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TITLE: STATISTICAL ANALYSIS OF A LASL STUDY OF PLUTONIUM IN U.S. AUTOPSY TISSUE

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STATISTICAL ANALYSIS OF A LASL STUDY OF PLUTONIUM IN U.S. AUTOPSY TISSUE

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ABSTRACT

The Autopsy Tissue Program was begun in 1960. To date, tissues on 900 or more persons in 7 geographic regions have been collected and analyzed for plutonium content. The tissues generally consist of lung, liver, kidney, lymph, bone, and gonadal tissues for each individual. The original objective of the program was to determine the level of plutonium in human tissues due solely to fall-out from weapons testing. The baseline thus established was to be used to evaluate future changes. From the first, this program was beset with chemical and statistical difficulties. Many factors whose effects were not recognized and not planned for were found later to be important. Privacy and ethical considerations hindered the gathering of adequate data. Since the chemists were looking for amounts of plutonium very close to background, possible contamination was a very real problem. Widely used chemical techniques introduced a host of statistical problems. The difficulties encountered touch on areas common to large data sets, unusual outlier detection methods minimum detection limits, problems with aliquot sizes, and time-trends in the data. The conclusions point out areas to which the biologists will have to devote much more careful attention than was believed.

I. Introduction

Plutonium is extremely rare in nature, hence non-occupational exposure to ^{239}Pu is usually a result of fallout from atmospheric weapons testing. Occupational exposures may take place in facilities producing or using plutonium. Exposures can result from external radiation, ingestion, inhalation, or wounds. Data on exposed persons have been collected at several laboratories but on a less extensive scale than at Los Alamos.

The autopsy tissue program at Los Alamos Scientific Laboratory (LASL) was established in 1960. Its original objective was to validate urine bioassay estimates of plutonium in occupationally exposed laboratory employees and to determine the pattern of plutonium deposition in the body. A second objective which developed from the first is that of establishing baseline concentrations of plutonium in tissues of the non-occupationally exposed general population in various geographic areas. Once established, such baselines will be

useful in monitoring changes related to the growth of the nuclear industry. It should be emphasized that the total amounts of plutonium found in tissue samples of an individual in this study are 3-4 orders of magnitude smaller than the ICRP recommended maximum permissible body burden of 40 nCi of plutonium for occupational exposures.

Tissues from seven geographic regions are collected. These regions include (1) Los Alamos, New Mexico (2) New Mexico (other than Los Alamos) (3) Colorado (4) New York (5) Pennsylvania (6) Illinois (7) Georgia-South Carolina. The tissues collected include bone (rib and/or sternum and/or vertebral wedge) kidney, liver, lung, lymph node, spleen, thyroid, and gonadal tissue. Pathologists from around the country provide these tissues as permitted by their local and state autopsy laws.

When these tissues are received, they are ashed and dissolved in acid. Only a fraction of the

solution (the aliquot size) is analyzed, the remainder being retained as an archival sample.

The samples are passed through an ion-exchange column and the isolated plutonium electrodeposited on stainless steel planchets. For samples analyzed before 1972, ^{236}Pu tracer was added (just prior to ion-exchange) to estimate the fraction (R) of plutonium recovered. Since June, 1972, ^{242}Pu has been the tracer of choice because of its longer half-life and lower energy of alpha decay. Beginning in 1976, the tracer has been added to the wet tissue prior to ashing in order to give an indication of the recovery for the entire analytical procedure. The α-activity of the ^{239}Pu spectrum is measured for 50,000 seconds. The measured activity is divided by an efficiency factor (E) which is the fraction of the total activity reaching the detector. The result is given in disintegrations per minute (D),

$$D=(S/t_1 - B/t_2)/RE$$

where S is the sample count, B the average background count, and t_1 and t_2 the respective times (in minutes) for which the sample and backgrounds are counted. One disintegration per minute of ^{239}Pu is approximately equivalent to 1.14×10^{-12} grams of ^{239}Pu.

The data gathered to date (approximately 900 cases) are given in a special issue of Health Physics (Mc79). The data consist of the measured concentrations on each sample and an indication of whether the measurement is significantly greater than zero. Two methods were used to assess the significance of the sample count. In the first method a minimum detection limit (the 99th percentile of the net background for reagent blanks) was set up and samples whose net count fell below the detection limit were declared not to be significantly different from zero. i.e. nothing was detected. This method did not, however, take into account the recovery, efficiency, or count rate for the sample, and the second method consisted of

constructing an approximate 95% confidence interval on the concentration (D) of each sample, based on propagation of error formulae. If the confidence interval included zero, the activity in the sample was judged not to be significantly different from zero. With the published data there is an expanded account of the history of the program, the measurement process, and the quality control program.

B.G. Bennett of the Health and Safety Laboratory (Fallout Program Quarterly Summary Report, January 1, 1974, HASL-278) has estimated that 320 kCi of ^{239}Pu were dispersed globally during atmospheric weapons testing. Beginning in 1965, levels of ^{239}Pu in surface air were measured on a monthly basis at a number of localities throughout the world (Environmental Measurements Laboratory EML-355, Appendix). Annual averages, as calculated at McClellan Air Force Base, appear in Fig. 6, which shows that the levels of plutonium in the stratosphere began rising sharply about 1961, reached a peak about 1963, then fell off to the

former levels in about 1967. Unfortunately, the localities at which the measurements were made do not coincide with those at which the autopsy tissues were taken (except NYC), but a study of the data for 1966-77 for three widely separated localities in the U.S. (New York City, Miami, and Sterling, Va.) indicates that these localites do not differ significantly in the total amount of ^{239}Pu received, despite the fact that some localities lag others by a month. However, surface air data for Salt Lake City (the closest station to the Colorado, New Mexico, and Los Alamos sites) differs considerably from that on the east coast, so that fallout patterns across the country might have been quite different and could account for some geographical differences seen later.

There are also highly significant differences in the amounts of ^{239}Pu in the air from month to month within a year for a given station. In Table 11 are given the annual total amounts of

^{239}Pu collected by one air sampler at the given stations. These data show sizeable year-to-year differences.

As a result, some time trends in the data are to be expected, particularly since people are still inhaling plutonium which has retention times in the lung of 100-1000 days and in the bone and liver of 40-200 years.

The form of the fallout was most probably PuO_2 and inhalation is believed to be the only significant pathway into the body. Bennett used a compartmental model to the plutonium intake and resulting burdens in the lung, liver, and bone, basing his estimates on the ICRP Task Group on Lung Dynamics model and observed levels of fallout in oil and air samples in New York City.

In Figures 2 and 3 we have plotted the annual median lung and liver concentrations for the New Mexico cases, as squares since it is the earliest data available. The plots also show the results Bennett's calculations as a solid line. The shape

of his curves agrees with the autopsy data, and it is surprising that the agreement in magnitude is as good as it is. It is quite conceivable that a refinement in Bennett's parameters or our data could produce even better agreement. The autopsy data, then, does lend support to the theoretical model and does show that there are definite trends with time. The implication from these time trends is that reporting a single mean or median for a given locality is not sufficient; a summary for each year is necessary for future work.

2. Statistical Nature of the Sample

It is important to realize that autopsy samples do not, in general, constitute random samples from all deaths. The reason for this is that some causes of death are more heavily represented in autopsy cases than in a sample of all deaths. Traumatic deaths or deaths from unknown causes (including unattended deaths) are more likely require autopsy, although practices vary from place to place. As long as the "reason" for autopsy has nothing to do

with the plutonium concentration in the tissue, the sample may be treated as a random one. Traumatic deaths and deaths from unknown causes are not believed to have anything to do with exposure to fallout. In order to verify this belief, we present in Tables 1 and 2 some common causes of death in our sample along with the associated plutonium concentration in lung and liver tissue. A chi-square test of independence was used to measure association between cause of death and plutonium concentration. Chi-square values of 32.5 and 36.4 with 28 degrees of freedom indicate no detectible association. We conclude from this that our sample may be treated as a random sample with respect to plutonium concentration.

Many autopsies are done because the pathologist has obtained consent of the person or his next of kin. If a person knew or feared that he had been (occupationally) exposed to plutonium other than fallout, he or his next of kin may have been more likely to give consent for autopsy. This might have

been cause for real concern, but if there was even the slightest evidence of occupational exposure, the sample was classified as such and does not appear in the published data with which we are dealing here.

Table 3 gives the number of samples in each geographic-tissue-sex category. The age distributions for each geographical region are shown in Figure 1. (The number of cases shown in Fig. 1 and Table 3 do not agree because the age was not known for every subject in the data base). These may or may not be typical of the general population (New York is not), but the effect of age will be dealt with in Section 5.

The years during which the data was collected is given in Table 4. The effect of time is discussed in Section 4.

3. Data Editing

In every large set of data one finds outliers (observations which do not appear to be a part of the bulk of the data). These may result from errors in observation, transcription, keypunching, or a failure to measure what was intended (such as

contaminated or misclassified samples). In our data, the plutonium concentration is near background, and even slight contamination may have a significant effect. Some contamination from natural uranium and thorium has been observed in freshly purchased reagents, on new stainless steel planchettes, and as a result of processing a sample with a high activity along with other samples. The amount of contaminant added to the autopsy during the analysis may have been equal to the activity in the sample, thus causing the measurement process to give erroneously high results.

