An Updated Evaluation of data from the 1980 Statistical Analysis of Plutonium in U.S. Autopsy tissue

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INTRODUCTION

In a 1980 paper and 1979 paper in the Health Physics Journal, T. Fox et.al. and McInroy et.al. analyzed the results from tissues of approximately 900 individuals from various regions in the United States. The objective was to determine the level of Plutonium-239 in these tissues due to global fall-out from weapons testing. A comparison was made between 7 regions, including non-worker residents in the vicinity of Los Alamos National Laboratory (LANL). It was concluded that there were "no regional differences in plutonium concentrations in the vertebrae…with small differences in other tissues". This study discusses a re-evaluation of the data from the Fox study. A regrouping of the residents living near LANL into pre and post 1960 sample groups, a reassessment of excluded outliers and a calculation of liver to bone ratios of plutonium will be evaluated to examine the hypothesis that higher concentrations of Pu-239 are present in residents living near LANL in the 1945-60 time frame.

BACKGROUND

The human tissue analysis program was a 35-year effort by LANL to study the levels of plutonium in workers and in the general population of the United states. The general population was exposed to plutonium from atmospheric testing of nuclear weapons occurring predominately in the early1960's. Autopsy data was collected from 7 regions in the US: Los Alamos New Mexico, the rest of New Mexico, Colorado, New York, Pennsylvania, Illinois and Georgia.

The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) Project is attempting to prioritize off-site releases from LANL. This effort appears to indicate that plutonium releases from LANL were highest in the 1940's and 1950's. Thus, dividing the Los Alamos residents into two groups, pre and post 1960 Los Alamos arrival times, may provide a more viable picture of the plutonium deposition during this time.

This calculation attempts to demonstrate that excess plutonium may be present in non-worker residents living in Los Alamos in the pre-1960 period over what would be expected from global fallout from nuclear weapons testing. The data analyzed by LANL demonstrated that the differences between US states in the median values of plutonium concentration in tissue were small. However, the autopsy results from deaths at the Los Alamos Medical Center (designated as either Los Alamos residents or residents of Northern New Mexico) were generally the highest values for nearly all organs, as compared to other states.

HYPOTHESES

Hypothesis #1 - *Null:* Pu-239 in vertebrae, liver and lung tissues of residents living near LANL in the 1948 to 60 time frame will be similar to those residents living near LANL who arrived after 1960. *Alternate:* The concentration of Pu-239 in vertebrae, liver and lung tissues of residents living near LANL in the 1948 to 60 time frame will be higher than the post 1960 sample group

Hypothesis #2 – *Null:* Residents living near LANL in the 1948 to 60 time frame will demonstrate a similar "skeleton to liver" ratio of Pu-239 in their tissues when compared to the other sample groups. *Alternate:* Residents living near LANL in the 1948 through 1960 time frame will demonstrate a higher "skeleton to liver" ratio of Pu-239 in their tissues when compared to other sample groups, demonstrating that Pu-239 has been in their bodies for a longer period of time.

Hypothesis #3 – *Null:* Pu-239 in tissues of the pre-1960 residents living near LANL will be indistinguishable from sample groups from other regions in the United States. *Alternate:* Pu-239 in tissues of the pre-1960 residents living near LANL will be distinguishable from sample groups from other regions in the United States.

Decision Rule: These hypotheses were evaluated by calculating the level of significance using the Kruskal-Wallis test and the Mann-Whitney U-test, demonstrating a confidence level of at least 95% (α = 0.05), that the null hypothesis will be rejected.

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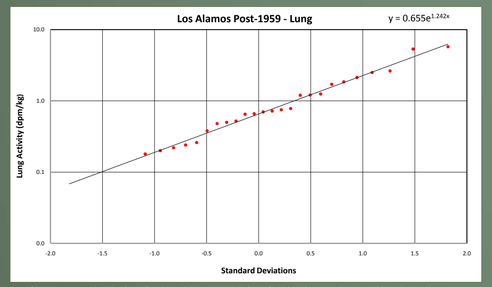

Figure 1. CFD Graph of median lung tissue concentration of Pu-239 for Los Alamos residents Post-1959

Mann Whitney test:	Significance Level p-value - α = 0.05		
	Bone	Liver	Lung
Los Alamos Pre-1960 -vs- Los Alamos Post-1959	0.665	0.133	0.0006

Table 1. P-value results from the Mann Whitney test for the first hypothesis.

