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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
04/21/2005	00-A	New technical information bulletin for assignment of K-25 internal doses based on coworker bioassay data. Initiated by Robert N. Cherry.
06/10/2005	00-B	Incorporates internal review comments. Initiated by Robert N. Cherry.
07/19/2005	00-C	Incorporates NIOSH review comments. Initiated by Robert N. Cherry.
08/09/2005	00	First approved issue. Initiated by Robert N. Cherry.
07/21/2006	00 PC-1	Approved page change revision to add updated language to Section 1.0 on pages 5 and 6. Details were added to page 6 in Section 2.0. The date in Section 5.1 and in Table 5.1 on page 8 was changed from 1948 to 1945. Attachment C, Estimate of Intake Rates for 1945-1947 was added to pages 18 and 19. Incorporates internal and NIOSH formal review comments on pages 6, 7, 8, and 9 in Sections 2.0, 4.0, 5.1, and 5.2 respectively. No sections were deleted. This revision results in no change to the assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Thomas R. LaBone. Approval: Document Owner: Signature on File 07/12/2006 John M. Byrne, Task 3 Manager Signature on File 07/12/2006 Edward F. Maher, Task 5 Manager Signature on File 07/20/2006 Kate Kimpan, Project Director Signature on File 07/21/2006 James W. Neton, Associate Director for Science

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1.0 PURPOSE

Technical Information Bulletins (TIBs) are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather working documents that provide historical 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. TIBs may be used to assist the NIOSH staff in the completion of individual work required for each dose reconstruction.

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 [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA defines a DOE facility as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)" [42 U.S.C. § 7384l(12)]. Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the POC [probability of causation[1]] guidelines established under subsection (c) …" [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work.

As noted above, the statute includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program" [42 U.S.C. § 7384l(12)]. While this definition contains an exclusion with respect to the Naval Nuclear Propulsion Program, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty"] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all occupationally derived radiation exposures at covered facilities in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external dosimetry monitoring results are considered valid for use in dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction. NIOSH, however, does not consider the following exposures to be occupationally derived:

[1] The U.S. Department of Labor is ultimately responsible under the EEOICPA for determining the POC.

- Radiation from naturally occurring radon present in conventional structures
- Radiation from diagnostic X-rays received in the treatment of work-related injuries

The purpose of this TIB is to provide information for the application of K-25 coworker data in estimating unmonitored internal exposures. Some employees were not monitored for internal ionizing radiation exposure during the course of their employment at a U.S. Department of Energy (DOE)[2] facility, or the records of such monitoring are incomplete or unavailable. In such cases, data from monitored coworkers may be used to estimate an individual's possible exposure.

2.0 OVERVIEW

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

Bioassay results were obtained from the Oak Ridge Institute for Science and Education (ORISE) Center for Epidemiologic Research (CER) Dosimetry Database, which contains urinalysis records from the K-25 site for 1948 to 1988. ORISE obtained these data from K-25 to conduct an epidemiological study of site workers. The urinalysis results, labeled "gross alpha," are in units of disintegrations per minute per 100 mL (dpm/100 mL). Results labeled "Uranium" were also available that included units of mass rather than activity concentration. It is not possible to convert mass concentration to activity concentration accurately for dose assessment purposes without knowing the isotopic abundances. Therefore, only the gross alpha data were used because these data were adequate and complete.

A statistical analysis of the gross alpha data was performed in accordance with ORAUT (2004a). The resultant values were input to the Integrated Modules for Bioassay Analysis (IMBA) Expert™ OCAS-Edition computer software (ACJ 2004), and a fit to the data was performed to obtain intake rates for assigning dose distributions.

Technetium-99 bioassay results were similarly obtained from the ORISE CER Dosimetry Database, which contains ^{99}Tc urinalysis records from the K-25 site for 1978 to 1988. During these years, operations with purified ^{99}Tc were conducted which could result in intakes of ^{99}Tc without commensurate intakes of uranium. The ^{99}Tc urinalysis results are in units of dpm/mL. A statistical analysis of these data was performed in accordance with ORAUT (2004a). The resultant values were input to IMBA, and a fit to the data was performed to obtain intake rates for assigning dose distributions.

An analysis of the urinary excretion data for 1948-1988 was used to develop the most probable urinary excretion rate for 1945-1947, when there were no direct bioassay measurements. This analysis, which is detailed in Attachment C, concludes that the chronic intake rates calculated for 1948-1988 are appropriate for use in 1945-1947.

3.0 DATA

[2] References to DOE in this document include DOE's predecessors, the Manhattan Engineer District (1942 to 1946), the U.S. Atomic Energy Commission (1947 to 1975), and the Energy Research and Development Administration (1975 to 1977), as well as DOE (1977 to the present).

3.1 SELECTED BIOASSAY DATA

Uranium urinalysis data from 1948 to 1988 were extracted from a Microsoft® Access table named "tblK25_Urinalysis_rawData" in a subdatabase named "K25_Urinalysis_to_COC_10-8-2004.mdb" in the ORISE/CER Dosimetry Database.

Technetium-99 urinalysis data were similarly extracted and analyzed for 1978 to 1988.

