Coworker Model Implementation Guide
SRS Coworker Model - Example

Timothy D. Taulbee, PhD, CHP

Associate Director for Science

SEC Issues and SRS Workgroup Meeting
Covington, Kentucky | December 5, 2019

Overview

- Background leading to development of Coworker Model Criteria
- Draft Criteria for the Evaluation and Use of Coworker Datasets
- SRS Coworker Model Example
  - *a priori* stratification
  - Data Adequacy
  - Data Validation
  - Statistical Analysis
  - Intake Modeling
- Summary

Background leading to development of Coworker model criteria

Coworker Background

- 2003: Original coworker is a bounding approach of ORAUT-OTIB-0001 (SRS - high five approach)
- 2010: Concern that some coworker models using raw bioassay were dominated by few individuals
  - ORAUT-RPRT-0053 One Person One Statistic (OPOS)
- 2012: Series of NIOSH/ORAUT Reports
  - ORAUT-RPRT-0055 – Trivalent Coworker Comparison
  - ORAUT-RPRT-0056 – Neptunium Comparison
  - ORAUT-RPRT-0058 – Mixed Fission Product Comparison

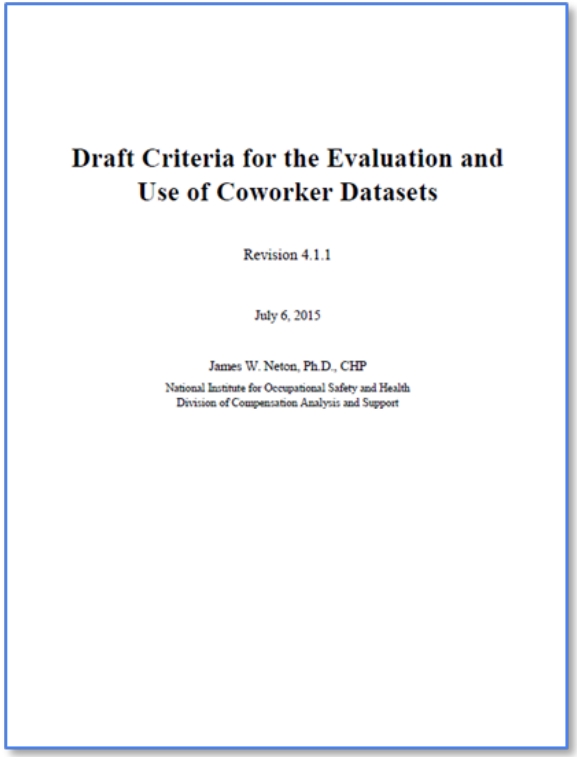
Coworker Background – cont.

- 2013: ABRWH/SC&A reviews of comparison methodology
- 2014: Multiple SEC Issues Workgroup meetings discussing OPOS, stratification, statistical comparison methodology, etc

- The 2014 discussions promulgated the development of the Draft Criteria for the Evaluation and Use of Coworker Datasets

Coworker Model Implementation Guide

- Timeline
  - *June 2, 2014 - Rev 1*
  - *September 30, 2014 - Rev 2*
  - *October 30, 2014 – Rev 3*
  - *February 26, 2015 – Rev 4*
  - *March 12, 2015 – Rev 4.1*
  - *July 6, 2015 – Rev 4.1.1*
- SEC Issues Workgroup requested a demonstration or pilot (SRS and INL)



Draft Criteria for the Evaluation and Use of Coworker Datasets

Revision 4.1.1

July 6, 2015

James W. Neton, Ph.D., CHP
National Institute for Occupational Safety and Health
Division of Compensation Analysis and Support

Coworker Model Implementation Guide – Pilot

- ORAUT-OTIB-0081 Rev 3 – November 22, 2016
  - 3 Radionuclides
    - (Americium, Curium, Californium), Tritium, and Thorium
  - Subsequent discussion of stratification and applicability to subcontractor Construction Trades Workers (CTWs)
  - General Workgroup consensus needed the full model to evaluate all aspects
- ORAUT-OTIB-0081 Rev 4 – March 13, 2019
  - Contained models for all radionuclides

Draft Criteria for the Evaluation and Use of Coworker Datasets (rev 4.1.1)

July 6, 2015 – By J. Neton

Coworker Model Implementation Guide - Elements

- Data Adequacy
- Data Completeness and Validation
- Applicability to Unmonitored Workers
- Analysis and Application to Unmonitored Population
- Time Interval of the Modeled Data
  - One year interval no more than 3 years without significant justification
- Evaluation of Stratification

Data Adequacy

- Review of sampling methods and laboratory analysis, consideration should be given to:
  - Representativeness of bioassay collection methods
  - Radiochemical recovery
  - Counting efficiency (self absorption)
  - Reliability of measurement method

Data Completeness

- Evaluate whether the data are either sufficiently representative or bounding of the exposure potential
  - Recommended minimum 30 person measurements per year
  - Assess temporal trends (gap analysis)
  - Assess data quality
    - Accuracy of the data (transcription errors)
  - Evaluation of potentially missing data
    - Compare to claimant files (NOCTS data)

Applicability to Unmonitored Workers

- Hierarchical Order
  1. Routine, representative sampling
  2. Routine measurement of highest exposure potential
  3. Collection of samples after the identification of an incident

- Representative sample of exposed population ***OR*** workers with the highest potential for exposure

Analysis and application to the Unmonitored Population

- Sufficient data to construct a representative coworker model
  - Recommend use of 30 workers per interval, however, less data can be used if the data fit a distribution reasonably well
- Data can be reasonably represented by a statistical distribution
- Time-Weighted One Person One Statistic (TWOPOS)

  When multiple bioassay samples are present during a monitoring period for a given individual, it is appropriate to average the values so that a single statistic can be computed for that individual.

Evaluation of Stratification

- Should be evaluated where:
  1. Accurate job categories or descriptions can be obtained for all workers
  2. There is reason to believe that one job category is more highly exposed
  3. There are unmonitored workers in this job category

Note: Stratification by individual job categories was never our intention from the standpoint of coworker models

SRS Coworker Model (ORAUT-OTIB-0081)

SRS Coworker Models – *a priori* Stratification

- *a priori S*tratification
  - Construction Trades Workers (CTWs)
  - Non-Construction Trades Workers (non-CTWs) (*all other workers)*
- There has been a lot of discussion about differences in monitoring methods and frequency and exposure potential (high vs. low potential) during previous workgroup meetings
  - Recall, we presented ORAUT-RPRT-0053 in the past
  - No consensus / agreement on quantitative approach

SRS Coworker – Stratification Decision

- NIOSH settled on qualitative exposure potential differences as the basis for stratification *(professional judgement)*
  - Routine operations vs. non-routine operations
  - We found it difficult to make the argument that the exposure potential was similar for the two types of workers
  - For example, consider when a glovebox is purposely breached
    - Loss of engineering control used to protect operations workers vs. after breach respiratory protection used to protect non-routine workers

SRS Coworker Models – Stratification cont.

- Previous quantitative comparison methods were heavily critiqued by the ABRWH and SC&A
  - Former Workgroup members opined

    "I think it's going to be hard to generalize on that because there are just so many different situations that might change our evaluation of that statistical analysis" (Melius 2015)
- No single statistical analysis (quantitative analysis) could be identified *a priori*
- In reality, the initial CTW vs. non-CTW stratification of the coworker model was the hard part

SRS Coworker Models – Stratification cont.

- If the SRS and SEC Issues Workgroups disagree with stratification
  - Fairly easy to put the groups back together and would result in better statistical analysis if the two groups are the same potentially worse if they are different
- What remains unclear, based on mixed comments, is the recommendation of the respective Workgroups
  - No Stratification needed
  - CTWs and non-CTWs
  - Subcontractors vs. non-Subcontractors (all DuPont)

SRS Coworker Models – Stratification cont.

- We have demonstrated that we can stratify
  - *Do we need to stratify?*
    - *Please note, NIOSH's preference is to not stratify*

- ***Can we postpone the stratification discussion for later during the Comment/Resolution time on the agenda?***
  - *Applicability of the methods to SRS CTWs and subcontractors is the subject of ORAUT-RPRT-0092 scheduled for discussion later*

SRS Coworker Models - Example

- Let us determine whether we can agree on the basic elements of the coworker evaluation methodology and how we have implemented it for a non controversial population (non-CTWs)
- *Why?* We have several coworker models under development
  - Idaho National Laboratory
  - Fernald
  - Additional sites need updated to use the TWOPOS methodology
- If we need to change something in the criteria or the implementation method, we should do so now

SRS Coworker Models – Data Needs

- ORAUT-OTIB-0018 bounding approach actually takes care of a large number of the claimants who would need a coworker model
- Goal is to supplement ORAUT-OTIB-0018 with a best estimate coworker model
- Need coworker model for all major radionuclides at SRS

SRS Coworker Models – Radionuclides

4.1 Americium/Curium/Californium (Trivalent radionuclides)

4.2 Tritium

4.3 Plutonium

4.4 Uranium

4.5 Fission Products (Strontium)

4.6 Cobalt-60

4.7 Cs-137

4.8 Neptunium

4.9 Thorium

Individual Radionuclide Discussion / Format Closely Follows Coworker Implementation Guide Criteria

- Data Adequacy
  - Discussion of Personnel Monitoring
  - Applicability to Unmonitored Workers
  - Bioassay Analysis Technique
- Data Validation
  - Data Completeness and Quality
  - Data Interpretation
  - Data Exclusion

Individual Radionuclide Discussion / Format Closely Follows Coworker Implementation Guide Criteria – cont.

