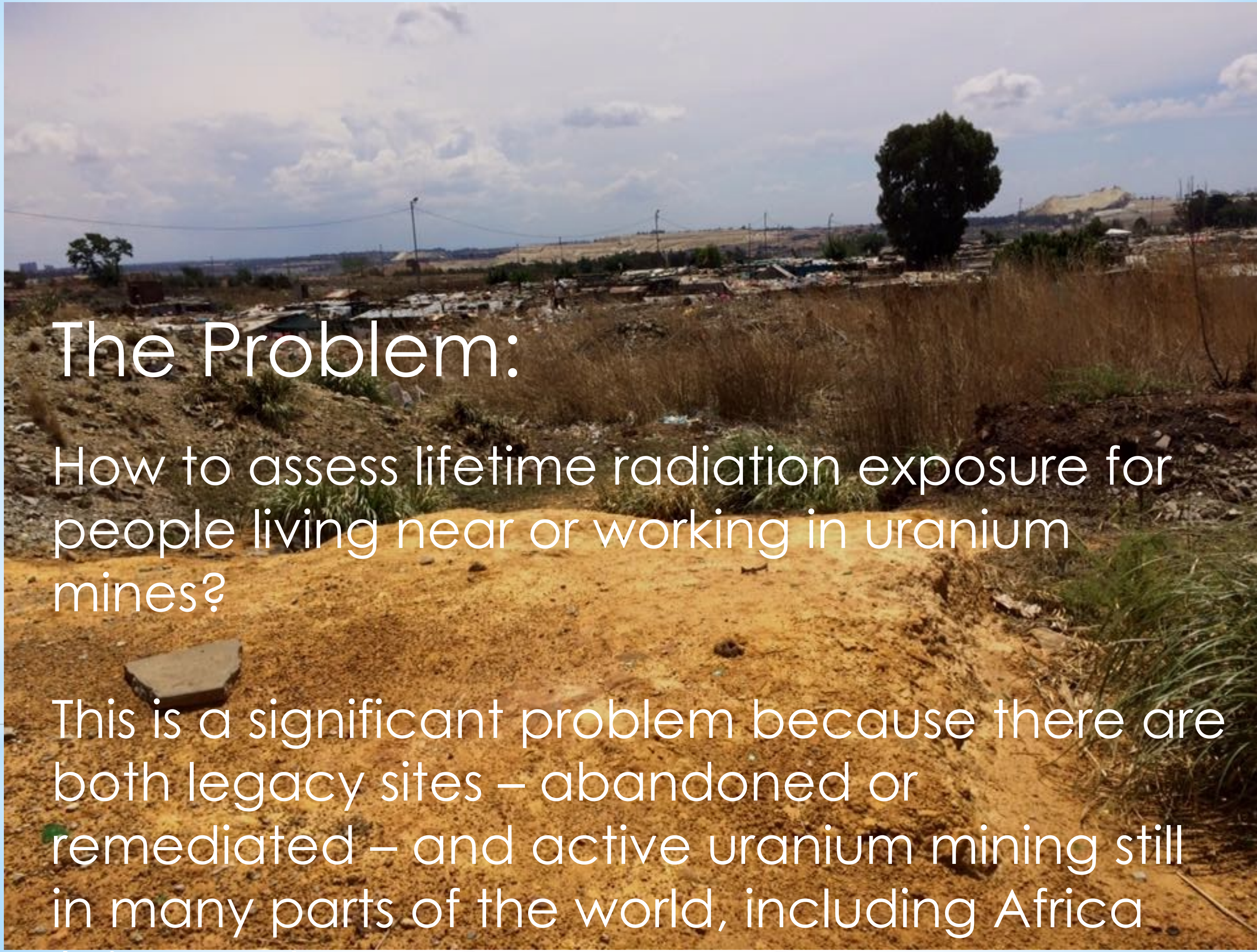
Measuring Radon in Exhaled Breath

Andreas Nidecker[1], Doug Brugge[2], Frank Winde[3], Urs Ruegg[4], Martin Röösli[5]