3.2 ANALYSIS

Bioassay data were analyzed by year. A lognormal distribution was assumed, and the 50th and 84th percentiles were calculated for each year using the method described in ORAUT (2004a).

Many results in the database were listed as less than (<) a value. For 1953 and 1977 through 1988, for every record in the "Result" field that contained the less-than symbol followed by a number, that number was included in the ranking but not in the fit.

Tables A-1 and A-2 show the uranium and ^{99}Tc statistical analysis results, respectively.

4.0 INTAKE MODELING

Although K-25 operations began in early 1945, uranium bioassay results are not currently available for years earlier than 1948. The derivation of intake rates for 1945-1947 is discussed in Attachment C.Assumptions

Each result used in the intake calculation was assumed to be normally distributed. 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, so all results were normalized to 1400 mL, the volume of urine excreted by Reference Man in a 24-hour period.

Because of the nature of work at K-25, a chronic exposure pattern best approximates the true exposure conditions for most workers with a potential for intakes. Intakes were assumed to be by way of inhalation using a default breathing rate of 1.2 m^3/hr and a 5-µm activity median aerodynamic diameter particle size distribution.

The database file for uranium lists all results as activity concentrations. Because a variety of enrichments is possible at the K-25 site, ^{234}U was assumed for the IMBA intake modeling. The dose coefficients (also referred to as dose conversion factors) in International Commission on Radiological Protection (ICRP) Publication 68 for ^{234}U are 7% to 31% larger than those for ^{235}U, ^{236}U, and ^{238}U (ICRP 1995). Therefore, use of the ^{234}U dose conversion factor will overestimate doses and is therefore a claimant-favorable assumption.

4.1 BIOASSAY FITTING

IMBA was used to fit inhalation intakes to the bioassay results. Data from January 1948 to December 1988 were fit as one or more chronic intakes.

4.2 MATERIAL TYPES

4.2.1 Uranium

Uranium urinalysis results were fit in IMBA using types F, M, and S materials to derive intake rates for 1948 to 1988. The solid lines in Figures B-1 to B-6 show the individual fits to the 50th- and 84th-percentile excretion rates. The same intake periods were applied for both percentiles because the bioassay values modeled followed a similar pattern.

4.2.2 Technetium-99

Urinalysis results for ^{99}Tc were fit in IMBA using types F and M materials to derive intake rates for 1978 to 1988. [Type S material is not considered in ICRP (1995) for ^{99}Tc.] The solid lines in Figures B-7 to B-10 show the individual fits to the 50th- and 84th-percentile excretion rates. The same intake periods were applied for both percentiles because the values followed a similar pattern.

The bioassay data showed a significant change in excretion rate between 1982 and 1983, which required different fits for the periods from 1978 to 1982 and from 1983 to 1988.

5.0 ASSIGNMENT OF INTAKES AND DOSES

5.1 INTAKE RATE SUMMARY

The derived 50th- and 84th-percentile uranium excretion data are relatively constant from 1948 to 1988, as shown in Figures B-1 to B-6. Therefore, a single intake period was assumed. Table 5-1 summarizes the derived uranium intake rate that produced the fits, including the extrapolated intake rates for 1945-1947.

Table 5-1. Derived uranium intake rate, 1945 to 1988.

Type F material			Type M material			Type S material		
50th percentile (dpm/d)	84th percentile (dpm/d)	Geometric standard deviation	50th percentile (dpm/d)	84th percentile (dpm/d)	Geometric standard deviation	50th percentile (dpm/d)	84th percentile (dpm/d)	Geometric standard deviation
21.5	76.2	3.54	88.3	313	3.54	990	3,460	3.50

The derived 50th- and 84th-percentile ^{99}Tc excretion data are relatively constant from 1978 to 1982 and, at lower rates, from 1983 to 1988, as shown in Figures B-7 to B-10. Therefore, two intake periods were assumed. Table 5-2 summarizes the derived ^{99}Tc intake rates that produced the fits. Although the modeling resulted in lower GSDs, a GSD of 3 is assigned to all of the Tc-99 intakes for 1978 through 1988 to adequately account for uncertainty in the biokinetic modeling.

Table 5-2. Derived ^{99}Tc intake rates.

	Type F material			Type M material		
Years	50th percentile (dpm/d)	84th percentile (dpm/d)	Geometric standard deviation	50th percentile (dpm/d)	84th percentile (dpm/d)	Geometric standard deviation
1978–1982	13,900	24,900	3.0	15,570	27,860	3.0
1983–1988	3,160	6,890	3.0	3,420	7,499	3.0

5.2 CONTRIBUTION FROM CONTAMINANTS IN RECYCLED URANIUM

Spent fuel from fission reactors was processed throughout the DOE complex to recover uranium for recycling. Because the uranium streams at K-25 contained recycled uranium at various times, the

dose from the added constituents, including plutonium, neptunium, and ^{99}Tc, must be included during dose reconstruction. ORAUT (2004c) provides information about recycled uranium at K-25.

Results of bioassays analyzed specifically for ^{99}Tc are available for 1978 to 1988, as noted above. These bioassays could have been performed for workers on decontamination efforts because "^{99}Tc was concentrated at K-25 for purposes of recovery and removal" (ORAUT 2004d).

