COLUMBIA UNIVERSITY, DIVISION OF WAR RESEARCH

Project SAM

714410

Columbia Serial No._____

File Index_____

Date_____

[redacted]

Classification

This 2 document consists of _____ pages and 0 figures. (This cover sheet is page 1)

Distribution
Series A

Copy No. 2
(Copy No. Series Letter)

Dr. R.S. Stone

Short Title of Document or Addressee of Letter

G. Failla

Author

REPOSITORY NARA - Wash, DC
RG 326
COLLECTION Argonne Natl Lab - U of Chicago - Met Lab
BOX No. 5 (BX-1) NN3-77-85-1
FOLDER November 1944

CLASSIFICATION CANCELLED
DATE 8/2/62 T
For The Atomic Energy Commission
Edgar A. Thurin for the
Chief, Declassification Branch

W-7405-Eng.-50

BEST COPY AVAILABLE

[redacted]

In general, a classified document shall not be copied or duplicated. If additional copies are necessary they should be requested from the originator. In an emergency, the originator may give telegraphic approval for reproductions, specifying series letter and number of copies. The originator must be notified immediately of the distribution of the reproductions. All duplicating sheets, stencils, etc., should be burned.

1090680

This document consists of
2 page and 0 figures
No. 2 of 2 copies

[redacted]

November 15, 1944

Dr. R.S. Stone
Clinton Laboratories
P.O. Box 1991
Knoxville, Tenn.

Dear Dr. Stone:

Following the request from your secretary for authorization to issue a Series C of the report titled "Alpha Ray Emitters in Bone", I have gone over the text to see whether any changes should be made.

I find that at the time I used the same letter Q to represent quantities of radioactive material expressed in curies or in grams. From the context it is obvious which is which, but it would be better to use two different symbols and avoid possible confusion. I am, therefore, enclosing the last two pages of the report with this change of symbols, and minor additions in wording.

Yours sincerely,

GF:KR

G. Failla

[redacted]

1090681

April 4, 1944

REPOSITORY NARA - WASH D.C.
RG ARGONNE NAT'L LAB
COLLECTION U OF CHICAGO MET LAB
BOX No. 5 (2x-1) NN3-77-85-1
FOLDER NOVEMBER 1944

Alpha Ray Emitters in Bone

by G. Failla

It is assumed at the present time that 1 microgram of radium "fixed" in the human body constitutes a hazard from the point of view of possible production of osteogenic tumors. It is probable that this amount is somewhat low, but it is best to be on the safe side. In the radium luminous material industry 0.1 microgram of radium "fixed" in the body is considered to be the maximum allowable amount. Radium may be considered to be "fixed" in the body when the rate of elimination is such that a period of many years (without further exposure) would be required to eliminate one half of the initial amount.

Take 110 lbs (= 50 kg.) as the weight of a radium dial painter, and assume that the weight of the skeleton is 15% of the body weight and the radium is all in the skeleton.

Weight of bone = 7500 grams

If 1 microgram of radium is uniformly distributed throughout the bones, concentration is

$$\frac{1 \times 10^{-6}}{7500} = 1.33 \times 10^{-10} \text{ gram Ra/gram bone}$$

Energy released by radium alone in the form of alpha particles = $3.7 \times 10^{10} \times 4.74 \times 10^{6} = 1.76 \times 10^{17}$ e.v./sec/gram Ra

BEST COPY AVAILABLE

1090682

Energy released by radon, Ra A and Ra C' in the form of alpha particles = $3.7 \times 10^{10} \times 19.1 \times 10^{6} = 7.1 \times 10^{17}$ e.v./sec/curie Rn. Assume that when radium is fixed in the body 50% of the equilibrium amount of radon is retained.

Thus energy released by fixed radium

$$= (1.76 + 0.5 \times 7.1) \times 10^{17}$$

$$= 5.26 \times 10^{17} \text{ e.v./sec./gram Ra.}$$

Therefore, for 1 microgram of fixed radium in the skeleton, energy release is

$$5.26 \times 10^{17} \times 1.33 \times 10^{-10} = 7 \times 10^{7} \text{ e.v./sec./gram Bone}$$

This may be increased 5% to include the energy contributed by beta and gamma rays. Thus energy release per microgram fixed in the skeleton = 7.3×10^{7} e.v./sec./gram of bone.

