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AUTHOR(S): James F. McInroy, Howard A. Boyd and Bernard C. Eutsler

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University of California

LOS ALAMOS SCIENTIFIC LABORATORY
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Deposition and Retention of Plutonium in the United States General Population

J. F. McInroy
H. A. Boyd
B. C. Eutsler

Epidemiology Group
Health Division
Los Alamos National Laboratory
University of California
Los Alamos, New Mexico 87545

ABSTRACT

Since 1959, a Los Alamos National Laboratory study has analyzed over 5000 tissues from 1100 individuals of the nonoccupationally exposed general population for fallout plutonium. These data have been useful in determining the tissue distributions and the annual baseline levels of environmentral plutonium in the United States population. The effects of age, sex, date of death, cause of death and geographic location of residence on the observed plutonium deposition have been evaluated. Because of the difference in biological turnover times of plutonium in the various organs of the body and the changing concentrations of plutonium in the atmosphere, the plutonium concentration ratios between tissues have changed as a function of time. However, our data indicate that over the past 10 years, the highest concentrations in the general population are found in the tracheobronchial lymph nodes and the liver and the lowest concentrations are in the spleen, gonads and kidney. The median body burdens of plutonium in the U.S. population are estimated to have reached 12 pCi during the 1960's and have declined to about 2 pCi in 1977. Large errors in estimated skeletal burdens of plutonium may exist because of small specimen sample sizes and a lack of knowledge concerning the relative distribution of plutonium among the various bones of the human body.

INTRODUCTION

The Los Alamos National Laboratory has collected human autopsy specimens over the past twenty years (1959-1979) to determine their plutonium content. Tissues and organs from the U.S. general population, exposed primarily to fallout plutonium resulting from the atmospheric testing of nuclear weapons, have been radiochemically analyzed. The tissues collected at the beginning of the program were lung, tracheobronchial lymph nodes, liver, kidney and bone (usually a rib or vertebral wedge). Whole organs were requested but, typically, one lung and half of the liver were all that were received. Beginning in 1973, we added the gonads, spleen and thyroid to the list of requested organs. The samples are obtained through the cooperative efforts of pathologists located throughout the United States. At present, we have collected specimens from 26 states, with most of the samples coming from Colorado, Georgia, Illinois, New Mexico, New York, Pennsylvania and Washington.

The major thrust of this study is to measure actual human exposure (depositions) to plutonium resulting from environmental sources before a major expansion of the nuclear industry occurs. This information has been useful in establishing the current annual baseline levels of plutonium in the tissues of the general population because of worldwide or regional environmental fallout from radioactive contamination

and will aid in the identification of the uptake and distribution patterns of plutonium in the human body.

The following is a report to this workshop of work still in progress and is not intended to represent our final analysis and interpretation of the data we are continuing to collect.

METHODS

The tissue specimens requested are identified and weighed by the pathologist at the time of the autopsy. Each sample is individually packaged in pre-labeled plastic bags and frozen. The sets of tissues from each autopsy case are packed in Dry Ice and sent to our laboratory by air freight. Upon receipt, the specimens are thawed, reweighed, grossly dissected to remove extraneous tissue if present, and analyzed for plutonium.

We request, for each autopsy case, information concerning the cause of death, date of death, age, sex, race, weight, and the residential and occupational histories. The residential and occupational data are not always readily available to the pathologist; therefore the data we receive are not as complete as we would like it to be.

The detailed analytical methods used for the analyses of plutonium in human autopsy specimens are described elsewhere in this publication (Bo81). In summary, a known amount of tracer solution containing ^{242}Pu is added to each tissue. The specimens are dry ashed in a furnace for four days with gradual increase of the temperature from 150° to 500°C. The ash is alternately wet and dry ashed until all visible carbonaceous material is destroyed. All samples are subsequently treated by

adding a mixture of $LiNO_3$-$NaNO_3$ to the residue and continuing the wet and dry ashing until the sample will dissolve completely in 7.8M HNO_3. An aliquot of the HNO_3 tissue solution is adjusted to the appropriate pH, the plutonium isolated by anion exchange and electrodeposited onto stainless steel planchets. The activity is assayed by alpha spectrometery, counting the alpha activity on the planchet with a 300-mm^2 silicon surface-barrier detector for 50000 sec and correcting the measured $^{239\text{-}240}Pu$ activity by the average background of the detector and the fraction of the tracer solution recovered. In our spectrographic analyses, we are unable to distinguish between the 5.15 MeV alpha of the ^{239}Pu and the 5.16 MeV alpha of ^{240}Pu. Therefore, all results we report as ^{239}Pu are actually the sum of any ^{239}Pu and ^{240}Pu present.

The count data from each detector are stored in the memory of a multichannel analyzer, transfered to a magnetic tape, and read into the computer for evaluation by a computer code that propagates the errors in each measurement. The final result and the associated error of each measurement, along with the appropriate information on the case number, tissue type, fraction analyzed, and the fraction of the tracer recovered are entered into a general purpose data base management system which operates on a CDC 6600 computer. This enables the rapid retrieval of all data in a form determined by the investigator for various statistical analyses.

RESULTS AND DISCUSSION

The results to date of our analyses for ^{239}Pu in the tissues of the U.S. general population have recently been published in-toto (Mc79). Tissue concentrations from 1100 persons in 7 geographic regions throughout the U.S. were reported. Preliminary attempts to summarize the data in the above report involved the estimation of median tissue concentrations from log-normal plots of individual tissue data collected since the beginning of the study. We now realize that the plutonium tissue concentrations change with time (see discussion under Time Trends) and that annual median tissue concentrations are necessary for making regional comparisons. Tables 1-4 show the regional median tissue concentrations of ^{239}Pu in lung, tracheobronchial lymph nodes, liver and vertebrae (vertebral bodies) for the years 1970-77. The annual median concentrations of all available data for each tissue type are indicated as "All Data." For comparison, the annual concentrations in each tissue predicted by Bennett (Be76), using the measured and inferred concentrations of fallout plutonium in the New York City area and the ICRP Task Group Lung Model to estimate plutonium deposition in the lung and transfer to other body organs, are also shown.

The agreement in magnitude between the predicted tissue concentrations and the observed values is reasonable for lung and liver data, with 75-95% of the values within a factor of two of the predicted value. The lymph node and vertebrae,

however, vary significantly from the model. The observed lymph node concentrations are all an order of magnitude or more lower in concentration than the predicted values. This suggests that the model parameters for transfer of plutonium into and from the pulmonary lymphatic system may be grossly in error or that the analytical process is not measuring the plutonium in this tissue accurately because of the small mass of the sample. Measurements of tracheobronchial lymph node concentrations of fallout plutonium in New York City autopsy cases have been made recently by other investigators (Fi79). Lymph node specimens were pooled to increase the mass being analyzed. Their results confirm a much lower concentration than that predicted by the ICRP model.