Median tissue concentration levels – CFD Graphs						
	Bone		Liver		Lung	
Region	Median Activity (dpm/kg)	Standard Deviation	Median Activity (dpm/kg)	Standard Deviation	Median Activity (dpm/kg)	Standard Deviation
Los Alamos Pre 1960	0.465	3.795	1.166	0.92	1.749	1.143
Los Alamos Post 1959	0.509	1.823	2.164	1.736	0.655	1.242

Table 2. Median tissue concentration levels of Pu-239 for bone, liver and lung generated by the cumulative frequency distribution graphs.

	Median Values for Bone/Liver Ratios - CFD Graphs	
Region	Ratio	Standard Deviation
Los Alamos Pre 1960	5.220	1.944
Los Alamos Post 1959	0.884	1.205
Colorado	1.730	1.342
Georgia	0.511	0.821
New Mexico	2.267	1.774
New York	2.481	0.761
Pennsylvania	0.442	0.986
General Population (All regions combined excluding Los Alamos Pre-1960)	1.441	1.378

Table 3. Median values for the bone/liver ratios of Pu-239 from all regions generated by the cumulative frequency distribution graphs.

MATERIALS AND METHODS

Data for the population of non-worker residents, including the 900 individuals previously mentioned was acquired from the LAHDRA project, Shonka Research associates, the McInroy study and Fox study.

The data for each region was organized into cumulative frequency distribution graphs using the NORMSINV function from Excel®. Each of these graphs are scaled in terms of median Pu-239 tissue concentration, *dpm/kg* for lung, liver and bone and the standard deviations of each set of data. All the data values are grouped from small to large then each value is assigned a rank. The NORMSINV function returns the inverse of the standard log-normal cumulative distribution. The data was transformed to a log-normal distribution to achieve normality. A trend line $y = b_0 \times \exp(b_1)$ is fitted to the rankits on the semi-log graph and b_0 and b_1 are the estimates of the median and *geometric* standard deviation of this distribution respectively (figure 1).

Graphs were created for all seven regions, including the Los Alamos Pre-1960 and Post-1959 groups; in addition, graphs were created for the General Population that included all the cities except the Los Alamos Pre-1960 group. Similar methods were also used to calculate skeleton to liver ratios for each of the sub-groups. Results for the cumulative frequency distribution graphs are listed in tables 2, 3 and 6.

All the excluded outliers in the original study were included in the data for this calculation. Data for all these regions were input into the statistical program MINITAB® (vers. 15) to perform the comparisons between each of the groups using the previously mentioned nonparametric tests. The **first hypothesis** included a comparison of Pu-239 tissue concentrations in vertebrae, liver and lung tissues of residents living near LANL in the 1945 to 1960 time frame and those living near LANL who arrived after 1960. The data for each group was inputted into Minitab utilizing the Mann-Whitney test for all three organs. The **second hypothesis** compared the skeleton to liver ratios between the LANL pre-1960 sample group and the other sample groups using the Kruskal-Wallis and Mann-Whitney tests. **The third hypothesis** was analyzed by using these same tests to compare the three organ tissues of the pre-1960 Los Alamos residents with the other sample groups.

RESULTS

Table 1 shows the results of the Mann-Whitney test for hypothesis #1. There was no significant difference of tissue concentration of Pu-239 in bone and liver tissues between the two sample groups. However, there was a significant difference between the two sample groups for lung tissue. No significant difference supports the null hypotheses and a significant difference supports the alternate hypotheses. The results for the comparison of bone/liver ratios (i.e. Hypothesis #2) are listed in table 4. The Kruskal-Wallis test compares all the sample groups together and demonstrates a significant difference. The Mann-Whitney test demonstrates a difference in bone/liver ratios between the Los Alamos pre-1960 group and the post-1959 group, the general population, Georgia and Pennsylvania. Colorado, New Mexico and New York did not demonstrate a significant difference.

Table 5 shows the results of hypothesis #3, the comparison of tissue concentrations for all regions. Kruskal-Wallis reveals a significant difference for all regions in bone and lung and no difference in liver tissue. Mann-Whitney demonstrates a difference between Los Alamos (LA) pre-1960 and all other regions in lung tissue and no difference in bone and liver for all regions with the exception of Georgia.