[1] Prof. (em.) MD, U of Basel / Switzerland
[2] Prof. Public Health, Tufts Univ. Boston Mass. / USA
3 Prof. Geogr. & Environmtl Studies NW Univ. / Rep. S Africa
[4] Prof. (em.) Pharmacology, U of Geneva / Switzerland
[5] Prof. Environmntl Epidemiol. Swiss Tropical & Public Health Inst. assoc. with U of Basel



The Problem:

How to assess lifetime radiation exposure for people living near or working in uranium mines?

This is a significant problem because there are both legacy sites – abandoned or remediated – and active uranium mining still in many parts of the world, including Africa (pictured)

Possible Approaches

Urine samples – they represent short-term exposure, not lifetime, and uranium is not the main radiation source in ore.

Modeling exposure - based on monitoring and sampling – difficult to extrapolate back over a lifetime.

Whole body monitoring - possible for lifetime measuring gamma radiation only, but high cost of non-portable machine.

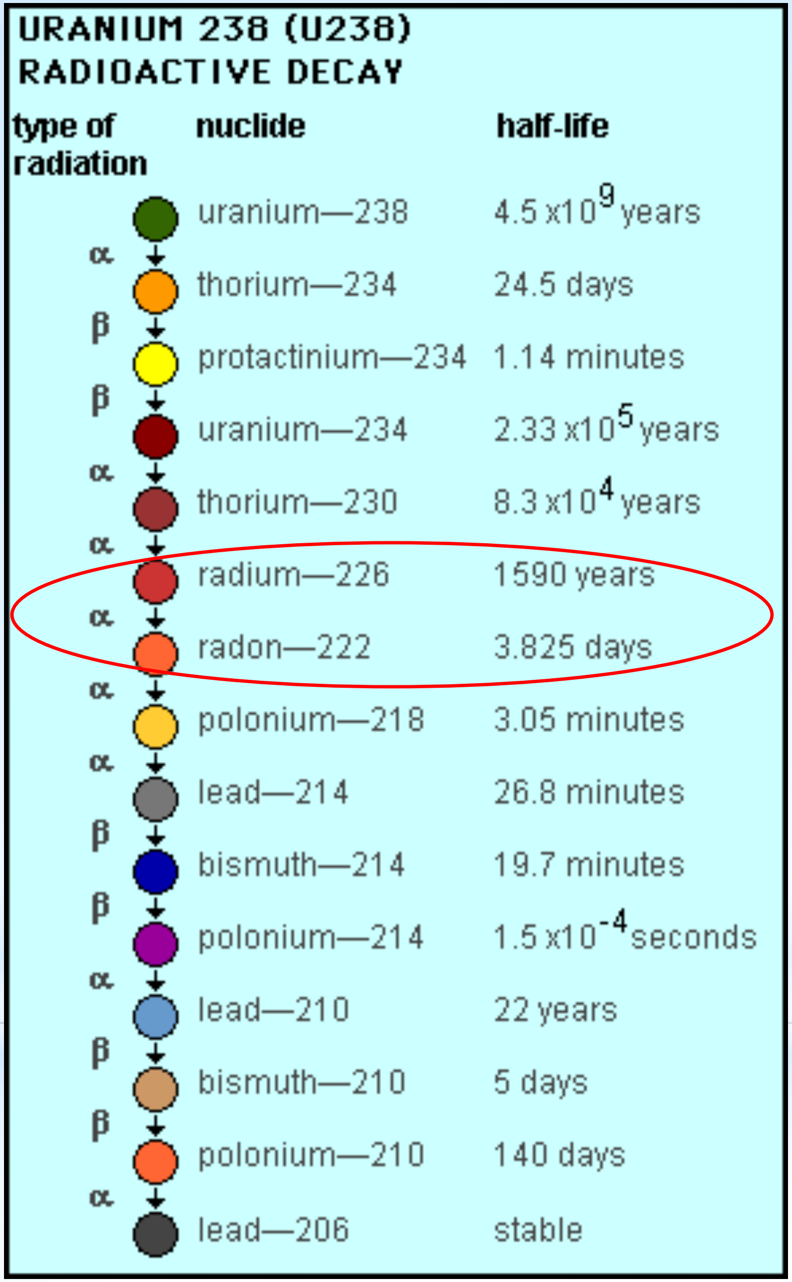
Radon in exhaled breath - in our opinion the best indicator for assessing lifetime exposure.