The bone concentrations appear to be in close agreement with Bennett's skeletal values. However, our concentrations are based on wet weights of the bone and any marrow present, while the reported concentrations are calculated on the basis of a 5-kg mineral bone skeleton. In extrapolating to whole skeleton burdens, our data are higher by a factor of two and also suggest a shorter residence time than that used by ICRP. We are currently fitting the model to our data with the expectation that better estimates of the model parameters will result in a compartmental model able to predict more accurately the distribution and retention of inhaled fallout plutonium in the human body.

Fox et al. have examined the data we have collected to identify possible regional differences and time and age trends in plutonium tissue concentrations (Fo79). They have also

tested each of our autopsy cases to determine possible bias in the data and to identify outliers in our analyses. They have reported the following conclusions:

Sample Selection

Autopsies do not, in general, represent a random sampling of all deaths. Tramatic deaths, unattended deaths, and deaths from unknown or medically interesting causes are more likely to result in an autopsy. To verify that the cause of death in our autopsy population was not biasing the amount of plutonium found in the tissues, the medical information provided by the pathologist and the results of our tissue analyses for plutonium were tested using a chi-square test of independence to measure the association between the cause of death and plutonium concentration in tissues. The lung and liver were selected as the tissues containing the largest amounts of plutonium and, because of their mass, the tissues in which we have the most confidence in the measured values. Chi-square values of 32.5 and 36.4 with 28 degrees of freedom, indicate no detectable association and, thus, no cause for concern about bias in our data because of autopsy selection.

Outliers

In every large set of data, one finds outliers (observations that do not appear to be consistant with the bulk of the data). These may result from possible errors in analysis, transcription of information, from contamination of the sample, small sample sizes, etc. The concentrations of plutonium for the general population are near background and even a slight contamination may have a significant effect on

the values measured. Certain α- emitting nuclides may interfere with the accurate determination of ^{239}Pu. These may be present in the chemical reagents used, including the tracer added to each sample, on the stainless steel planchets or on the electrodeposition apparatus from an earlier processing of a sample with high activity. The amount of contaminant analyzed with the autopsy specimen may have been equal to the activity in the sample, thus causing the current analysis to give erroneously high results. Other contributors to outliers are the analysis of small aliquots, small tissue samples and improperly prepared samples with undissolved solids that interfere with the measurement process. Finally, there is the possibility that, despite all efforts to identify the history of all samples, some occupationally exposed cases may have been included in the general population data.

Using the Grubbs' statistic as a test for single outliers and the Tietjen - Moore test (Ti72) as a test for multiple outliers, 139 high results out of 4373 observations, or 3.2% of the data, were declared outliers. These specimens are being reanalyzed where samples are still available. If no sample remains, the outliers are removed from the data base or are identified as being a questionable result.

Age Trends

The age at death of the persons included in our study is an uncontrolled variable and may not be typical of the population at large. The age distributions for all cases collected since the beginning of the program are shown in Fig. 1. Although the distributions resemble each other generally, the New York City

data are a clear exception: the individuals from that population are much younger than those from other areas. This may be because the New York City samples were largely from traumatic deaths, which are more frequent in younger males.

If age has an effect on the deposition and retention of plutonium, it is important to identify such trends and to adjust for them before making geographical comparisons. Excluding the New York City data, separate regression analyses indicated no dependence between the age at death and geographical location of residence. In order to test for age related trends on the deposition of plutonium in tissues with the autopsy tissue data presently available, four very short segments of time (1968-69; 1970-71; 1972-73; 1974-75) were selected, as periods when the trends would be nearly constant. For the liver and lung tissue data (over all ages and locales), 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 was significantly different from zero were made. For the liver, the slopes for each time period are consistently different from zero, but a single line for the whole time period fits as well as separate lines for each time period. This indicates that the slopes for different time periods are very similar. It was concluded that the linear relationship, $C_1 = 0.91356 + 0.01682 \times (\text{age})$, where C_1 is the liver concentration of ^{239}Pu in dpm per kg

tissue, best represents the effect of age on liver concentration. Over an 80 year lifetime, an increase of about 1 pCi could be expected in the liver. From age 40 to age 80, the increase would be about 0.6 pCi in the liver due to age alone.

For lung tissue, the evidence of age related trends on the deposition of plutonium was not convincing.

For kidney, tracheobronchial lymph nodes, rib and male gonadal tissue, there was no detectable effect of age for any of the time periods.

For vertebrae, the slope of the regression line relating concentration vs age at death was significantly different from zero for the 1974-75 data and the 1968-75 data. Significantly, perhaps, the slopes for this tissue are negative (or near zero), supporting the hypothesis that the skeleton is being remodeled with age and the plutonium is being transferred from the skeleton to the liver.

Sex Differences

There are roughly twice as many males in the study as females. To test the hypothesis of sex differences, the Colorado 1970-77 data, adjusted for age trends, was examined using the Mann - Whitney test. See Table 5. The results show that there are no significant differences in the concentration of plutonium in the tissues shown due to sex. Gonadal tissues were not compared because of the obvious anatomical differences between the testes and ovaries.

Geographical Differences

To compare the levels of plutonium concentrations in the populations of various geographic areas within the U. S., we attempted to eliminate the dependence of age at death and year of death by considering very short segments of time (i.e., year of death was 1967-68 and 1974-75) and subtracting out the age trends found during those time periods. Almost all of the subjects in the sample were born before 1945 and, therefore, had nearly equal exposure times to fallout plutonium.

Use of the W-test for normality (Sh75) indicated that there was no evidence that the concentrations of plutonium in any of the tissue types studied were normally distributed. Because of this, nonparametric testing procedures recommended by Lin and Haseman (Li73) and Conover (Co71) were used to test for geographical differences in plutonium concentrations in tissues. These procedures utilize a Kruskal - Wallis test of the significance of among-region differences at the 0.05 level, and if this test indicated overall significance, Mann - Whitney tests were performed for all pairwise comparisons of the geographic regions (at the 0.05 level). If the Kruskal - Wallis test was not significant, then all pairwise comparisons were declared not significant. Table 6 summarizes the results of the above testing. For each tissue, those regions underlined with the same line do not differ from each other in their concentrations of plutonium in the indicated tissue. Median concentrations (dpm per kg) are given in parentheses. However, even where statistical differences are indicated, the differences in the medians are quite small, often on the order of 1 dpm per kg tissue.

