*Mulga Rock Uranium Project Radon test-work: Technical Note

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Introduction:

The following describes the nature and results of the test-work carried at Mulga Rock in late January/early February 2015, to measure radon and thoron emanation from ore samples, firstly dry, then after wetting, and finally after addition of a clay cap.

The testwork was carried out firstly by the classical charcoal can method, and then by sniffing from enclosed drum head space via a Durridge RAD-7.

The Charcoal Can Procedure:

The “charcoal can” method, first described in Countess RJ, “Radon 222 Flux Measurements with a Charcoal Canister”, Health Physics 31, p455ff 1976, was also written up by Spehr and Johnston, in Radiation Protection in Australia Vol 1 No 3, pp 113-116, 1983, and by Gan, Peggie, and Wilson, Radiation Protection in Australia, Vol 1 No 3, pp 117-119, 1983.

The mathematics is given in Spehr and Johnston but a simplified formula is shown below.

In the charcoal can method, a charge of some tens of grams of activated charcoal (we use 30g) is packed in brass canisters and held in place by a disc of stainless steel mesh or brass mesh located in the canister with a circlip. The canisters (collection area = 38.5 cm^2) are sealed to the surface whose emanation rate is to be estimated. If it is soil, tailings, or crushed ore, we simply twist the can into the surface; if it is to be affixed to solid wall rock in an underground drive, then some sort of quicksetting sealant/adhesive is needed.

Early versions describe use of a bed of silica gel to absorb moisture in the air, but Spehr & Johnston showed that this is unnecessary. Early users advised 50 grams of charcoal but Gan et al showed that 25 g worked as well and gave somewhat better counting geometry.

Activated charcoal is used to adsorb radon during a collection period which is generally set as 24 hours (which we used). This radon then generates (over a period of 3 hours) an equilibrium activity of radon progeny within the canister. The activity of the bismuth-214 daughter is counted (we used 60 seconds) by observing either its 609 keV gamma emission full-width photopeak, or for higher efficiency, all photons above threshold set to discard noise) with a NaI scintillation crystal (in a lead castle, to minimise background) and single

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channel analyser with window width and threshold set appropriately. In our case, we used the full spectrum above threshold.

The charcoal can method is somewhat susceptible to results being biassed low because of the possibility of loss of radon via leakage during the collection time due to imperfect edge sealing. Thus it may be found necessary to discard obviously erroneous readings where counts were no more than background, but should have been higher. We did not have this problem. The charcoal can method also characteristically gives somewhat scattered results, so multiple tests need to be carried out.

The charcoal was prepared by heating in an electric frypan at high heat for 2 hours with occasional stirring, to drive off all adsorbed water vapour and other gases.

Brass cans (with internal diameter of 70 mm, for surface area of 0.00385m^2) and a depth of 45mm) were then filled with 30 gram charges of activated charcoal (two with 50 g charges, to better match the geometry of the calibration canister which contained a known radium activity of 418 Bq in a 50 g charge).

For re-use, the cans, with charcoal still in them, were heated in frypan, as above, to drive off adsorbed gases and vapours, and re-activate the charcoal, and then new background was recorded. This temperature and time must be checked to be adequate for driving off radon and re-activating, by checking that the can count rate has returned to nominal levels. As we found this did not completely return to background count, the cans were then cooked on a baking tray in the camp mess fan-forced oven for a further hour and thereby successfully returned to background countrates.

Gamma Spectrometer Description:

A Ludlum Model 2221 Single Channel Analyzer with integrated high-voltage supply is used to power, and analyse pulses from, a Ludlum 3” × 3” NaI scintillation crystal gamma detector. The crystal (and sample canister) are mounted in a lead shield to reduce background. The lead shield was constructed using lead sheet purchased from Bunnings. You need a lead ground slab, to attenuate gamms from soil or concrete slab, of thickness approx. 2.5 cm; and the shield sidewalls were made by wrapping lead sheet round a short length of 125 mm diam PVC drainage pipe, then strapped using gaffa tape. (see photos below).

System efficiency was obtained by recording counts in one minute from a sealed canister loaded with 418 (+/- 29) Bq of Ra^{226} solution (= 3144counts). This indicated a system efficiency of 11.7%. It is most important to note that the efficiency depends critically on all of

the spectrometer settings, and on the counting geometry. In this case, the cans were counted inverted, placed at the bottom of the shield, with the detector resting on them, so as to give closest possible spacing from radon-loaded charcoal to NaI crystal. See photos.

For complete mathematical details, see Gan et al (1983) and Spehr & Johnston (1983). 6 out for the 8 canisters add charges of 30g, on the basis that greater accuracies (via greater count rates) should be achieved than with 50g charges (see Gan et al for discussion).