Intake rates derived from these ^{99}Tc bioassay results will be used for ^{99}Tc from 1978 to 1988 rather than the assumed ^{99}Tc ratio of contaminant concentration in uranium. All other years will use the ^{99}Tc ratio as outlined in ORAUT (2004c)."

5.3 DOSE ASSIGNMENT

Doses to be assigned to individuals are calculated from the 50th-percentile intake rates. Dose reconstructors should select the material type that results in the largest probability of causation.

A comparison shows that intake rates derived assuming type S material are much greater than the intake rates derived assuming type M or type F materials for all periods. However, because type S material remains in the lungs for an extended period while types F and M materials are transferred to systemic organs, it is necessary to compare the annual doses on a case-by-case basis to determine which will deliver the largest dose to the organ of interest.

Recycled uranium contaminants, when appropriate for the period, should also be included in the above comparison.

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

REFERENCES

ICRP (International Commission on Radiological Protection), 1959, *Report of ICRP Committee II on Permissible Dose for Internal Radiation*, Publication 2, Pergamon Press, Oxford, England.

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

ORAUT (Oak Ridge Associated Universities Team), 2004a, *Analysis of Coworker Bioassay Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Rev. 00, Oak Ridge, Tennessee.

ORAUT (Oak Ridge Associated Universities Team), 2004b, *Coworker Data Exposure Profile Development*, ORAUT-PLAN-0014, Rev. 00, Oak Ridge, Tennessee.

ORAUT (Oak Ridge Associated Universities Team), 2004c, *Technical Basis Document for the K-25 Site – Site Description*, ORAUT-TKBS-0009-2, Rev. 00, Oak Ridge, Tennessee.

ORAUT (Oak Ridge Associated Universities Team), 2004d, *Technical Basis Document for the K-25 Site – Occupational External Dose*, ORAUT-TKBS-0009-6, Rev. 00, Oak Ridge, Tennessee.

ATTACHMENT A: TABLES

Table A-1. Summary of annual uranium urinary excretion rate analyses, 1948 to 1988.

Year	50th percentile (dpm/100 mL)	84th percentile (dpm/100 mL)
1948	0.450	1.134
1949	0.239	0.827
1950	0.430	1.233
1951	0.210	0.769
1952	0.173	1.372
1953	0.378	1.577
1954	0.256	1.184
1955	0.280	1.256
1956	0.332	1.342
1957	0.519	1.994
1958	0.420	1.666
1959	0.331	1.524
1960	0.359	2.081
1961	0.567	2.867
1962	0.572	2.355
1963	0.502	1.790
1964	0.623	1.803
1965	0.740	2.922
1966	0.393	1.330
1967	0.284	1.022
1968	0.199	1.027
1969	0.381	1.406
1970	0.352	1.341
1971	0.399	1.782
1972	0.495	1.798
1973	0.645	2.187
1974	0.424	1.409
1975	0.542	1.782
1976	0.265	0.981
1977	0.327	1.510
1978	0.159	0.767
1979	0.258	0.896
1980	0.405	1.139
1981	0.506	1.296
1982	0.506	1.166
1983	0.605	1.397
1984	0.610	1.809
1985	0.581	2.322
1986	0.657	1.643
1987	0.517	1.181
1988	0.648	1.166

Table A-2. Summary of annual ^{99}Tc urinary excretion rate analyses, 1978 to 1988.

Year	50th percentile (dpm/mL)	84th percentile (dpm/mL)
1978	2.804	4.602
1979	1.682	3.821
1980	0.961	2.384
1981	3.086	5.264
1982	2.444	3.560
1983	0.691	1.462
1984	0.661	1.714
1985	0.002	0.066
1986	0.553	1.000
1987	0.157	0.464
1988	0.428	0.788

ATTACHMENT B: FIGURES

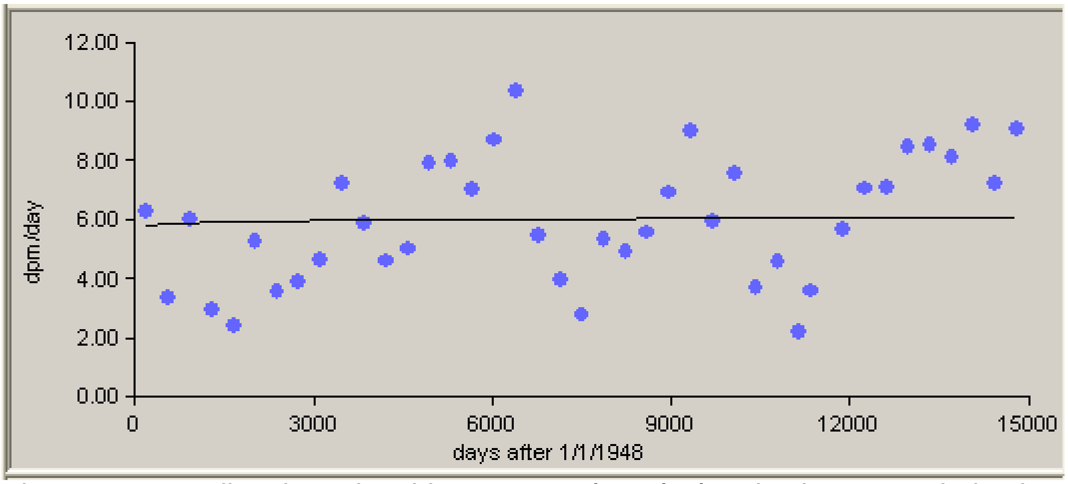

Figure B-1. Predicted uranium bioassay results calculated using IMBA-derived U intake rates (line) compared with uranium bioassay results (dots), January 1, 1948, to December 31, 1988, 50th-percentile, Type F.

