RADON VS PROGENY

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1. INTRODUCTION

Any one who has taken a radon training course should be familiar with the following quotation: "When a radon atom is inhaled, it is likely that it will be exhaled again before it decays. This is because it is inert and does not easily adhere to surfaces. Further, since it has a 3.8-day half-life, radon is unlikely to decay while in the lung. However, as radon concentrations increase, the quantity that decays in the lung increases, resulting in a greater health risk. Experts do not believe that radon gas, exclusive of its decay products, is a major contributor to the risk of cancer. This is why a filter respirator, which does not remove radon gas, can still provide substantial protection for mitigation workers."(1)

This is a contradiction in its self:.... "radon doesn't decay in the lungs, however, as radon concentrations increase, the quantity that decays in the lung increases, resulting in a greater health risk."

Actually the statement is partly true, it doesn't decay to zero while in the lung, but it does decay while in the lung but to completely decay it would take approximately 30 days, or 10 half lives, and that is why they say it does not remain in the lung long enough to decay. . On the other hand a portion of the all the RPDs that are breathed in remain in the lung and continue to decay to zero. The radon in the lung will be essentially equal to the room ambient concentration, whereas the breathed in RDPs will build up until the amount that decays per unit time is equal to the amount breathed in.

The chart below shows the relation between ambient radon and the resulting build-up of RDPs in the lung.

ER		Inhaled/Breath		Reach Alveoli		Equilibrium		Total	
Rn-222, 1	pCi/L	4	pCi	4	pCi	14	pCi	14	PCi
Po-218, 0.9		3.6	pCi	0.486	pCi	26	pCi	40	PCi
Pb-214, 0.45		1.8	pCi	0.243	pCi	140	pCi	154	pCi
Bi-214, 0.225		0.9	pCi	0.1215	pCi	183	pCi	197	pCi

These total includes 14 pCi of each of the progeny resulting from the decay of radon in the lung, and assumes that all of the RDPs remain in the lung until depleted. Some of the RDPs will be flushed out of the system through the blood, etc.

2. SUMMARY

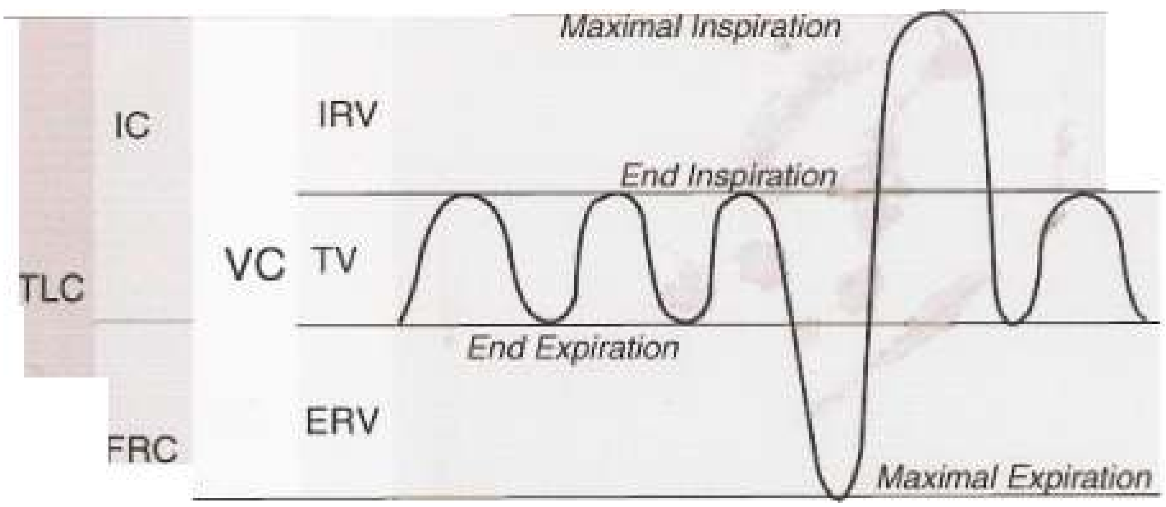
Radon does decay while in the lungs, and the health risk due to the breathed-in RDPs is about 11 times greater than the health risk due to RDPs resulting from the decay of radon in the lung, **NOT 200 T0 250 TIMES!, and the RDPs resulting from the decay of radon in the lungs should not be ignored.**

The solution is to reduce the radon as low as possible and take appropriate steps to reduce the RDPs where possible.

