A NOTE ON $(MPC)_a$ FOR Rn^{222}

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Dr. Stewart's letter of July 28, 1958, raises the question of the best value to list for $(MPC)_a$ for Rn^{222}. Since this is of considerable practical importance, the evidence on which it is based is reviewed here. Your judgment concerning the proper choice of value is solicited.

Dr. Morgan's memo of 1951[1] (revised 1954) is enclosed since it gives a review of the various values selected for $(MPC)_a$ for radon in the past, and the calculations given there indicate the critical assumptions which are involved.

In 1956 two studies concerned with these assumptions were reported. Taken together they strongly support the view that for Rn^{222} in unfiltered air the maximum dose is delivered to the Trachea and results largely from the daughters. There is evidence that filtration or other practices of ventilation may greatly reduce the concentration of daughter products and this would allow a correspondingly higher $(MPC)_a$. Shapiro[2] in experiments on rats, dogs and man estimates the dose to the lungs as 0.029 mrad/hr. (Page 174) from an equilibrium concentration of 10^{-8} μc/cc of atmospheric air. On the basis of the dog experiments, the dose to the trachea may be ten times this amount (Page 175). The dose delivered to the trachea is roughly proportional to the breathing rate (Ref. 3, Page 324). Using an RBE of 10 for the radiation which largely consists of α particles, the dose to the trachea for a 40 hour week is then

$$\frac{20\ \text{l./min}}{10\ \text{l./min}} \times 0.029\ \left(\frac{\text{mrad}}{\text{hour}}\right) \times 40\ \left(\frac{\text{hours}}{\text{week}}\right) \times 10\ (\text{RBE}) \times 10\ \left(\frac{\text{trachael dose}}{\text{lung dose}}\right)$$

$$= 240\ \text{mrem/week.}$$

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Chamberlain and Dyson[3] attempted to check the fractional amounts of daughter elements present by using a model to estimate the dose received in the trachea. They estimate that at the 20 liter/min breathing rate the lower trachea receive 17 mrads/hr from an air concentration of 10^{-6} μc/cc and the main bronchi receive 23 mrads/hr. Thus, at the 10^{-8} μc/cc level, the dose is 23 x 40 x 10/100 = 92 mrem/wk.

These estimates, interpreted literally, give $(MPC)_a = 1.25 \times 10^{-8}$ μc/cc for the 40 hour week value using Shapiro's estimate and 3.3×10^{-8} μc/cc using Chamberlain and Dyson's value. While various uncertainties remain the assumptions are not deliberately conservative. As indicated by Dr. Morgan's comments in the Minutes of the Plenary Session of the ICRP, April 9, 1956, the value of 10^{-7} μc/cc in the 1955 ICRP report was inadvertently listed without correction for continuous exposure and should have been 3×10^{-8} μc/cc.

To summarize, the best available experimental and theoretical work seems to indicate that 10^{-8} μc/cc of Rn^{222} together with its daughter products in atmospheric air delivers a dose of 100 - 300 mrem/wk to the trachea when inhaled continuously. There are various uncertainties present (see Chamberlain and Dyson, Page 324) which might suggest the lower value. Actual operating experience strongly suggests that lung cancer incidence is high at levels circa 2×10^{-6} μc/cc even for employment periods much less than 50 years. Because of uncertainties in exposure periods and exposure levels this can hardly be called quantitative evidence but does suggest caution for very long exposure periods. Since the majority of lung cancers seem to develop first in the bronchi, there does not seem to be any convincing evidence that it is less radio-sensitive than most other tissues or should be allowed to take a greater dose.

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Since Rn^{222} is the only case in which the Handbook value assumes the presence of daughters, it will be starred to refer to a section of the text where the basis for this value is discussed. Here it might be appropriate to give a rule such as that suggested by Shapiro (see Page 8). "The $(MPC)_a$ value listed for Rn^{222} + daughters assumes equilibrium, but the principal contribution to the dose is from the daughters. If it is determined that the daughter products are present in less than equilibrium amounts, the $(MPC)_a$ value listed may be divided by the fraction of these equilibrium amounts actually present."

Chamberlain and Dyson do not give a dose estimate for the thoron chain. A rough calculation seems to indicate it would give a much smaller dose to the bronchus than Rn^{222}. Assuming 10^{-6} μc/cc of Tn, Chamberlain and Dyson estimate .008 $\frac{\text{atoms}}{\text{cc}}$ and 1.1 $\frac{\text{atoms}}{\text{cc}}$ of ThA and ThB respectively, these being only the uncombined atoms. (See ref. 1, page 324). According to their Figure 4, page 320, 0.1% of the daughter activity that is airborne will be deposited per cm^2 of tracheal surface, taking as they do the distance from the vocal fold as 7 cm. Thus, for a breathing rate of 20 l./min, we find $.008 \times 20 \times 10^3 \times 60 \times 0.001 = 9.6$ ThA atoms/cm^2/hr deposited on the trachea, and 1320 ThB atoms/cm^2/hr deposited on the trachea. At equilibrium the number of disintegrations per hour equals these numbers.

Assuming 50 microns as the range of the 7 MeV α particle emitted by ThA, the dose due to these disintegrations is then

$$\frac{9.6 \times 7 \times 1.6 \times 10^{-3}}{50 \times 10^{-4} \times 100} = .22 \text{ mrads/hr from ThA.}$$

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A disintegration of ThB releases a β of .35 MeV (88%), another β of .59 MeV (12%), and a γ of .24 MeV. The total energy is thus at most .62 MeV of which only a rather small fraction would be absorbed in a thin layer of the trachea. Thus, the dose due to the ThB is at most

$$\frac{1320 \times .62 \times 1.6 \times 10^{-3}}{50 \times 10^{-4} \times 100} = 2.62 \text{ mrads/hr.}$$

This is an overestimate insofar as absorption within the 50 μ layer is concerned and it also neglects ciliary action in removing the deposit. (See ref. 1, page 324, for a discussion of this.)

Nevertheless, the dose for the entire thoron chain is thus only 2.8 mrads/hr in contrast to 30 mrads/hr for the same concentration of radon. This would suggest that the $(MPC)_a$ for Tn might be larger, perhaps by an order of magnitude, than the $(MPC)_a$ of Rn^{222}.

However, these calculations and measurements cannot be considered as entirely accurate. Exhalation is neglected, and the deposition of the particulate matter will certainly depend upon particle size and the individual's breathing habits. These deviations may be more serious in the case of the relatively long-lived ThB than for RnA. A ballot for the thoron (Rn^{220}) $(MPC)_a$ is therefore also included.

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BALLOT

Choice of $(MPC)_a$ for Rn^{222} + daughters for 40 hour week.

$3 \times 10^{-8} \frac{\mu c}{cc}$	$1 \times 10^{-8} \frac{\mu c}{cc}$	(Other)

Comments concerning fraction of equilibrium rule: _____

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$(MPC)_a$ for Rn^{220} + daughters for 40 hour week.

Ra^{220} value same as Rn^{222}	Ra^{220} value $= 10 \times (MPC)_a$ of Rn^{222}	(Other)

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REFERENCES

1. Chamberlain, A. C., and Dyson, E. D., "The Dose to the Trachea and Bronchi from the Decay Products of Radon and Thoron," Brit. J. of Radiology, 29, 317 (1956).

2. Morgan, K. Z., "Maximum Permissible Concentration of Radon in the Air," Revised Memorandum published October 27, 1954, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

3. Shapiro, Jacob, "Radiation Dosage from Breathing Radon and Its Daughter Products," A.M.A. Archives of Industrial Health, 14, 169-177 (August, 1956).

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