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OAK RIDGE NATIONAL LABORATORY

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NUCLEAR DIVISION

POST OFFICE BOX X
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September 11, 1969

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BOX No. 1
FOLDER Sternglass

Dr. Paul C. Tompkins
Executive Director
Federal Radiation Council
Washington, D.C. 20449

Dear Sir:

In reply to your letter of August 26, 1969, I am sending you a portion of our annual report for 1964 where the distribution of stable Sr in tissue of adults is given. I think this data is relevant to your question, although it does not completely answer it.

The first question is to consider what we mean by a state of equilibrium. I think you will recognize that one must first specify what exposure situation he is envisaging. For example, I favor defining it as the status a population would reach when exposed to environmental ^{90}Sr which had reached a state of equilibrium in the food chains, i.e., more or less in proportion to stable strontium. One could define it in other ways, e.g., each individual takes in the same intake per day, but I think you will agree this second situation is somewhat artificial. If ^{90}Sr is present in the environment and generally distributed in the various foods,and if a population has been exposed for a generation or two, then I would consider this as close to a state of equilibrium as we can come. You see at once, I think, that the distribution of stable Sr in the body is then a rather good guide for the distribution of ^{90}Sr in the tissues of such a population.

As you know, we have collected tissue samples of grossly normal individuals who come to autopsy (usually victims of accidents, homocides, etc.) and we have analyzed these for a variety of trace elements. Figure 21.6 indicates the mean concentrations of stable Sr found in the various tissues. The concentration is on the abscissa and the height of the line is two standard deviations. The number of samples analyzed is indicated also at the end of the line. The organs listed along the ordinate were all less than 0.1 μ g/g and we did not try to show them individually. As you will note, concentration in ovaries is lower than concentration in bone by a factor of about 1/180and testes are even lower. Of course, these are analyses

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Human Studies Project

on the gross organ and do not preclude that this small amount of Sr might be present in some very special form — say in DNA. On the basis of average dose of an individual, one can say that for ^{90}Sr the testes and ovaries would be lower than bone by a factor of approximately 1/100. This allows for a differential of a factor of two reduction due to decay of ^{90}Sr in the bone.

Figure 21.7 indicates the fraction of body burden present in the various tissues but this is not so closely related to dose.

Figure 21.8 indicates the cumulative distribution of the concentrations in bone (dotted line) and these would be expected to be similar to the distribution of doses in bone of a population at equilibrium. It is not directly relevant to your present question, but may be of some interest for other reasons. The confidence bands here are obtained by non-parametric statistics, i.e., they do not assume normality, or log normality, or any other form for the distribution.

We have some similar data on stable Sr in tissues of stillbirths, children and teen-agers, but the number of individuals sampled is much smaller. My colleague, Dr. Rohwer, is resurrecting this data from our files and is analyzing it to help provide an answer to your question. We will send you this as soon as we get it worked up.

What I think it will indicate is that there is no large age difference in the concentration of stable Sr in the various tissues. This has already been asserted by Rajewsky et al, (H.P., Vol. 11, 1965, p. 162) as being the case for ^{226}Ra in bone and probably also for soft tissue though he doesn't have much data.

I might also call to your attention an article by Baratta and Ferri, ^{90}Sr, ^{137}Cs and ^{210}Po in Human Tissues, (Rad. Health Data, May 1967, pp. 298-299). Here ^{90}Sr appears to be higher than soft tissues by about a factor of 20 or somewhat less. However, these data are not necessarily in conflict with the data on stable Sr since one would expect the bone concentration to increase more in the years ahead than would the soft tissue concentrations.

Finally, I mention the U.K. report, Med. Res. Council, Monitoring Report No. 16, which gives data for ^{90}Sr and stable Sr for 1967. Rohwer is also looking at this data from the point of view of age dependence. He is also working on some of the data in Rad. Health from the same point of view.

We will send you these other portions within a week or two, but meanwhile, we send you this first installment of data relating to your question.

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Please call me if you have any difficulties in interpreting any data in the report or any statements in this letter.