Time Trends in Tissue Concentration

Direct measurements of plutonium concentrations in the air were not made routinely in this country until the late 1960's. Plutonium concentrations in the air before that time were estimated from ^{90}Sr concentrations in air and the known $^{239}Pu/^{90}Sr$ ratios (Be76). Annual averages of plutonium air concentrations indicate that the levels of plutonium in the stratosphere began rising sharply about 1961, reached a peak about 1963, and then decreased steadily with a half-time of about 10 months to the present levels of about 2 kCi (Ha79). China and France have added to the atmospheric inventory of plutonium with their continuation of above ground testing of nuclear weapons

As a result, some time trends in the data are to be expected. Bennett (Be76), using the International Commission on Radiological Protection (ICRP) Task Group on Lung Dynamics model (IC72) and the calculated plutonium intake (using the New York City air concentration data from 1954 to 1976), estimated the plutonium burdens in lung, liver, lymph node, kidney and skeleton (Fig. 2). Figures 3 and 4 show our preliminary estimates of the median liver and lung burdens for the U.S. general population superimposed on the ICRP predicted values. The autopsy data appear to agree with the ICRP model quite well in magnitude and in the shape of the curves, thus lending support to the theoretical model. These data may prove useful in refining the parameters used in the model to give a more realistic fit to the data.

The lymph node, kidney and skeletal data (Figs. 5-7) do not fit the predicted values as well as the lung and liver appear to fit. However, this may be related to the sensitivity of the analytical procedure and the difficulty in making realistic skeletal extrapolations. Lymph nodes are relatively small organs, there being about 15g of tracheobronchial lymph nodes in the average individual (Po66). At the low levels of plutonium presently seen in the tissues of the general population, the statistical certainty of being able to measure plutonium in a few grams of this tissue is relatively low. Consequently, the majority of the analyses of lymph nodes are at or below our minimum level of detection (MDL) of 0.01 pCi/sample. We have not pooled the lymph node samples from different individuals to increase the mass of the sample analyzed because we were concerned about the loss of identity of the samples. If there were an unusually high concentration in one of the lymph nodes, the activity would be diluted by the other tissues present and, therefore, we could not identify the high sample and probably would not even be aware that this unusual sample existed.

Similar problems exist with the kidney. Although the two kidneys combined are a much larger organ (310g) than lymph nodes, the amount of plutonium retained in the kidney is small. Therefore, the amount of plutonium in this organ is also near our MDL.

The bone samples are a special problem in at least two ways. Although the bone is a "target" organ for the deposition

of plutonium with about half of the systemic plutonium burden residing in the skeleton (IC59), the total amount of plutonium in the skeleton of the general population is low while the mass of the skeleton is high (about 14% of the body weight). This results in very low concentrations of plutonium in the bones with the measurements generally very close to our MDL. Also compounding this problem, plutonium deposits on bone surfaces, resulting in higher concentration in trabecular bone than in the dense mineral (cortical) bone. Plutonium, then, is notuniformily distributed throughout the skeleton, thus making the extrapolation of the skeletal burden from an anatomical specimen of bone (usually 30-200g of rib, sternum or vertebral body, all largely trabecular bones) very inaccurate. We are just now beginning to make the measurements on whole human skeletons, obtained from occupationally exposed individuals, that will give us some knowledge of the distribution of plutonium in the entire skeleton and allow the extrapolations of skeletal burdens from a single bone measurement.

Summary and Conclusions

Tissues from 1100 nonoccupationally exposed individuals in the United States have been analyzed for their ^{239}Pu content. These data have been useful in determining the tissue distributions of plutonium and to illustrate the changing baseline levels of environmental plutonium in the U.S. population. Time trends in the retention of plutonium in the individual tissues were confirmed and related to the changing atmospheric inventory of fallout plutonium and the biological

turnover times for this element. The causes of death were examined for the general population autopsy cases and it was concluded that there was no bias in the sample with respect to plutonium concentrations in the tissues. Outliers in the data were identified and removed before estimates of central tendency were made.

Small changes in the deposition and retention of plutonium in the liver and skeleton were identified, suggesting thatremodeling of the bone mineral with age may mobilize plutonium deposited there for eventual deposition in the liver.

There were no significant differences in the concentration of plutonium in the tissues due to sex.

The data were examined for geographic differences, using short segments of time to eliminate any influence of the year of death, and subtracting out the age trend found in these time periods. For the years 1967-68, no geographic differences in lung, liver or vertebral concentrations of ^{239}Pu were found. Individuals dying in 1974-1975 (the sources for the bulk of our data) had no regional differences in ^{239}Pu concentrations in the vertebrae, kidney, spleen and female gonads. Small regional differences were identifiable in all other tissues.

The measurement of plutonium distribution in whole skeletons is needed to give the information necessary for the extrapolation of skeletal burdens from the small bone specimens readily available during an autopsy.

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TABLE 1 MEDIAN LUNG CONCENTRATIONS OF ^{239}Pu (pCi/kg wet weight)

Area/year	1970	1971	1972	1973	1974	1975	1976	1977
Los Alamos	0.45(6)	0.17(3)	0.38(8)	-------*	0.22(10)	0.18(19)	0.15(5)	0.34(3)
New Mexico	0.28(15)	0.20(8)	0.29(12)	0.18(15)	0.19(8)	0.20(9)	-------*	------*
Colorado	0.29(11)	0.19(62)	0.25(42)	0.16(38)	0.23(9)	0.11(38)	-------*	0.20(6)
Georgia and S. Carolina	------**	------**	0.21(17)	------**	0.14(61)	0.14(36)	0.16(33)	0.12(8)
Illinois	------**	------**	------**	0.14(3)	0.09(7)	0.04(23)	-------*	------**
Pennsylvania	------**	------**	------**	------**	0.14(46)	0.11(85)	0.09(16)	0.15(10)
All data	0.37(32)	0.19(73)	0.27(79)	0.17(56)	0.14(141)	0.11(210)	0.10(54)	0.16(27)
Predicted†	0.32	0.26	0.19	0.13	0.12	0.09	0.08	0.05

Numbers in parentheses are the number of samples included in the analyses.

* Less than three samples received and/or analyzed.

** No samples received.

† Data from Be76.