3. STATIC LUNG VOLUMES

Reprinted from RESPIRATORY CARE (Respir Care 2001; 46(5):531-539)

2.1 Static lung volumes are determined using methods in which airflow velocity does not play role. The sum of two or more lung-volume subdivisions constitutes a lung capacity. The subdivisions and capacities, are expressed in liters at body temperature and pressure saturated with water vapor (BTPS).



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RV

Fig. 1 Subdivisions of Lung Volume

2.2 Tidal volume is the volume of air that is inhaled or exhaled with each respiratory cycle.! (Although both V t and TV have been used to denote this volume; TV is used in this guideline.)

2.3 Inspiratory reserve volume (IR V) is the maximal volume of air that can be inhaled from TV end-inspiratory level.

2.4 Expiratory reserve volume(ERV) is the maximal volume of air that can be exhaled after a normal tidal exhalation (ie, from functional residual capacity, or FRC).
2.5 Residual volume (RV) is the volume of gas remaining in the lung at the end of a maximal

expiration.! It may be calculated by subtracting ERV from FRC (RV = FRC - ERV) or by subtracting vital capacity (VC) from total lung capacity, or TLC (RV = TLC - VC).
2.6 Inspiratory capacity (IC) is the maximal volume of air that can be inhaled from the tidal- volume end-expiratory level (ie, FRC). It is equal to the sum of TV and IRV.
2.7 Vital capacity (VC) is the volume change that occurs between maximal inspiration and maximal expiration. The subdivisions of the VC include TV, inspiratory reserve volume (IRV), and expiratory reserve volume (ERV). determined at any level of lung inflation; however, it is most commonly determined at or near FRC} As an alternative, lung volume may be tracked continuously, and FRC determined from VTG by addition or subtraction of volume.
2.10 Total lung capacity (TLC) is the volume of air in the lung at the end of a maximal inspiration. It is usually calculated in one of two ways: (1) TLC = RV + VC or (2) TLC = FRC + IC.

4.ASSUMPTIONS

1. The average man has a lung capacity of 4 liters.(RV + ERV + TV)
2. Tidal volume (TV) of each breath is 1 liter
3. The average lung volume is 3.5 liters.(RV + ERV + 1/2TV)
4. Average man breaths 12 times a minute
5. Ambient radon concentration is 4.0 pCi/L

5. EFFECT OF AEROSOL CHARACTERISTICS ON DECAY PRODUCTS

“Radon itself is an inert gas with a half-life of about 4 days and almost all the gas that is inhaled will be breathed out again. However, the decay products are isotopes of solid elements and will quickly attract to themselves molecules of water and other atmospheric gases. These, in turn, attach to natural aerosol particles. If inhaled, the decay products, whether attached to aerosol particles or “unattached”, will be deposited on the surface of the respiratory tract and, because of their short half-lives (less than half an hour) will decay there. Because strong evidence on the risk of inhaled radon is available from epidemiological studies, it is normal to derive risk factors from this source.”(4)PAGE 391 “If inhaled, radon itself is mostly exhaled immediately. Its short lived progeny, however, which are solid, tend to be deposited on the bronchial epithelium, thus exposing cells to alpha irradiation.”(4)

“Perhaps 10% of all the activity of radon decay products is associated with the unattached fraction(Porstendoerfer and Reineking 1992, NRC 1999a).

As I recall, when I took the EPA course, we were told that only the un-attached portion would reach the alveolar and that the attached portion would be captured in the upper airways of the trachea and would be carried away by mucus. Now we are told the opposite, that only the attached RDPs would be carried to the alveolar.

"It is interesting to consider the relative magnitude of doses to different organs and tissues from inhalation of radon gas. Doses are generally much lower than those from decay products. **As with the decay products, the lung is the organ receiving one of the highest doses, in this case largely because of the contribution from decays in the air within the lung. Over half the committed effective dose is due to lung dose."(3) page 394 bold print added**

"The characteristics of any particular mixture of aerosol particles are described by the activity medium aerodynamic diameter(AMAD). Half of the total radioactivity contained in the aerosol is attached to particles larger than the AMAD and half to smaller ones. Relatively small aerosols are predominately deposited by diffusion, which is a thermodynamic process. The activity median thermodynamic diameter(AMTD) is used to summarize the thermodynamic characteristics of an aerosol, just as the AMAD describes the aerodynamic behavior.