Very sincerely yours,

Walter S. Snyder

Walter S. Snyder
Assistant Director
Health Physics Division

WSS:ms

Enclosure

cc. F. D. Sheehan

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FEDERAL RADIATION COUNCIL
WASHINGTON, D.C. 20449

August 26, 1969

AUG 29 1969

Dr. Walter Snyder
Health Physics Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

Dear Walter:

I'm sorry I wasn't clear yesterday as to what kind of dose estimates for strontium 90 I am interested in at this time. As you know, Dr. Sternglass has raised quite a furor by attributing "excess fetal and infant mortality" to strontium 90 from past fallout. Although people at the policy level here are willing to accept the view that he has no case, I am unwilling to make the statement that strontium 90 has no genetic effect at all and find myself embarassed to be unable to answer the question of how would the genetically effective dose from strontium compare with the gonadal doses computed by FRC and UNSCEAR.

FRC report 2 related a steady state intake of strontium 90 in the diet to annual dose rate to bone and bone marrow, but did not make any estimates of the dose rate to soft tissues and gonads that would be simultaneously present. Presumably, when a continuous intake at a constant level of strontium 90 has gone on long enough, the strontium 90 content of soft tissues, blood, and bone will be constant, and there will be an equilibrium between intake, body burden and excretion. Therefore, the relative dose rate between tissues and organs will be constant. These are the numbers I'm interested in.

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Neither fallout nor retention patterns leading to a dose per microcurie fit this condition exactly, but I'm sure I'll need such estimates to defend our intake guides for strontium 90 in FRC report 2.

Sincerely,

Paul

Paul C. Tompkins
Executive Director.

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ORNL-3697
Excerpt

INTERNAL DOSIMETRY

Reprinted from

HEALTH PHYSICS DIVISION
ANNUAL PROGRESS REPORT
FOR PERIOD ENDING JULY 31, 1964

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

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DISTRIBUTION OF STABLE STRONTIUM IN BONE AND SOFT TISSUES AND ITS APPLICATION TO METABOLISM OF STRONTIUM-90

W. S. Snyder M. J. Cook

Strontium has been shown to be a bone seeker in both human and animal studies. Little attention has been focused upon the distribution of strontium in soft tissues; however, every tissue examined in our program on the analysis of human tissues has been found to contain a measurable amount of stable strontium. For this study the age of the individuals was restricted from 20 through 59 years, which would include the majority of working people. Over 2200 soft tissue samples and 160 bone samples were examined spectroscopically, and the data are analyzed here to estimate the distribution of strontium under near equilibrium conditions. It is found that bone contains ~99% of the strontium present in the body, thus differing significantly from ^{226}Ra for which estimates of as low as 80% of the body burden have been given for bone.[9]

In Fig. 21.6 are presented the means of the concentration for 27 different soft tissues and bone, with the number of samples of each tissue analyzed given in parentheses. The length of the vertical line is equal to two standard deviations on the vertical scale. If the vertical line representing the mean concentration of any tissue is turned 90° to either the right or left, plus or minus two standard deviations may be ascertained. Based on the concentration of strontium, the tissues seem to fall into three classes: (1) bone, which is in a class to itself; (2) trachea, larynx, and aorta, which are higher in calcium than the majority of soft tissues; and (3) the remaining soft tissues.

At the meeting of the International Commission on Radiological Protection (ICRP), December 2–5, 1963, Committee 2 proposed to calculate maximum permissible concentration (MPC) values for nuclides that are incorporated into gonadal tissue on the basis of mean dose equivalent delivered to the whole gonadal tissue. On this basis of averaging over the entire organ, it is found that at the 95% confidence limit the concentration of stable strontium in the ovary differs from that in the testes. The mean concentration in the ovary is about 2½ times that in the testes.