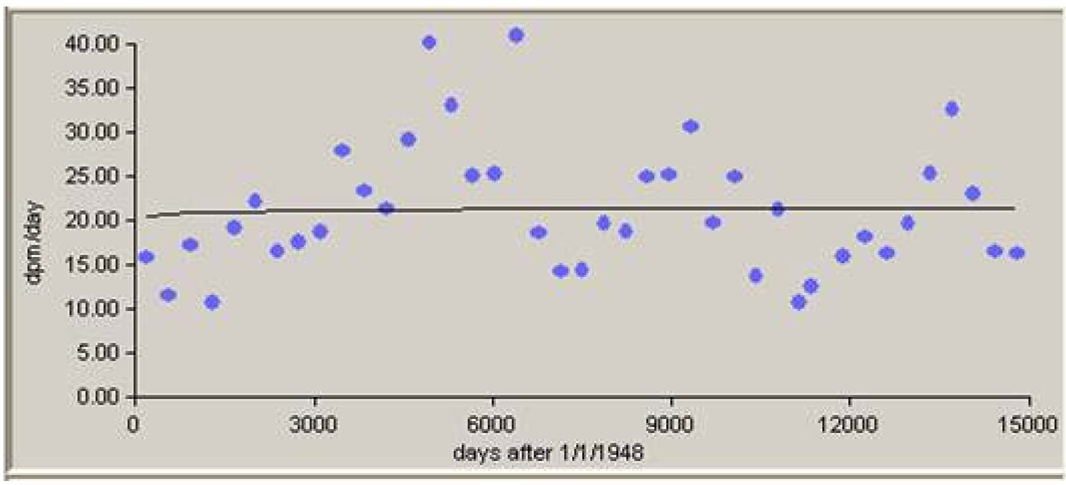

Figure B-2. Predicted uranium bioassay results calculated using IMBA-derived U intake rates (line) compared with uranium bioassay results (dots), January 1, 1948, to December 31, 1988, 84th-percentile, Type F.

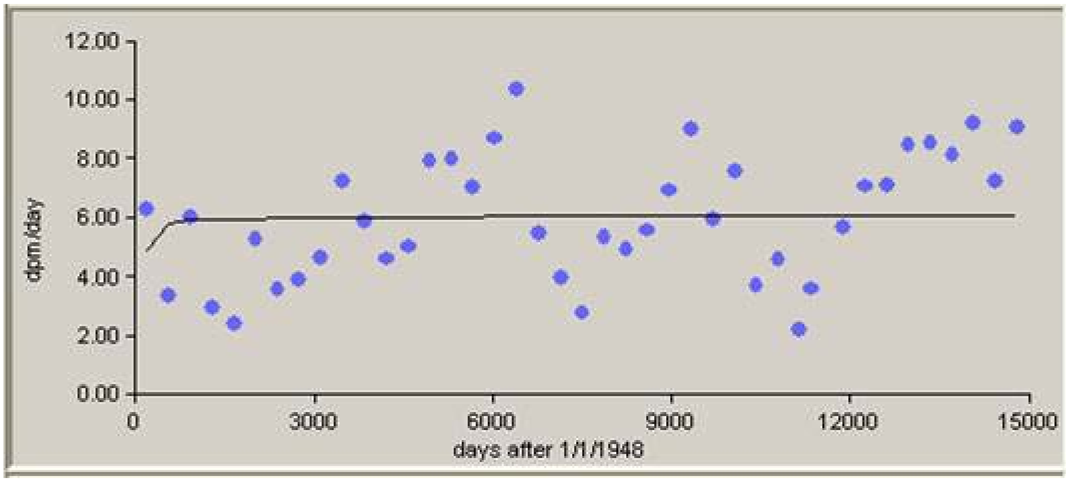

Figure B-3. Predicted uranium bioassay results calculated using IMBA-derived U intake rates (line) compared with uranium bioassay results (dots), January 1, 1948, to December 31, 1988, 50th-percentile, Type M.