Studies of uranium ore exposure have not yet used radon in exhaled breath:

NIH* and CDC funded studies of uranium exposure measured urinary levels of uranium, and Rn exposure was estimated based on the situation in the U mines …**

* National Institutes of Health (USA) www.nih.gov
** Centers for Disease Control and Prevention(USA)
www.cdc.gov/niosh/pgms/worknotify/uranium.html

Radium deposits in bone with long biological and radiological half lives

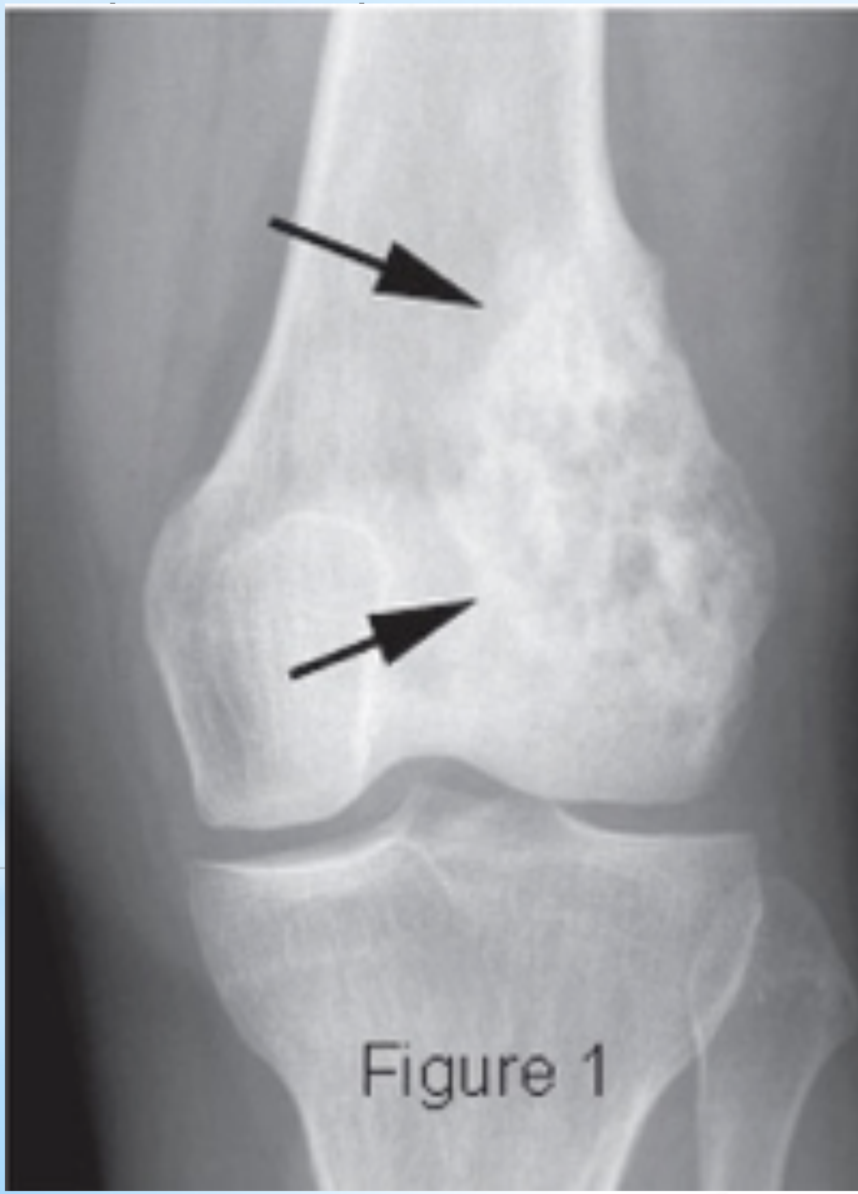


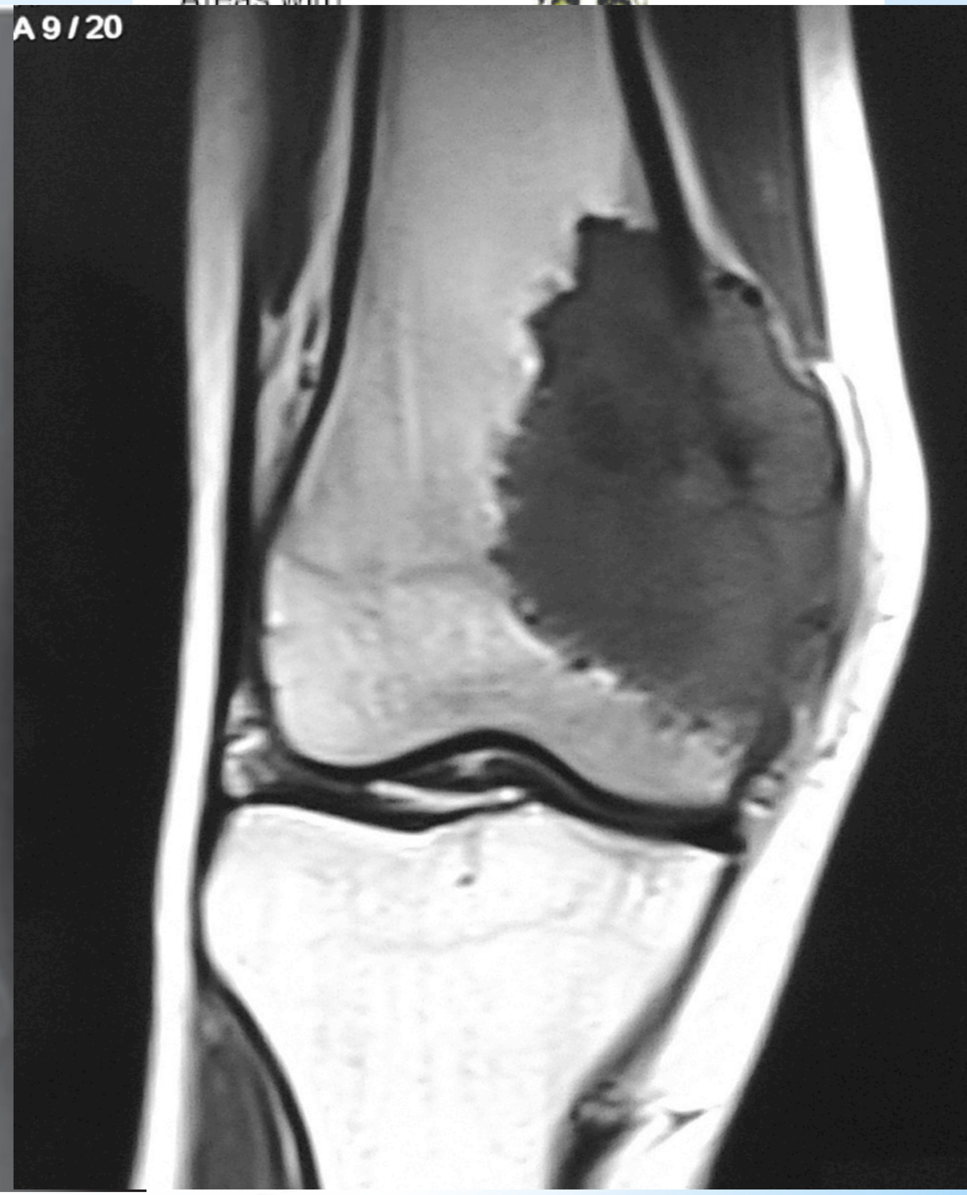
(3.825 d = 91.8 hrs)