- Statistical Analysis
  - Development of the TWOPOS
- Intake modeling
  - Fitting TWOPOS bioassay distribution in IMBA to obtain intakes

SRS Plutonium Coworker Models – Data Adequacy

- Personnel Monitoring (who was monitored)
  - Bioassay Control procedures starting in 1968 (attachment C) identify types of workers and frequency of monitoring within specific areas
  - *Construction Trades Workers monitored every 3 years*
- Applicability to Unmonitored Workers
  - Number of workers monitored relatively constant over time
  - No temporal gaps in data
  - Workers with highest exposure potential monitored more frequently

SRS Pu Coworker Models – Personnel Monitoring

ATTACHMENT C
BIOASSAY DATA TYPES AND FREQUENCIES (continued)

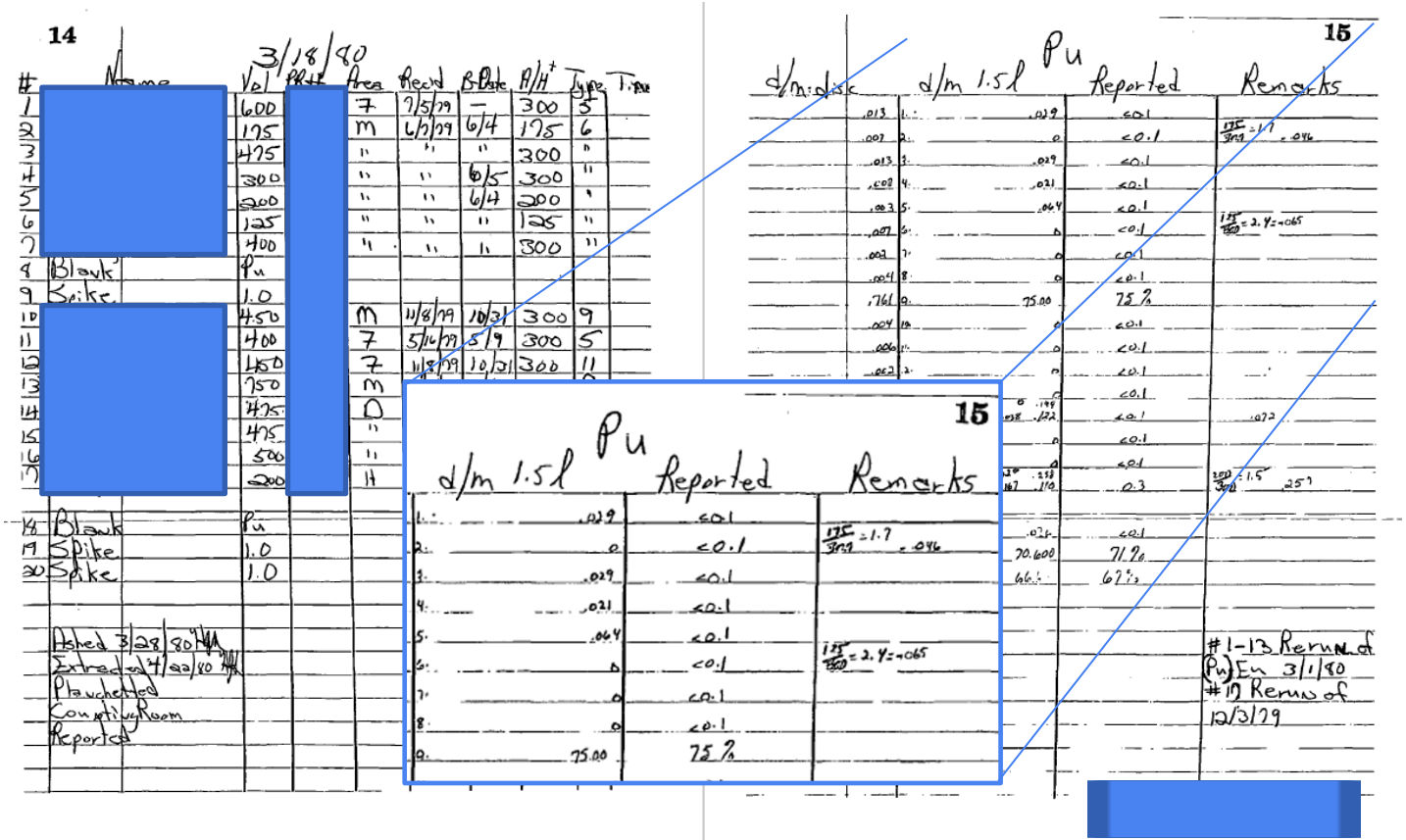
Table C-6. 1976 bioassay frequencies (samples per year or counts per year by analysis type) (DuPont 1976).[a]

Personnel work assignment	Pu samples	EU samples	U samples	IA/FP samples	Am/Cm/Cf samples	Sr samples	H3 samples	FP samples	Days counts	Shift counts
Minimum Potential. Personnel working in tritium facilities, 200-FH facilities not mentioned below, 723-A (EED), and 305-M. Selected 100-Area and 773-A personnel.	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	(b)	N/A	1 ea. 3 yr[c]	1 ea. 3 yr
221-FH. All operators, Separations Technology, HP, and 4th-Level personnel; E&I, Maintenance, Clerical, and Service Department personnel assigned to process areas. **241-FH, 211-FH, 723-F, A-Line, 643-G & 244-H.** All assigned personnel. **772-F & 235-F.** Personnel assigned to nonprocess areas. **Patrol & T&T.** All personnel assigned to 200-FH Areas. **773-A.** Selected clerical and supervisory personnel. 100-Areas. Selected personnel.	1	(d)	(e)	N/A	(f)	(g)	N/A	N/A	1	2
221-HB Line, 221-FB Line, JB-Line. All assigned personnel. **235-F.** Personnel assigned to process areas. **772-F.** Personnel assigned to process areas. **773-A.** Selected ACD, SED, SCD, NMD, HLC, Radiation Control, Building Services, and Maintenance personnel.	4	(d)	N/A	N/A	(f)	N/A	N/A	(c)	1[h]	2
313-M. All assigned personnel.	N/A	N/A	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
322-M & 772-F (UO_3 Section). All assigned personnel. **320-M.** All laboratory and selected radioactive material personnel. **773-A.** Reactor Engineering and 777-M personnel.	1 ea. 3 yr	1	4	N/A	N/A	N/A	N/A	N/A	(i)	(i)
321-M. All assigned personnel except those in Casting Area.	1	4	N/A	N/A	N/A	N/A	N/A	N/A	1 ea. 3 yr	1

SRS Pu Coworker Models – Analysis Method

- Bioassay Analysis Techniques
  - 1954 bismuth phosphate and lanthanum fluoride coprecipitation
  - 1959 nitric acid/hydrogen peroxide dissolution and ion exchange
  - 1966 tri-iso-octylamine (TIOA) liquid extraction
  - 1981 coprecipitation technique with alpha spectrometry
- Reporting / Censoring Level = 0.1 dpm/day
  - ***(This is a reporting level NOT necessarily the LOD or the MDA)***

Plutonium Logbooks – Censored Data (SRDB# 51887)

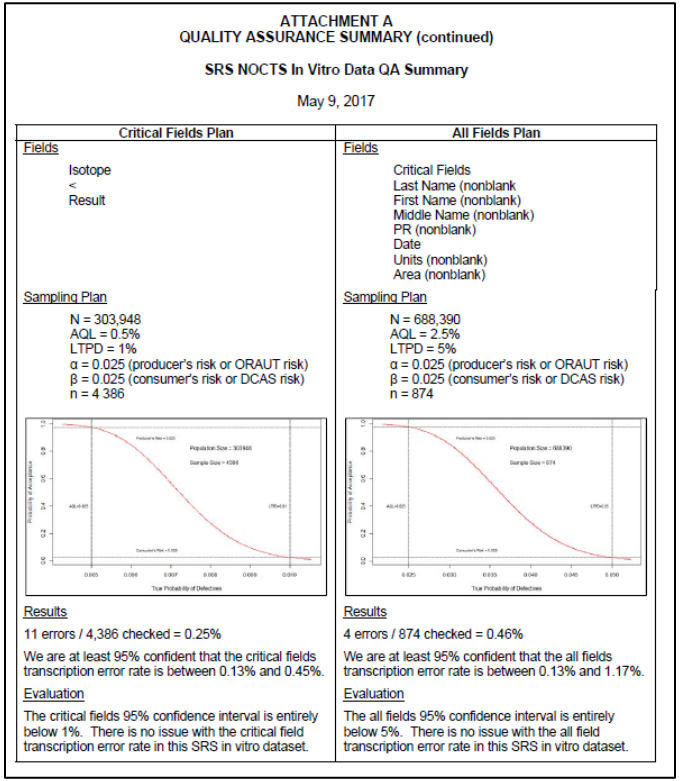


SRS Pu Coworker Models – Data Interpretation

- Most measurements were gross alpha
- During the 1980s ^{238}Pu and ^{239}Pu reported separately
  - Merged into gross alpha, assumed to be 12% 10-year aged plutonium (chosen to be claimant favorable)
- Data exclusions
  - Chelation or indication of DTPA use
  - LIP (lost in process) samples
  - Insufficient identifying information
  - Samples given per unit mass (likely fecal samples)