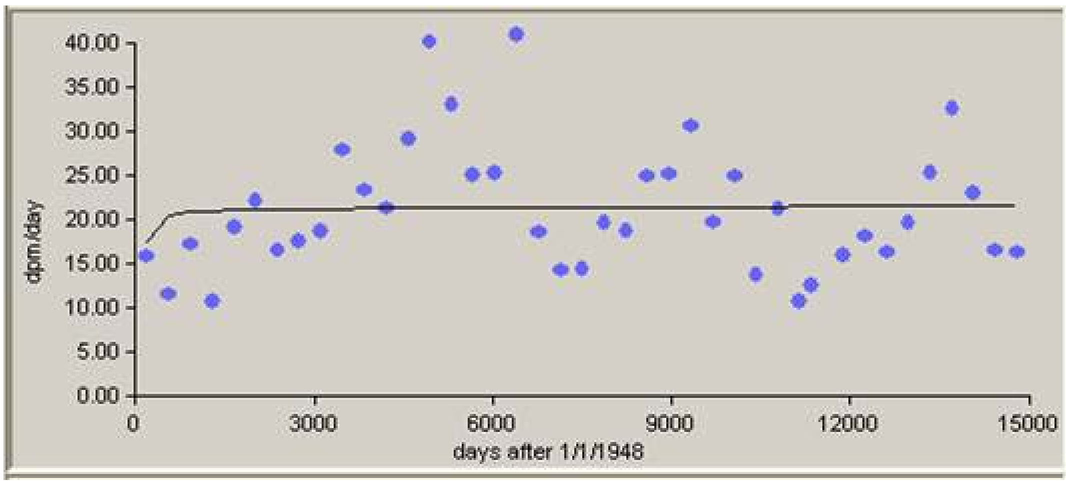

Figure B-4. Predicted uranium bioassay results calculated using IMBA-derived U intake rates (line) compared with uranium bioassay results (dots), January 1, 1948, to December 31, 1988, 84th-percentile, Type M.

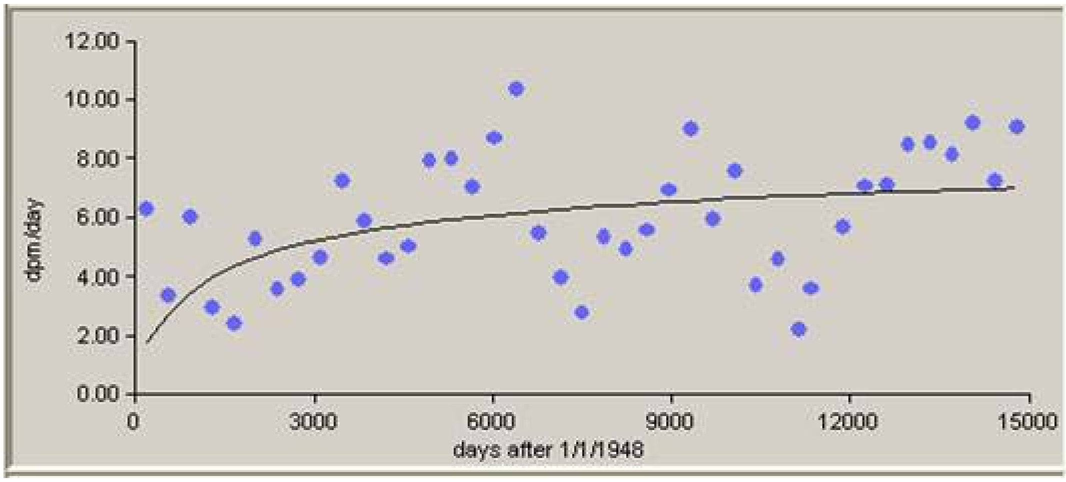

Figure B-5. Predicted uranium bioassay results calculated using IMBA-derived U intake rates (line) compared with uranium bioassay results (dots), January 1, 1948, to December 31, 1988, 50th-percentile, Type S.

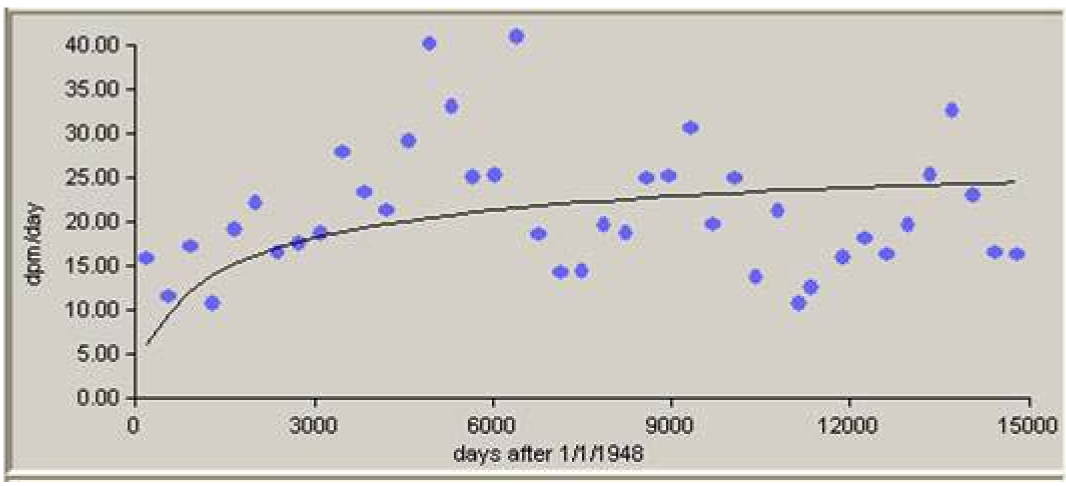

Figure B-6. Predicted uranium bioassay results calculated using IMBA-derived U intake rates (line) compared with uranium bioassay results (dots), January 1, 1948, to December 31, 1988, 84th-percentile, Type S.

