



Multiple Imputation use in Co-exposure models - *A brief primer*

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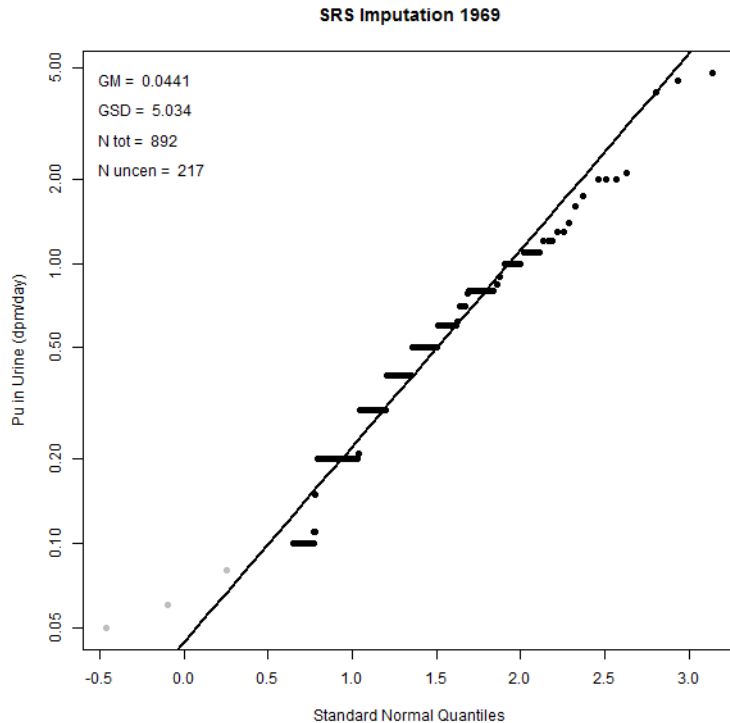
Multiple Imputation

- Multiple imputation is a better and more statistically appropriate method for estimating censored data compared to the LOD/2 method
- As the Dose Reconstruction program evolves, new and more robust statistical methods can and should be expected to replace initial methods and assumptions
- It is well known that both external dosimetry data and bioassay data tend to follow lognormal distributions

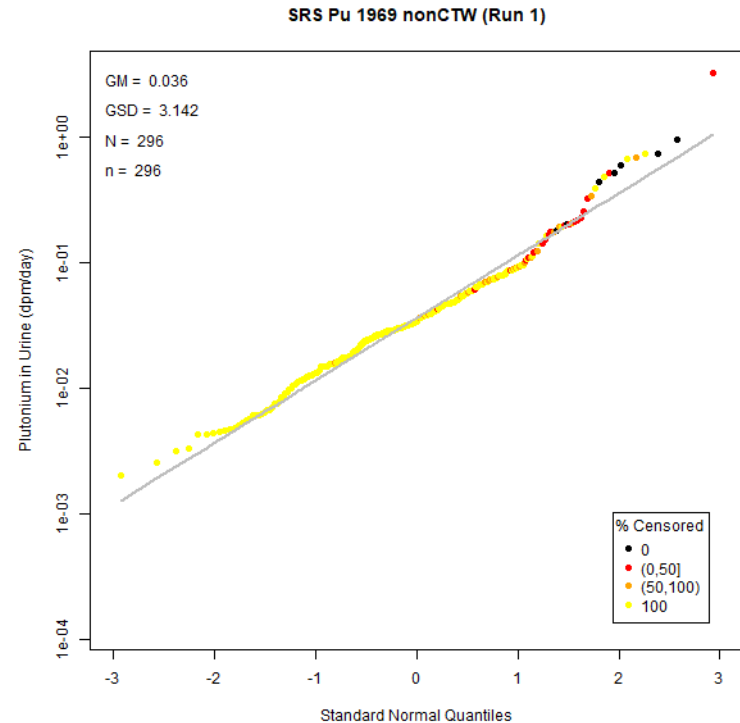
Multiple Imputation Method

1. Regression on Order Statistics (ROS) of all the bioassay data for a given year, thus creating an *Imputation model*
2. Use the imputation model to estimate/replace the censored data for an individual's data that are censored
3. Calculate Time-Weighted One Person One Statistic (TWOPOS) using the individual's data which can be a combination of uncensored and imputed data
4. Repeat the process for each individual for a given year to obtain the first TWOPOS Imputation
5. Repeat Steps 2 through 4 for the second and subsequent TWOPOS Imputations