We show later that measurements using small aliquots and small tissue samples are much more variable than samples from larger aliquots and larger tissues, and this fact plays a part in creating outliers. A third contributor to outliers is the fact that some solids may interfere with the measurement process. Finally, there is a possibility that, despite all efforts to prevent it, some occupational exposures may have crept into the

data base. Frequently the only indication that an observation is an outlier is its magnitude. If it is much larger than the bulk of the data, we suspect the measurement process.

Large erroneous observations can seriously impair the statistical analysis of the data. They can bias the mean upward, increase variances, cause tests of hypotheses to fail. For these reasons, we have omitted observations which have been identified as outliers by a standard statistical test. We believe such omissions will give more realistic estimates of means, standard deviations, and percentiles. We have used the Grubbs' statistic as a test for single outliers and the Tietjen - Moore test (1972) as a test for multiple outliers.

In Table 5, we present the results of our outlier testing. For each geographic location, sex, and tissue type, the number of observations in that set (n) and the number of outliers detected (k) is given. Suspected observations are declared to be outliers only when found to be significant at the

α=.05 level. Also presented are the case number, the concentration, and the percentile (percentage of observations less than) corresponding to the concentration.

The case against an outlier cannot be proven absolutely with statistical methods. There may be statistical evidence that the observation does not belong with the bulk of the data, but there is always some chance (however remote) that the measurement in question may not be erroneous. To assist in deciding the case against an outlier, we give some related information which, in many cases, supports the evidence that the observation is indeed erroneous. Since small aliquot fractions and small wet weights can lead to high apparent concentrations, aliquot size and wet weight of the tissue involved are reported. It is expected that when one tissue of a given individual shows a relatively high concentration of plutonium, other tissues from that individual also be high. If this is not the case, the high tissue value is suspect.

We have, therefore, presented the percentiles of related tissues for the same individual. Altogether we detected and omitted 139 outliers in the 4373 observations (3.2%). For the most part, the outliers were obvious (from their magnitude) even without statistical tests; frequently they were several orders of magnitude larger than the closest observation.

4. Estimates of Central Tendency

After the outliers have been identified and removed, it is appropriate to estimate central tendencies (i.e. means, medians, etc.). Each geographic region, sex, and tissue combination is examined separately. For each of these sets the 10th, 25th, 50th, 75th and 90th percentiles are calculated. These give a good idea of the spread of the data as shown in Table 5. The 50th percentile is the median.

Shown on Table 3 are the median and two means: unweighted and weighted. The unweighted mean is the arithmetic mean of the data. The weighted means are

related to aliquot sizes and wet weights. Measurements derived from small aliquot sizes and small wet weights are more variable than those from larger aliquots and larger tissues. The reason for this is that count data are considered to have a Poisson distribution with a parameter λ which is the average count per time interval. For a Poisson distribution both the mean and variance are equal to λ. A 25% aliquot would yield a sample with an average count (or variance) of $\lambda/4$. For such an aliquot, the measured activity x is multiplied by 4, hence the quantity of interest is the variance of $y=4x$. The variance of y is $4^2(\mathrm{Var}(x)) = 16\ \mathrm{Var}(x) = 16\ (\lambda/4) = 4\lambda$, so that the variance of a 25% aliquot is four times that of the undivided sample. In other words a 25% aliquot has twice the standard deviation of a 100% aliquot. The same is true of a tissue with small wet weight. The weighted means in Table 3 use inverse variances as weights so that small tissues and small aliquots get less weight.

5. Age Trends

The age at death of the persons considered in this report was an uncontrolled variable, and the observed age distributions might not be typical of the population at large. The age distributions over the entire time period are shown by locality in Figure 1. While the distributions resemble each other generally, the New York data is a clear exception: the individuals from that population are much younger than those from other areas. This difference may be due to the fact that the New York samples are largely from unclaimed bodies and traumatic deaths which occur more frequently in younger males.

It has been suggested (Annual Report of the Biomedical and Environmental Research Program, Jan-Dec 1973, LASL Health Division, LA 5633 PR, p. 32) that for a given exposure the amount of plutonium in the liver increases with age. The same effect, to a far lesser degree, was noted for lung tissue. If age trends are present, it is important

to adjust for them before making geographical comparisons. Separate regressions indicate no dependence between age and geography. In order to test for such trends with the autopsy tissue data presently available, we selected four very short segments of time (1968-69; 1970-71; 1972-73; 1974-75) during which time trends should be nearly constant. For the liver and lung tissue data (over all ages and localities), the plutonium concentration versus age at death was fitted to a linear relationship by least squares for each of the four short time periods. Another line was fitted to the data (for each tissue separately) over the whole time period (1968-75). Tests of whether the slope of the line is significantly different from zero were made. For the liver, the slopes are consistently different from zero, but a single line fits as well as separate lines for each time period. We conclude from this that the linear relationship, (dkg) = .91355 + .01692 (age) best represents the effect of age on liver

concentration. Over an 80 year lifetime, an increase of about 1.3 dkg could be expected in the liver. From age 40 to age 80, the increase would be about 0.67 dkg due to age alone.

For lung tissue, the evidence of a trend with age is not convincing.

For kidney, lymph tracheobronchial node, rib, and male gonadal tissue, there is no detectible effect of age for any of the time periods.

For vertebrae, the slope (of concentration vs. age at death) is significantly different from zero for the 1974-75 data and the 1968-75 data. More importantly, the slopes for this tissue are negative (or near zero), and this supports the hypothesis that the skeleton is being remodeled by transfer of plutonium from skeleton to liver. Moreover, the slopes do not seem to differ from each other, particularly if the 1968-69 data is omitted. An estimate of the slope (from the 1970-75 data) is -.0073. A single regression line is not adequate; the age effect is affected by the year of death.

(i.e. the biological effect of aging is also a function of atmospheric concentration). This makes it necessary to report both year of death and age at death when reporting means or medians.

6. Sex Differences

There are roughly twice as many males in this study as females. To test the hypothesis of sex differences, we used all the Colorado 1970-77 data adjusted for age trends. The results are presented in Table 7. The Mann-Whitney Test shows that there are no significant differences due to sex.

7. Geographical Comparisons

We now wish to compare levels of plutonium concentration in the various geographical regions. Since the data depend upon age at death and year of death, we attempt to eliminate these factors by considering only very short segments of time (i.e. year of death) (1974-75 and 1967-68) and subtracting out the age trends found during those time periods. Almost all of the subjects in this sample were born before 1945, hence had nearly equal exposure times.

Plots of median plutonium concentration versus age at death for lung and liver tissue for 1974-75 are given in Figures 4 and 5. These periods of time were selected because they include the major portion the data and because they are the only periods where data is available from certain geographical locations.

There is no evidence that the concentrations are normally distributed in any of the tissues. The kidney, vertebrae and gonadal tissues are the only tissues in which the concentrations appear to be lognormally distributed. The W-test (Sh75) was used to establish this conclusion.

As a result of the above testing, we have chosen to use a nonparametric procedure. The procedure we use has been recommended by Lin and Haseman (Li78) and Conover (Co71). This procedure consists of a Kruskal-Wallis test of the significance of among-region differences at the $\alpha=.05$ level. If this test indicates overall significance, Mann-Whitney tests are performed for

all pairwise comparisons of the geographic regions (at the α=.05 level). If the Kruskal-Wallis test is not significant, then all pairwise comparisons are declared not significant.

In Table 8 we present the medians adjusted for age trends. They are ordered from largest to smallest. This indicates which geographic regions have consistently large medians.

Table 9 presents the results of the Kruskal-Wallis tests. For those tissues in which the p-value exceeds .05 no significant differences among regions are indicated. For the other tissues, there is an overall effect, and we proceed to test pairwise differences with the Mann-Whitney test.

Table 10 summarizes the results of the Mann-Whitney testing. For each tissue, those regions underlined with the same line do not differ significantly. Median values are given in parentheses. Even in the cases where there are significant differences, however, the differences in median are quite small--on the order of one

disintegration per minute per kilogram of tissue--so that they may not be of any practical significance.

For example,

tissues	interpretation
Kidney, Vertebrae, Female Gonad, Spleen, all 1957-58 tissues	No significant differences
Liver	LA, NM, GA not sig. diff. IL, PA, CO not sig. diff. LA, NM, GA sig. greater than IL, PA, CO
Lymph Node	NM, LA, CO not sig. diff. PA sig. lower than NM, LA, CO
Rib	LA, NM not sig. diff. PA sig. lower than LA, NM
Male Gonad	LA, PA not sig. diff. GA, CO, NM not sig. diff. LA, PA sig. greater than GA, CO, NM
Thyroid	LA, PA, CO, IL not sig. diff. GA, NM not sig. diff. LA, PA, CO, IL sig. greater than GA, NM
Lung	IL sig. lower than other tissues. The remaining tissues divide into two groups NM, LA, GA, CO on the high end and GA, CO, PA on the low end; with GA and CO belonging to both groups.

8. Relationships between liver concentration and concentration of other tissues of the same individual

We wish to investigate the relationship between plutonium concentration in the liver and plutonium concentration in selected other tissues (lung, vertebrae, gonad) of the same individual.

Combining the data for all geographic regions, we selected those non-occupationally exposed individuals who had measurements for both liver and the related tissue in question.