SRS Plutonium Coworker Models – Data Validation

- NOCTS In Vitro Dataset
  - (which contains Pu, U, EU, FP)
- Critical Fields (1%)
  - Isotope, “<“, and Result
  - 11 errors / 4386 checked = 0.25% (0.13%-0.45%)
- All Fields (5%)
  - Last Name, First Name, Middle Name, Payroll ID, Date, Units, Area
  - 4 errors / 874 checked = 0.46% (0.13%-1.17%)



ATTACHMENT A
QUALITY ASSURANCE SUMMARY (continued)

SRS NOCTS In Vitro Data QA Summary

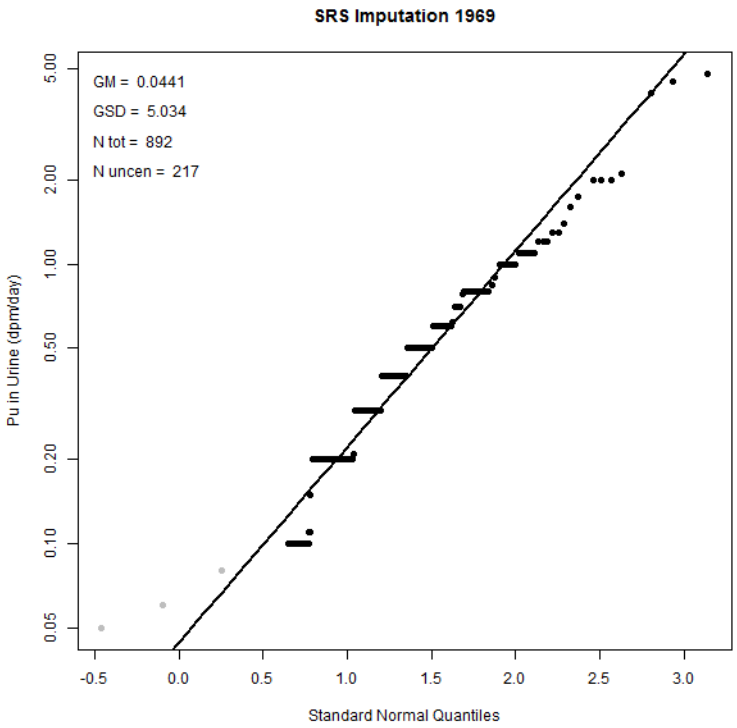
May 9, 2017

Critical Fields Plan	All Fields Plan
Fields Isotope < Result	Fields Critical Fields Last Name (nonblank) First Name (nonblank) Middle Name (nonblank) PR (nonblank) Date Units (nonblank) Area (nonblank)
Sampling Plan N = 303,948 AQL = 0.5% LTPD = 1% α = 0.025 (producer's risk or ORAUT risk) β = 0.025 (consumer's risk or DCAS risk) n = 4 386	Sampling Plan N = 688,390 AQL = 2.5% LTPD = 5% α = 0.025 (producer's risk or ORAUT risk) β = 0.025 (consumer's risk or DCAS risk) n = 874
Results 11 errors / 4,386 checked = 0.25% We are at least 95% confident that the critical fields transcription error rate is between 0.13% and 0.45%.	Results 4 errors / 874 checked = 0.46% We are at least 95% confident that the all fields transcription error rate is between 0.13% and 1.17%.
Evaluation The critical fields 95% confidence interval is entirely below 1%. There is no issue with the critical field transcription error rate in this SRS in vitro dataset.	Evaluation The all fields 95% confidence interval is entirely below 5%. There is no issue with the all field transcription error rate in this SRS in vitro dataset.

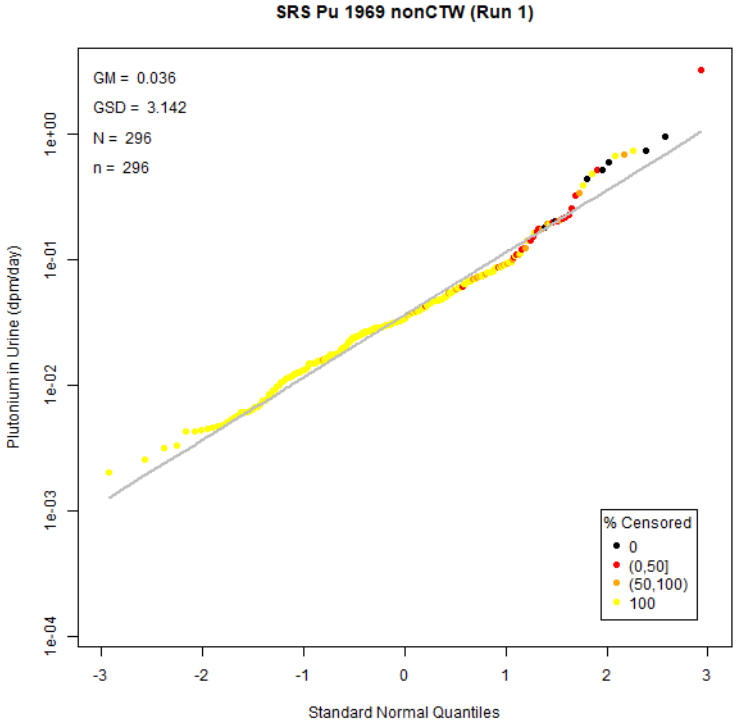
Statistical Analysis

- *Time-Weighted* One Person One Statistic (TWOPOS) Methodology
  - *ORAUT-RPRT-0053, Analysis of Stratified Coworker Datasets*
  - TWOPOS data are fit to lognormal distributions during the statistical analysis
- ***Most*** of the bioassay data is censored (data reported as "less than" some value)
  - Analysis method uses multiple imputation for censored data
  - *ORAUT-RPRT-0096, Multiple Imputation Applied to Bioassay Coworker Models*

Multiple Imputation Methodology

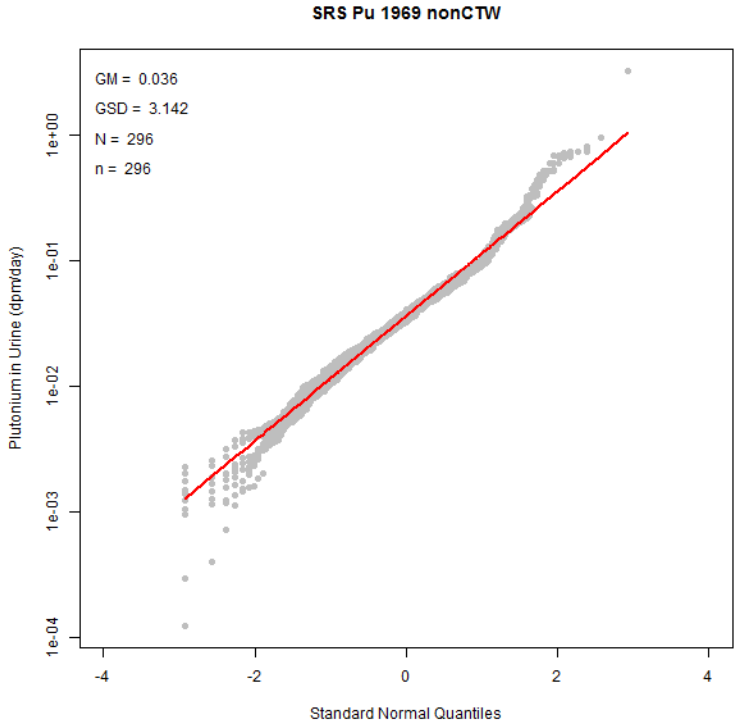


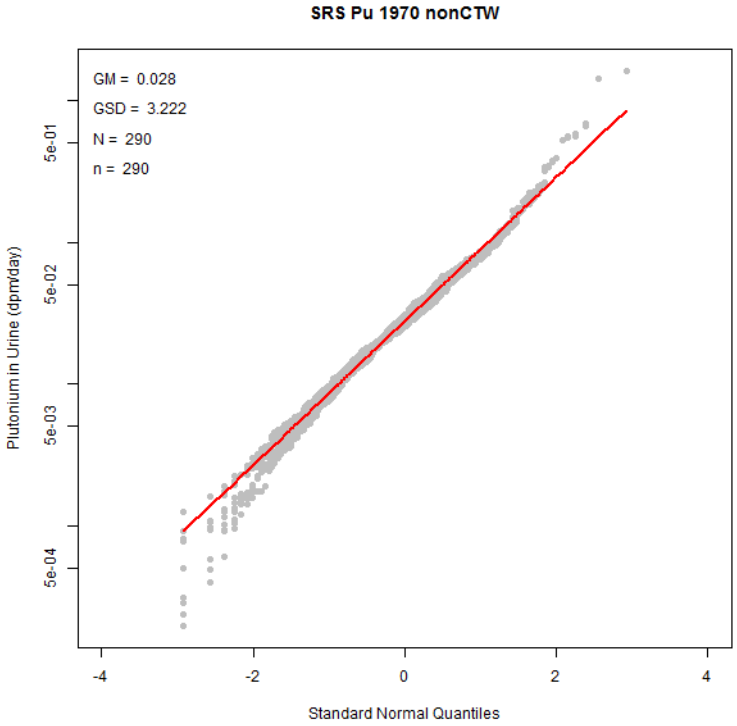
1969 Imputation Model



1969 First TWOPOS Imputation

TWOPOS Pu Plots – After Multiple Imputation





Statistical Analysis

Example from Table 4-4. Calculated 50th- and 84th-percentile urinary excretion rates of plutonium based on a lognormal fit to the TWOPOS data, 1955 to 1990 (dpm/d).