TABLE 2 MEDIAN LYMPH NODE CONCENTRATIONS OF ^{239}Pu (pCi/kg wet weight)

Area/year	1970	1971	1972	1973	1974	1975	1976	1977
Los Alamos	0.99(6)	------*	4.17(6)	3.86(3)	3.09(9)	3.98(14)	3.38(4)	1.33(3)
New Mexico	2.00(14)	8.85(7)	1.93(11)	1.36(15)	3.10(6)	1.00(5)	------*	------*
Colorado	1.35(13)	1.58(50)	4.02(34)	0.56(17)	3.00(9)	0.35(4)	------*	0.09(8)
Georgia and S. Carolina	------**	------**	------**	------**	0.92(4)	------*	0.44(3)	0.72(5)
Pennsylvania	------**	------**	------**	------**	1.58(36)	0.35(37)	0.70(6)	1.16(11)
All data	1.34(33)	2.70(59)	4.04(53)	1.81(35)	2.00(64)	0.87(65)	0.71(15)	0.83(25)
Predicted†	39.4	35.6	32.3	29.1	26.5	24.4	22.6	21.1

Numbers in parentheses are the number of samples included in the analyses.

* Less than three samples received and/or analyzed.

** No samples received.

† Reference Be76.

TABLE 3 MEDIAN LIVER CONCENTRATIONS OF ^{239}Pu (pCi/kg wet weight)

Area/year	1970	1971	1972	1973	1974	1975	1976	1977
Los Alamos	0.82(5)	1.45(3)	0.80(8)	-------*	0.95(9)	1.12(18)	0.61(5)	1.18(3)
New Mexico	1.04(14)	0.83(8)	0.65(12)	0.86(15)	0.65(8)	0.89(9)	------*	------*
Colorado	1.08(12)	0.74(61)	0.81(43)	0.63(38)	0.63(9)	0.55(42)	------*	0.94(6)
Georgia and S. Carolina	------**	------**	0.51(18)	------**	1.06(60)	0.73(36)	0.67(33)	0.25(8)
Illinois	------**	------**	------**	0.75(3)	0.64(7)	0.73(21)	-------*	------**
Pennsylvania	------**	------**	------**	------**	0.48(46)	0.69(88)	0.34(13)	0.30(11)
All data	1.04(31)	0.80(72)	0.80(81)	0.71(56)	0.73(139)	0.70(214)	0.55(51)	0.36(28)
Predicted†	0.49	0.51	0.52	0.53	0.54	0.54	0.54	0.54

Numbers in parentheses are the number of samples included in the analyses.

* Less than three samples received and/or analyzed.

** No samples received.

† Reference Be76.

TABLE 4 MEDIAN VERTEBRAE CONCENTRATIONS OF ^{239}Pu (pCi/kg wet weight)

Area/Year	1970	1971	1972	1973	1974	1975	1976	1977
Los Alamos	0.65(5)	0.62(3)	0.80(7)	0.23(3)	0.23(9)	0.19(12)	------*	0.21(3)
New Mexico	0.25(9)	0.46(7)	0.49(12)	0.20(13)	0.27(7)	0.43(8)	------*	------*
Colorado	0.28(14)	0.29(19)	0.40(27)	0.26(20)	0.31(5)	-------*	------*	0.12(6)
Georgia and S. Carolina	-----**	-----**	0.33(12)	------**	0.18(47)	0.17(20)	0.18(23)	0.39(3)
Pennsylvania	------**	------**	------**	------**	0.18(11)	0.17(48)	0.22(13)	0.10(9)
All data	0.28(28)	0.35(29)	0.45(58)	0.23(36)	0.19(79)	0.19(90)	0.22(37)	0.13(22)
Predicted†,‡	0.18	0.18	0.19	0.20	0.20	0.20	0.21	0.21

Numbers in parentheses are the number of samples included in the analyses.

* Less than three samples received and/or analyzed.

** No samples received.

† Reference Be76.

‡ Assumes uniform distribution in 5-kg skeleton.

TABLE 5 SEX COMPARISONS IN COLORADO

Tissue	Female*	Male*	p-value**
Kidney	49	92	0.7096
Lymph node	42	88	0.4851
Rib	10	22	0.1932
Spleen	18	31	0.5611
Thyroid	12	14	0.3031
Vertebrae	27	44	0.1356
Lung	60	120	0.3594
Liver	64	124	0.1528

* Number of cases

** Significant if less than 0.05

TABLE 6 RESULTS OF MANN-WHITNEY TESTING FOR REGIONAL DIFFERENCES IN TISSUE CONCENTRATIONS OF ^{239}Pu

1974-75						
Kidney	PA(0.114)	LA(0.108)	CO(0.081)	GA(0.075)	NM(0.063)	
Liver	LA(2.399)	NM(2.123)	GA(1.942)	IL(1.461)	PA(1.398)	CO(1.276)
Lung	NM(0.535)	LA(0.447)	GA(0.316)	CO(0.301)	PA(0.271)	IL(0.104)
Lymph node	NM(6.500)	LA(6.553)	CO(2.917)	PA(1.923)		
Rib	LA(1.125)	NM(0.966)	PA(0.460)			
Vertebrae	NM(0.673)	CO(0.631)	GA(0.400)	PA(0.363)	LA(0.213)	
Female gonad	CO(2.769)	LA(0.667)	PA(1.000)			
Male gonad	LA(0.568)	PA(0.319)	GA(0.042)	NM(0.063)	CO(0.063)	
Spleen	LA(0.350)	PA(0.164)	GA(0.160)	NM(0.147)	CO(0.101)	
Thyroid	LA(1.303)	PA(0.749)	CO(0.363)	IL(0.286)	NM(0.00)	GA(0.194)
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)			

Unadjusted medians in parentheses (dpm per kg)

Figure 1 Age distributions of geographical groups. The dots represent the 10th, 50th, and 90th percentiles. The end points of the rectangles are at the 25th and 75th percentiles so that they include the middle 50% of the data.

Figure 2 Inhalation intake and computed burden of fallout $^{239,240}Pu$ in man from the ICRP model (Be76).