For each of the three selected related tissues, we ran a linear regression of the related tissue concentrations on liver concentration. The results were:

(males only)

Related tissue:	Lung	Vertebrae	Gonad
number of observations	712	352	199
intercept	0.518	1.12	0.912
slope	0.074	-0.021	-0.04
correlation coefficient	0.1	-0.02	-0.045
R^2*	0.01	0.0004	0.002

*Amount of variability in the related tissue concentration explained by the regression on liver concentration.

We conclude that knowledge of liver concentration is of little use in predicting the concentration in other tissues in the same individual. The explanation for the lack of relationship is that both the liver tissue and the lung tissue concentrations, for example, are changing with time and age, but at vastly different rates (one is increasing and the other decreasing). It is, therefore mathematically impossible for these ratios to be constant.

Table 1. Lung Tissue: Number of persons in each cause of death category

Plutonium Concentration

Cause Of Death	.2dkg*	.2 - .4dkg.	4-.8 dkg.	.8-2 dkg.	2 dkg	Totals
Homicide	2	8	9	7	4	30
Accident	7	2	4	3	2	18
Injury	3	5	4	3	4	19
Heart	14	23	13	5	8	64
Pneumonia	8	8	2	4	1	23
Cancer	6	8	3	4	3	24
Alcohol, Drugs	3	7	8	2	0	20
Other	16	21	23	13	3	76
Totals	59	82	66	42	25	274

$\chi^2 = 32.53$ with 28 d.f.

Table 2. Liver Tissue: Number of persons in each cause of death category

Plutonium Concentration

Cause of Death	.4dkg*	.4-1 dkg	1-2 dkg	2-3 dkg	3 dkg	Totals
Homicide	3	6	10	6	5	30
Accident	1	3	5	3	6	18
Injury	7	3	5	2	4	21
Heart	4	12	20	13	9	58
Pneumonia	4	6	11	3	4	28
Cancer	3	6	3	6	7	25
Alcohol, Drugs	9	7	4	2	4	25
Others	10	10	25	16	8	69
Totals	41	53	83	51	47	275

$\chi^2 = 36.40$ with 28 d.f.

*dkg = dis/min per kilogram of wet tissue

Table 3. ESTIMATES OF CENTRAL TENDENCY
(dis/min per kg wet tissue)

GEOGRAPHIC REGION* -SEX-TISSUE	WEIGHTED MEAN	UNWEIGHTED MEAN	MEDIAN	N
LA F GONAD	.3141	.7551	0.0000	11
LA M GONAD	.7240	.6629	.5685	10
LA F KIDNEY	.4310	.6610	.1240	56
LA M KIDNEY	.3808	.7130	.3700	39
LA F LIVER	1.5547	1.7574	1.5850	62
LA M LIVER	2.3421	2.0875	1.9755	38
LA F LUNG	1.2257	1.7679	1.0240	63
LA M LUNG	1.0745	1.5398	.9860	36
LA F LYMPH NODE	18.2887	23.6345	8.3330	53
LA M LYMPH NODE	16.7592	20.2821	5.9285	34
LA F THYROID	.2063	.7210	.8110	15
LA M THYROID	3.2724	4.3034	1.6580	14
LA F VERTEBRAE	1.0091	.9759	.4320	32
LA M VERTEBRAE	.8280	1.3463	.7730	18
NM M GONAD	.0728	.1453	.0525	26
NM F KIDNEY	.2141	.3514	.0810	39
NM M KIDNEY	.2250	.4381	.1095	86
NM F LIVER	1.6310	1.7476	.7210	33
NM M LIVER	2.0498	2.0487	1.7645	84
NM F LUNG	1.5973	1.4863	.9540	33
NM M LUNG	1.0337	1.0035	.6135	84
NM F LYMPH NODE	12.5212	14.6945	6.6670	31
NM M LYMPH NODE	8.5974	12.7800	5.4235	82
NM M RIB	1.0588	1.2274	.9580	19
NM M SPLEEN	.1856	.2081	.1510	23
NM M THYROID	1.0785	.9864	.5380	25
NM F VERTEBRAE	1.0219	1.5089	.5560	21
NM M VERTEBRAE	1.0787	1.6225	.7730	63
CO F BONE	1.2260	1.3576	.8800	17
CO M BONE	1.8941	1.9441	1.5055	32
CO F GONAD	.4942	.2784	.0470	14
CO M GONAD	.3755	.4144	.1110	74
CO F KIDNEY	.2266	.4887	.1400	49
CO M KIDNEY	.1693	.3877	.1010	92
CO F LIVER	1.5338	1.6215	1.4010	72
CO M LIVER	1.8423	2.0132	1.7350	129
CO F LUNG	.5252	.4950	.4005	68
CO M LUNG	.5885	.6093	.4360	125
CO F LYMPH NODE	4.6883	13.2410	7.0495	42
CO M LYMPH NODE	4.4788	20.2287	3.0385	88
CO F RIB	.7936	.6645	.7430	10
CO M RIB	.4742	.4488	.4145	22
CO F SPLEEN	.1420	.1488	.1075	18
CO M SPLEEN	.1071	.1130	.1190	31
CO F THYROID	.2681	.2545	.4365	12
CO M THYROID	.8503	.8813	.3330	14
CO F VERTEBRAE	.5834	.6641	.4590	27
CO M VERTEBRAE	.9400	1.0822	.7225	44

NY M GONAD	1.1291	1.4324	1.0000	29
NY M LIVER	1.5789	1.7680	1.5000	27
NY M LUNG	.9426	1.0999	.6290	31
NY M VERTEBRAE	1.4080	2.8785	1.5395	26
PA F GONAD	.6732	.7051	.7665	12
PA M GONAD	.6531	.8522	.3135	108
PA F KIDNEY	.1496	.1523	.0990	51
PA M KIDNEY	.1419	.1671	.1115	150
PA F LIVER	1.3121	1.4467	1.4970	41
PA M LIVER	1.3644	1.4988	1.2900	121
PA F LUNG	.4494	.5017	.3025	42
PA M LUNG	.3532	.3729	.2540	117
PA F LYMPH NODE	6.9043	6.8241	4.0630	19
PA M LYMPH NODE	2.2742	3.9771	1.6160	73
PA F RIB	.9732	1.0404	.9270	13
PA M RIB	.5062	.5604	.4310	68
PA F SPLEEN	.2007	.2318	.1520	42
PA M SPLEEN	.1966	.2839	.1645	148
PA F THROID	1.2062	1.9023	.9620	20
PA M THYROID	1.2326	1.5684	.5750	101
PA F VERTEBRAE	.3772	.3892	.3630	11
PA M VERTEBRAE	.4571	.4556	.3650	67
GA M GONAD	.1055	.1362	.1050	21
GA F KIDNEY	.0835	.1004	.0520	49
GA M KIDNEY	.1451	.1853	.1155	62
GA F LIVER	1.6440	1.7958	1.5270	57
GA M LIVER	2.1169	2.2240	2.1470	76
GA F LUNG	.3188	.3454	.2985	56
GA M LUNG	.5994	.6252	.3325	76
GA F SPLEEN	.2047	.2362	.1730	47
GA M SPLEEN	.1667	.1854	.1635	48
GA F VERTEBRAE	.5651	.6083	.6075	28
GA M VERTEBRAE	.4081	.3870	.4000	43
IL F LIVER	1.4967	1.5170	1.4430	22
IL M LIVER	1.6514	1.7810	1.7445	14
IL F LUNG	.1358	.1568	.1170	23
IL M LUNG	.1023	.1128	.0975	14

*LA = Los Alamos
NM = New Mexico (other than Los Alamos)
CO = Colorado
NY = New York
PA = Pennsylvania
GA = Georgia and South Carolina
IL = Illinois

Table 4

YEARS DURING WHICH DATA WERE COLLECTED

GEOGRAPHIC REGION	YEARS
LOS ALAMOS	1960-1963, 1966-1977
NEW MEXICO	1960-1963, 1966-1977
COLORADO	1970-1977
NEW YORK	1967-1968
PENNSYLVANIA	1974-1977
GEORGIA-SOUTH CAROLINA	1972-1976
ILLINOIS	1973-1977

