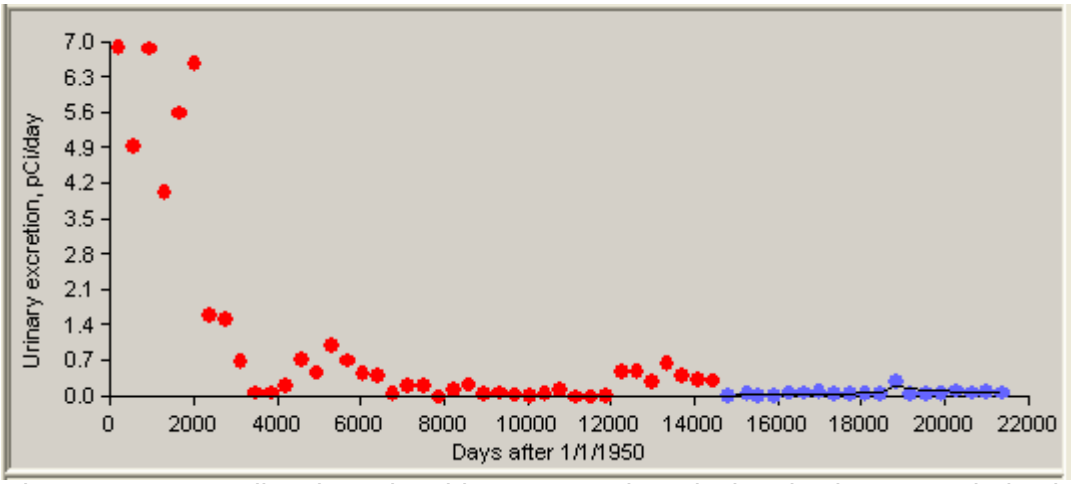

Figure B-112. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1990 to 2008, 50th percentile, type S.

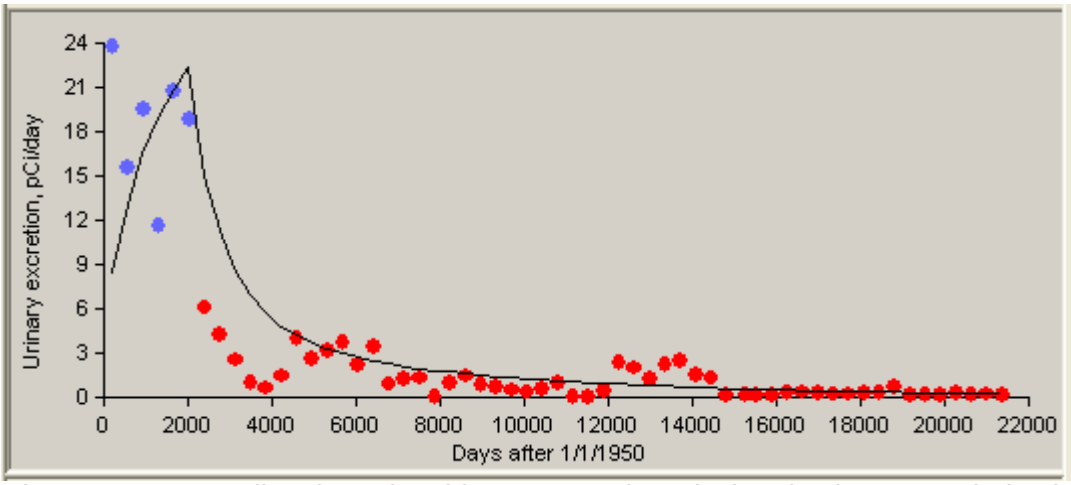

Figure B-113. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1950 to 1955, 84th percentile, type S.

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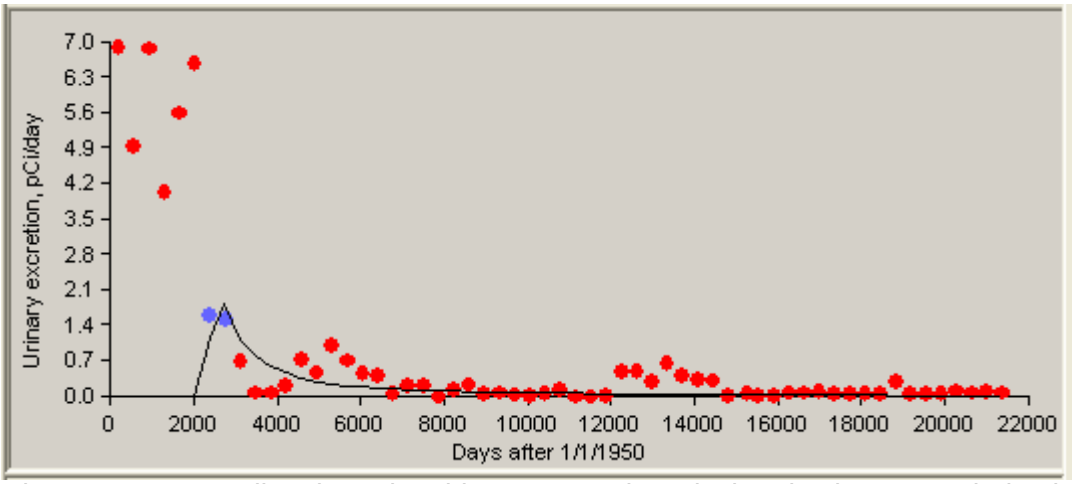

