K. Z. Morgan

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

726778

DEPARTMENT OF PHYSICS

CAMBRIDGE 39, MASS.

January 13, 1950

Dr. Wright H. Langham
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

LAB H-4

Dear Dr. Langham:

This is in response to your letter of December 28, 1949, concerning the Chalk River Permissible Dose Conference recommendations, especially as they relate to plutonium. It is true that the only definitative quantitative data which we have on the long term effects of internal alpha emitters on humans comes from studies of chronic radium poisoning, and from a few cases of liver damage following the injection of thorotrast. You will be glad to know that the results of the last 16 years of observations of patients with radium poisoning are being written up at last. There are about 25 cases. Louie Hempelmann is now going over all of the clinical records of the patients whom Dr. Aub has seen and on whom I have made measurements, and Louie expects to have the first draft of a joint paper on these patients ready within two or three weeks. At the same time Dr. Harrison Martland is writing up all of the cases which he has seen during this period, and on which I have made radium measurements. He too hopes to have a manuscript available soon. In bold outline the results are something like this: 6 cases containing less than 1.0 μg radium are symptom free after about 25 years; 2 (?) out of 5 cases in the 1.0 to 2.0 μg domain have symptoms; 3 out of 5 patients containing 2.0 to 9 μg are symptom free after 20 to 25 years of exposure; out of 5 patients who contained more than 10 μg of radium, one who contained 18 μg of radium is dead (death certificate said leukemia), one who carried about 24 μg of radium has just died in her mid-seventies of heart disease, another who carried 10 μg of radium is alive and reasonably well, etc. Louie has all my files on these patients, and what I have just said is given from memory, and may therefore contain a few minor errors. We are all struck by the fact that the osteogenic sarcomas which Martland saw about 20 years ago are notably absent from the new series. It is presumed that this is associated with the dosages, and that the earlier patients may have contained a great deal more radium than the present survivors.

I am enclosing a reprint of the paper on "Radium Metabolism in Rats, and the Production of Osteogenic Sarcoma by Experimental Radium Poisoning" by Evans, Harris and Bunker, Am. J. Roent. 62, 353, (1944). There are some fragmentary statements on page 366 of this paper about humans, and reference 10 (Evans and Aub, to be published) refers to the clinical material which Louie Hempelmann is now working up.

It is our belief that most cases of chronic radium poisoning which are seen by physicians anywnere in the United States eventually come to the attention of Dr. Martland, or Dr. Aub, or myself, and the two series include all such cases. The number of people who carry similar quantities of radium in their skeleton but have not developed clinical symptoms is unknown. Also, the total number of people originally exposed in the luminous dial industry, by drinking radium nostrums, and by the medical administration of radium, can only be roughly estimated. Martland told me by phone yesterday that in one plant alone there were 500 to 600 workers during World War I, and that he would estimate that several thousand people had been exposed in all plants. I find that in an article on radium poisoning in the October 1933 issue of the American Journal of Public Health I said, "Due to labor turnover, probably about 800 people worked long enough to endanger their lives." Those who died in the late 1920's, and who make up the main bulk of the approximately 40 known deaths, contained large amounts of radium. The measured values at death run up to 180 μg in the body.

You asked for an estimated answer to the question "How many persons in ten thousand may be expected to be damaged by 0.1 and 1.0 μg of radium fixed in the body?" My own guess would be that none would be damaged by 0.1 μg, and that less than 10 individuals would be damaged by 1.0 μg of radium, if fixed in the body for about 30 years, which is the present limit of our actual experience. I have also asked Hempelmann and Martland to give independent estimates on your questions. Hempelmann says he "would be surprised to find more than 1 or 2" damaged out of ten thousand at 0.1 μg radium; and that he "would not be surprised to find 25 to 50 people with nonfatal, nonmalignant symptoms within 25 years" out of ten thousand at 1.0 μg radium. In making this estimate, Hempelmann presumably had in mind 1.0 μg radium content terminally, that is as seen in the series which he is now going over. As the measured half value time of radium in the human is about 45 years, this would mean that these latter individuals might have contained closer to 2 μg radium in their skeletons originally. Martland's answers to your questions are: for 0.1 μg, less than 1 case out of ten thousand exposures; and for 1.0 μg he "would be surprised to find any cases if 1.0 μg of radium was the maximum skeletal content of the individuals" out of ten thousand over a 30-year period.

You asked about rats. The enclosed reprint contains the data on these animals, and the answer to your question is that adult rats exhale 85 per cent of the radon produced by the radium contained in their skeleton.