Year	non-CTW 50th percentile	non-CTW 84th percentile	non-CTW GSD	non-CTW # of individuals	CTW 50th percentile	CTW 84th percentile	CTW GSD	CTW # of individuals
1967	0.00629	0.0387	6.14	358	0.00375	0.0263	7.00	152
1968	0.01186	0.0608	5.13	414	0.00957	0.0530	5.54	146
1969	0.03617	0.1136	3.14	296	0.03434	0.1188	3.46	108
1970	0.02776	0.0894	3.22	290	0.02591	0.0872	3.37	98

Basic Steps of Coworker Intake Model Development

- Intake modeling for each of the nine radionuclide categories
  - 50^{th} and 84^{th} percentiles for each year and solubility type are used for intake modeling
  - Selection of time intervals of similar results
    - *Internal Dosimetry professional judgement*
  - Assume a chronic intake scenario for each time interval to determine intake

SRS Plutonium Intake Modeling – Time Interval #1

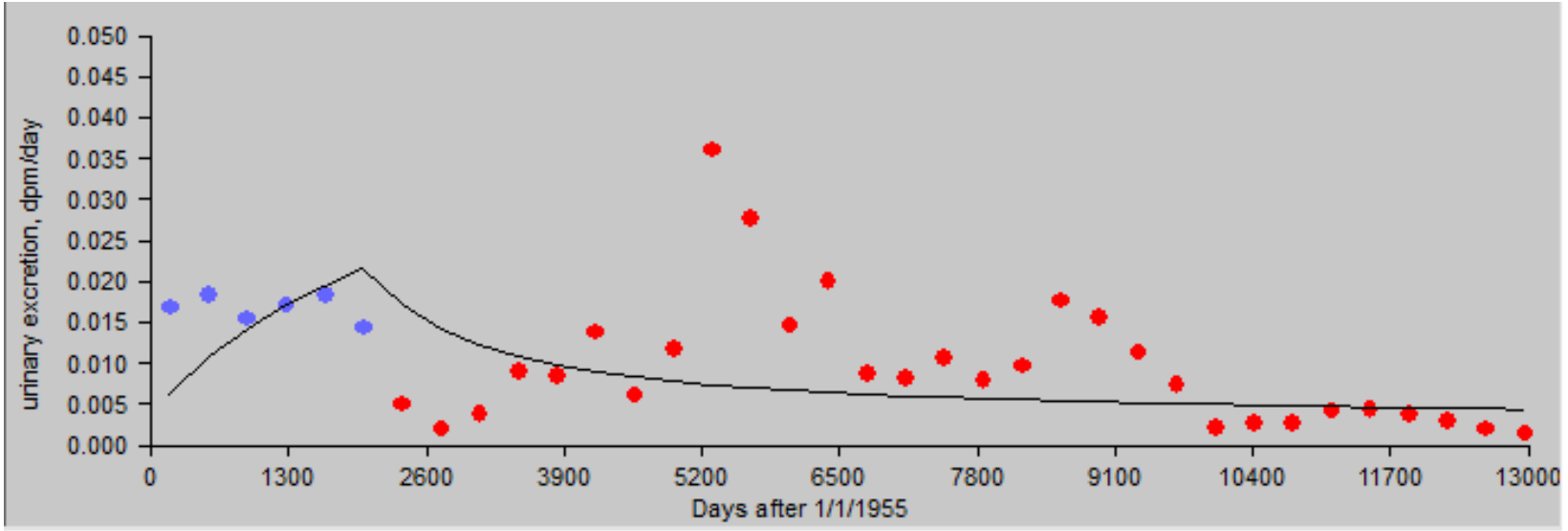


Figure F-17. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, non-CTW 1955 to 1960, type M.

SRS Plutonium Intake Modeling – Time Interval #2

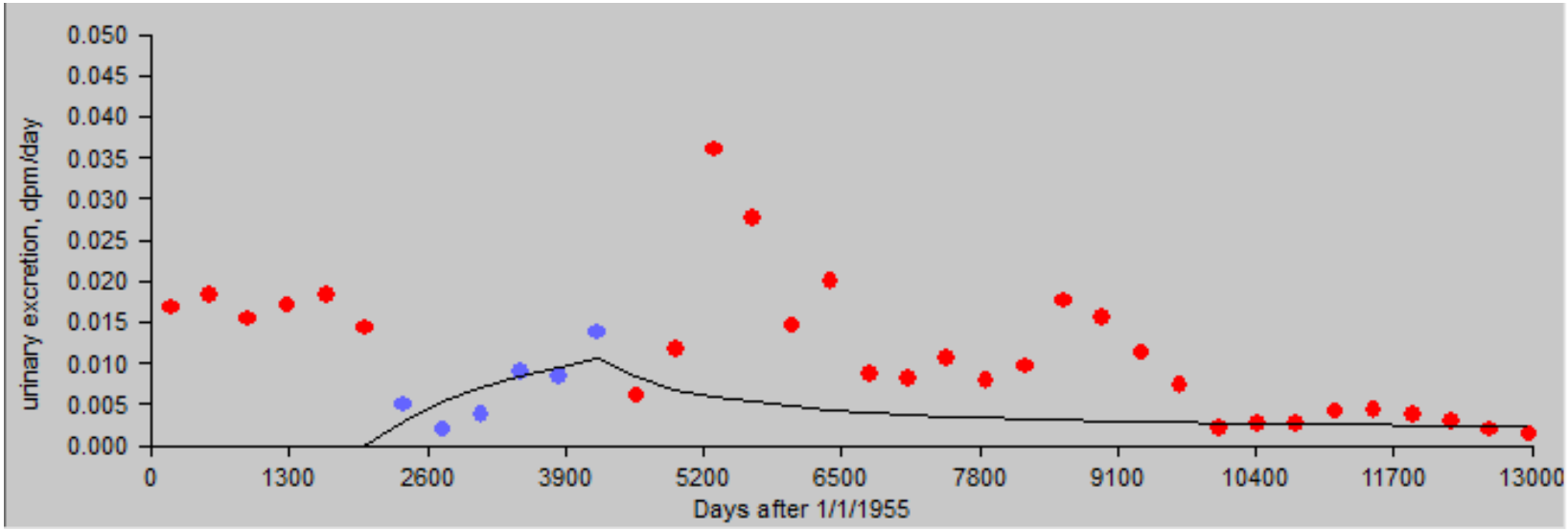


Figure F-18. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, non-CTW 1961 to 1966, type M.

SRS Plutonium Intake Modeling – Time Interval #3

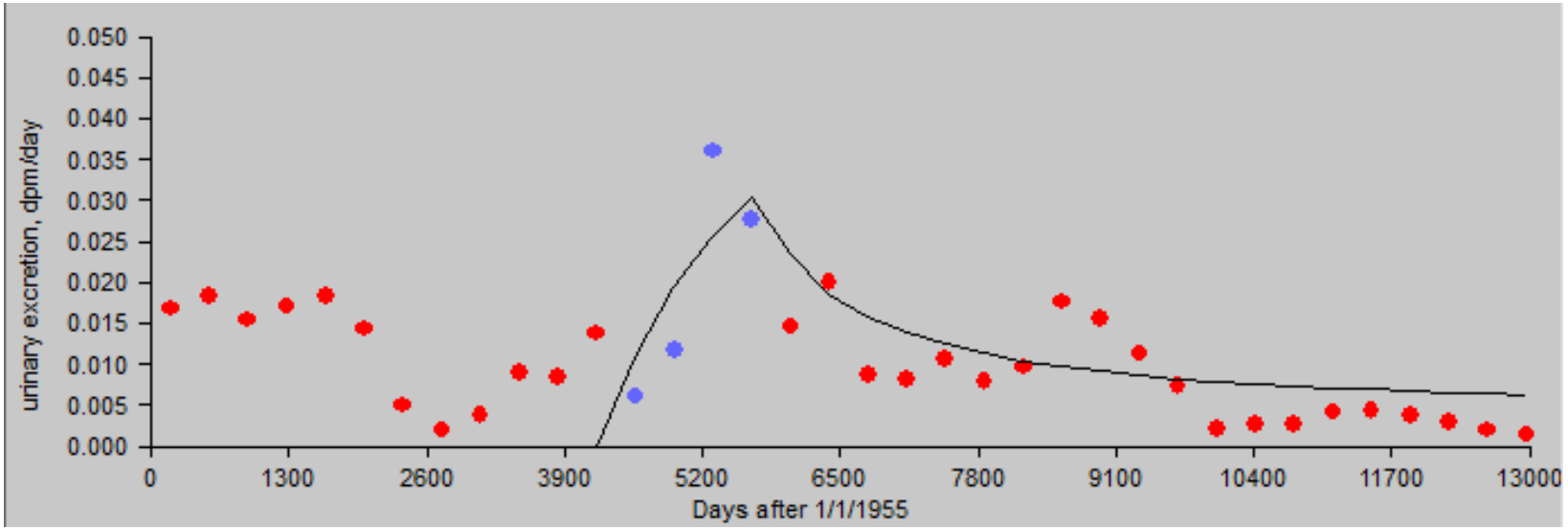


Figure F-19. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, non-CTW 1967 to 1970, type M.

