ORAU Team **Dose Reconstruction Project for NIOSH** Estimation of Radium-226 Activity in the Body from Breath Radon-222 Measurements	Document Number: ORAUT-OTIB-0025 Effective Date: 04/05/2005 Revision No.: 00 Controlled Copy No.: ______ Page 1 of 5
Subject Expert: Michael G. Stabin Document Owner Approval: Signature on File Date: 03/31/2005 Cindy W. Bloom, Team Leader Approval: Signature on File Date: 03/31/2005 Judson L. Kenoyer, Task 3 Manager Concurrence: Signature on File Date: 04/01/2005 Richard E. Toohey, Project Director Approval: Signature on File Date: 04/05/2005 James W. Neton, Associate Director for Science	Supersedes: None

RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
Draft	12//03/2004	00-A	A new technical information bulletin to provide information for converting radon breath analysis results to radium whole body activities. Initiated by Cindy W. Bloom.
Draft	12/09/2004	00-B	Updated to address ORAU Team comments. Includes modification of radon-222 release fraction. Initiated by Michael G. Stabin.
Draft	12/15/2004	00-C	Unit changes in table on page 3 and first equation on page 4 based on comment by Donald Bihl. Initiated by Cindy W. Bloom.
04/05/2005	04/05/2005	00	First approved issue. Initiated by Cindy W. Bloom.

Radium-226 is a member of the ^{238}U decay series. It has a half-life of about 1,600 years, and decays by α emission to ^{222}Rn ("radon"), which in turn decays by α emission to ^{218}Po and several other members of this decay series, before reaching stable ^{206}Pb (see Figure 1).

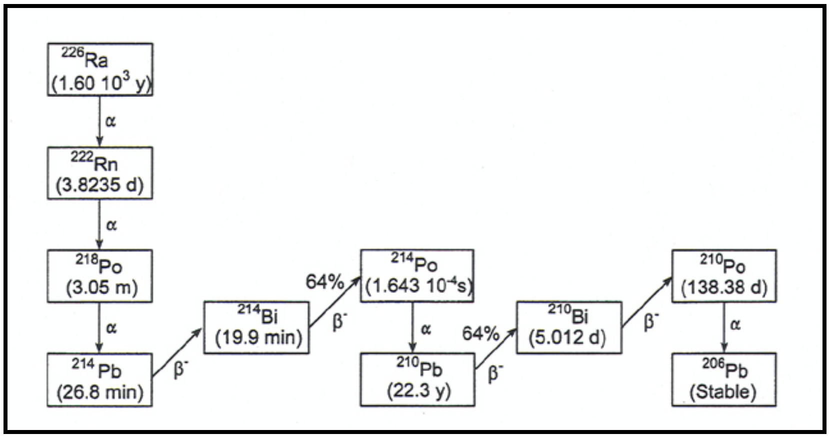

Figure 1. Ra-226 decay series (from ICRP 1998).

Radium-226 entering the body via inhalation is deposited primarily in bone, but is also deposited in soft tissues (ICRP 1998). The radon formed by ^{226}Ra decay can escape from the body by virtue of its being a noble gas, which is soluble in blood and can thus pass to the lungs, pass the lung/blood interface, and exit the body through exhalation. Srivastava et al. (1986) estimate that about 84% of ^{226}Ra in the body can escape from the body, based on the assumption that the equilibrium percentages of ^{226}Ra in the body after inhalation intakes are 33%, 39%, 14%, and 14% in lungs, cortical bone, trabecular bone, and other soft tissues, respectively, and that 100% of radon formed in lung and soft tissue will be released and 70% of that formed in bone will escape (this results in a radon release fraction of 84% in breath). International Commission on Radiological Protection (ICRP) Publication 67 cites the work of a number of investigators who note that the long-term retention of radon in bone will result in a $^{222}Rn/^{226}Ra$ ratio of about one third at long times after intake, which is consistent with the above assumption (ICRP 1994). In addition, ICRP Publication 67 presents a recycling model with predicted results for adults that are in reasonable agreement with the values cited above for bone/soft tissue ratios of activity.

Srivastava et al. (1986) note that the body content of ^{226}Ra can be estimated from the amount of exhaled radon by the relationship:

$$Q = \frac{C_{Rn}\, I}{\lambda_{Rn}\, f}$$

where

- Q = the quantity of ^{226}Ra present in the body (pCi)
- I = the breathing rate of the subject (L/h)
- λ_{Rn} = the decay constant of ^{222}Rn (per h)
- C_{Rn} = the concentration of ^{222}Rn in the breath sample (pCi/L)
- f = the release fraction for ^{222}Rn

Subjects should breathe radon-free air (from a tank of oxygen, for example) for a few minutes before performing the test. The test is best performed at the beginning of a workday on a Monday, so that radon breathed in the workplace is not still present in the lungs and available to influence the results.

The location where the test is performed should be as radon-free as possible. Environmental radon, from soil, building materials, and other sources fluctuates considerably and can interfere with interpretation of the test results. Toohey, Keane, and Rundo (1983) noted that "the exhalation of radon increases by a factor of two and then returns to 'normal' in a period of 1-2 hr following a meal," so measurements might be better made before work on a Monday but some time after a morning meal. For retrospective dose assessment, of course, no further control is possible over the data gathering, but dose reconstructors should keep these possible interferences in mind when evaluating individual cases.

As noted above, Srivastava et al. (1986) cite a value of 0.84 for f. This value is probably most applicable to workers who have been in mines for several years and thus chronically exposed for an extended period. An Oak Ridge Associated Universities memorandum suggests instead a value of 0.65 for f, use of which will result in larger estimates of the ^{226}Ra activity in the body (Dolan 1989). This is consistent with assuming an emanating fraction of 0.63 ± 0.06, which has been shown in a number of radium dial workers with long-term body burdens of ^{226}Ra (ingested and assumed to all be in bone) (Toohey 1983). In these subjects, both ^{226}Ra body content and ^{222}Rn exhalation rates were measured at the same time, which lends additional credibility to the values. Assuming a value of 0.63 and a standard breathing rate of 1.2 m^3/hr ["light work" from ICRP Publication 66 (ICRP 2004)], a value of 1 pCi/L of radon in the breath corresponds to approximately 0.25 μCi of ^{226}Ra in the body:

$$\frac{1\ pCi}{L}\ \frac{1200L}{h}\ \frac{91.8\ h}{\ln(2)}\ \frac{1}{0.63} = 252{,}000\ pCi$$

$$= 0.252\ \mu Ci$$

This indicates that 1 pCi/L in breath would indicate the presence of 0.25 μCi in the whole body and approximately 0.13 μCi in the bone. Based on the above calculation, the conversion factor for breath ^{222}Rn in pCi/L to whole-body activity of ^{226}Ra in pCi is 2.52×10^5.

The method discussed here relates only to quantification of ^{226}Ra activity in the body and calculation of dose from this activity (and the activity of its progeny, including ^{222}Rn, which can be formed in the body). This method is not applicable to quantifying radiation doses due to exposure to ^{222}Rn gas (and its progeny) in the workplace.

Example

A breath radon-222 measurement gives a value of 0.05 pCi/L. The estimated ^{226}Ra activity in the whole body is:

$$\frac{0.05\ pCi}{L}\ \frac{2.52E+5\ pCi}{pCi/L} = 1.26E+4\ pCi$$

The radiation dose to various organs from ^{226}Ra in the body can be derived by selecting an appropriate intake scenario and applying appropriate dose factors to the derived ^{226}Ra activity level.

REFERENCES

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