You asked my opinion on three methods of estimating the permissible dose of plutonium. I definitely prefer methods which are based on known data from the chronic exposure of humans to internal alpha ray emitters, that is on the radium data. It is certainly necessary to include the energy delivered by the alpha rays from that portion of the radon and its decay products which are retained in the body. As you have pointed out correctly on page 2 of your letter, this definitely means that the human absorbs three times as much alpha ray energy as is

represented by the radium alpha rays alone. Then if one takes the permissible radium dose as 0.1 μg radium, this corresponds energetically to 0.3 microcuries of plutonium, or 4.5 micrograms of plutonium. It is true that the details of distribution of deposited plutonium and radium differ. Robert Dudley, in our laboratory, has recently completed quantitative studies of the inhomogeneity of distribution of radium in the bones of humans who have carried several micrograms of radium chronically for several decades. The highest local concentrations which he finds correspond to ten times the local energy dissipation per gram as would be expected if the radium were absolutely uniformly distributed throughout the entire bone. I would be very much interested in comparing your data on the distribution of plutonium in human bones with the results which we have obtained on radium. Also I would think it very much worth while if you could arrange to send me a few typical bone specimens. Then we could have Dudley study these materials using exactly the same technique which he used for radium, and thus assuring strictly comparable results. I assume that this material is classified, so you will want to know that Dudley has a Q clearance, serial No. NY 5359.

I believe it is difficult or impossible to justify the use of acute toxicity experiments in attempting to estimate the relative effects of chronic exposure to radium and to plutonium. This is because the details of the over-all biological effects of the radiation may very well be quite different for acute lethal effects and for chronic effects. For example, comparing rat and man the acute whole body lethal dose of gamma radiation is nearly the same, the rat requiring about 1.5 times as much radiation. For the production of osteogenic sarcoma in chronic radium poisoning on these two species, the relative doses are dramatically different. As is shown in Table V the rat requires 150 times as much radium per kilogram of body weight as does man in order to produce similar chronic effects in a comparable fraction of the life span of the two species. The ratio would be even greater if the calculation were based on unit weight of skeleton in the two species.

Following the Research and Development Board Panel meeting at Chicago, Dr. Brues and I discussed on December 16 some aspects of the comparison of acute and chronic dosages. We did not actually discuss the plutonium problem, but I believe you will find that Dr. Brues's opinion has changed since December 15. Brues himself pointed out to the Panel that there are important but unknown differences in the biological effects of acute and chronic radiation, and that the effects of chronic radiation cannot be determined accurately from acute experiments. This point came up in connection with the report of George Sacher, who has been comparing the effects of gamma radiation on the mouse and the dog, giving both acute radiation and chronic radiation simulating RW conditions. It is found that the ratio of the acute MLD for dog to mouse is not the same as the chronic MLD when the same quality of radiation is given in the four experiments. I do not have a memorandum of the actual ratios observed in the chronic experiments, but I do recall that the results appeared compelling.

As you have pointed out, even a highly conservative calculation assuming some kind of equivalence between chronic alpha radiation, and an RBE of 20, and a whole body gamma radiation of 0.3 rep per week, leads to plutonium values of the order of 1.8 μg of plutonium. I feel that the other calculations based on the known effects for radium are much to be preferred radiobiologically. The gamma ray calculation can be used as supporting evidence if desired.

It would appear that there is a safety factor of the order of magnitude of 10 in the permissible radium value of 0.1 μg. I do not feel that in the state of our present knowledge it is justified to introduce an additional safety factor of 15 when estimating the effects of plutonium relative to radium. I do not feel that the Chalk River proposals for plutonium are "absolutely necessary to insure a sensible and reasonable protection of the personnel working with the materials in question."

In our telephone conversation you asked me to jot down some of my remarks concerning dust. A number of my earlier ideas on this subject were discussed in the colloquium on 16 April 1948 at the Sigma building. These and some supplementary calculations were written up and sent in to the H division on 30 April 1948. You may find something useful in those notes, which are unclassified and which are headed "Chronic Radium Poisoning".

In Table I of the Chalk River Conference, there are several instances where the proposed maximum permissible amount of alpha ray emitting substances in air are even lower than the naturally occurring radioactivity. One is tempted to abandon the word "conservative", and use the word "absurd" in speaking of some of the entries in this table. To begin with, the naturally occurring radium content of ordinary rocks and soil throughout the earth's crust is 10^{-12} gms radium per gm. Simple arithmatic shows the startling but true fact that in every square mile of soil to a depth of one foot there is a total of one gram of radium, and three tons of uranium! Thorium has about three times the natural abundance of uranium in rocks and soil. Because of the longer lifetime of thorium, its contribution to the total radioactivity per gram of rock or soil is substantially equal to that of uranium. Thus in each gram of soil there are 8 alpha ray emitters of the uranium series and 6 alpha ray emitters of the thorium series, or 14 in all, and each has the specific activity of 10^{-12} curies per gram of rock.