Figure B-114. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1956 and 1957, 84th percentile, type S.

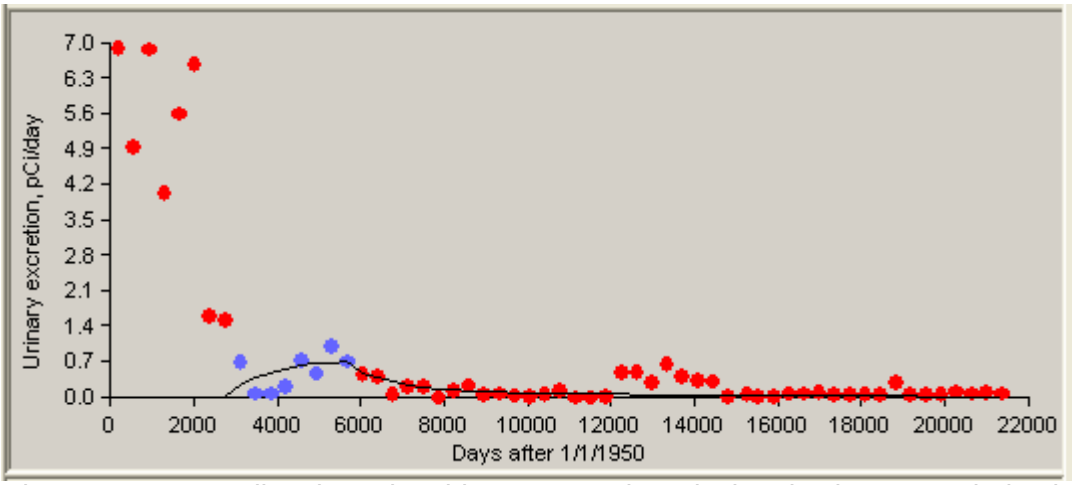

Figure B-115. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1958 to 1965, 84th percentile, type S.

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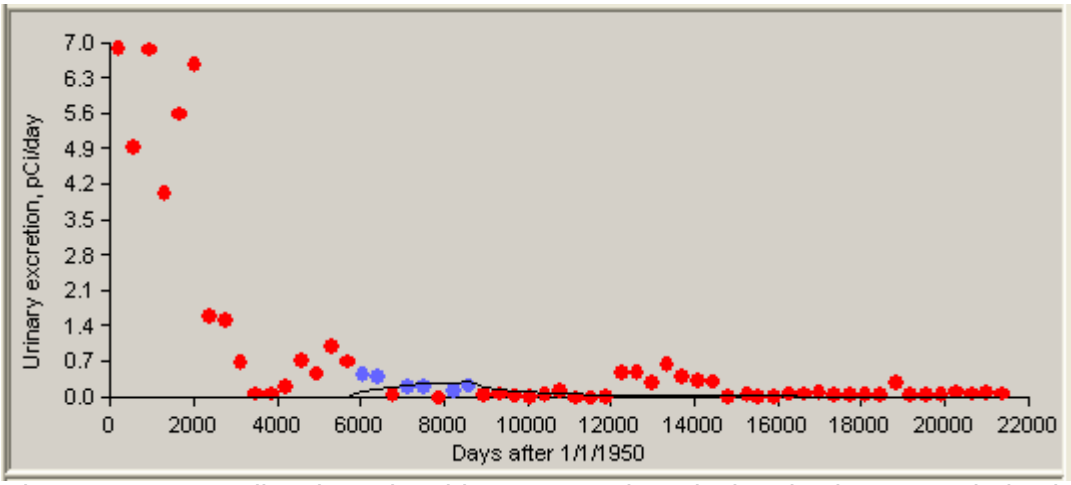

Figure B-116. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1966 to 1973, 84th percentile, type S.