TABLE 5.
GEOGRAPHIC REGION-SEX-TISSUE

								PERCENTILES OF RELATED TISSUES								
	n	k	CASE NO.	DKG*	OUTLIER PERCENTILE	ALIQUOT SIZE (%)	WET WEIGHT (KG)	BONE	GONAD	KIDNEY	LIVER	LUNG	LYMPH NODE	RIB	SPLEEN	THYROID	VERTEBRAE
LA-F-Kidney	58	2	3-38	11.055	98	10	.199				66	80	32				92
			1-142	7.647	97	10	.170				58	53	66				
LA-M-Kidney	40	1	3-36	17.651	98	10	.315				67	69	75				
LA-F-Liver	64	2	11-82	43.904	98	25	1.00		27	40		19	55		27	69	
			1076	7.000	97	10	.700			91		91	39				
LA-F-Lung	64	1	11-18	8.783	98	25	.475				34		84		36	6	25
LA-M-Lung	38	2	3-62	14.081	97	2.5	.767			95	54		60				86
			1-88	7.655	95	20	.307			71	38		80				
LA-F Lymph Node	56	3	7-114	857.692	98	40	.0013			5	65	60			92	44	58
			7-2	369.512	96	40	.0041			12	81	22					61
			5-2	290.00	95	20	.003			41	25	50					47
LA-M-Lymph Node	39	5	1-60	1093.182	96	40	.0022			12	64	3					18
			3-124	327.5	95	20	.002			56	36	18					9
			11-128	293.33	93	50	.0009		55	90						93	
			1-60	227.273	90	10	.0066			12	64	3					18
			11-150	218.947	88	50	.0019			34	92					20	
LA-F-Spleen	11	2	7-114	3.554	92	10	.121			5	65	60	98			44	59
			11-86	2.857	83	50	.217		81	62	66	61	38	71		81	33
LA-F-Thyroid	16	1	11-138	8.000	94	50	.004		36		30	13	70				
LA-F-Vertebrae	36	4	2-146	23.256	97	2	.215			71	25	47	80				
			2-102	20.974	95	4	.267			38	41	94	93				
			3-38	9.559	92	4	.170			98	66	80	32				
			5-56	9.143	89	10	.070			67	13	56	5				
LA-M-Vertebrae	21	3	3-76	49.80	95	10	.050			78	3	28	70				
			3-82	19.737	91	10	.038			29	74	49	23				
			3-62	18.750	86	4	.088			95	56	97	60				
NM-M-Gonad	28	2	7-128	5.385	97	50	.013			42	35	6	65	20	78	40	38
			11-58	4.333	93	99.9	.015			70	40	17	85	55	85	88	82
NM-F-Kidney	41	2	1-82	25.937	98	10	.320					32	38				
			1-84	4.701	95	10	.234					59					

*dkg = dis/min per kg wet tissue

TABLE 5.
GEOGRAPHIC REGION-SEX-TISSUE

	n	k	CASE NO.	DKG	OUTLIER PERCENTILE	ALIQUOT SIZE (%)	WET WEIGHT (KG)	PERCENTILES OF RELATED TISSUES: BONE	GONAD	KIDNEY	LIVER	LUNG	LYMPH NODE	RIB	SPLEEN	THYROID	VERTEBRAE
NM-M-Kidney	87	1	7-50	5.761	99	50	.309				6	12	42				85
NM-F-Liver	35	2	7-92	120.705	97	25	.596			52		41	14				69
			5-22	9.003	94	50	1.555			2		86	73				73
NM-F-Lung	36	3	2-104	46.626	97	10	.163			14	19		14				7
			2-28	36.315	95	5	.863			14	89		54				
			3-64	9.653	92	2.5	.750			67	44		57				88
NM-M-Lung	85	1	3-94	231.82	99	2.5	.[illegible]			14	27		68				31
NM-F-Lymph Node	36	5	5-12	400.00	97	20	.001			60	50	27					58
			3-52	385.00	95	20	.002			79	25	62					92
			7-94	256.667	92	40	.0015			10	14	51					73
			5-88	188.750	89	40	.002			67	31	68					54
			11-56	142.00	86	50	.001			90	69	11					62
NM-M-Lymph Node	85	3	11-112	305.714	99	50	.007		70	68					43	46	
			2-32	277.50	98	20	.004			78	76	75					
			3-92	141.25	97	20	.004			10	18	68					78
NM-M-Rib	21	2	11-8	7.000	95	50	.012		67	53	55	30	39		22	65	26
			11-94	4.957	91	50	.023		78	63	47	67	79		91	62	68
NM-M-Spleen	24	1	11-76	1.192	96	50	.022			34	49	38	69			12	53
NM-M-Thyroid	27	2	11-120	18.00	96	50	.004		7						74		
			11-140	10.667	93	50	.003		63	7			30				
NM-F-Vertebrae	25	4	3-56	125.796	96	4	.063			88	83	65	46				
			3-52	60.00	92	4	.070			79	25	62	95				
			3-64	52.00	88	4	.050			57	44	92	57				
			5-46	14.643	85	25	.115			71	78	78	43				
NM-M-Vertebrae	69	6	3-30	77.00	99	4	.075			60	93	76	48				
			3-42	35.769	97	4	.130			91	58	92	76				
			3-50	33.857	96	4	.175			84	51	70	45				
			2-148	17.368	94	4	.321			81	95	96	69				
			7-10	16.842	93	5	.076			91	57	25	62				
			2-150	12.556	91	4	.223				72	85	37				
CO-M-Bone	33	1	8-12	16.667	97	2	.300			24	99	98					
CO-F-Kidney	53	4	8-38	56.711	98	10	.076				96	26		17			7
			6-134	9.115	96	10	.113				52	59	98				93
			8-2	7.719	95	10	.114				86	71	4	67			48
			6-124	7.213	93	10	.122				11	23	76				66

TABLE 5.
GEOGRAPHIC REGION-SEX-TISSUE

								PERCENTILES OF RELATED TISSUES									
	n	k	CASE NO.	DKG	OUTLIER PERCENTILE	ALIQUOT SIZE (%)	WET WEIGHT (KG)	BONE	GONAD	KIDNEY	LIVER	LUNG	LYMPH NODE	RIB	SPLEEN	THYROID	VERTEBRAE
CO-M-Kidney	94	2	6-126	30.357	99	10	.196				69	41	51				32
			8-66	10.972	98	10	.072				45	91	4	48			
CO-M-Liver	131	2	8-12	10.824	99	25	.306	97		24		98					
			8-116	10.611	98	25	.286		28	18			33				
CO-F-Lung	69	1	6-4	3.372	99	9	.325	50			84		84				
CO-M-Lung	128	3	8-24	67.533	99	25	.890		28	55	78		73	24			
			8-12	15.951	98	25	.163	97		24	99						
			6-10	4.950	98	50	.404	35			97		59				
CO-F-Lymph Node	44	2	6-134	76.136	98	40	.0022			96	52	59					93
			8-44	73.333	96	40	.0015			76	41	17		83			
CO-M-Lymph Node	89	1	6-150	537.50	99	40	.002		97	77	86	88					
CO-F-Rib	11	1	8-64	0.235	92	50	.017			35	67						
CO-M-Rib	24	2	8-18	2.429	96	20	.140				93	69	63				
			8-68	2.203	92	20	.227			86	42	11					
CO-M-Spleen	33	2	8-136	1.321	97	50	.268		44	46	25	95		84			
			22-4	1.087	94	50	.046		61	46	35	60	47			50	
CO-F-Thyroid	13	1	8-130	3.412	93	50	.017		33	52	14	4	2		16		
CO-M-Thyroid	17	3	16-36	21.684	94	50	.019		45	36					59		
			16-42	20.824	89	50	.017		15						50		
			8-128	5.500	83	50	.004		28	65	28	9	16		68		45
CO-F-Vertebrae	28	1	8-16	12.620	97	20	.271			63	18	64	13	50			
CO-M-Vertebrae	46	2	6-150	18.156	98	20	.282		97	77	86	88	99				
			8-4	6.549	96	20	.142			95	21	93	84	16			
NY-M-Gonad	32	3	4-16	214.25	97	20	.020				97	71					69
			4-52	45.50	94	20	.030				83	12					17
			4-6	10.60	91	20	.025				27	68					83
NY-M-Liver	29	2	4-16	6.618	97	5	.550		97			71					69
			4-10	6.579	93	5	.456		61			79					97
NY-M-Lung	33	2	4-8	10.958	97	5	.480		76		20						77
			4-2	8.000	94	5	.615		79		73						73
NY-M-Vertebrae	29	3	4-10	23.529	97	4	.170		61		93	79					
			4-30	19.583	93	4	.180		52		13	76					
			4-46	19.112	90	4	.242		64		7	15					
PA-F-Gonad	15	3	19-64	13.714	94	50	.007				93	14	5		29		
			19-110	9.000	88	50	.002			62	61	36			4		
			14-22	7.333	81	30	.005			88	86	87	45		62	83	