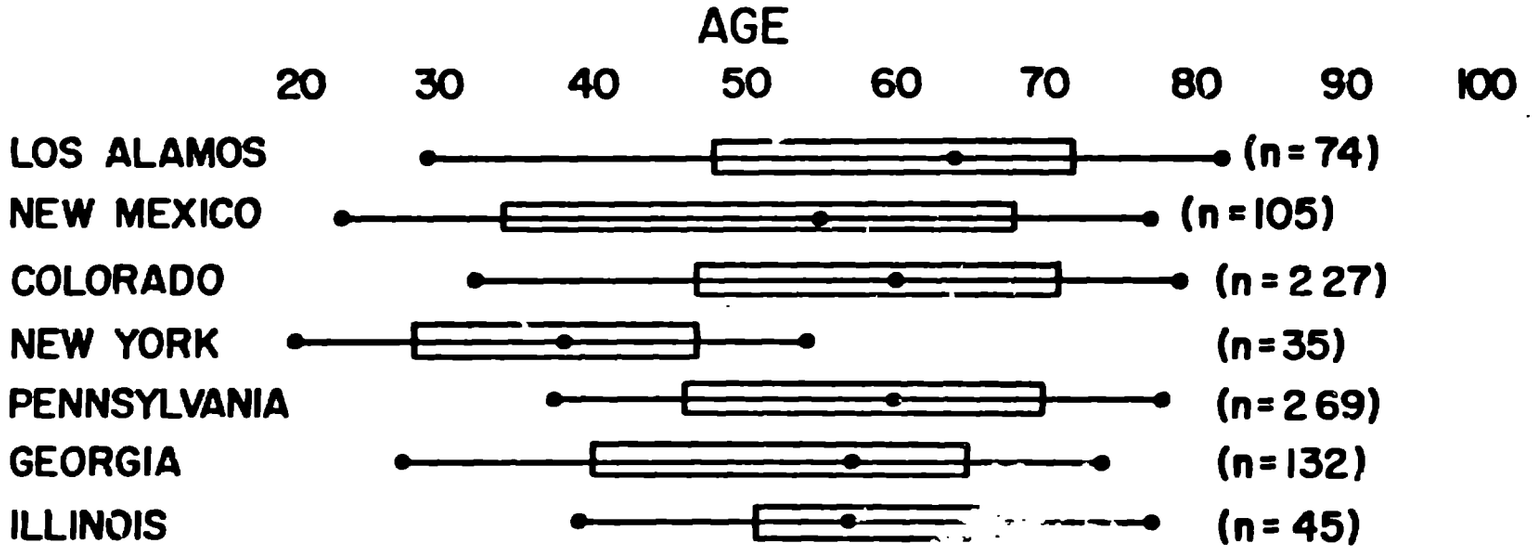
Figure 3 U.S. general population median liver burdens.

Figure 4 U.S. general population median lung burdens.

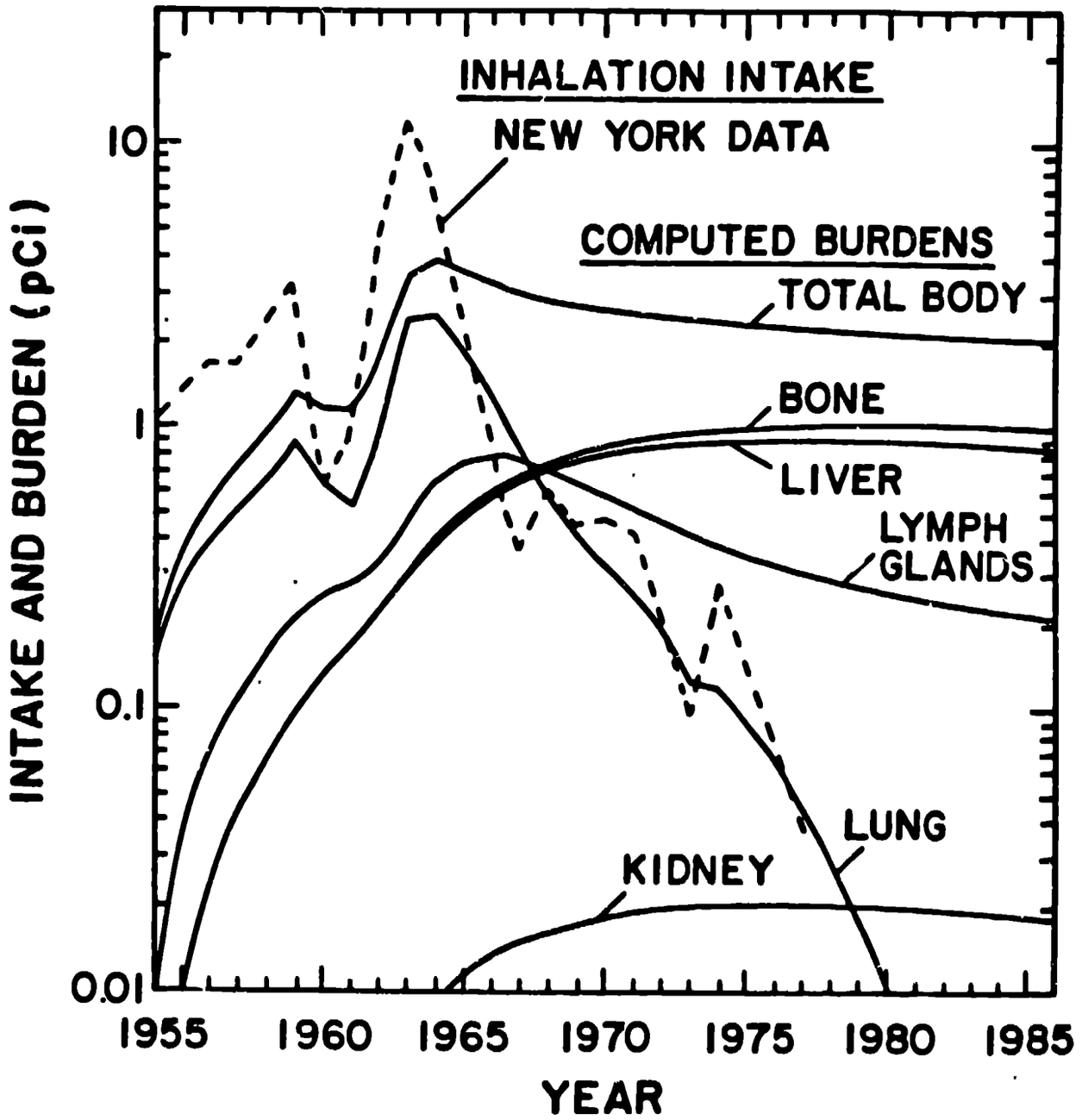
Figure 5 U.S. general population median tracheobronchial lymph node burdens.