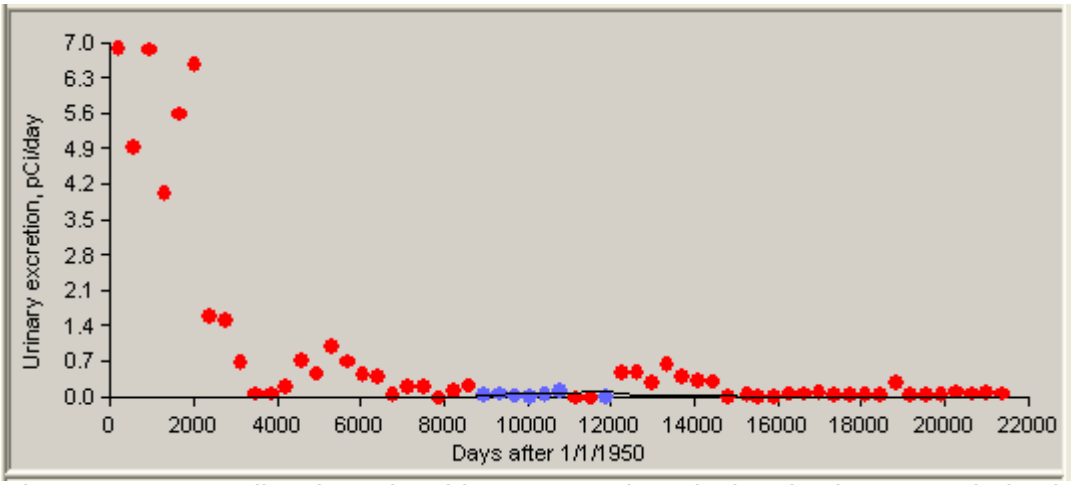

Figure B-117. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1974 to 1982, 84th percentile, type S.

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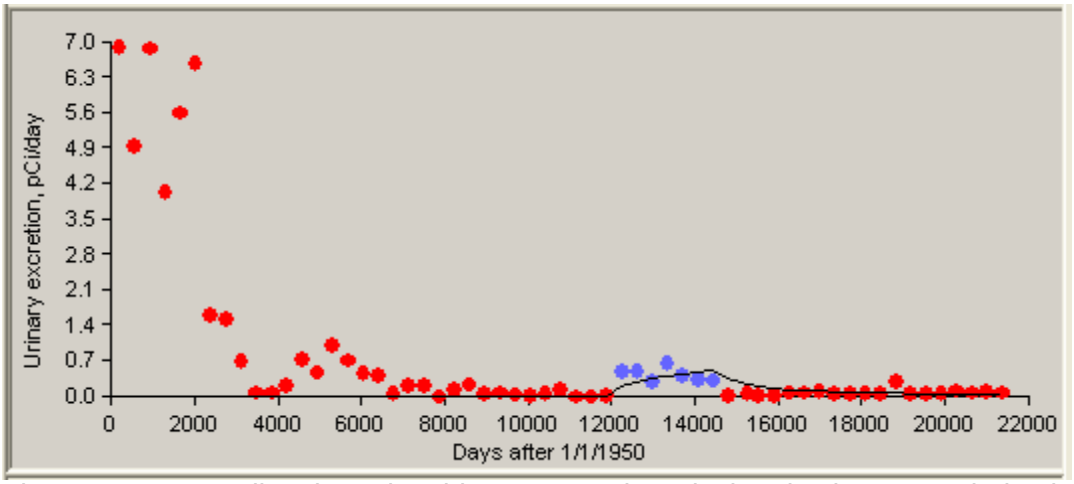

Figure B-118. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1983 to 1989, 84th percentile, type S.