"The very small particles (1nm AMAD or 0.6nm AMTD) considered in this paper are very mobile and the great majority (almost 90 %) are deposited by diffusion in the airways of the head and neck before reaching the lung. The larger particles(200nm AMAD)are less mobile, they can penetrate deeper into the lung but most are breathed out again. Only 30% are retained in the airways, two-thirds of which are in the deep, alveolar, region."(3)

6. RADIOACTIVITY DELIVERED TO LUNGS FROM AIRBORNE DECAY PRODUCTS

In an environment of 4 pCi/L of radon and an equilibrium ratio of Rn 1: Po-218 0.9 Pb-214 0.45 :Bi-214 0.225, there will be 3.6 pCi/L of Po-218 suspended in the ambient air. Ten percent of these will be un-attached and will not reach the alveolar. Half of the remaining 3.24 pCi/l will be attached to small particle aerosols (1.62 pCi/L) of which almost 90% (1.458 pCi/l)will be deposited in the head and neck when inhaled. (3) Therefore only 0.162 pCi/L attached to small particle aerosols, and 0.324 pCi/L of those attached to large particle aerosols will reach the alveolar for a total of 0.486 pCi/L, or 13.5 % of the airborne PO-218.

Our average man will breath in 1 liter of air with each breath. This air will contain 3.24 pCi(attached portion) of Po-218, 1.62 pCi of Pb-214, and 0.81 pCi of Bi-214 of which 50 % will be attached to small particle aerosol, and 50 % attached to large particle aerosol.

Po-218: A total of 0.486 pCi of Po-218 will reach the alveolar each breath and with a half- life of 3.05 minutes will reach equilibrium with Pb-214 And Bi-214 at 26 pCi each

Pb-214: A total of 0.243 pCi of Pb-214 will reach the alveolar each breath and with a half- life of 26.8 minutes will reach equilibrium with Bi-214 at 114 pCi each

Bi-214: A total of 0.1215 pCi of BI-214 will reach the alveolar each breath with a half-life of 19.9 minutes will reach equilibrium at 43 pCi

Total build-up due to breathed in RDPs:

Po-218	26 pCi
Pb-214	26 + 114 = 140 pCi
Bi-214	26 + 114 + 43 = 183 pCi

There will also be 14 pCi each of the progeny due to the decay of radon within the lung.

7. ENERGY DELIVERED TO LUNGS AS A RESULT OF 4 pCi/L AMBIENT RADON WITH EQUILIBRIUM RATIOS OF RN 222: 1, Po-218: 0.9, Pb-214: 0.45, BI-214: 0.225

Atoms resulting from breathed-in Po-218 = (26 x 2.22)/(.227261370675)) = 254
Atoms resulting from breathed-in Pb-214 = ((140 x 2.22)/(0.0258637007672))= 12,017
Atoms resulting from breathed-in Bi-214 = ((183 x 2.22)/(.0348315166111))= 11,664

Potential energy from breathed in progeny
Po-218: (254 x 13.948) = 3543MeV
Pb-214: (12,017 x 7.833) = 94,129MeV
Bi-214: (11,614 x 7.833) = 91,364MeV

Total potential energy from breathed in progeny = 189,036MeV = 1.45 WL

Atoms resulting from RDPs due to decay of radon in the lung:
4 pCi/L x 3.5 L = 14 pCi.
Po-218: (14x2.22)/(.227261370675)= 136
Pb-214: (14x2.22)/(.0258637007672)=1190
Bi-214: (14x2.22)/(.0348315166111)= 885

Potential energy from RDPs due to radon in the lung:
Po-218: 136 x 13.948= 1897MeV
Pb-214: 1190 x 7.833 = 9321MeV
Bi-214: 885 x 7.833 = 6932MeV

Total MeV from RDPs due to decay of radon in the lung =18,150 MeV= 0.14 WL

8. CONCLUSIONS

Reduce the radon to as low as possible, and especially the progeny which results in approximately 11 times more energy delivered to the lung than the breathed in radon and it's resulting progeny. Be especially careful of exercise areas because in these areas a person could be breathing in more than twice the amount of ambient air of a sedentary person.

(1) Radon Measurement Proficiency Course
(2) (Journal of Pulmonary Medicine)
(3) G. M. Kendall and T. J. Smith Doses to organs and tissue from radon and its decay products. J. Radiol . Prot. 22(2002) 389-406
(4) BMJ, dol:10.1136/bmj.38308.477650.63(21December(2004)