SRS Plutonium Intake Modeling – Time Interval #4

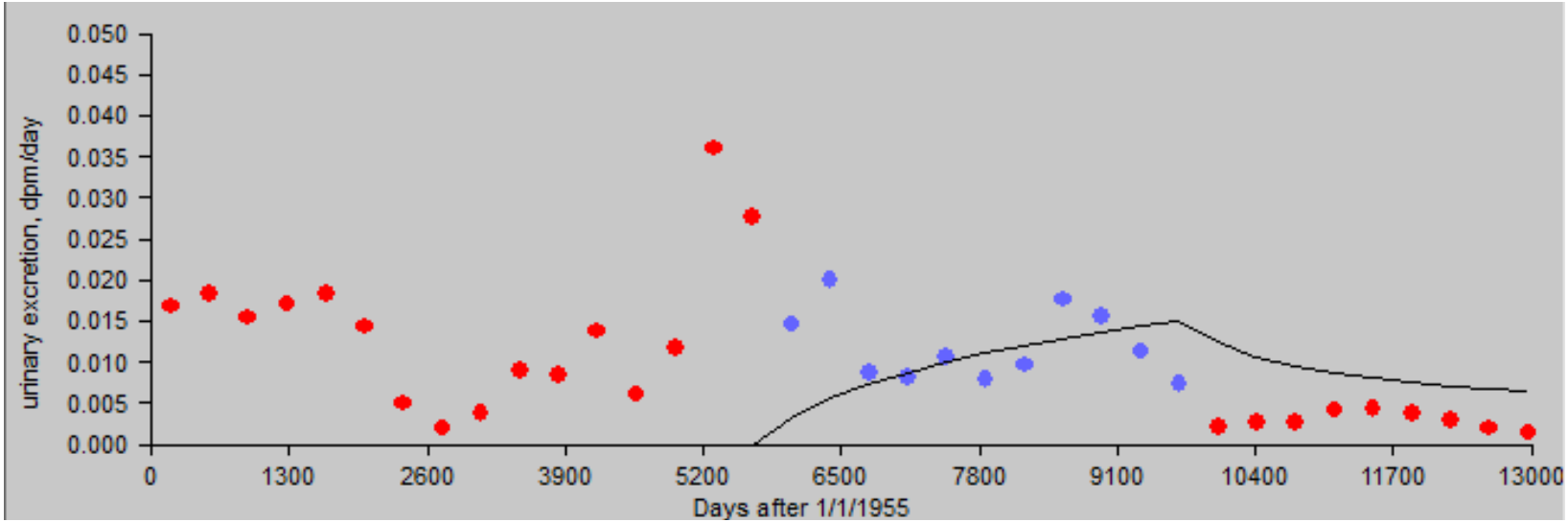


Figure F-20. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, non-CTW 1971 to 1981, type M.

SRS Plutonium Intake Modeling – Time Interval #5

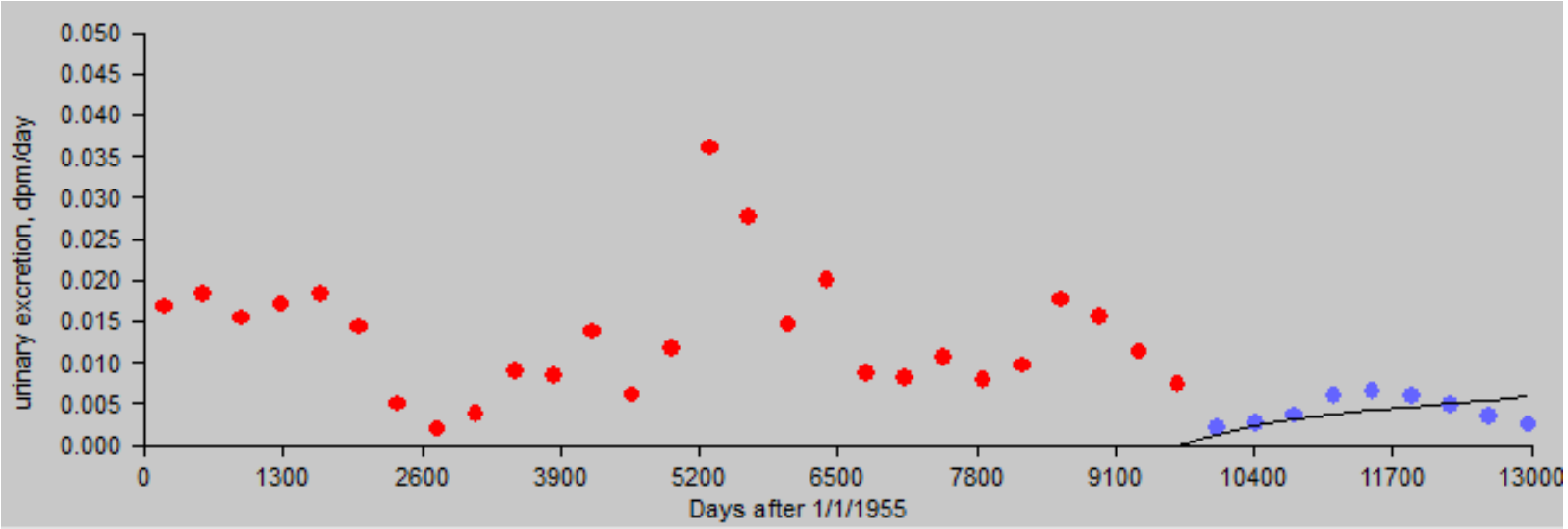


Figure F-21. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, non-CTW 1982 to 1990, type M.

Complete SRS Coworker Plutonium Intake Model

Table F-3. Summary of plutonium non-CTW intake rates (dpm/d) and dates, type M.

Start	End	50th percentile	84th percentile	GSD	Adjusted GSD	95th percentile
01/01/1955	12/31/1960	3.265	9.742	2.98	3.00	19.90
01/01/1961	12/31/1966	1.606	6.453	4.02	4.02	15.83
01/01/1967	12/31/1970	5.778	20.170	3.49	3.49	45.17
01/01/1971	12/31/1981	1.692	7.678	4.54	4.54	20.37
01/01/1982	12/31/1990	0.724	5.03	6.94	6.94	17.5

SRS Plutonium Intake Modeling – Full Interval

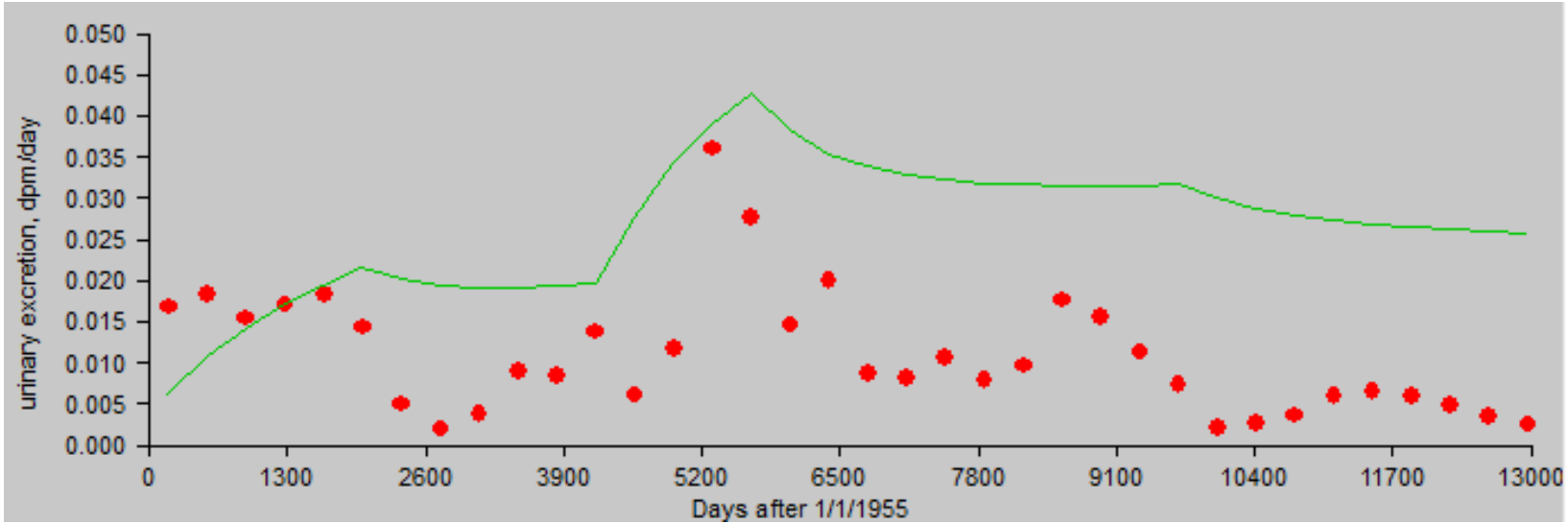


Figure F-57. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), non-CTW 50th percentile, all years, type M.