Since no whole bodies are available for analysis, the estimate of strontium for the whole body had to be based on samples available, and several compromises were necessary. First, many samples only contained a fraction of the entire organ or tissue being sampled, and the weight of the entire organ or tissue was not known. The amount of strontium in various organs was estimated by multiplying the weight of the organ as given for standard man[10] by the mean concentration observed in the wet tissues. Second, it was not feasible to separate bone and marrow in the course of analysis; therefore, the analytical values reported for bone also include strontium present in the marrow. Since no samples of marrow were available, we have assumed that the concentrations of strontium in red and yellow marrow are comparable to the concentrations of strontium in spleen and fat respectively. The calculated estimate of strontium content of marrow was subtracted from the analytical values reported for bone plus marrow. Finally, some tissues were not sampled, and assigned weights could not be found in literature for some other tissues. However, these tissues only account for about 1200 of the 70,000 g of standard man. The average concentration of the soft tissues which were sampled and analyzed but for which no body weights could be assigned was used as the mean concentration value for the remaining tissues for which no weights were found and for tissues not sampled. By this method the total body burden of stable strontium was estimated to be ~0.33 g.

In calculating MPC and body-burden values for radioisotopes, the fraction of the body burden in an organ is needed. This factor is designated by f_2 in the ICRP[10] and NCRP[11] internal dose reports. In Fig. 21.7 these values are presented. Of the stable strontium in the body, 98.5% is found in the bone. Although muscle has a very low concentration on a microgram per gram wet basis, it may be noted that due to its mass, which comprises

[9] J. D. Harsh and Arvin Lovaas, *Nature* 198, 265–68 (1963).

[10] Recommendations of the International Commission on Radiological Protection, ICRP Publication 2, *Report of Committee II on Permissible Dose for Internal Radiation (1959)*, p. 151, Pergamon, London.

[11] "Maximum Permissible Body Burden and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," *Natl. Bur. Std. (U.S.), Handbook 69*, GPO, Washington, 1959.

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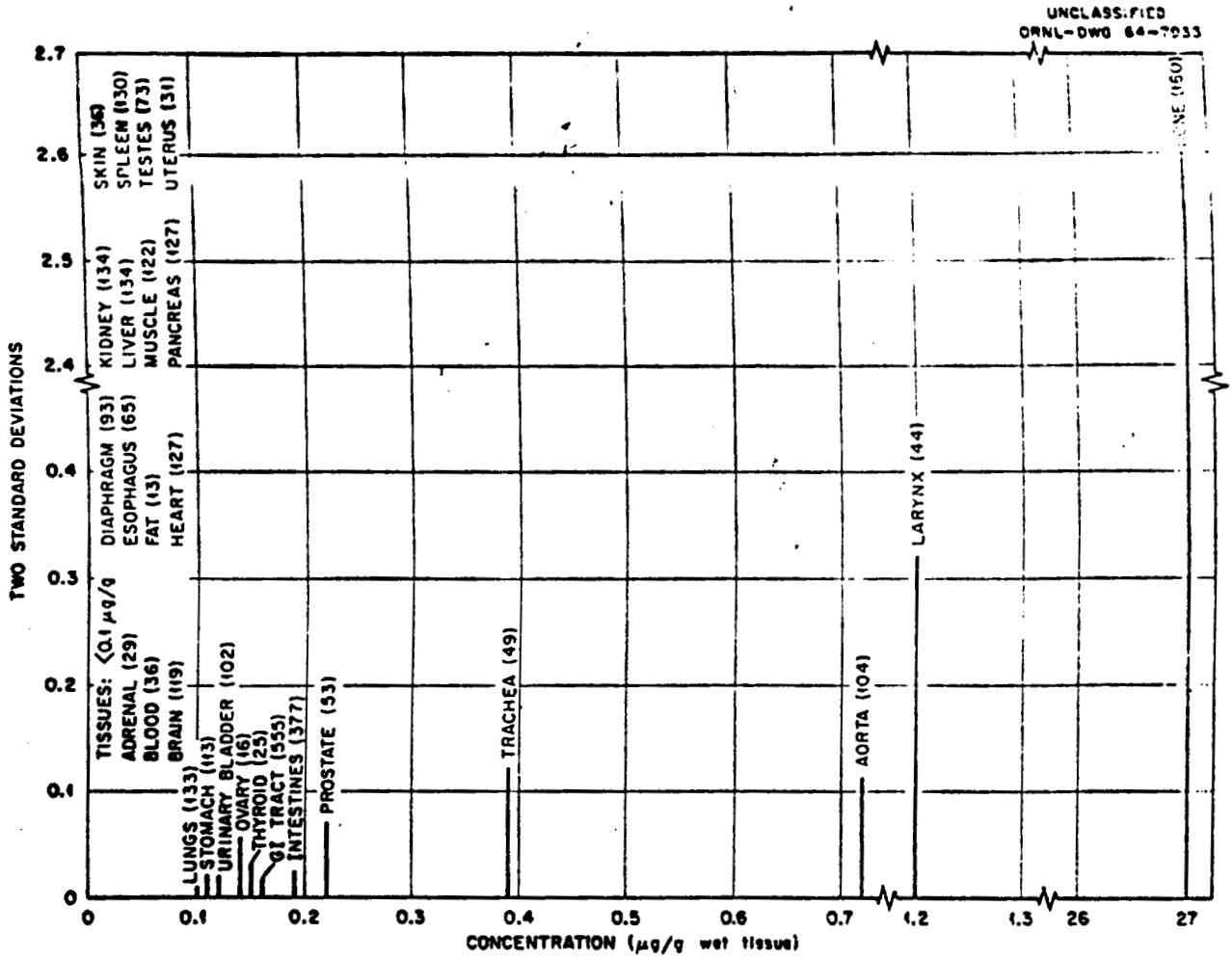

