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LOS ALAMOS SCIENTIFIC LABORATORY

OF THE UNIVERSITY OF CALIFORNIA

LOS ALAMOS, NEW MEXICO

LA-1469

THEORETICAL CONSIDERATIONS OF ACUTE EXPOSURE OF MAN TO HTO OR T_2O ACTIVITY IN THE ATMOSPHERIC ENVIRONMENT

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THEORETICAL CONSIDERATIONS OF ACUTE EXPOSURE OF MAN TO HTO OR T_2O ACTIVITY IN THE ATMOSPHERIC ENVIRONMENT

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HEALTH AND SAFETY

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ABSTRACT

The quantity of tritium taken into the body of man on exposure to an atmosphere containing HTO or T_2O vapor is proportional to the length of exposure and the activity of HTO or T_2O per unit volume in the atmosphere. The theoretical quantity of HTO or T_2O required to produce lethality can be introduced into the body of man in a few seconds of exposure or in the time required to take one breath if the atmosphere is saturated with T_2O vapor. It is indicated that personnel working with T_2O should be extremely cautious with procedures which might possibly lead to exposure to tritium water vapor.

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Fig. 1. The length of acute exposure required to introduce tolerance and lethal doses of tritium into the body of man at various levels of HTO and T_2O activity in the atmospheric environment 7

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1. INTRODUCTION

This report is a consideration of the radiation hazard to personnel working with high specific activities of tritium in laboratories or in industry where the possibility of acute exposures to high activities for a few seconds, minutes, or hours may exist. The dangers inherent in short acute exposures to HTO or T_2O vapor are defined in the light of recently acquired data on the rate of transfer of HTO from the environment into the body of man through the skin and respiratory tract. For exposure times of only a few seconds, the hazard can be shown to be great for the high activities that are possible with HTO or T_2O vapor in the atmospheric environment.

2. METHODS AND ASSUMPTIONS

The quantity of tritium introduced into the body of man exposed to an atmosphere containing HTO or T_2O is dependent primarily on the activity per unit volume of atmosphere, the length of exposure, the volume of atmosphere inspired per unit time, the percentage of inspired activity retained by the body, and the rate of absorption of activity through the skin. In this paper it was assumed that the volume of air inspired per minute by man was 20 liters when working at the usual laboratory and industrial jobs.[1] It was assumed that man would absorb into the body all the activity contained in inspired air. Experiments reported by the author[2] showed that man actually absorbed between 98 and 99 per cent of all HTO activity inspired. It was also assumed that the activity absorbed into the body through the total skin area on exposure to any given activity in the atmosphere was equal to that absorbed through the lungs. Experiments on the HTO absorption rate through the skin of man[3] warrant this assumption when the exposure is longer than 10 min. For exposures of less than 10 min the activity absorbed through the skin appeared to be somewhat less than that absorbed through the lungs. The tritium activity taken into the body of man during an exposure of 1 hr to an atmosphere containing 1 mc of HTO or T_2O per liter of atmosphere is estimated as follows:

$$1 \text{ mc} \times 20 \text{ liters/min} \times 60 \times 100 \times 2 = 2.4 \text{ c/hr}.$$

In the above calculation 20 liters/min is the inspired volume, 100 per cent is the absorption of the activity inspired, and 2 is the multiplication factor for including the absorption through the skin.

In this report it is assumed that the activity introduced into the body is distributed principally in the body water and, therefore, distributed fairly uniformly throughout the body to produce essentially equal whole body radiation exposure. Seventy kilograms (158 lb) was

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taken as the weight of an average man with 70 per cent of the body weight as water.[1] The length of time the tritium remains in the body, and consequently the radiation dose delivered to the whole body by any quantity of HTO or T_2O, is a function of the apparent volume of body water in which the activity is contained and the rate of water turnover. It has been shown[4] that tritium elimination from the body of man is an exponential function of the rate of turnover of the body water. Using 2.5 liters as the average normal daily water intake and excretion by man,[1] a half-time of 14 days was calculated for tritium elimination $\left(\frac{70 \times 0.7}{2.5} \ln 2 = 14 \text{ days}\right)$. Experiments at Los Alamos on men on ad libitum water intake showed a half-time for tritium elimination from body water ranging from 9 to 13 days.[4] This half-time was reduced to 2.5 days by forcing fluids at the rate of 12.8 liters/day.[4] In calculating the integrated radiation doses in this report, the 14 day half-time recommended as the standard value[1] was used as the slowest and the 2.5 day half-time was used as the fastest practical elimination rate.