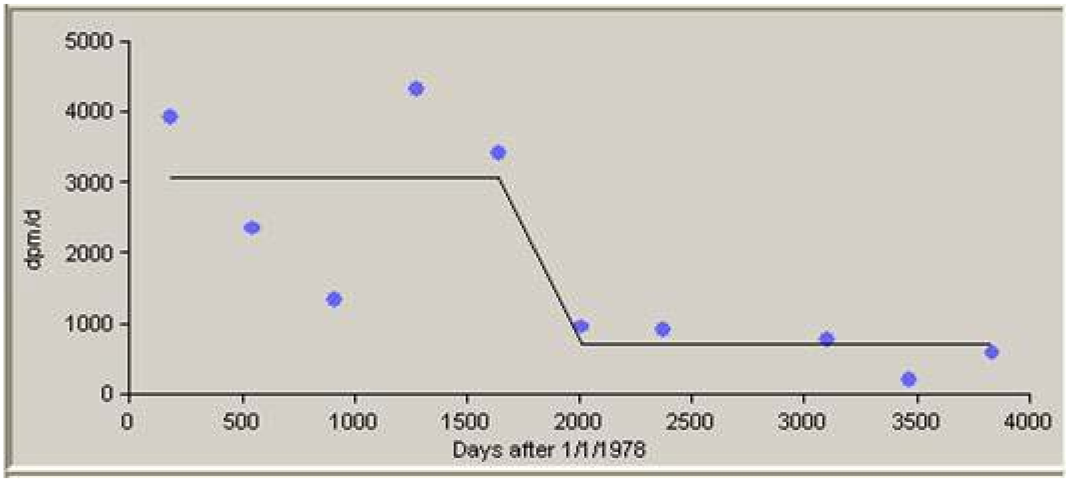

Figure B-7. Predicted technetium-99 bioassay results calculated using IMBA-derived ^{99}Tc intake rates (line) compared with uranium bioassay results (dots), January 1, 1978, to December 31, 1988, 50th-percentile, Type F.

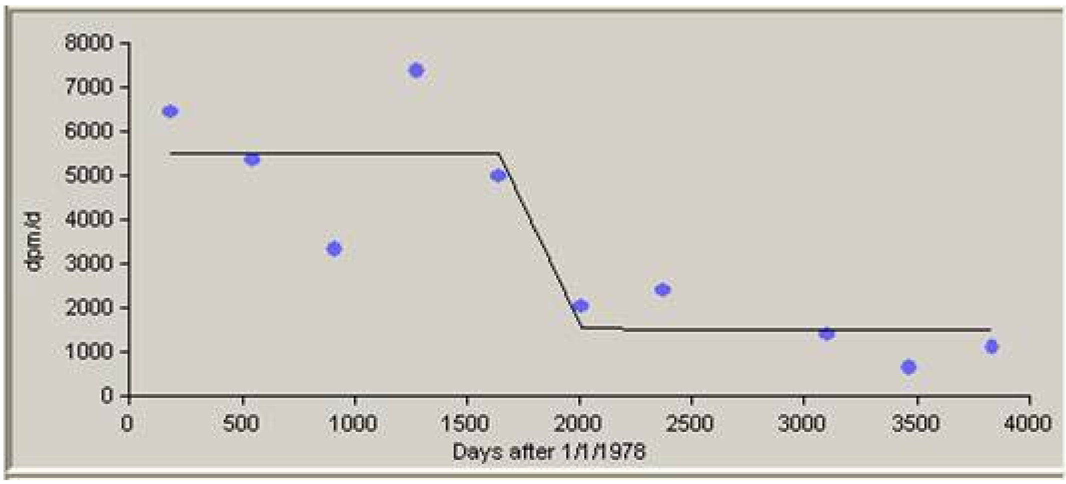

Figure B-8. Predicted technetium-99 bioassay results calculated using IMBA-derived ^{99}Tc intake rates (line) compared with uranium bioassay results (dots), January 1, 1978, to December 31, 1988, 84th-percentile, Type F.