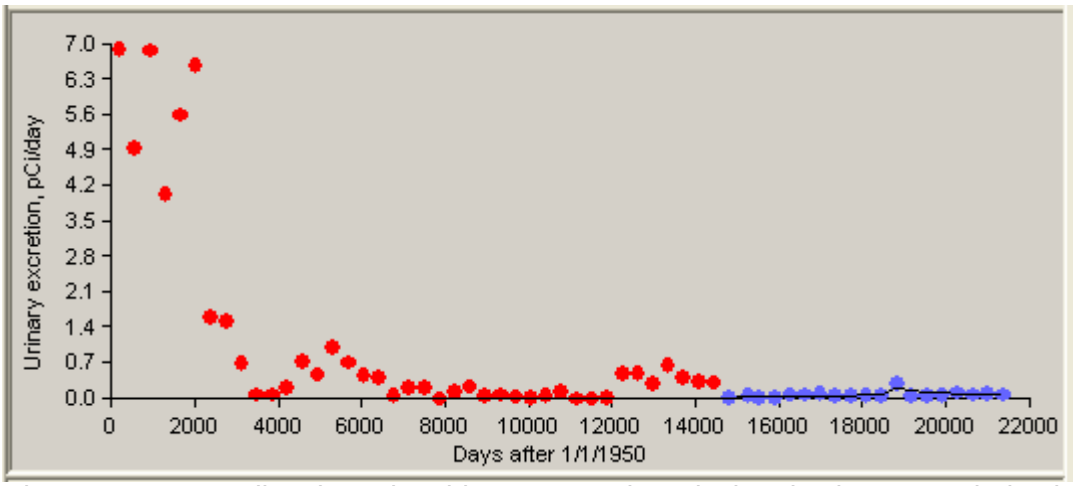

Figure B-119. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1990 to 2008, 84th percentile, type S.

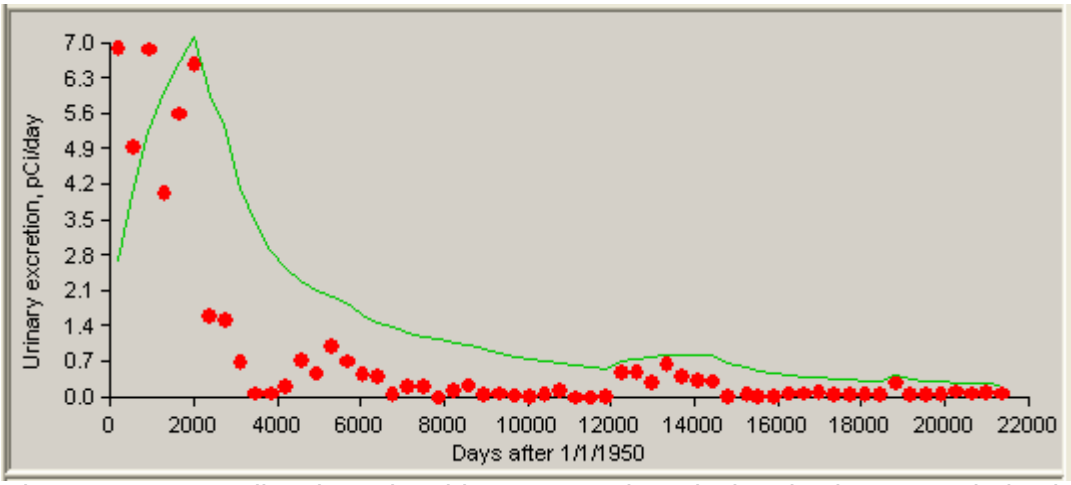

Figure B-120. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), all intake periods, 50th percentile, type S.

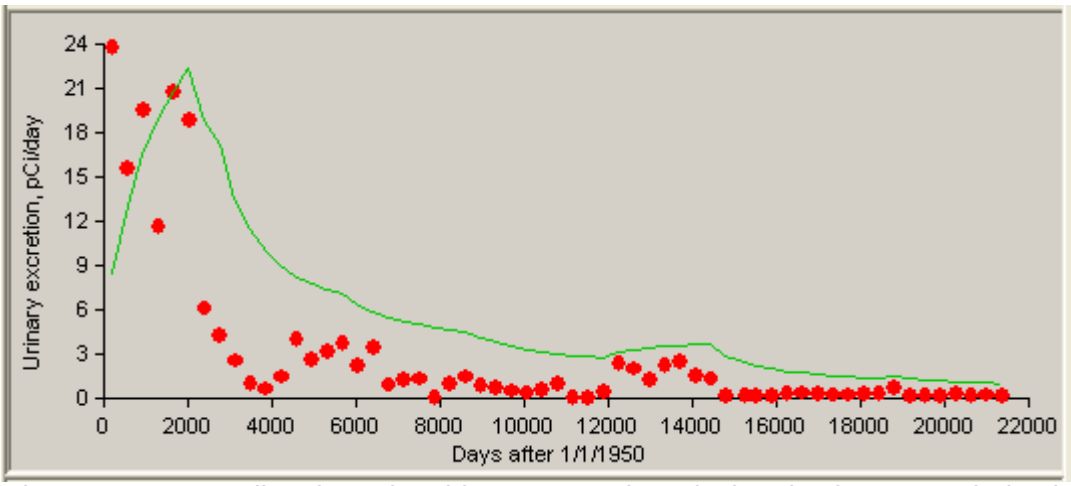

Figure B-121. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), all intake periods, 84th percentile, type S.