Radon daughter isotopes

http://www.atral.com/U2381.html

Radium deposited in





The method of **radon in exhaled breath** has been used with uranium miners who had very high exposures

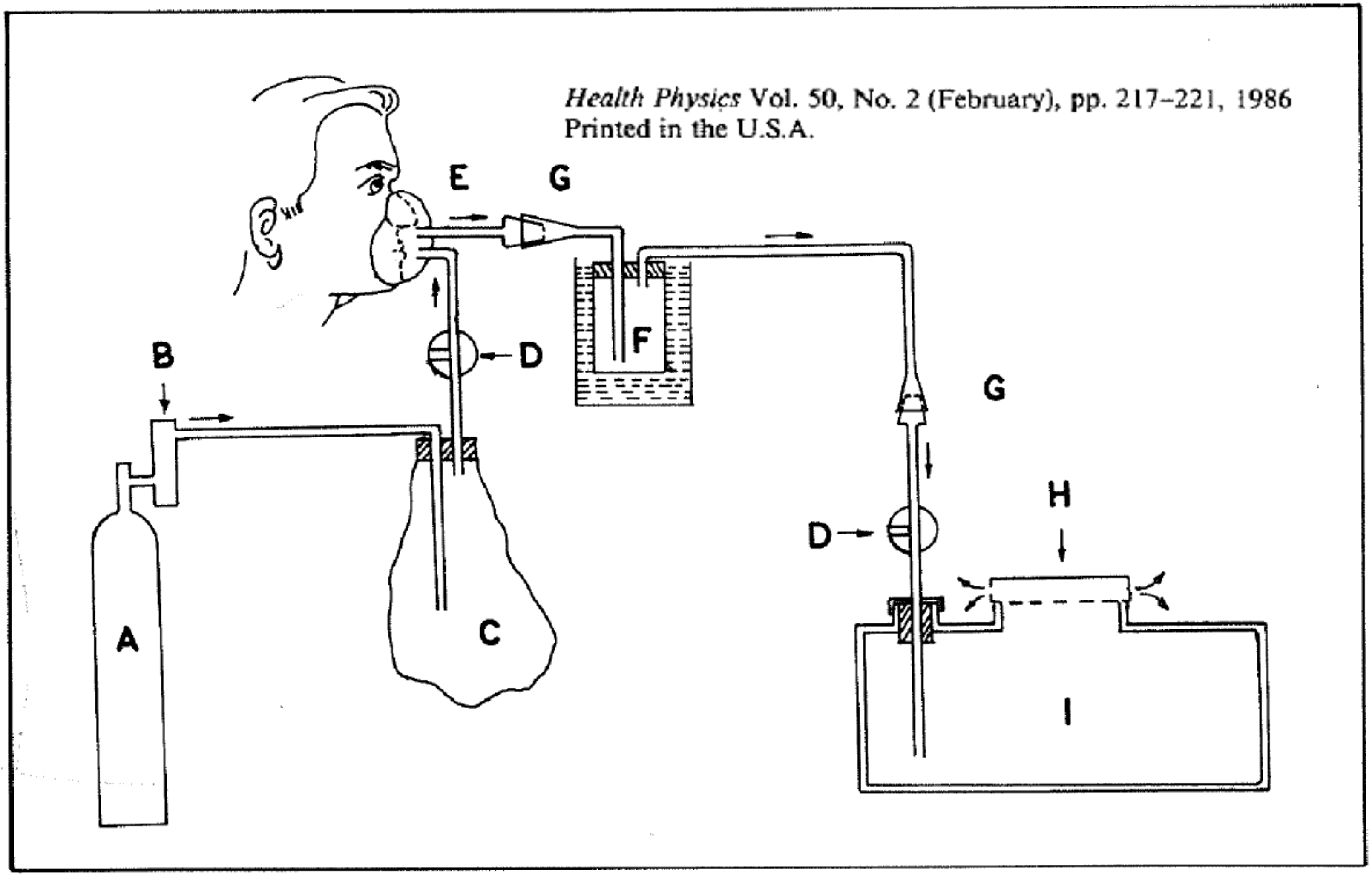


FIG. 1. Experimental setup for measurement of Rn in breath. A = medical oxygen cylinder, B = flow meter, C = plastic bag, D = three-way stopper, E = respirator, F = moisture trap, G = coupling, H = hair hygrometer, I = Rn collection chamber.

Radiation detectors: A version is available from Pylon*.

But sensitivity is still too low to measure low-level exposures.