We may compare this with the energy absorption resulting from exposure to gamma rays at the rate of 0.1 r/8-hr. day. Taking a 5.5 day working week the gamma ray dose is 0.55 r which corresponds to

$$0.55 \times 5.35 \times 10^{13} = 2.95 \times 10^{13} \text{ e.v./gram of Air}$$

The energy absorbed per gram of bone is greater than this due to the fact that bone contains elements of higher atomic number than air. The difference will be greater the softer the gamma radiation. However, for the present purpose we shall neglect this difference and assume that the mass energy absorption in air and bone is the same. We may then say that 0.55 r of gamma radiation produces (at least) 2.95×10^{13} e.v./gram of bone.

1090683

The release of energy by 1 microgram of radium in the skeleton in one week is

$7.3 \times 10^7 \times 7 \times 24 \times 3600 = 4.4 \times 10^{13}$ e.v./gram bone

Accordingly, the release of energy in the skeleton due to 1 microgram of radium uniformly distributed therein is approximately the same as that resulting from exposure of the whole body to 0.1 r/ 8 hr. day of hard gamma radiation.

On this basis alone one would conclude that 1 microgram of radium fixed in the body is a safe amount. However, the approximate equality of energy absorption in bone results from the assumption that the radium is <u>uniformly</u> distributed throughout the bones. Now since the radium is carried to the bones by the blood, it is to be expected that the concentration would be greater in the bone layers which are not too far from circulating blood. The actual distribution would depend on the period of time during which the radium has accumulated in the body and the time when exposure to radioactive dust ceased. At any rate, it is probable that the radium is not evenly distributed throughout the bone. It is also probable that some parts of bone in which metabolic processes are more active will contain more radium. Thus it is obvious that local concentrations of radium may exist and that in these regions the rate of release of energy may be much higher than the value given above, which is based on a uniform distribution of the radium

1090684

in the total bony mass. Furthermore, some allowance should be made for the possibly greater biological effectiveness of alpha particles in relation to the biological effect under consideration (tumor production). It would seem then that 0.1 microgram of radium fixed in the body is reasonable as the tolerance amount for man. If we wish to take into account the weight of an individual we may set the tolerance limit at 2×10^{-9} gram Ra/Kg body-weight. (This refinement is hardly justified by the state of our knowledge of the subject, but is logical).

To determine the radium equivalent of any other radioactive element which tends to collect in the bones <u>in the same way as radium does</u>, we may proceed as follows: In the first place, if the mode of accumulation is the same, the local concentrations of radioactive material may be assumed to be very similar to those occurring in the case of radium - whatever they may be. Therefore, the equivalence may be based on the <u>average</u> release of energy per gram of bone.

For 2×10^{-9} gram Ra/Kg. body weight the energy release is 7.3×10^{6} e.v./sec./gram of bone. For any alpha ray emitting radioactive substance, the energy emission is

$$\frac{3.7 \times 10^{10} \times \cancel{C} \times E}{150} \text{ e.v./sec./gram of bone}$$

where C = "amount" of radioactive material in curies per kilogram of body weight.

E = energy of alpha particle in e.v.

1090685

150 = grams of bone per Kg of body weight (assuming 15%)

Therefore $\frac{3.7 \times 10^{10} \times \cancel{Q}\, C \times E}{150} = 7.3 \times 10^{6}$

and $\cancel{Q}\, C = \frac{7.3 \times 10^{6} \times 150}{3.7 \times 10^{10} \times E}$

$= \frac{0.03}{E}$ curie/Kg of body weight

Since 1 curie of radium = 1 gram and 1 curie of any radioactive element $= \frac{\text{H.V.L. of the element}}{\text{H.V.L. of radium}} \times 1$, in grams

$Q = \frac{0.03\ (\text{H.V.L.})}{1690\ E}$ when (H.V.L.) is expressed in years,

or $Q = 1.75 \times 10^{-5} \frac{(\text{H.V.L.})}{E}$ grams/Kg of body weight.

Q is the amount (in grams) of a radioactive material that releases alpha particle energy at the same rate as 2×10^{-9} gram of radium fixed in the body (in which case, it will be recalled, only 50% of the equilibrium amounts of radon and subsequent products are retained in the body). From the point of view of radiation effect, therefore, Q represents the tolerance amount of a radioactive element fixed in the body per kilo of body weight (or the equivalent of 0.1 microgram of radium fixed in the body of a 50-kg. person).

For an alpha ray emitter of

H.V.L. = 2.4×10^{4} years

and E = 5×10^{6} e.v.

$Q = 8.4 \times 10^{-8}$ gram/Kg. of body weight corresponding to 4.2 micrograms in a 50-Kg. person.

1090b86