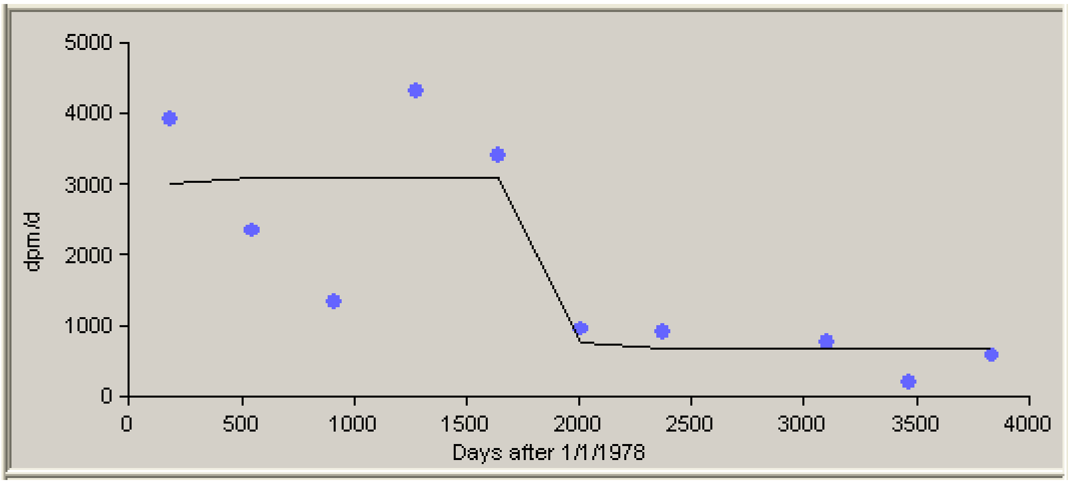

Figure B-9. Predicted technetium-99 bioassay results calculated using IMBA-derived ^{99}Tc intake rates (line) compared with uranium bioassay results (dots), January 1, 1978, to December 31, 1988, 50th-percentile, Type M.

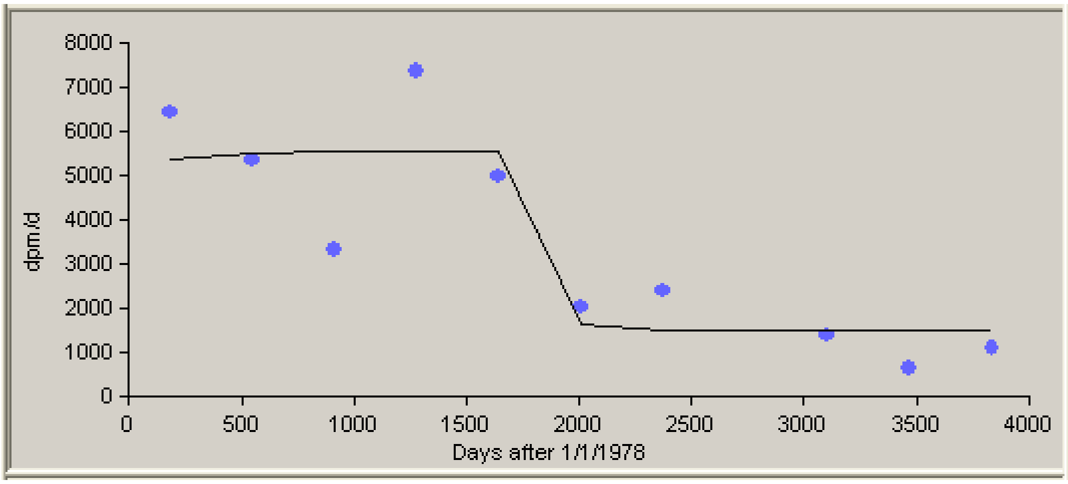

Figure B-10. Predicted technetium-99 bioassay results calculated using IMBA-derived ^{99}Tc intake rates (line) compared with uranium bioassay results (dots), January 1, 1978, to December 31, 1988, 84th-percentile, Type M.

Attachment C: Estimate of Intake Rates for 1945-1947

There are no urine bioassay results available for K-25 during the period of 1945-1947 from which to calculate intake rates. One approach to estimate the intake rates during 1945-1947 would be to examine the relationship between a parameter like uranium production levels and urine concentrations during 1948-1988, when there were bioassay data. Then, the urine concentrations during 1945-1947 could be inferred from the production levels during that period. However, there does not appear to be any parameter available to perform such an analysis. An alternative approach is to examine how the urine concentrations varied from 1948-1988 and assume that the urine concentrations varied in a similar fashion during 1945-1947.

The median urine concentration (dpm/100 mL) and geometric standard deviation (GSD) for the urine samples analyzed in each year are shown in the plot below. The median urine concentrations are relatively constant, i.e., the slope of the line fit to the data is close to zero.