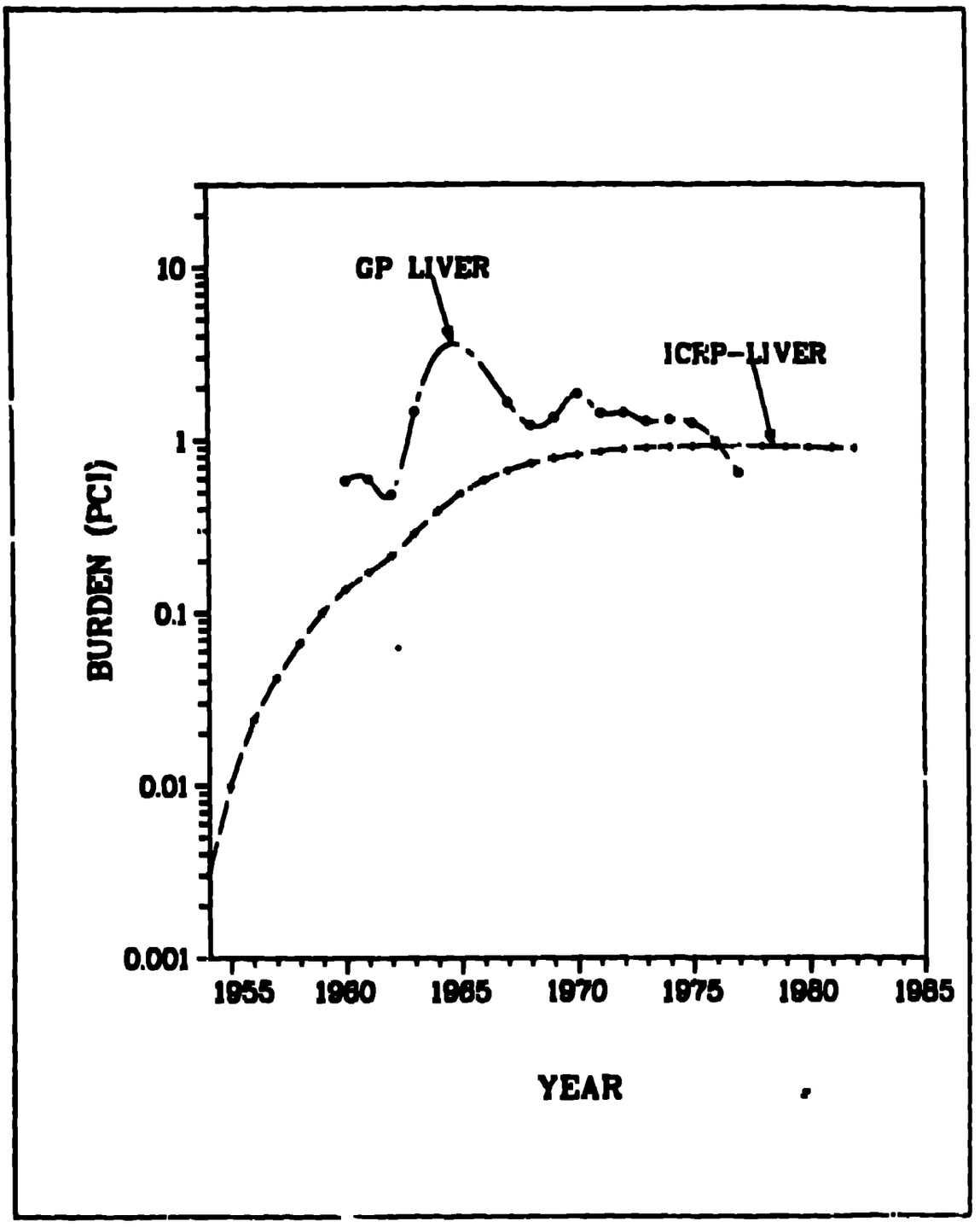
Figure 6 U.S. general population median kidney burdens.

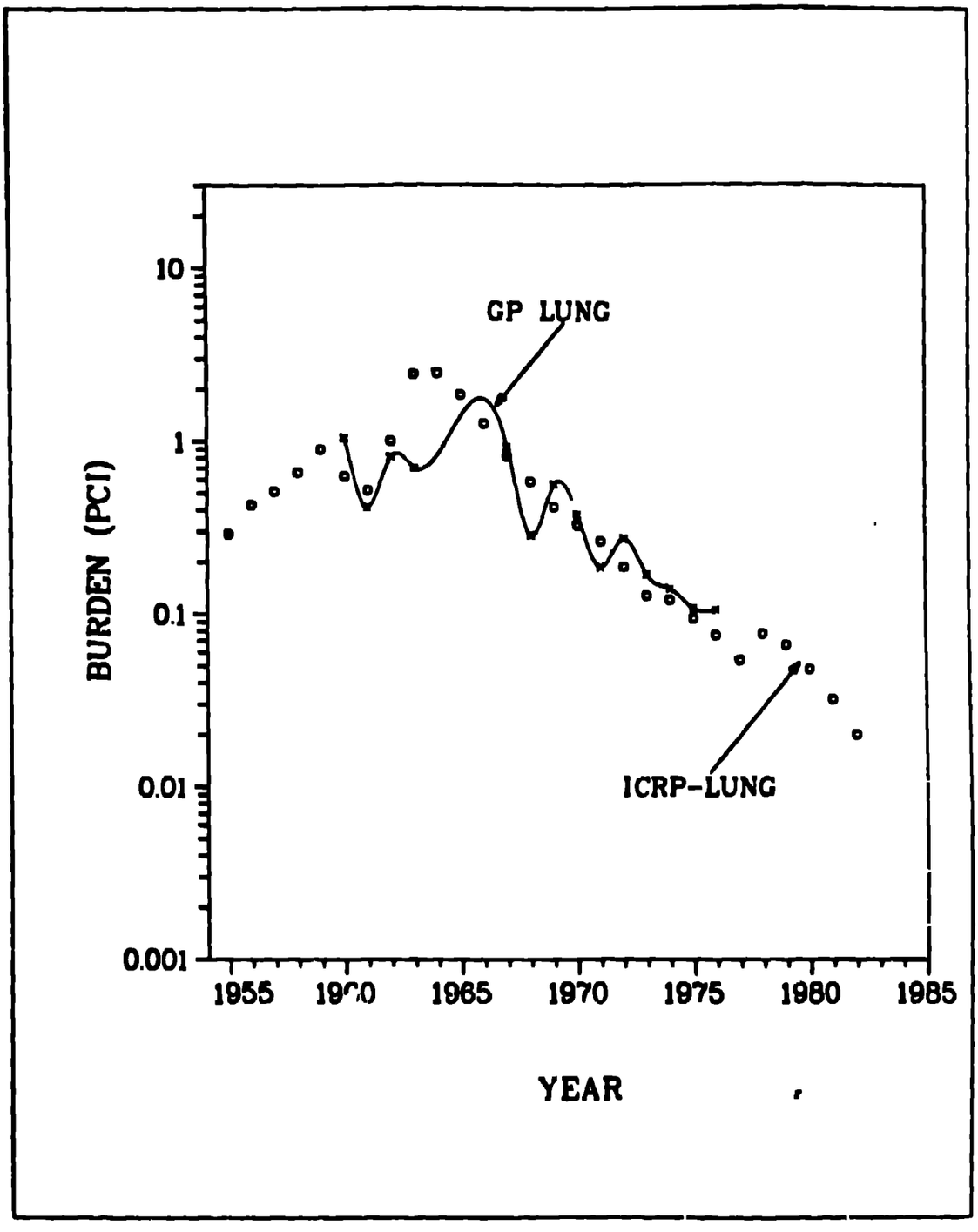
Figure 7 U.S. general population median skeletal burdens.