Multiple Imputation Methodology

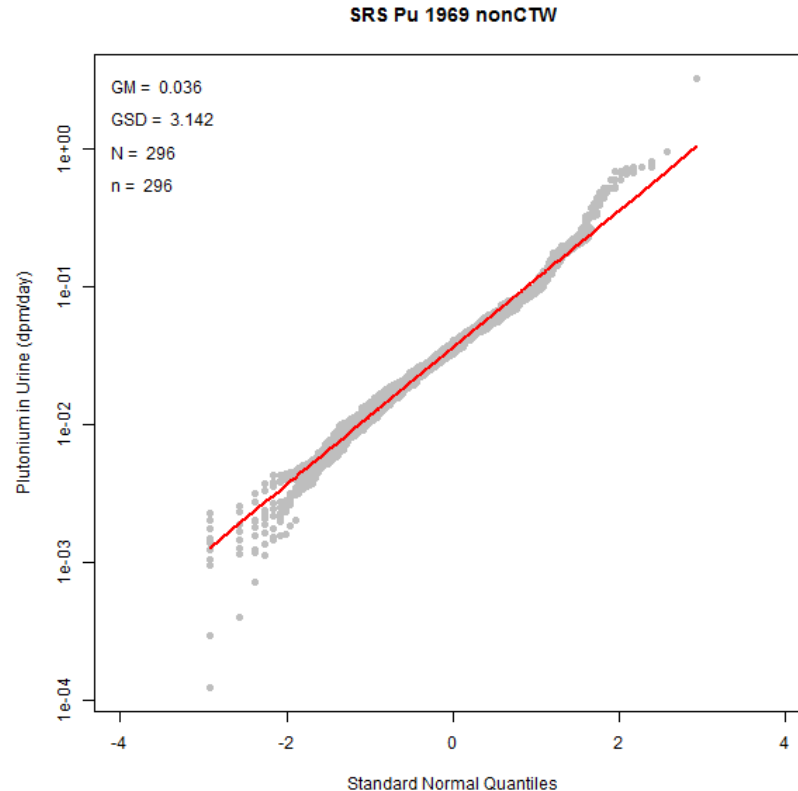


1969 Imputation Model



1969 First TWOPOS Imputation

TWOPOS Pu Plots – After Multiple Imputation



Statistical Analysis – TWOPOS Data

Example from Table 4-4. Calculated 50th- and 84th-percentile urinary excretion rates of plutonium based on a lognormal fit to the **TWOPOS** data, 1967 to 1970 (dpm/d).

Year	non-CTW 50 th percentile	non-CTW 84 th percentile	non-CTW GSD	non-CTW # of individuals	CTW 50 th percentile	CTW 84 th 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

SRS Plutonium Intake Modeling – Time Interval #3

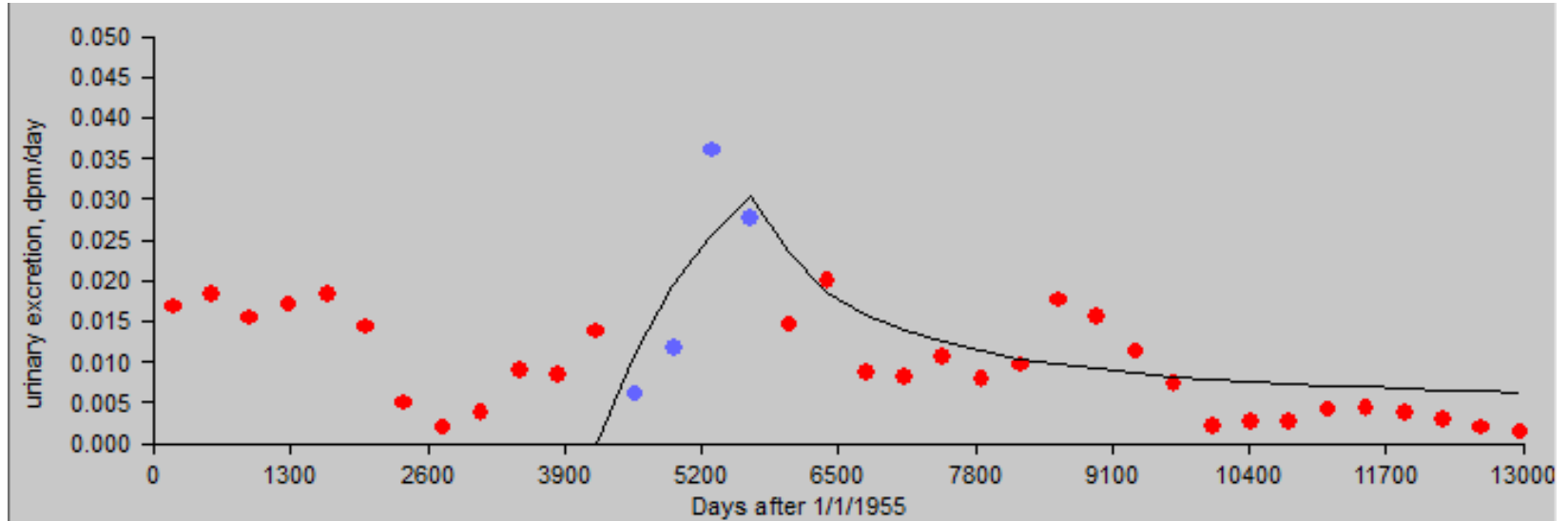


Figure F-19. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, non-CTW 1967 to 1970, type M.

Complete SRS Co-exposure Plutonium Intake Model

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

Start	End	50 th percentile	84 th percentile	GSD	Adjusted GSD	95 th 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

Application of Co-exposure 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 co-exposure distribution on a case-by-case basis as determined by the Dose Reconstructors (*Professional Judgement*)