SRS Plutonium Intake Modeling – Full Interval

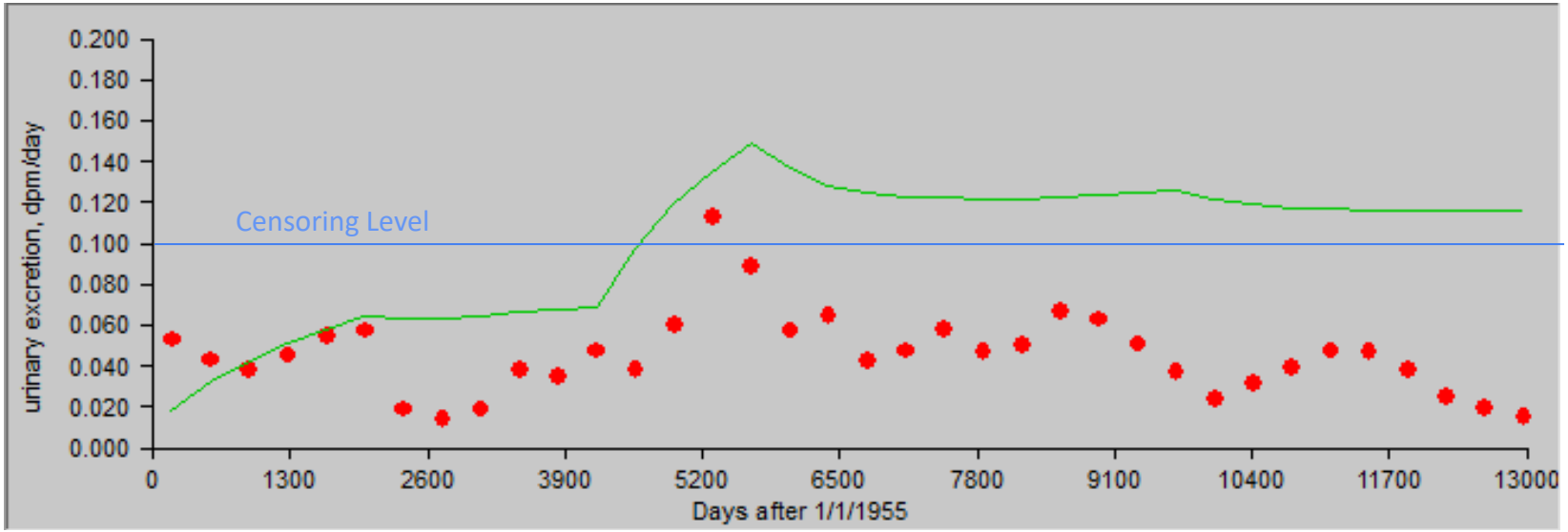


Figure F-58. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), non-CTW 84th percentile, all years, type M.

SRS Plutonium Intake Modeling – Full Interval

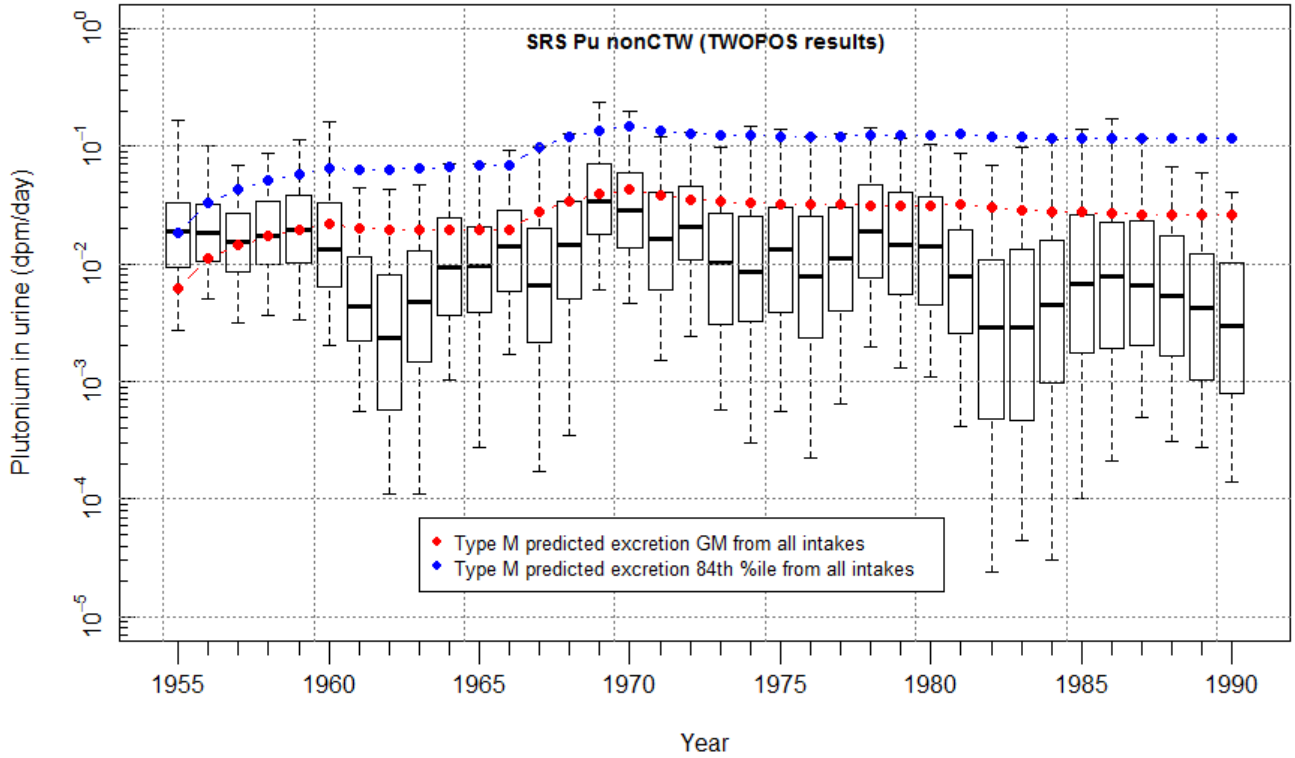
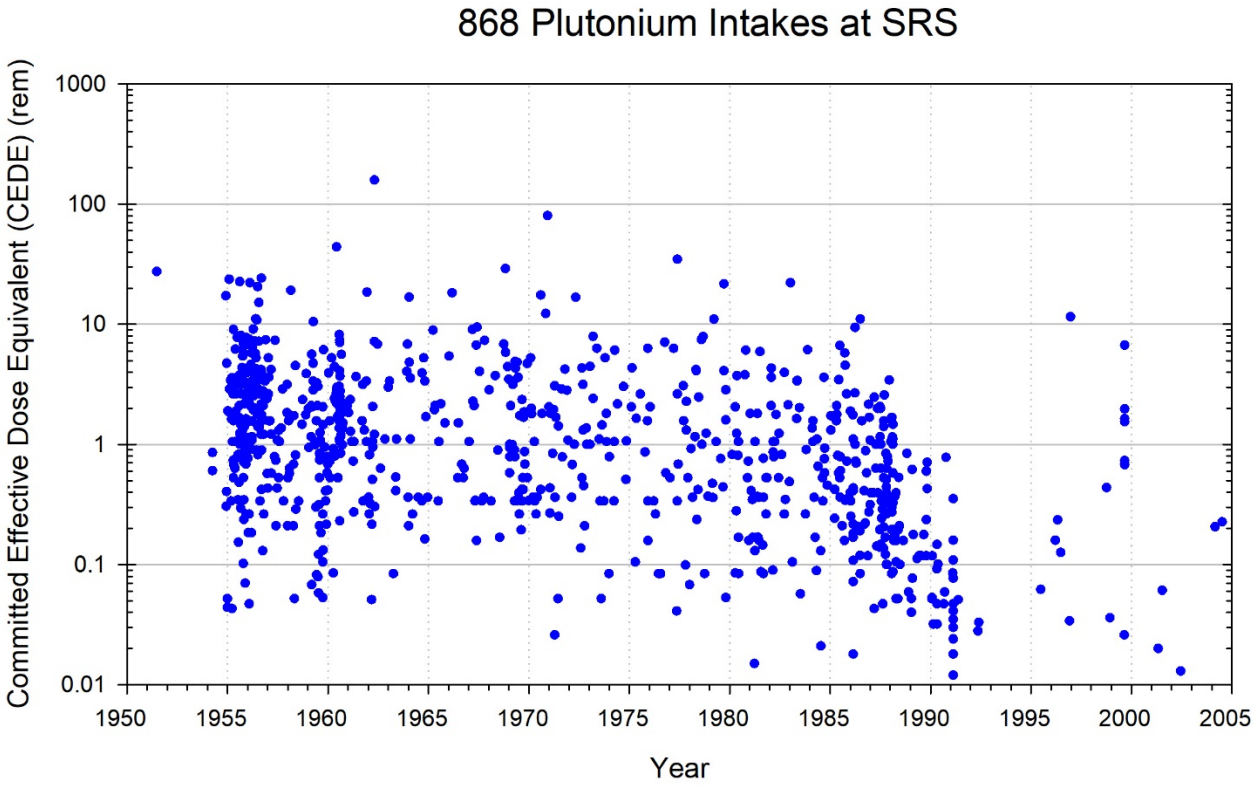
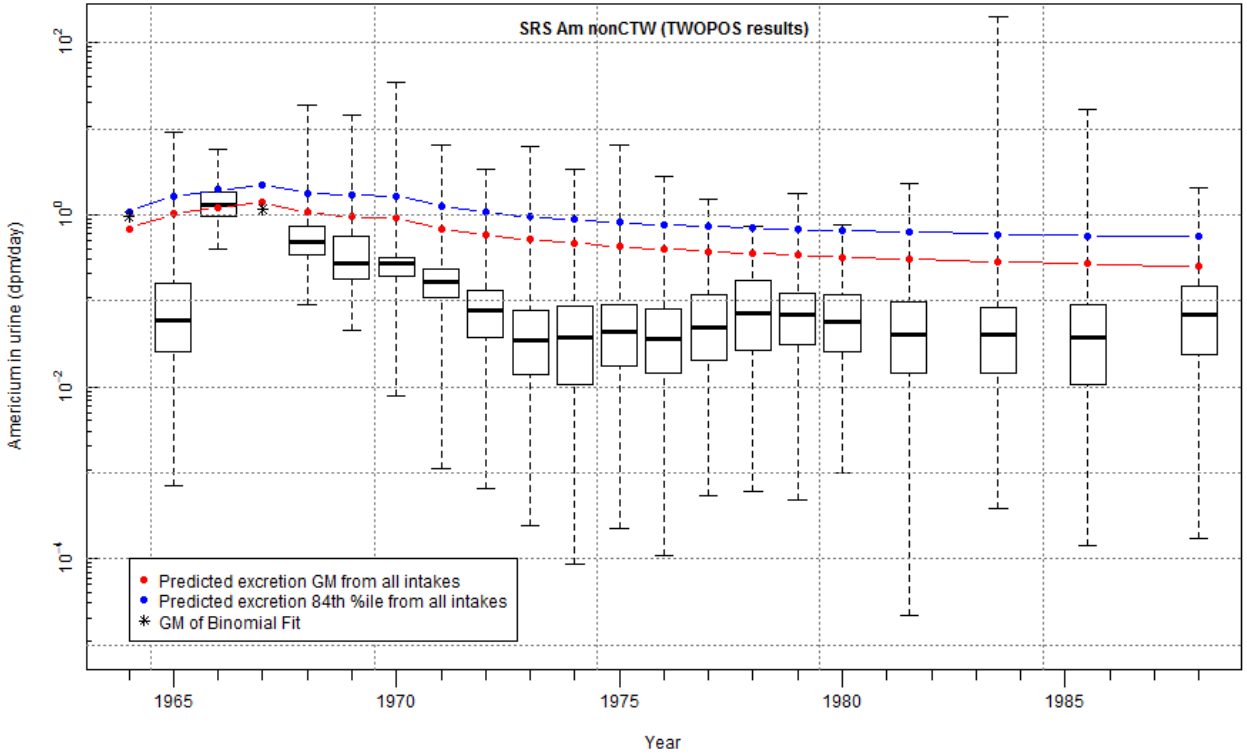