Fig. 21.6. Concentration of Stable Strontium in Wet Tissue.

almost half of the total weight of the body, muscle has the largest fraction of strontium of any of the soft tissues.

The dose which an organ receives from a radioactive element may be calculated from the concentration of this radionuclide in the tissues. A stable isotope of the same element should indicate, on the average, the pattern of distribution to be expected at near-equilibrium conditions for the radioactive element, provided suitable allowance is made for radioactive decay. Statistical methods given by Brunk[12] and by Dixon and Massey[13] have been described and applied to the data for some elements[14] and have now been applied to stable strontium in the bone. These data are presented in Fig. 21.8. The small, dotted, center line is the cumulative sample distribution of strontium in wet bone for people in the United States between ages of 20–59. The two solid lines determine a band such that at each concentration value one may assert with 95% confidence that the true distribution function for the population being sampled lies below (above) the upper (lower)

[12] H. D. Brunk, *An Introduction to Mathematical Statistics*, Ginn and Co., New York, 1960.

[13] W. J. Dixon and F. J. Massey, Jr., *Introduction to Statistical Analysis*, McGraw-Hill, New York, 1957.

[14] W. S. Snyder and M. J. Cook, *Health Phys.* 9, 417–23 (1963).

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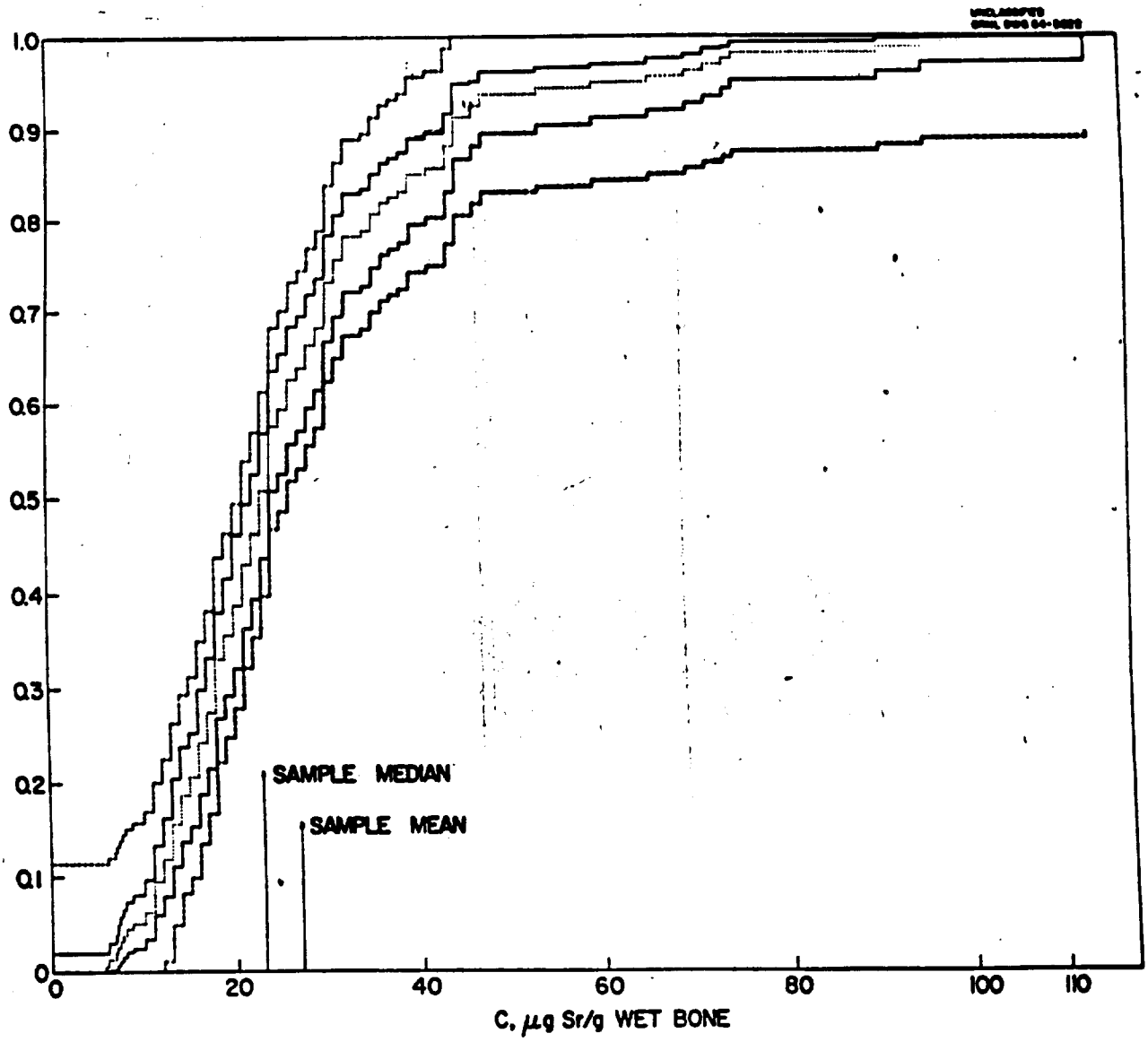
As one illustration of the usefulness of this more detailed estimate of distribution in the body, we note that the concentration of strontium in bone is about 190 times greater than the concentration in the ovary. Even if we allow for a reduction in bone of 30% due to radioactive decay, this would indicate that the ovary gets no more than $^1/_{130}$ of the bone dose. Thus, if the average dose to bone does not exceed 0.5 rem/year, the radiation protection guide recommended by the Federal Radiation Council, then the dose to the ovary should not exceed about 4 mrem/year and the dose to testes should be even less. This is much lower than estimates based on the values listed for the whole body which have sometimes been used, in the absence of anything better, as a basis for assessing genetic dose.



—— MASSEY $m + \frac{1.36}{\sqrt{160}}$ AND $- \frac{1.36}{\sqrt{160}}$ CONFIDENCE BAND FOR THE POPULATION CUMULATIVE DISTRIBUTION

—— m SAMPLE CUMULATIVE SAMPLE SIZE, $n = 160 \frac{1}{160} = m, \frac{2}{160} = m, \frac{160}{160} = m$

—— BRUNK 95% CONFIDENCE BOUNDS AT EACH CONCENTRATION (c)

Fig. 21.8. Ninety-five Percent Confidence Bands for the Distribution of Stable Strontium in Human Bones (Ages 20–59) ORNL Trace Element Data.

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