TABLE 5.
GEOGRAPHIC
REGION-
SEX-TISSUE

	n	k	CASE NO.	DKG	OUTLIER PERCENTILE	ALIQUOT SIZE (%)	WET WEIGHT (KG)	PERCENTILES OF RELATED TISSUES: BONE	GONAD	KIDNEY	LIVER	LUNG	LYMPH NODE	RIB	SPLEEN	THYROID	VERTEBRAE
PA-M-Gonad	110	2	19-96	81.111	99	50	.018				86	54	28	83	63	86	
			15-70	13.714	98	50	.021			8				1		42	53
PA-F-Liver	43	2	15-2	61.394	98	25	1.004			17		49					
			19-42	6.506	95	25	.482					72					
PA-M-Lung	120	3	19-92	20.714	99	25	.336		82		84		86	56	69	63	62
			20-94	13.674	98	25	.356			16	8		51		72	64	94
			23-80	7.109	98	25	.341		40	11	79		45	62	62		65
PA-M-Lymph Node	77	4	14-26	150.00	99	60	.002			83	52	33			85	89	
			15-92	123.33	97	50	.006		85	17	42						
			14-24	56.25	96	60	.008			92	13	84			95	69	
			15-36	55.00	95	50	.004		41	2						93	
PA-F-Rib	14	1	14-2	9.60	93	25	.01			98	80	35	20		96	88	
PA-M-Rib	70	2	14-32	8.571	99	50	.028		54	98	36	34			29	22	
			14-58	4.300	97	50	.02		39	88	46	11			45	22	
PA-F-Spleen	44	2	15-76	3.059	98	50	.017		13	37			55	7		13	
			14-2	2.175	96	25	.057			98	80	35	20	99		88	
PA-M-Spleen	149	1	19.150	6.624	99	50	.170			95	62	7		34			3
PA-F-Thyroid	23	3	14-54	26.500	96	50	.004		38	8	64	40			58		
			19-6	13.000	92	50	.008		31	19	77	72			84		
			14-2	12.50	88	30	.004			98	80	35	20	99	96		
PA-M-Thyroid	104	3	15-56	137.00	99	50	.008						82		83		
			19-98	69.867	98	50	.015		28		89	64			65		
			15-64	26.588	97	50	.017		96	38			27	25	49		10
GA-F-Kidney	52	3	9-14	30.00	98	10	.062				22	54					93
			17-86	1.747	96	50	.079				29	83			53		97
			17-52	1.505	94	50	.101				56	42			63		10
GA-M-Kidney	64	2	9-28	83.633	98	10	.245				85	1					
			9-12	3.75	97	10	.184				22	91					
GA-F-Liver	58	1	9-150	6.957	98	25	.445					86			78		23
GA-M-Liver	77	1	17-138	8.035	99	25	.458			69		64			92		73
GA-F-Lung	58	2	25-12	15.333	98	25	.372				59						
			25-10	4.014	97	25	.573				64						
GA-M-Lung	77	1	9-10	73.016	99	25	.425		77	94	35						82
GA-F-Spleen	48	1	9-126	1.650	98	50	.080			49	73	59					
GA-M-Spleen	49	1	17-32	1.244	98	50	.045			62	95	78					

TABLE 5.
GEOGRAPHIC
REGION-
SEX-TISSUE

	n	k	CASE NO.	DKG	OUTLIER PERCENTILE	ALIQUOT SIZE (%)	WET WEIGHT (KG)	PERCENTILES OF RELATED TISSUES: BONE	GONAD	KIDNEY	LIVER	LUNG	LYMPH NODE	RIB	SPLEEN	THYROID	VERTEBRAE
GA-F-Vertebrae	29	1	17-86	2.175	97	50	.080			96	29	83			53		
GA-M-Vertebrae	44	1	9-60	8.80	98	50	.050		32		91	28			70		
IL-M-Lung	15	1	13-24	0.471	94	25	.?80										

Table 6: PERCENTILES BY GEOGRAPHIC REGION, SEX, & TISSUE TYPE

GEOGRAPHIC REGION -SEX-TISSUE	10	25	50	75	90
LA F GONAD	-4.4572	-.2500	0.0000	3.6670	5.7056
LA M GONAD	-1.0951	-.1128	.5685	1.1065	2.9242
LA F KIDNEY	-.0453	0.0000	.1240	1.0790	2.3750
LA M KIDNEY	0.0000	.0550	.3700	.9200	2.4750
LA F LIVER	.1585	.7573	1.5850	2.5870	3.9052
LA M LIVER	.3117	.8913	1.9755	2.8468	4.2868
LA F LUNG	.2120	.4770	1.0240	2.3300	5.3882
LA M LUNG	.1423	.3930	.9860	2.1145	4.3154
LA F LYMPH NODE	-.3156	0.0000	8.3330	20.8845	93.7776
LA M LYMPH NODE	-.3815	1.2260	6.9285	22.5000	81.0715
LA F THYROID	-1.1000	0.0000	.8110	1.3330	2.7602
LA M THYROID	-.3215	.6670	1.6580	8.1968	14.5000
LA F VERTEBRAE	0.0000	.1633	.4320	1.5450	2.4326
LA M VERTEBRAE	-.2801	.3010	.7730	2.0645	4.2714
NM M GONAD	-.2589	-.0833	.0525	.3873	.7632
NM F KIDNEY	-.0320	0.0000	.0810	.5140	1.2400
NM M KIDNEY	-.0015	0.0000	.1095	.4608	1.5343
NM F LIVER	.0570	.4605	.7210	2.2690	5.5270
NM M LIVER	.2625	.7353	1.7645	2.8770	4.1410
NM F LUNG	.1634	.3650	.9540	2.4625	3.5846
NM M LUNG	.1855	.3973	.6135	1.2460	2.3010
NM F LYMPH NODE	-2.3302	0.0000	6.6670	18.1250	42.4286
NM M LYMPH NODE	-.2800	.6045	5.4285	18.5415	40.2292
NM M RIB	.3230	.6150	.9580	1.7780	3.0910
NM M SPLEEN	.0148	.0710	.1510	.3540	.5502
NM M THYROID	-1.4666	0.0000	.5380	1.7915	5.0356
NM F VERTEBRAE	0.0000	.0140	.5560	1.8330	5.2882
NM M VERTEBRAE	0.0000	.2720	.7730	1.8750	5.7600
CO F BONE	0.0000	.1665	.8800	2.0465	4.5890
CO M BONE	0.0000	.7105	1.5055	3.2240	7.2166
CO F GONAD	-4.7500	-1.3998	.0470	2.8268	4.1395
CO M GONAD	-.3750	-.0445	.1110	.5185	1.7370
CO F KIDNEY	-.0500	.0215	.1400	.5115	2.4240
CO M KIDNEY	-.0785	.0205	.1010	.5600	2.0381
CO F LIVER	.1512	.6718	1.4010	2.2913	2.9874
CO M LIVER	.1900	.8380	1.7350	2.9210	3.6240
CO F LUNG	.1153	.2013	.4005	.6408	1.0741
CO M LUNG	.1308	.2570	.4360	.7145	1.2698
CO F LYMPH NODE	-2.2977	0.0000	7.0495	26.1493	46.0000
CO M LYMPH NODE	-1.3148	0.0000	3.0385	13.4375	70.6365
CO F RIB	-.5706	.1875	.7430	1.0500	1.7058
CO M RIB	-.0749	.1615	.4145	.7560	.9564
CO F SPLEEN	-.0469	.0315	.1075	.2518	.3428
CO M SPLEEN	0.0000	.0190	.1190	.1740	.2868
CO F THYROID	-.9639	.2855	.4365	.7980	1.1617
CO M THYROID	-.0770	0.0000	.3330	1.5093	3.3445
CO F VERTEBRAE	.1018	.2130	.4590	.8700	1.8276
CO M VERTEBRAE	.1195	.3133	.7225	1.4653	2.9385

NY M GONAD	-.5130	.2105	1.0000	2.6015	3.5900
NY M LIVER	.2722	1.0440	1.5000	2.4040	3.2960
NY M LUNG	.0662	.2040	.6290	1.3570	3.1858
NY M VERTEBRAE	.0140	.5650	1.5395	4.0785	8.9797
PA F GONAD	-.3400	.0555	.7665	1.1875	1.8668
PA M GONAD	-.4305	-.0165	.3135	.8655	2.6067
PA F KIDNEY	-.2464	-.0440	.0990	.2670	.7156
PA M KIDNEY	-.0299	.0298	.1115	.2080	.4183
PA F LIVER	.1386	.6250	1.4970	2.1315	2.3090
PA M LIVER	.3096	.6135	1.2900	2.0160	3.2548
PA F LUNG	.0877	.1663	.3025	.6453	1.3316
PA M LUNG	.0548	.1380	.2540	.4045	.7262
PA F LYMPH NODE	-25.0000	0.0000	4.0630	18.0000	32.5000
PA M LYMPH NODE	-1.3136	.0985	1.6160	4.4485	14.8182
PA F RIB	-.0402	.5360	.9270	1.0690	3.0088
PA M RIB	.0669	.2323	.4310	.7228	1.4072
PA F SPLEEN	-.0399	.0278	.1520	.3183	.7521
PA M SPLEEN	-.0010	.0655	.1645	.3298	.6814
PA F THYROID	-.7906	0.0000	.9620	2.5748	8.0000
PA M THYROID	-.3974	0.0000	.5750	1.3810	3.8428
PA F VERTEBRAE	.1344	.1880	.3630	.5000	.7744
PA M VERTEBRAE	.1108	.1810	.3650	.6600	.9248
GA M GONAD	-.2178	-.0870	.1050	.3310	.7222
GA F KIDNEY	-.0400	-.0085	.0520	.1380	.4290
GA M KIDNEY	-.0218	.0258	.1155	.2150	.3949
GA F LIVER	.3780	.7675	1.5270	2.8685	3.5688
GA M LIVER	.3516	1.1203	2.1470	3.0433	4.3378
GA F LUNG	.0346	.1240	.2985	.4545	.7456
GA M LUNG	.1457	.2158	.3325	.7815	1.1691
GA F SPLEEN	-.0478	.0620	.1730	.4030	.6166
GA M SPLEEN	-.0379	.0843	.1635	.2905	.4292
GA F VERTEBRAE	.1736	.3123	.6075	.8378	1.1105
GA M VERTEBRAE	-.0218	.2400	.4000	.8000	.9242
IL F LIVER	.6396	.9330	1.4430	1.9470	2.5894
IL M LIVER	.6975	.9813	1.7445	2.4965	3.2505
IL F LUNG	-.0222	.0520	.1170	.3140	.3958
IL M LUNG	.0200	.0558	.0975	.1360	.2865