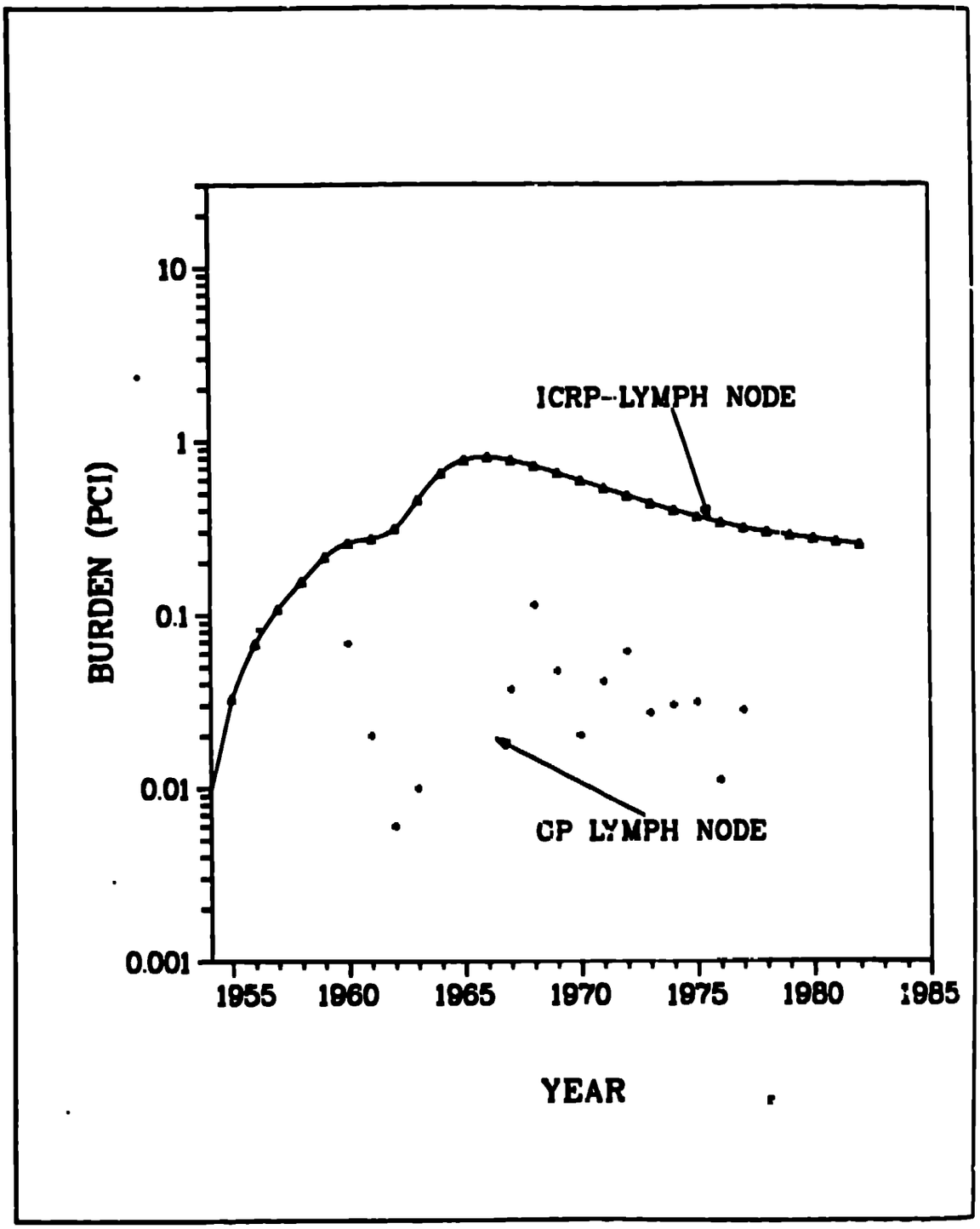


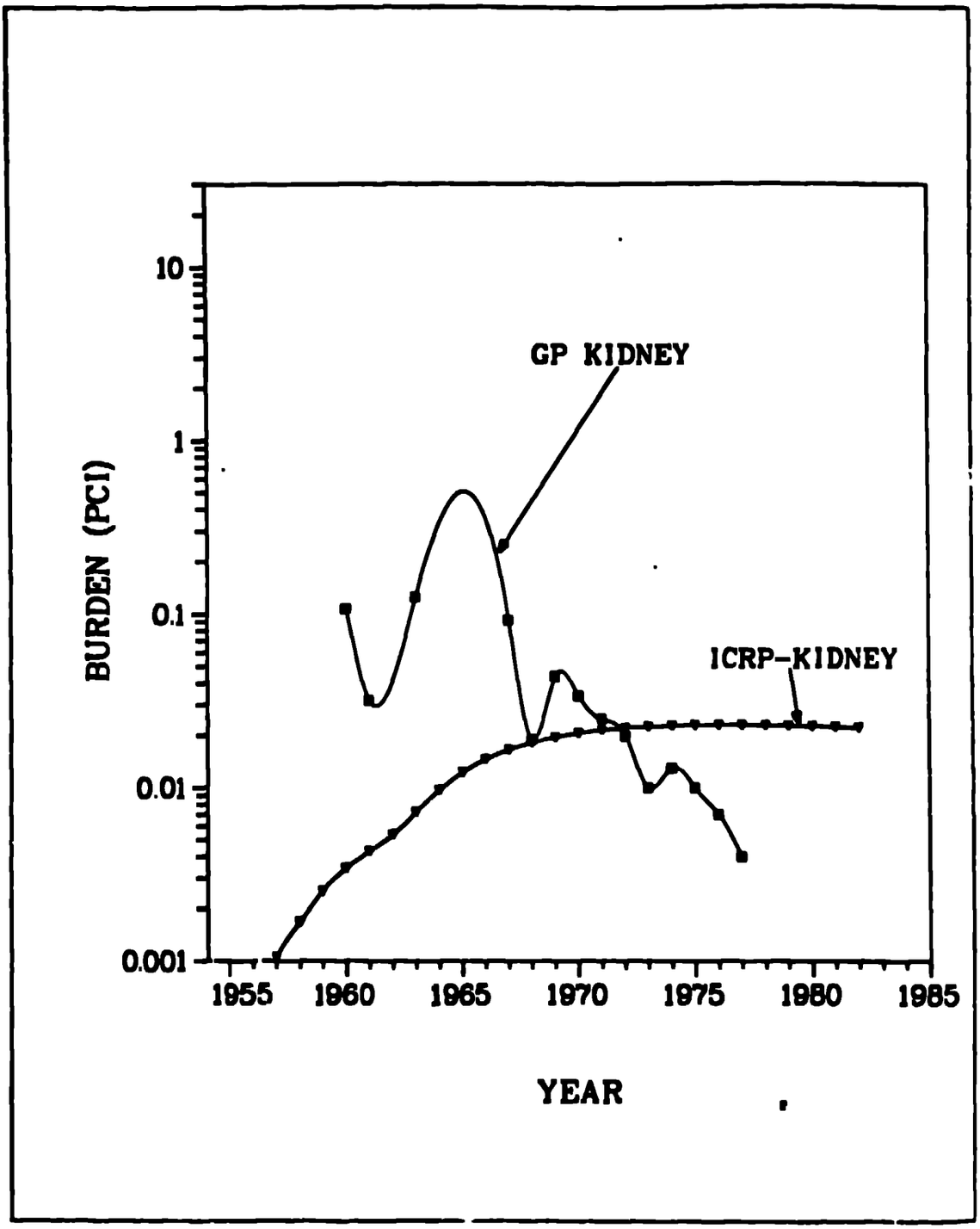
The dots represent the 10th, 50th, and 90th percentiles. The edges of the rectangles are at the 25th and 75th percentiles so that they include the middle 50% of the data.