In considering the lethal dose to man it was assumed that a total integrated dose of 400 rep delivered in 15 days would be lethal. This is strictly an assumption and the value may be low by a factor of 2 to 5 since 400 r delivered instantaneously is assumed to be the lethal dose of X or gamma rays for man. No correction is attempted for the fact that in the case of the 2.5 day half-time for elimination, 98.4 per cent of the ultimate total dose would be delivered in 15 days, whereas in the case of the 14 day half-time for elimination only about 53 per cent of the total dose would be delivered during the same time.

Three-tenths rep per week was taken as the beta ray tolerance value for the tolerance dose calculations.

The physical constants assumed in calculating the radiation doses were: 6000 ev = average energy release per tritium disintegration, 3.7×10^{10} d/sec = 1 curie, and 93 ergs/g of tissue = 1 rep.

3. RESULTS

Figure 1 indicates the times of exposure required to introduce tolerance and lethal quantities of tritium into the body of man at various levels of HTO or T_2O in the environment, based on the assumptions made above. The diagonal lines in this figure were drawn to indicate the exposure time required at the different atmospheric activity levels to introduce the quantity of tritium necessary to deliver the specified integrated dose of radiation when the excretion half-times are those specified on the graph. The shortest time given on the abscissa of Fig. 1 is 3.6 sec, this being about the length of time usually required to

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inspire and expire one breath of air in the normal breathing cycle. The results indicate that 11 mc of HTO or T_2O introduced into the body of an average size man gives a radiation dose of 0.3 rep during the first week following the introduction, assuming an elimination half-time of 14 days. This corresponds to the radiation tolerance dose established by the Division of Biology and Medicine of the Atomic Energy Commission. Since 1 μg of T_2O contains about 2.7 mc of tritium, 11 mc corresponds to about 4 μg of T_2O. An exposure of 3.6 sec to an atmosphere containing 5 mc/liter of tritium as HTO or T_2O would likely result in the introduction of a tolerance dose into the body.

An exposure to an atmosphere containing 4 to 12 c/liter of HTO or T_2O for 3.6 sec may be expected to introduce near lethal quantities of tritium into the body of man. As indicated in Fig. 1 the lethal dose (400 rep) for tritium as the oxide in man ranges roughly from 8 to 24 c, depending on the half-time for elimination. At 2.7 c/mg of T_2O the lethal dose would be 3 to 9 mg. An atmosphere saturated with T_2O vapor at 25°C will contain about 20 mg/liter (54 c) or a lethal quantity in less than half a liter. Thus more than a lethal quantity of T_2O can be inhaled in one breath of air saturated with T_2O vapor. Personnel working with T_2O should be extremely cautious with procedures which might possibly lead to exposure to the vapor. This applies to exposure of the skin as well as to exposure by inhalation since as much T_2O may pass through the total skin area of man per unit time of exposure as through the lungs.

4. SUMMARY

The quantity of tritium taken into the body of man on exposure to an atmosphere containing HTO or T_2O vapor is proportional to the length of exposure and the activity of HTO or T_2O per unit volume in the atmosphere. A lethal quantity of HTO or T_2O can be introduced into the body of man in a few seconds of exposure or in the time required to take one breath if the atmosphere is saturated with T_2O vapor. It is indicated that personnel working with T_2O should be extremely cautious with procedures which might possibly lead to exposure to the vapor.