Table 7. Sex Comparisons in Colorado

Tissue	Female	Male	p-value*
Bone	17	32	.1151
Kidney	49	92	.7096
Lymph Node	42	88	.4851
Rib	10	22	.1932
Spleen	18	31	.5611
Thyroid	12	14	.3031
Vertebrae	27	44	.1356
Lung	60	120	.3594
Liver	64	124	.1528

*Significant if less than .05

Table 8

Medians Adjusted for Age Effects

largest ⟶ smallest

1974-75						
Kidney	PA	LA	GA	CO	NM	
Liver	LA	NM	GA	IL	PA	CO
Lung	NM	LA	GA	CO	PA	IL
Lymph Node	NM	LA	CO	PA		
Rib	LA	NM	PA			
Vertebrae	NM	CO	GA	PA	LA	
Female Gonad	CO	LA	PA			
Male Gonad	LA	PA	GA	CO	NM	
Spleen	LA	PA	GA	NM	CO	
Thyroid	LA	PA	CO	IL	GA	NM
1967-68						
Liver	LA	NM	NY			
Lung	LA	NM	NY			
Vertebrae	NM	NY	LA			

Table 9

Kruskal - Wallis tests

1974-75	p-value
Kidney	.5764
Liver	.0000
Lung	.0000
Lymph Node	.0247
Rib	.0072
Vertebrae	.0560
Female Gonad	.9507
Male Gonad	.0077
Spleen	.0969
Thyroid	.0110
1967-68	
Liver	.8001
Lung	.1277
Vertebrae	.1202

Table 10

Results of Hypothesis Testing

largest ——————————→ smallest

(unadjusted medians in parentheses)

1974-75	
Kidney	PA(.114) LA(.108) GA(.075) CO(.081) NM(.063)
Liver	LA(2.399) NM(2.123) GA(1.942) IL(1.451) PA(1.398) CO(1.276)
Lung	NM(.535) LA(.447) GA(.316) CO(.301) PA(.271) IL(.104)
Lymph Node	NM(6.500) LA(6.553) CO(2.917) PA(1.923)
Rib	LA(1.125) NM(.966) PA(.460)
Vertebrae	NM(.573) CO(.631) GA(.400) PA(.363) LA(.213)
Female Gonad	CO(2.769) LA(0.667) PA(1.000)
Male Gonad	LA(.558) PA(.319) GA(.042) CO(.051) NM(.053)
Spleen	LA(.350) PA(.154) GA(.150) NM(.147) CO(.101)
Thyroid	LA(1.303 PA(.749) CO(.363) IL(.286) GA(-.194)NM(0.00)
1967-68	
Liver	LA(1.823) NM(1.730) NY(1.500)
Lung	LA(1.272) NM(1.165) NY(0.668)
Vertebrae	NM(4.557 NY(1.539) LA(0.769)

Table 11 Total ^{239}Pu concentrations in surface air for years 1966-1977. (atto curies/cubic meter)

	New York City	Sterling, Va.	Miami	Salt Lake City
1966	1475.10	1195.50	1014.79	
1967	511.40	402.86	593.43	
1968	965.70	829.00	848.80	
1969	652.70	629.90	550.80	
1970	774.05	659.00	752.20	
1971	719.80	629.10	728.74	1326.10
1972	326.29	275.60	327.90	727.50
1973	150.59	125.24	202.11	255.54
1974	464.91		534.20	690.30
1975	240.53		256.24	
1976	74.40		85.87	
1977	251.49		270.18	

References

Co71 Conover, W.J. 1971. Practical Nonparametric Statistics. New York: John Wiley and Sons, Inc.

Li78 Lin, F.A. and Haseman, J.K. 1973. "An Evaluation of some Nonparametric Multiple Comparison Procedures by Monte Carlo Methods," Communications in Statistics - Simulation and Computation. B7 (No. 2), 117-128.

Mc79 McInroy, J.F., Campbell, E.E., Moss, W.D., Tietjen, G.L., Eutsler, B.C., Boyd, H.A. 1979. "Plutonium in Autopsy Tissue," Health Physics (to appear).

Ti72 Tietjen, G.L., and Moore, R.H. 1972. "Some Grubbs-Type Statistics for the Detection of Several Outliers," Technometrics. 14, 583-597.

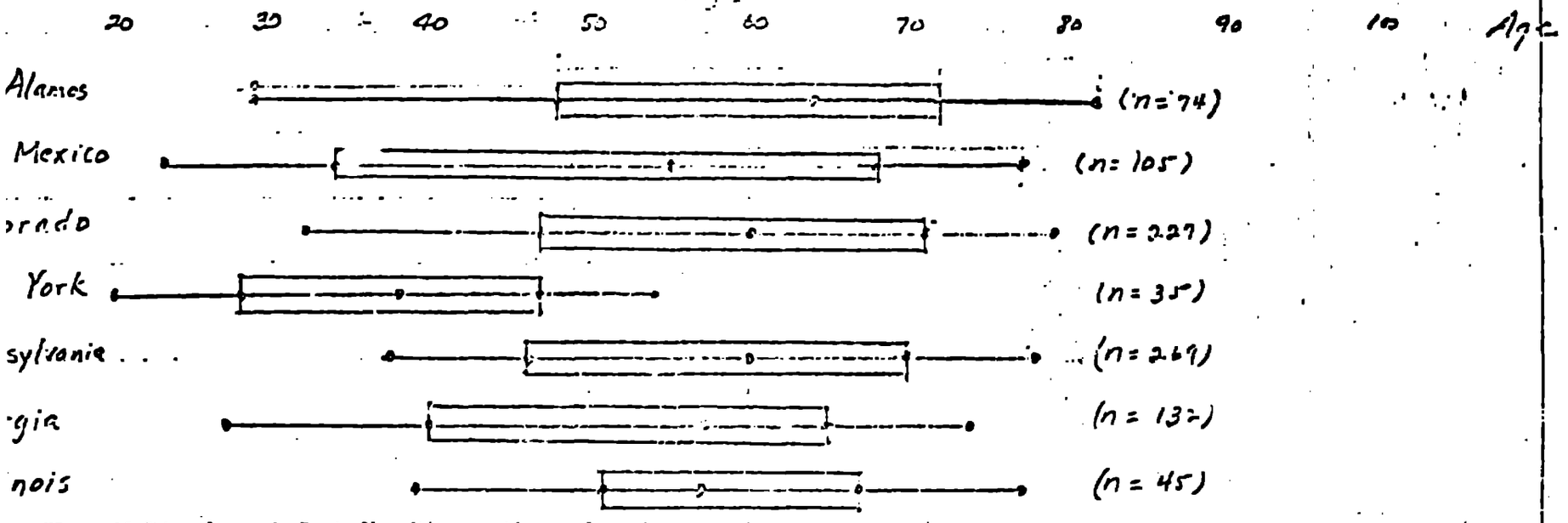
Sh75 Shapiro, S.S., and Wilk, M.B. 1975. "An Analysis of Variance Test for Normality (complete samples)," Biometrika. 52, 591-611.

List of Figures and Tables

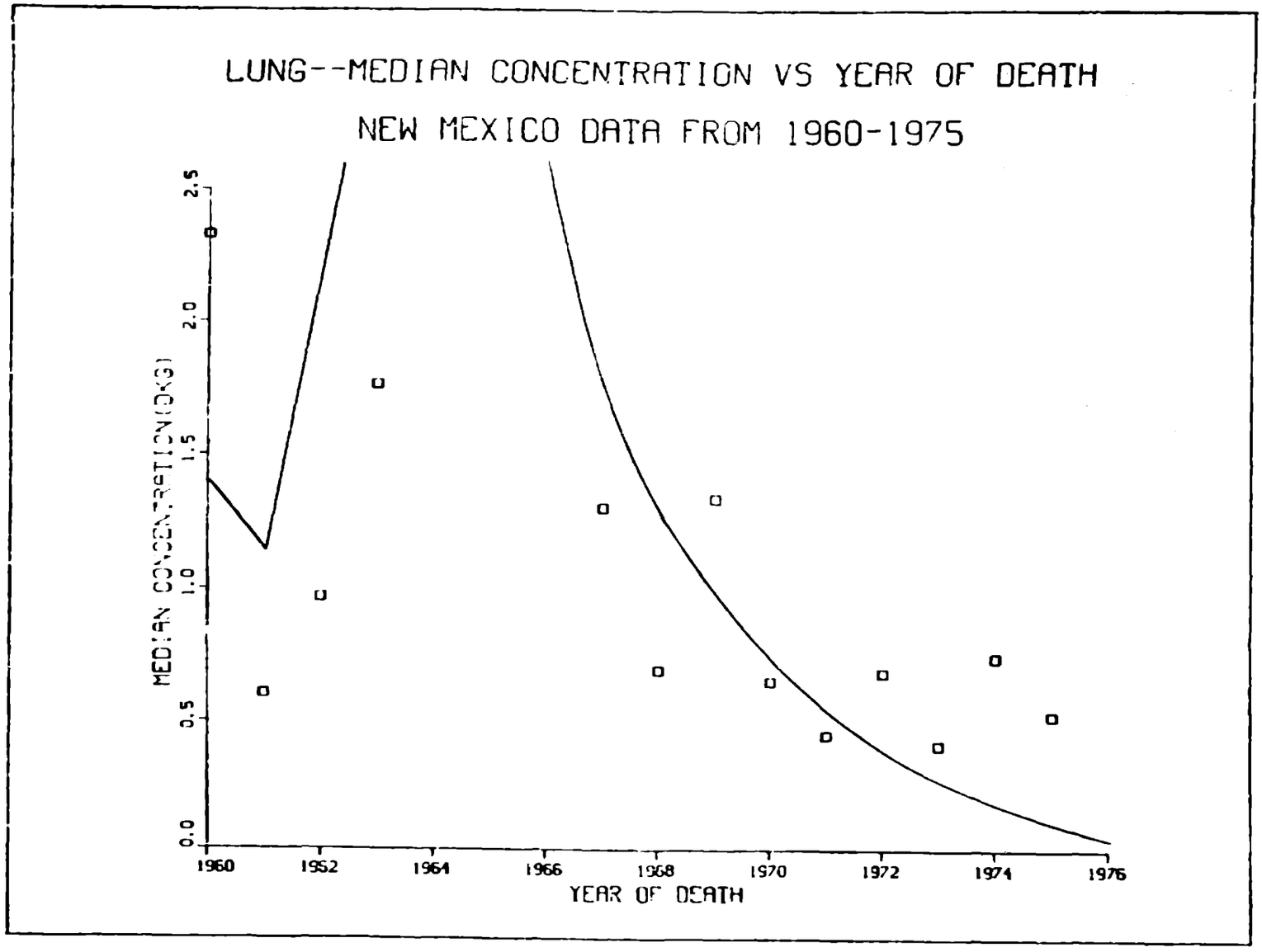
Figure 5 Liver tissue--median concentration vs. age at death