With respect to air, I have had a long talk with Mr. Gurney of the Liberty Mutual Insurance Company, who has done a great deal of dust particle counting. Dust counts are reported in millions of particles per cubic foot of air, and all the numerical values which I refer to in the following sentences will be understood to be in these units. Under ordinary conditions of microscope illumination, magnification, etc., dust particles having a size greater than 0.8 μ are counted. About 90 per cent of all the particles usually have a mean diameter of 2 μ or less, about 10 per cent are in the range of 2 to 3 μ, and there are

a very few particles on up to about 10 μ. Gurney has found that indoor air and outdoor look just about alike under the microscope, insofar as particle distribution size is concerned and also the dust found in industrial plant air is similar. Dust which is actually visible in the air, as along a country road, is ordinarily visible because of the large particles of 10 μ diameter or so, but these few large particles are accompanied by the ordinary distribution of fine particles. In respiration, the particles which are not filtered out and which actually get to the lungs are mainly those having a diameter of 2 μ or less. Normal dust counts in a city like Boston are found to be as low as 0.2 or 0.3 immediately following a rain. The counts taken on ordinary city air five stories or so above the street and on a clear, dry day, will run about 3 or 4. At the same location counts of 8 to 15 were regularly observed in Boston, even though the air looked perfectly clear to the eye, during the period of the Kansas dust storms. When dust is actually visible to the eye in the air, the particle count will be in the vicinity of 100 to well over 1,000, but the particle distribution size is substantially the same as on a clear day. The median diameter of the dust particles is about 1 μ, but because the actual volume of dust increases with the cube of the diameter of the particle, the particle size distribution is taken into account by using a diameter of 2 μ in calculating the weight of dust per unit volume of air.

Now with these data in hand we can calculate the alpha particle radioactivity of ordinary city air on a clear day. The result is that a particle count of unity (1 million dust particles per cubic foot of air) corresponds to 1 microgram of dust per liter of air. Taking the normal radioactivity of soil as given above, we come out with the figure of 10^{-14} microcuries of alpha activity per cc of air when the dust count is unity. Country air which still looks clear to the eye will have a dust count of about 10. and an alpha ray activity of 10^{-13} μc/cc, and dusty air, such as I remember so vividly at Los Alamos, will run 10^{-11} μc/cc. This is a higher value than that which is listed in Table I of the Chalk River report for plant personnel, and the Table contains a note that the maximum permissible dose for large populations is 1/100th of this amount. The tolerance proposals seem to be approaching small fractions of the alpha ray exposure which Mother Nature gives us every day. Therefore, I do not feel that these proposals are reasonable.

It should also be pointed out that the radon content of ordinary outdoor air is generally of the order of 1 to 5 × 10^{-13} curies per liter, or 10^{-10} μc Rn/cc. In addition there are the solid alpha ray decay products Ra A, Ra B, etc., which are generally deposited on dust and will augment the natural radioactive content of dust particles.

The natural radioactivity of drinking water runs in the neighborhood of 10^{-12} to 10^{-13} grams radium per gram of water. The Chalk River suggestions for the radium content of water fit for drinking by a large population is 4 × 10^{-13} grams radium per liter.

Some months ago Dr. Shields Warren was instrumental in helping me get started here a long range program on the measurement of the radium content of ordinary humans, and he has already supplied us with a number of bone samples obtained from amputations in his hospital. The National Institutes of Health have taken a great interest in this program, and we now have in addition the collaboration of Dr. Stewart, Dr. Dorn, Dr. Lorenz, and others in Washington, as well as Dr. Princi in Denver who will collect whole skeletons for us in connection with his program on environmental cancer. We look on this program as a very long range one, and hope to have some definitive numerical values, having statistical significance in, say, 3 to 5 years. I will keep you informed.

In accord with your suggestion I am sending a carbon copy of this letter to Shields Warren for his information. I would be glad to discuss these problems further with either of you at any time.

With warmest personal regards.

Cordially yours,

Robley D. Evans

Robley D. Evans
Professor of Physics

RDE:p
Enclosure
cc: Dr. Shields Warren