Figure 4-7. Plutonium type M non-CTW TWOPOS data box and whisker plot beginning in 1955.

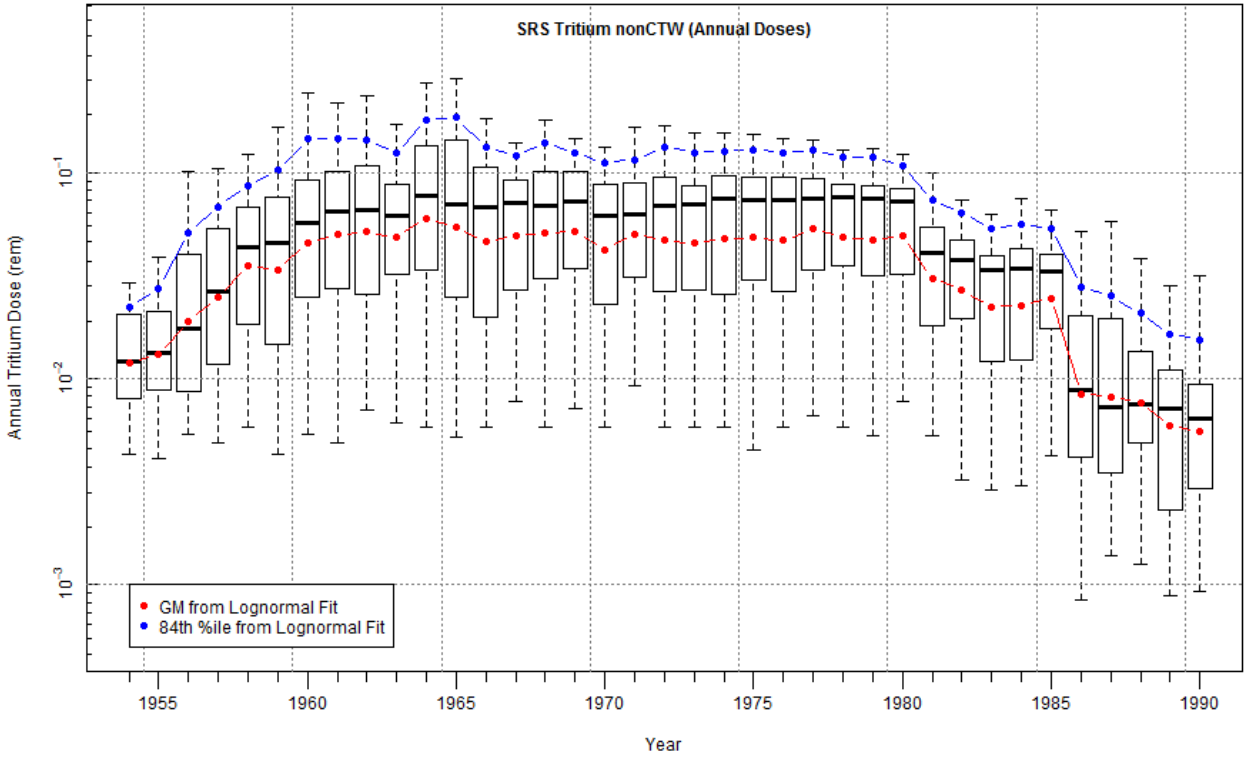
SRS Plutonium Intakes – Site Data



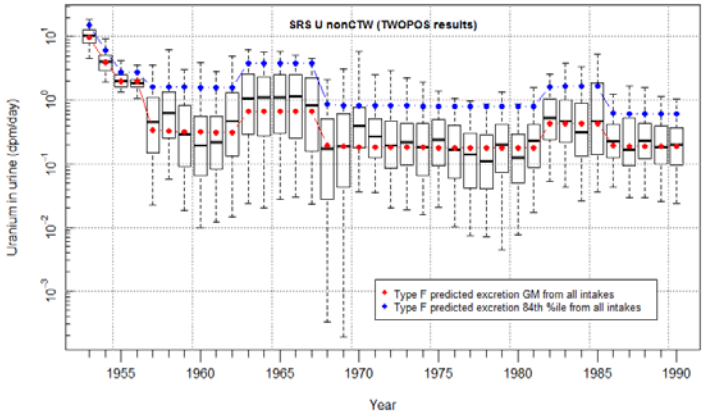
Americium Intake Results



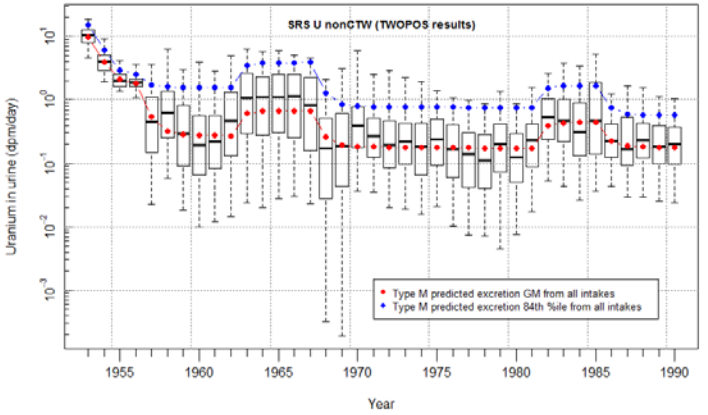
Tritium Dose Results



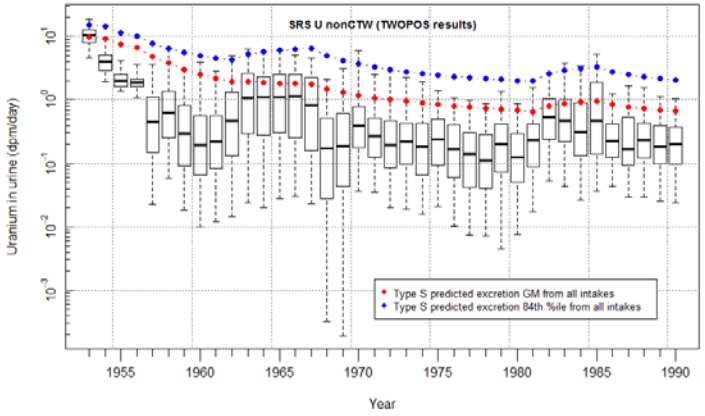
Uranium Intake Results



Type F

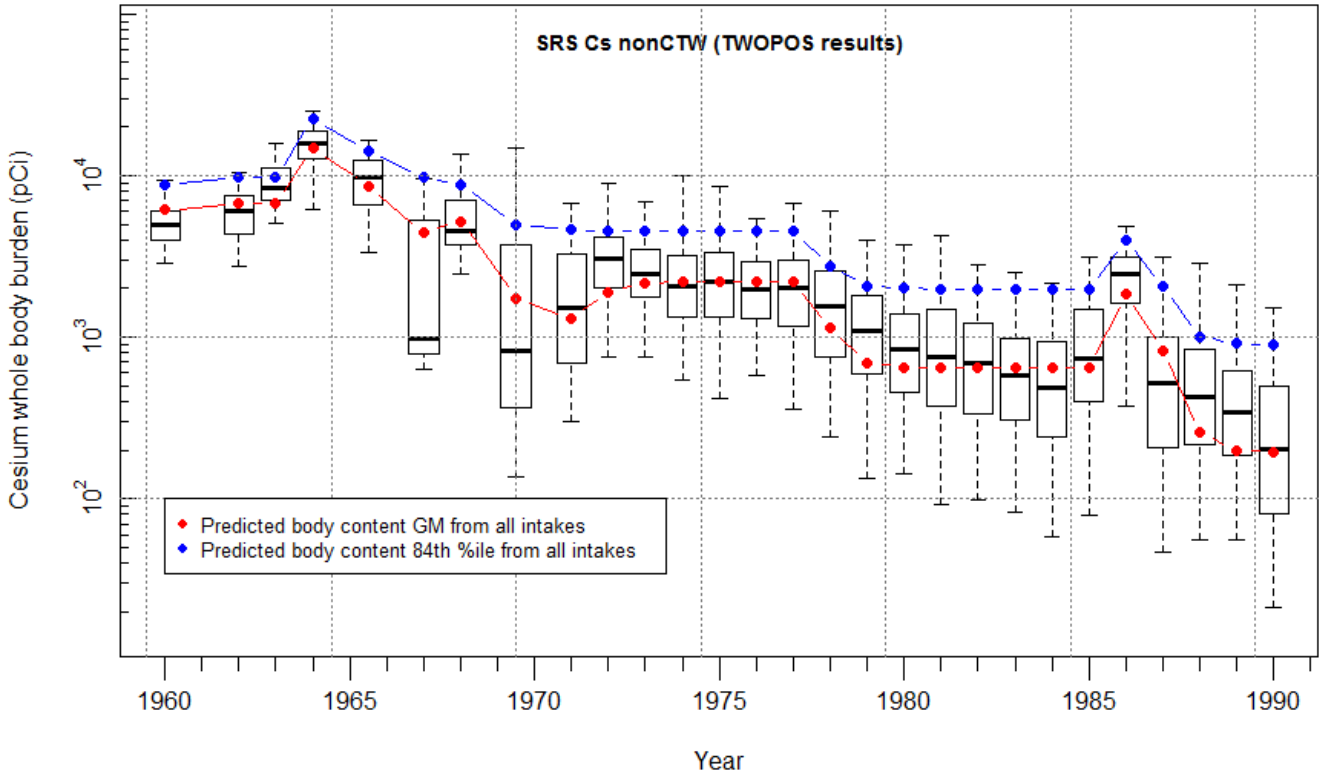


Type M

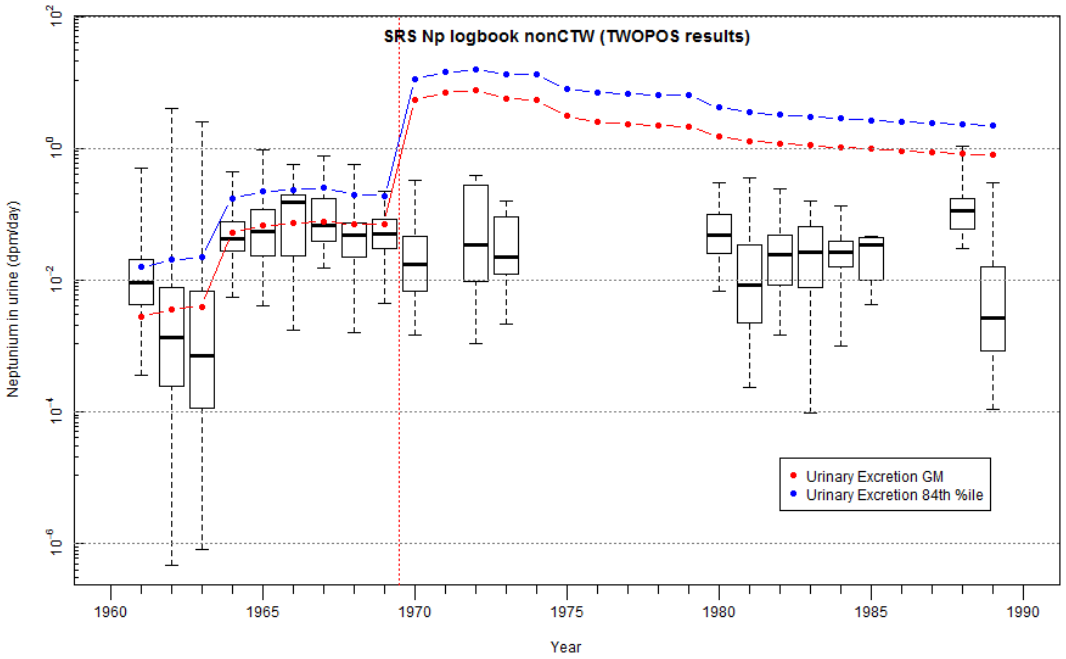


Type S

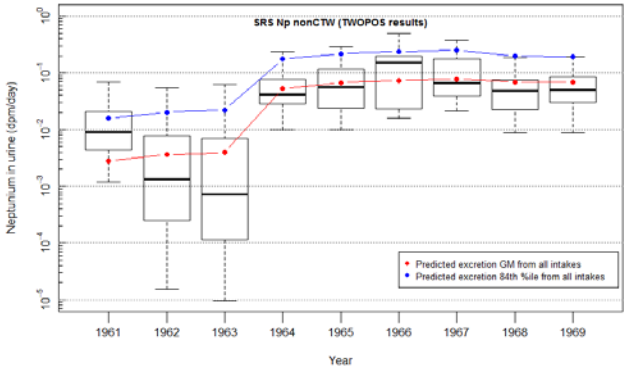
Cesium Intake Results



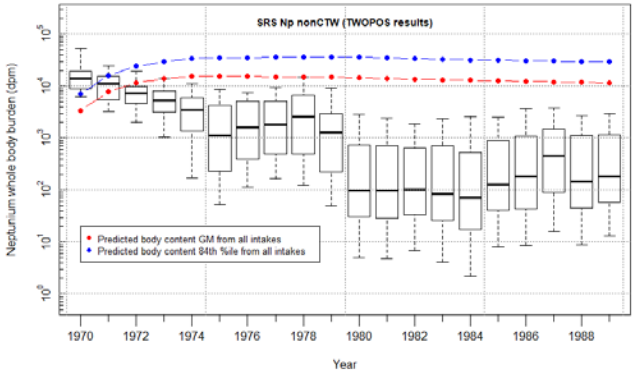
Neptunium Intake Results



urinalysis



Whole Body Count



4 Major Analysis Steps and Application

1
Individual Bioassay Quality Assurance

2
Individual TWOPOS Calculation

3
TWOPOS Lognormal Distribution Fit

4
Intake Modeling 50th and 84th percentiles

5
Application to unmonitored worker

Data-Averaging in Coworker Model Development

1. Individual results can be averages of multiple counts
2. Bioassay results for an individual worker are averaged into a single Time-Weighted One Person One Statistic (TWOPOS) value for the given year
3. TWOPOS results are fit to a lognormal distribution
4. TWOPOS 50^{th} and 84^{th} percentiles are fit in IMBA to develop the intake rate
   - Intake lognormal distribution (GSD) determined based on 50^{th} and 84^{th} percentiles intake rates

Application of Coworker Models to Unmonitored Workers

- Normally, the 50th percentile with full lognormal distribution will be assigned to workers who may have been exposed to greater than environmental levels but less than a typical operations worker
- Workers considered to have a high potential for exposure may be assigned the 95th percentile of the coworker distribution on a case by case basis as determined by the Dose Reconstructors *(Professional Judgement)*

Summary

- This example coworker model demonstrates how the Draft Criteria for the Evaluation and Use of Coworker Datasets will be implemented
  - NIOSH believes the intent of the Draft Criteria for the Evaluation and Use of Coworker Datasets has been met
  - NIOSH believes the coworker models presented are claimant friendly, reasonable, and adequately bound the potential doses for compensation purposes