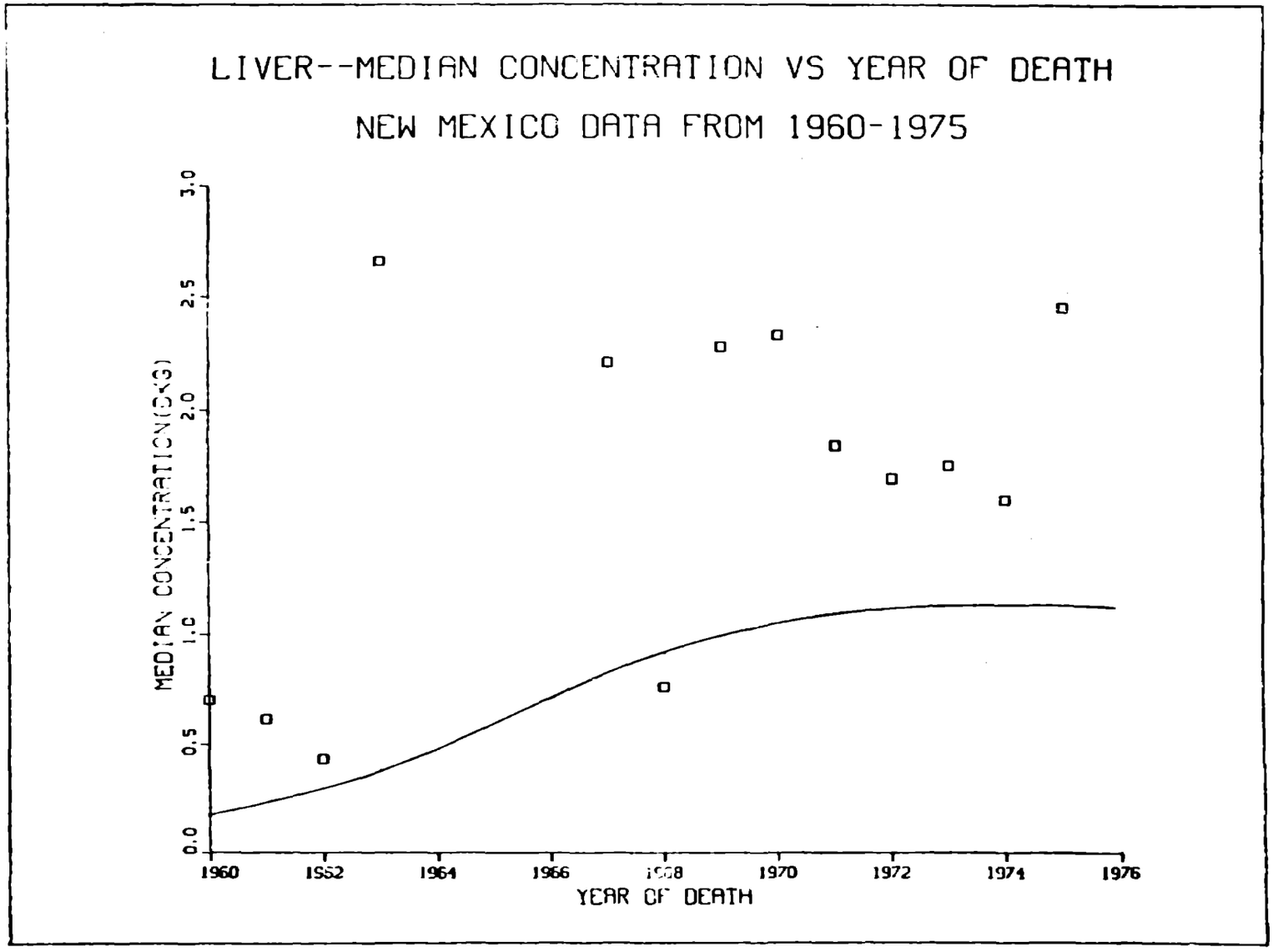
Figure 6 Atmospheric plutonium levels

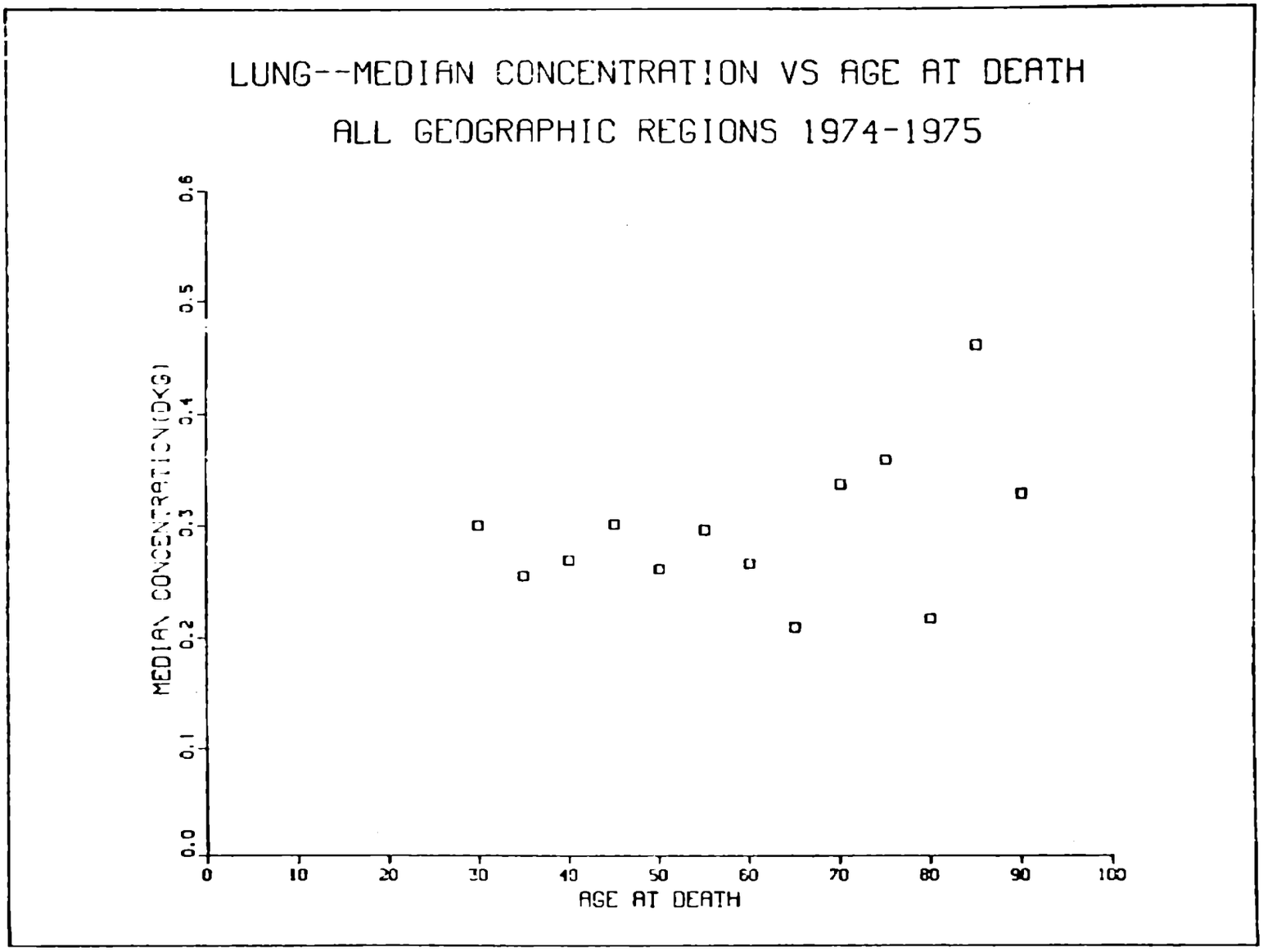
Age Distributions of Geographical Groups[1] (1967-1978)