* http://pylonelectronics-radon.com/

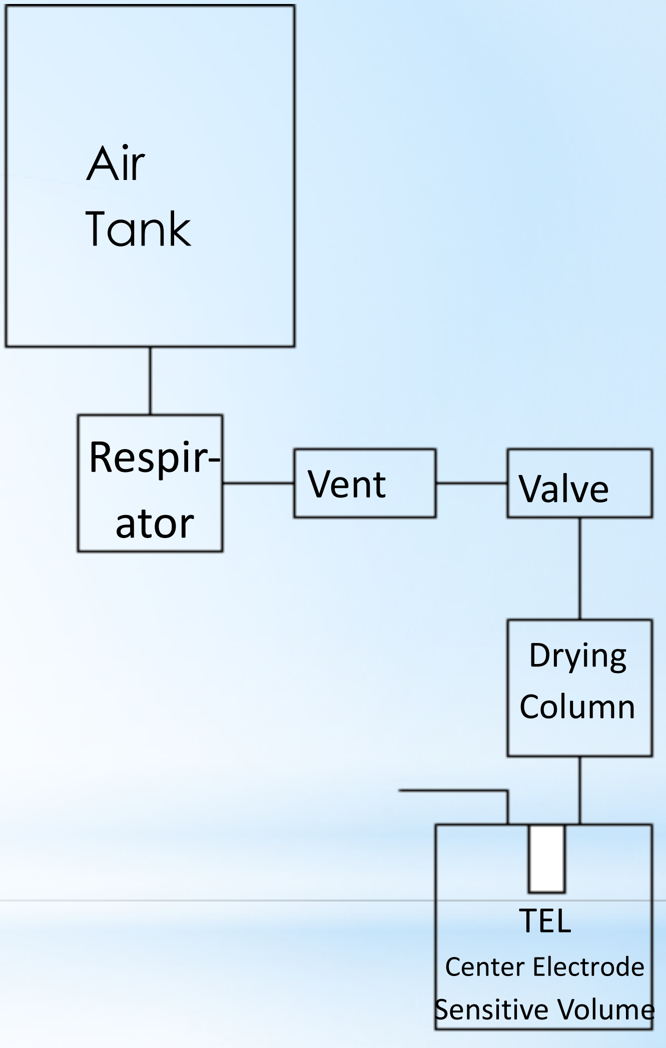


Figure 1
Sampling Setup for TEL Detector

The **Pylon Trace Level Radon Detector (TEL)** is the only commercially available radon detector with the **sensitivity of detection required** for measurements of radon in exhaled breath.

The high sensitivity of the TEL is due to its **large volume and low background noise level**.

But the **sensitivity should be further increased** by increasing the volume of the collection chamber. This would allow more rapid measuring individuals, thus facilitating epidemiological studies.