5. REFERENCES

1. Minutes of the Permissible Doses Conference, Chalk River, Canada, Sept. 29-30, 1949, R.M.-10.
2. E. A. Pinson, LA-1465 (1952) (in press).
3. E. A. Pinson, LA-1466 (1952) (in press).
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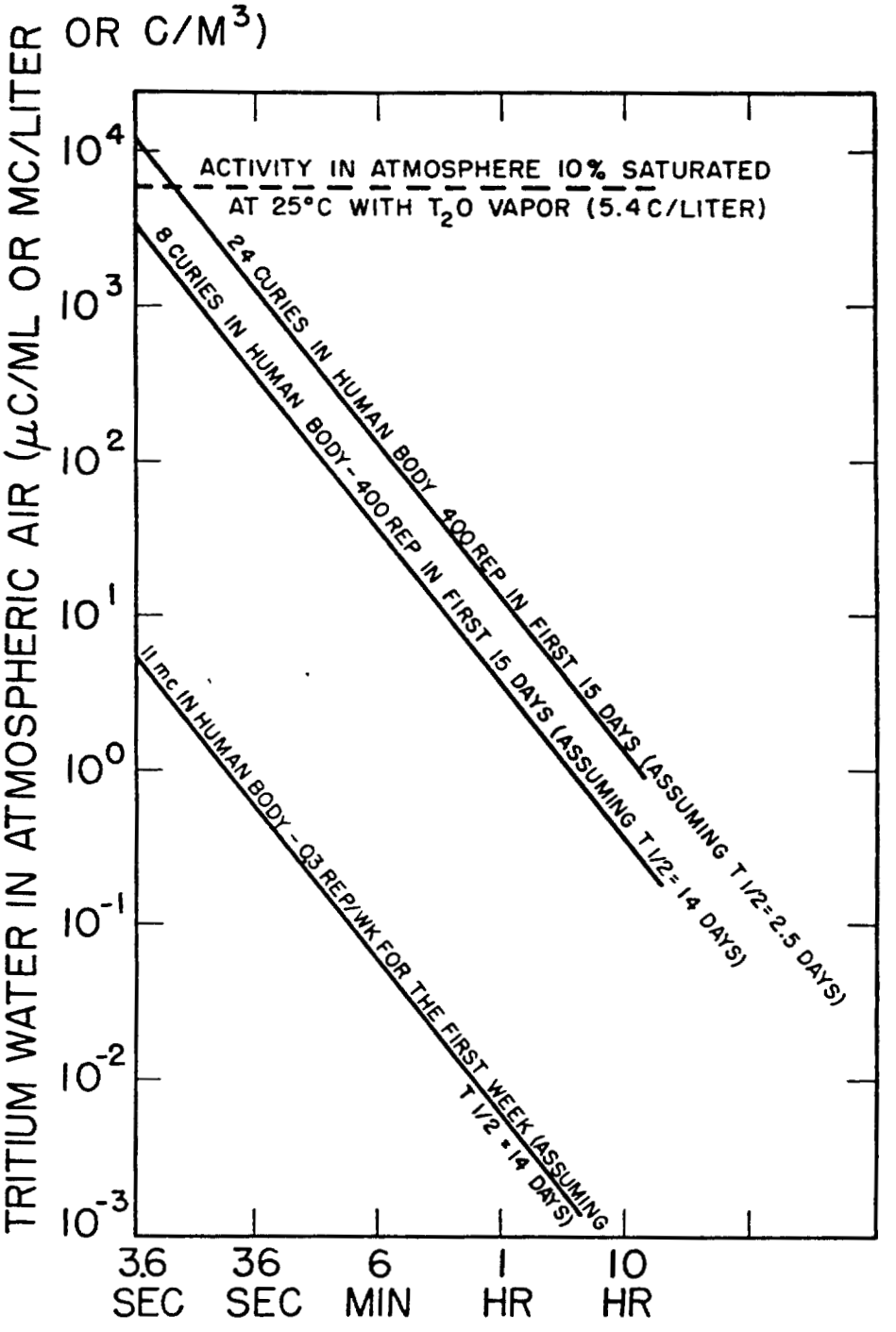

Fig. 1. The length of acute exposure required to introduce tolerance and lethal doses of tritium into the body of man at various levels of HTO and T_2O activity in the atmospheric environment.

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