Kruskal Wallis test:	Significance Level p-value - α = 0.05
	Bone/Liver Ratios
Los Alamos Pre-1960, Post-1959 and other regions	0.000
Mann Whitney test:	
	Bone/Liver Ratios
Los Alamos Pre-1960 -vs- Los Alamos Post-1959	0.0183
Los Alamos Pre-1960 -vs- General Population	0.0178
Los Alamos Pre-1960 -vs- Colorado	0.0633
Los Alamos Pre-1960 -vs- Georgia	0.0014
Los Alamos Pre-1960 -vs- New Mexico	0.1919
Los Alamos Pre-1960 -vs- New York	0.5947
Los Alamos Pre-1960 -vs- Pennsylvania	0.0019

Table 4. P-value results from the Mann Whitney test and Kruskal Wallis test for the second hypothesis.

Kruskal Wallis test:	Significance Level p-value - α = 0.05		
	Bone	Liver	Lung
Los Alamos Pre-1960 , Post-1959 and other regions	0.006	0.055	0.000
Mann Whitney test:			
Los Alamos Pre-1960 -vs- General Population	0.1430	0.2027	0.000
Los Alamos Pre-1960 -vs- Colorado	0.3241	0.1322	0.000
Los Alamos Pre-1960 -vs- Georgia	0.0004	0.0271	0.000
Los Alamos Pre-1960 -vs- Illinois	N/A	0.1707	0.000
Los Alamos Pre-1960 -vs- New Mexico	0.4016	0.9042	0.0019
Los Alamos Pre-1960 -vs- New York	0.9144	0.3214	0.0005
Los Alamos Pre-1960 -vs- Pennsylvania	0.1783	0.8455	0.000

Table 5. P-value results from the Mann Whitney test and Kruskal Wallis test for the third hypothesis.

CONCLUSION

The results from the nonparametric tests indicate there was not a significant difference in tissue concentrations of Pu-239 when comparing pre-1960 Los Alamos residents with other regions for bone and liver tissues. However, there is a significant difference in lung tissue. Tests demonstrated the Bone/Liver ratios were higher in the LA pre-1960 group indicating that the tissue concentrations of Pu-239 may have been in their bodies for a longer period.

Upon further evaluation of the data from the Fox and McInroy studies, it was determined that the full set of data used in their comparison tests is not listed in the tables provided in these original articles. All censored data is labeled as "<MRL" (less than minimum reporting levels) in the tables provided in the McInroy article and the tables provided by the LAHDRA project, where possibly the actual number may have been used in the original studies calculations. Therefore, it may be difficult to make direct comparisons to the results from the Fox study since the actual "<MRL" data is not available at this time. The New York data may also be difficult to make comparisons due to autopsy dates occurring earlier than the rest of the groups; in addition, the NY sample group was predominately young males as opposed to the other groups having a larger cross section of population.

The original tissue samples are still in existence and are currently stored by the U.S. Transuraniuum and Uranium Registries. A re-analysis of these samples using the latest technologies may provide a more accurate comparison of this data.

Median tissue concentration levels – CFD Graphs						
	Bone		Liver		Lung	
Region	Median Activity (dpm/kg)	Standard Deviation	Median Activity (dpm/kg)	Standard Deviation	Median Activity (dpm/kg)	Standard Deviation
Los Alamos Pre 1960	0.465	3.795	1.166	0.92	1.749	1.143
Los Alamos Post 1959	0.509	1.823	2.164	1.736	0.655	1.242
Colorado	0.365	1.799	1.292	1.029	0.394	1.083
Georgia	0.044	2.074	2.059	1.66	0.243	1.323
Illinois	ana	ana	1.445	0.548	0.010	2.732
New Mexico	0.166	3.295	1.098	1.275	0.800	1.449
New York	1.127	1.930	1.495	0.875	0.288	2.172
Pennsylvania	0.220	1.092	1.161	0.924	0.272	1.075
General Population (All regions)	0.160	2.510	1.285	0.991	0.332	1.403

Table 6. Median tissue concentration levels of Pu-239 for bone, liver and lung generated by the cumulative frequency distribution graphs for all regions.

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