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Table B-11. Summary of uranium type S intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1950	12/31/1955	1520	4760	3.13
1/1/1956	12/31/1957	655.5	2125	3.24
1/1/1958	12/31/1965	141	664.5	4.71
1/1/1966	12/31/1973	59.25	390.4	6.59
1/1/1974	12/31/1982	19.66	182.3	9.27
1/1/1983	12/31/1989	104.5	463.5	4.44
1/1/1990	12/31/2008	10.97	50.12	4.57
1/1/2001	12/31/2001	80.980	109.5	1.35

Note: The 2001 intake is additive to the 1990-2008 intake.

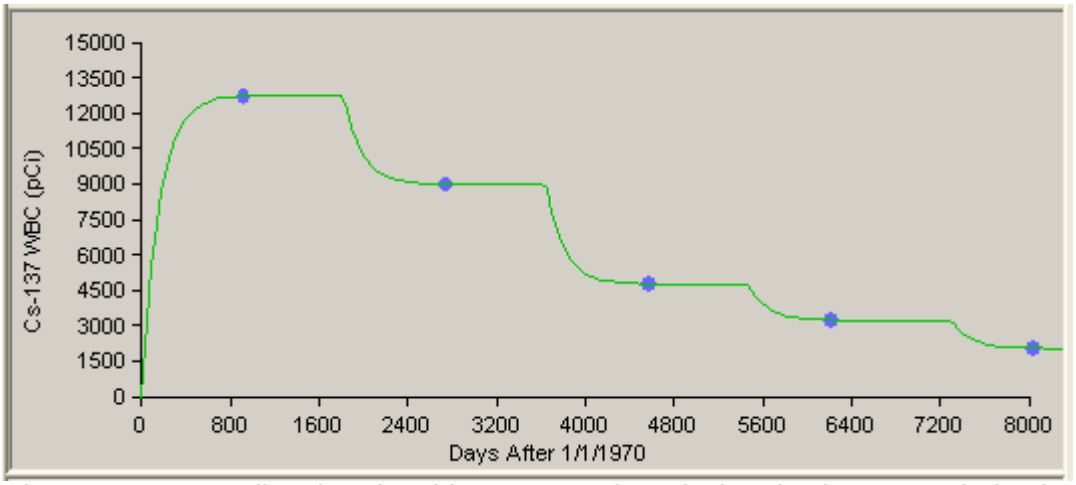

Figure B-122. Predicted cesium bioassay results calculated using IMBA-derived cesium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type F.

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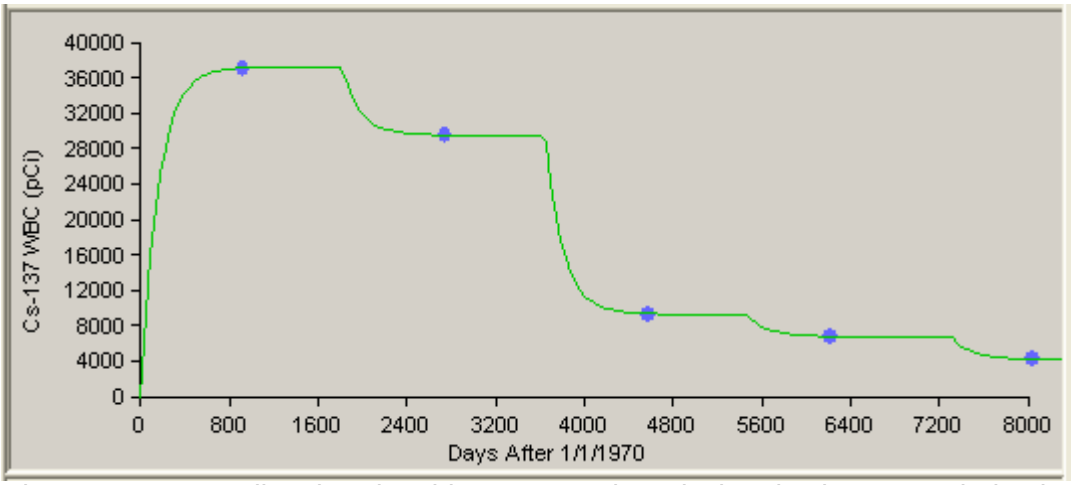

Figure B-123. Predicted cesium bioassay results calculated using IMBA-derived cesium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type F.

Table B-12. Summary of type F ^{137}Cs intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
1/1/1970	12/31/1974	185.5	540.9	2.92
1/1/1975	12/31/1979	130.7	428.9	3.28
1/1/1980	12/31/1984	69.47	136.2	1.96
1/1/1985	12/31/1988	47.36	99.75	2.11
1/1/1990	12/31/1993	30.16	62.85	2.08