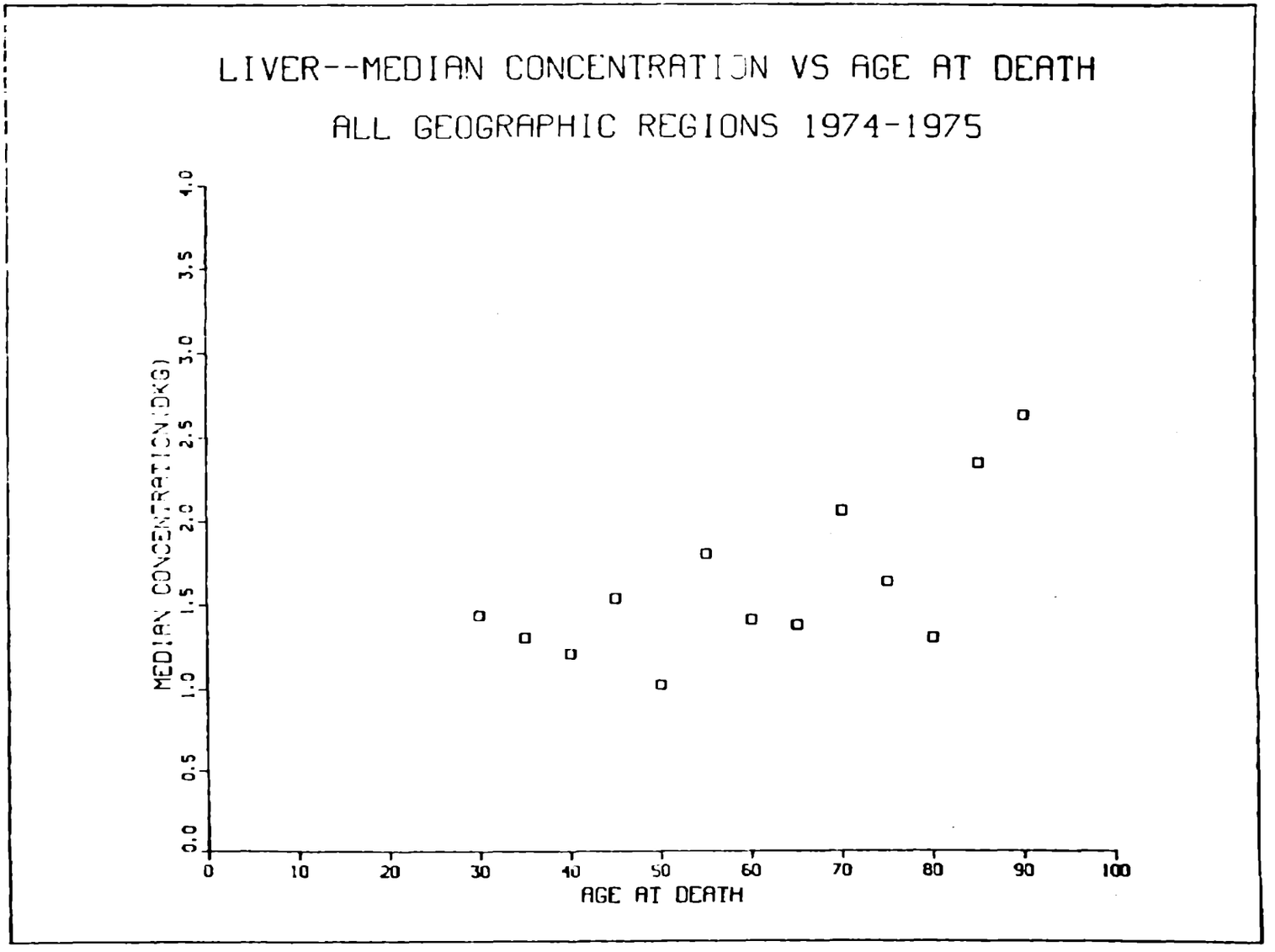


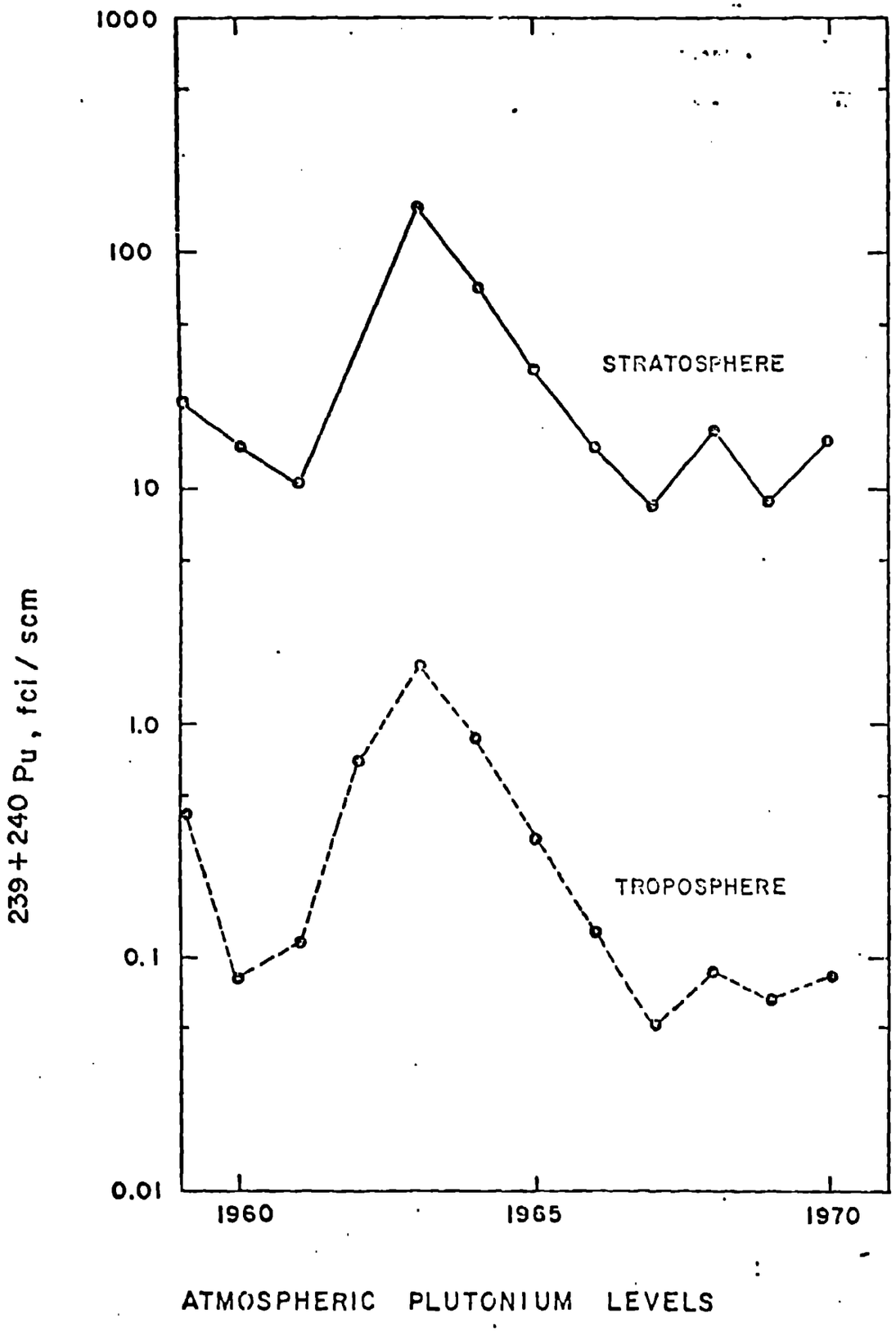
1 The dots represent the 10th, 50th, and 90th percentiles. The endpoints of the rectangles are at the 25th and 75th percentiles so that they include the middle 50% of the data.


LUNG--MEDIAN CONCENTRATION VS YEAR OF DEATH
NEW MEXICO DATA FROM 1960-1975
MEDIAN CONCENTRATION(PCI)
0.0
0.5
1.0
1.5
2.0
2.5
1960
1962
1964
1966
1968
1970
1972
1974
1976
YEAR OF DEATH


LIVER--MEDIAN CONCENTRATION VS YEAR OF DEATH
NEW MEXICO DATA FROM 1960-1975
MEDIAN CONCENTRATION(PPM)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1960
1962
1964
1966
1968
1970
1972
1974
1976
YEAR OF DEATH


LUNG--MEDIAN CONCENTRATION VS AGE AT DEATH
ALL GEOGRAPHIC REGIONS 1974-1975
MEDIAN CONCENTRATION(DKG)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
10
20
30
40
50
60
70
80
90
100
AGE AT DEATH


LIVER--MEDIAN CONCENTRATION VS AGE AT DEATH
ALL GEOGRAPHIC REGIONS 1974-1975
MEDIAN CONCENTRATION(UG)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
10
20
30
40
50
60
70
80
90
100
AGE AT DEATH



ATMOSPHERIC PLUTONIUM LEVELS