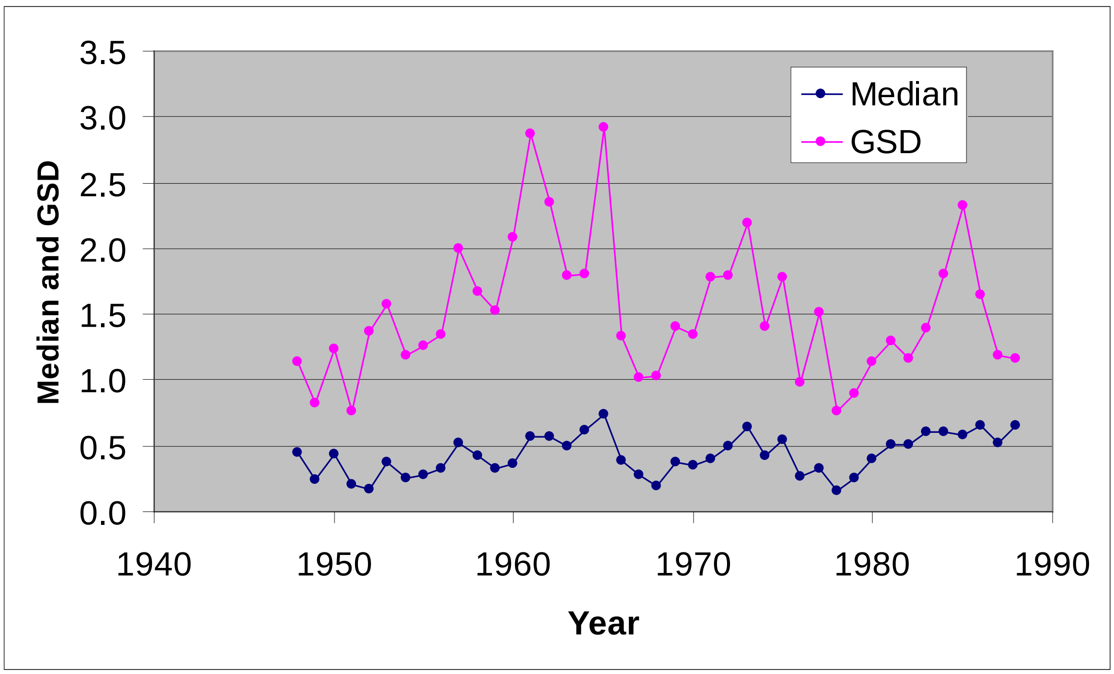

Figure C-1. The median urine concentration (dpm/100 mL) and geometric standard deviation for K-25 workers for 1948-1988.

Thus, the flat excretion rate expected from a chronic intake of soluble uranium fits the urinary excretion data quite nicely (see Figure B-1 through B-4 above). One can reasonably extrapolate the line of best-fit back to 1945, which gives basically the same intake rate for 1945-1947 as predicted for 1948-1988.

The median concentrations for the 1948-1988 period are normally distributed, as shown on the normal probability plot below. This plot demonstrates that whatever was making the median urinary excretion level vary from year to year was predictable in probabilistic sense. In other words, if it is assumed that the same (seemingly) random forces that were at work from 1948-1988 were also at work from 1945-1947, then the urinary excretion rate during 1945-1947 can be predicted with a given probability.

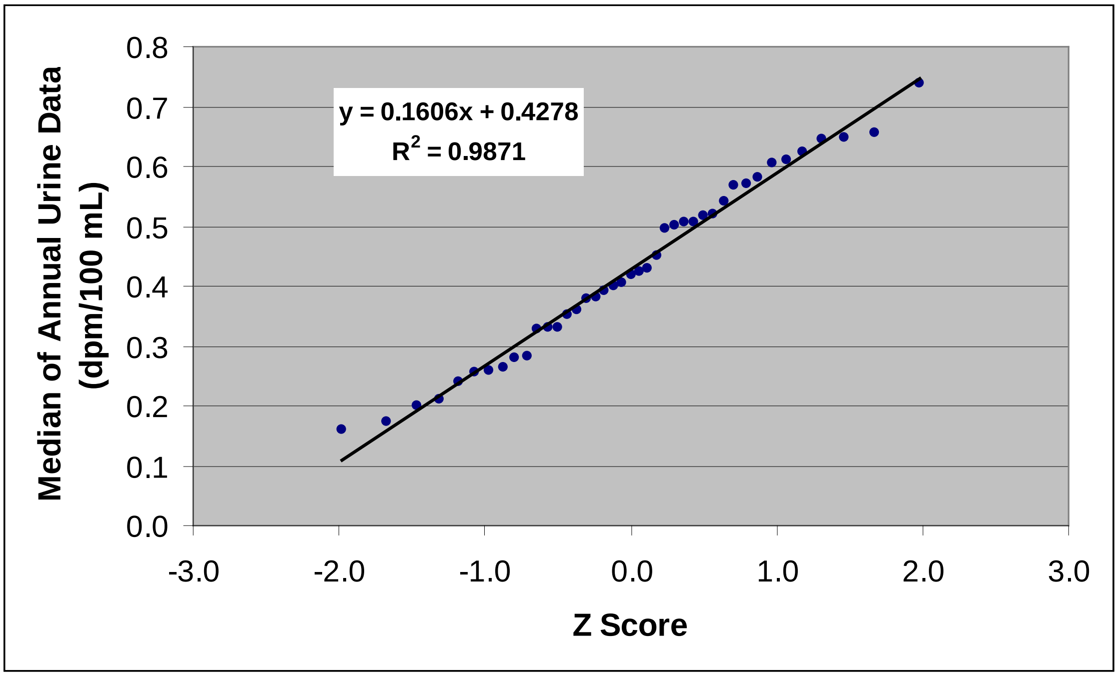

Figure C-2. Normal probability plot of the median urine concentration.

Based on this analysis, the best estimate of the urinary excretion during 1945-1947 is the mean of about 6 dpm/1.4 L (0.43 dpm/100 mL) from the plot above. By no coincidence, this also happens to be urine concentration predicted by the line of best fit for the Type F and M uranium on the IMBA plots, and the asymptote of the Type S uranium (the predicted excretion is not flat).

A third way of looking at the available information is to examine the 1948-1988 urine data for 120 of the workers who were working at K-25 from 1945-1947 and see if they appeared to be typical workers during 1948-1988 (uranium urine results consistent with the total population). A review of the urine data confirms the fact that they were indeed typical workers from 1948-1988, which supports the belief that they would have been typical workers during 1945-1947.

In conclusion, the available information supports the view that the best available estimates of the intake rates during 1945-1947 are the intake rates estimated for 1948-1988.