Estimating ^{226}Radium in the body from exhaled radon

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

Estimating the release fraction f for ^{222}Rn

Srivastava *et al.* (1986) cited a value of 0.84 for f. This value is applicable to miners with high exposure.

Others (Dolan 1989) instead quoted a value for f of 0.63 in radium dial workers with long-term body burdens of ^{226}Ra (Toohey *et al.* 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.

Srivastava *et al.* Radium-226 body burden in U miners by measurement of radon in exhaled breath. Health Phys. 50:217-21 (1986)

Dolan, B. Memorandum to P. Groer "Relationship between breath radon measurements and skeletal radium burdens". Oak Ridge Associated Universities, September 1 (1989)

Toohey RE, Keane AT, Rundo J. Measurement techniques for radium and the actinides in man at the center for human radiobiology. Health Phys.44 Suppl. 1:323-41 (1993)

Assuming a value of 0.63 and a standard breathing rate of 1.2 m^3/h [“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.**” (Bloom 2005).

This can be calculated by using the values above and equation (1) as shown below:

$$Q = \frac{1\,pCi}{L}\frac{1200L}{h}\frac{91.8h}{\ln(2)}\frac{1}{0.63} = 252{,}000\,pCi = 0.252\,\mu Ci$$

Using a modified TEL detector the **lowest detection level is given with 0.008 pCi/L**.

Bloom CW. Estimation of radium-226 activity in the body from breath radon-222 measurements. ORAU Team Dose Reconstruction Project for NIOSH (2005)

The lowest detection level of Rn

Using the manufacturer's suggested values of breathing rate and an f = 0.63, the following is obtained:

$$Q = (0.008 pCi/L)(1200 L/h)(91.8 h/\ln(2))(1/0.63) = 2{,}100\ pCi.$$

We estimate that a person exposed to background levels of radium might have a concentration between 0.016-0.023 pCi/g wet weight. Most of the radium is in bone; an adult weighing 60 kg has a skeleton that weighs about 12 kg or 12'000 g. 12000 g x 0.02 pCi/g = 240 pCi.

In contrast, uranium miner body burdens of radium ranged from 3'500-56'700 pCi (Srivastava *et al.*, 1986).

We expect exposed community residents to fall in between these values and to mostly be within measurement range of the modified Pylon instrument.

Srivastava *et al.* Radium-226 body burden in U miners by measurement of radon in exhaled breath. Health Phys. 50:217-21 (1986)

Estimating Dose to Red Marrow

Spiers *et al.* (1983) calculated the dose to the red marrow from ^{226}Ra and its retained daughter isotopes

$$Marrow\ Dose = 0.05 * 5.054\left(\frac{A * E}{BodyMass * 0.1}\right) Y\ mGy$$

Where A = whole-body Ra-226 content in Bq (=disintegrations/s) (from breath Rn-222)
E = alpha particle energy in MeV absorbed in the skeleton per disintegration
BodyMass = total body mass of the individual
Y = age of subject or time spent in study area in years

E can be calculated based on alpha particle energies of 4.77 MeV for ^{226}Ra, 5.49 MeV for ^{222}Rn, 6.00 MeV for ^{218}Po, 7.69 MeV for ^{214}Po and 5.30 MeV for ^{210}Po. For environmental ^{226}Ra, 30% retention is commonly assumed for its main decay products ^{210}Po and ^{210}Pb (Lloyd, 1991). This gives 11.32 MeV of alpha-particle energy per ^{226}Ra decay.

Spiers FW, Lucas HF, Rundo J, Anast GA. Leukaemia incidence in the U.S. dial workers. Health Phys. 44 Suppl. 1:65-72 (1993)

Lloyd RD & Bruenger FW. Rn:Ra ratios in bone of beagles injected with ^{226}Ra. Health Phys. 60:567-68 (1991)