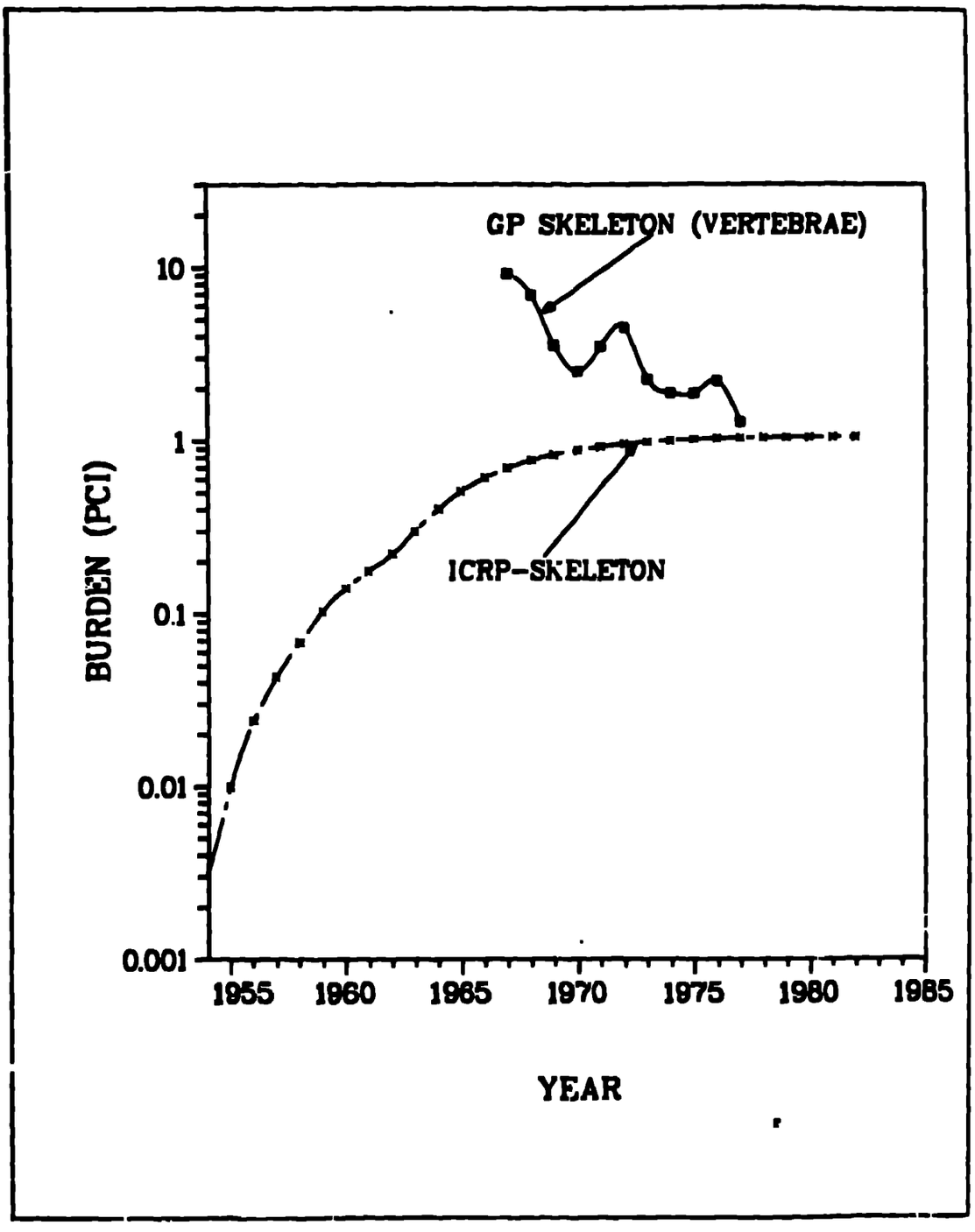

INHALATION INTAKE
NEW YORK DATA
COMPUTED BURDENS
TOTAL BODY
BONE
LIVER
LYMPH GLANDS
LUNG
KIDNEY
INTAKE AND BURDEN (pCi)
10
1
0.1
0.01
1955
1960
1965
1970
1975
1980
1985
YEAR


GP LIVER
ICRP-LIVER
BURDEN (PCI)
10
1
0.1
0.01
0.001
1955
1960
1965
1970
1975
1980
1985
YEAR


10
1
0.1
0.01
0.001
BURDEN (PCI)
GP LUNG
ICRP-LUNG
1955
1960
1965
1970
1975
1980
1985
YEAR


10
1
0.1
0.01
0.001
BURDEN (PCI)
ICRP--LYMPH NODE
CP LYMPH NODE
1955
1960
1965
1970
1975
1980
1985
YEAR


10
1
0.1
0.01
0.001
BURDEN (PCI)
GP KIDNEY
ICRP-KIDNEY
1955
1960
1965
1970
1975
1980
1985
YEAR


GP SKELETON (VERTEBRAE)
ICRP-SKELETON
BURDEN (PCI)
10
1
0.1
0.01
0.001
1955
1960
1965
1970
1975
1980
1985
YEAR