Cooking (reactivating) charcoal

Packing charcoal canisters

Measurement of blank canisters in lead chamber

Lead chamber set-up

Lignitic composite, nominal grade 831ppm U_3O_8

Clayey sand composite, grade 316ppm U_3O_8

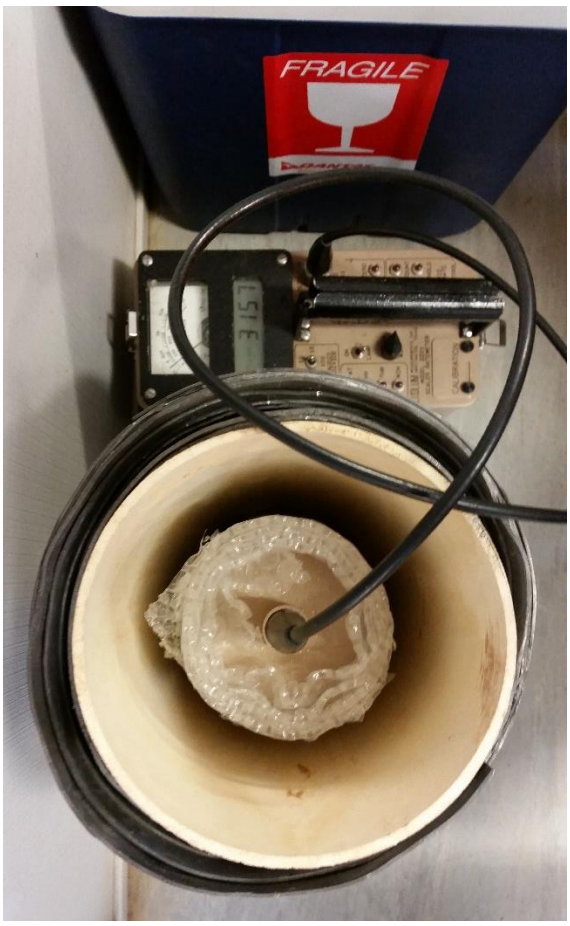
Capping clay composite

Shielding against thermal variations

Cans on lignite ore composite.

Cans on clayey sand composite

Capping and taping of the canisters



Counting:can at bottom, inverted, under detector)

Results of charcoal canister readings

The following formula was used to derive the emanation coefficients reported in Table

$$Rn\ flux = (Net\ cpm) * \frac{1}{60} * \frac{1}{SE} * \frac{1}{area}(m2) * Decay\ A * 1/\sec in\ 1\ day * Decay\ B$$

SE is system efficiency, = 0.117 and can area = 38.5 cm^2

Decay A accounts for the ingrowth during the initial 24hrs period

Decay B accounts for the ingrowth during the 3 hour post-sample delay

$$Rn\ flux = (Net\ cpm) * \frac{1}{60} * \frac{1}{0.117} * \frac{1}{0.00385} * 1.22 * \frac{1}{86{,}400} * 1.023 = (\boldsymbol{Net\ cpm}) * \mathbf{0.000534}$$

Charcoal Can ID #	Background (1 min)	Placement (Drum)	Total Count (1 min)	Net Count	Calculated Flux Bq/m2/s
1 - 50g	244	Lignite	2654	2410	1.29
2 - 50g	245	Sand	955	710	0.38
3	249	Lignite	3440	3191	1.70
4	238	Sand	1573	1335	0.71
5	237	Lignite	2448	2211	1.18
6	255	Lignite	2957	2702	1.44
7	249	Sand	1616	1367	0.73
8	252	Sand	741	489	0.26
1 - 50g	240	Lignite	2355	2115	1.13
2 - 50g	222	Sand	750	528	0.28
3	243	Lignite	3453	3210	1.71
4	233	Sand	1200	967	0.52
5	236	Lignite	3395	3159	1.69
6	244	Lignite	3361	3117	1.66
7	212	Sand	897	685	0.37
8	238	Sand	1019	781	0.42

Results

	Sand ore	Lignite ore
Average	0.46	1.48
Grade (ppm U_3O_8)	316	831
Normalised to 1000 ppm U	**1.7**	**2.1**

Findings:

This converts to average emanation rates (rounded) of 1.7 and 2.1 Bq/m^2/s on a 1,000ppm U basis for the two composites (sand and lignite, respectively).

These numbers enable sound estimates to be made of emanation of radon in future mining operations, for EIS purposes, given knowledge of ore grades and areas exposed.

Measurement of Radon and Thoron emanation using RAD-7 continuous monitors:

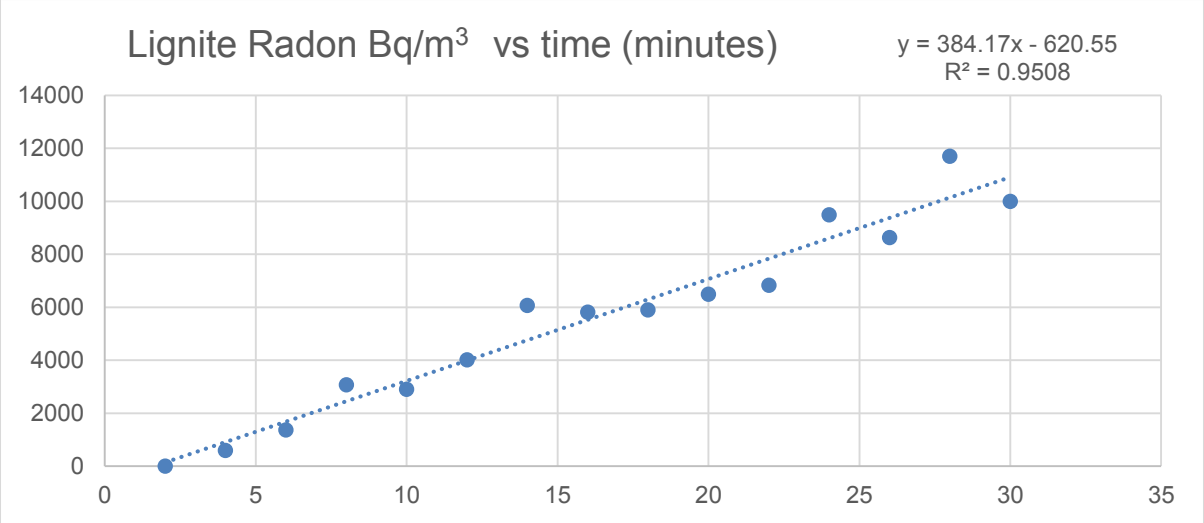
Durridge RAD-7 instruments were obtained on hire from Cameco, courtesy of their Environmental Manager Simon Williamson.

The RAD-7 is a real-time radon and thoron measuring instrument, originally developed mainly to look for radon in buildings. Its operating principle involves pumping filtered and dried air through a sensing chamber in which an electric field is set up between the (earthed) solid state detector and the surrounding (+2500V) positively biased hemispherical chamber. Radon (and thoron) daughters which are created during passage of the air through the chamber are electrostatically collected onto the solid state detector where they are counted and discriminated according to their energy. Alpha spectrometry allows identification of the different alpha-emitting decay products.

After completion of the Charcoal Can tests the two drums of ore (lignitic and sandstone) were sealed with lids which had hose connection holes drilled in them.

The RAD-7 instruments' inlet and outlet hoses were attached to the lids and the instruments were immediately set running in 'sniffer' (fast response) mode.

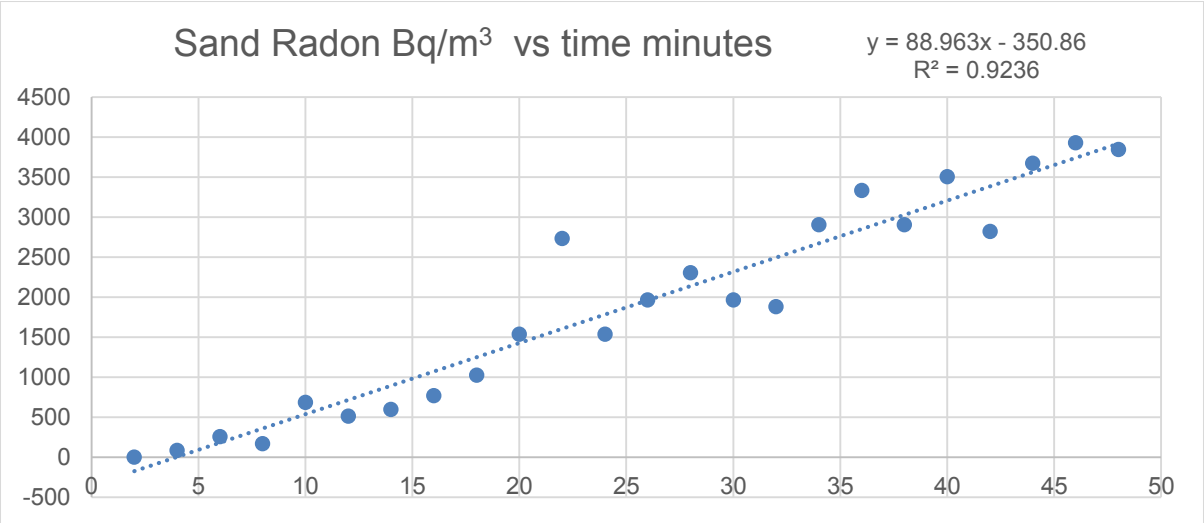
The time-increase of radon (Rn-222) was recorded for both drums, taking readings at 5 minute intervals. In both cases relatively linear concentration increases with time were seen (see graphs below).



This time trend of concentration increase, into drum head space of 35 cm, gives Emanation Rate as J ($Bq/m^2/s$) = (conc increase ($Bq/m^3/min$)/60 x vol m^3 (area x ht) / area m^2)

Thus 384/60 x 0.35 = 2.24 $Bq/m^2/s$. This material was grade 831 ppm U_3O_8, or 705 ppm U, therefore the emanation rate normalized to 1000 ppm U would be **3.2 $Bq/m^2/s$**.

Similarly for the sand ore:



The above slope gives J = 0.52 $Bq/m^2/s$, for a grade of 316 ppm U_3O_8, which when normalized to 1000 ppm U, gives **1.94 $Bq/m^2/s$**.

Findings:

We calculated emanation rates for the two ore types from the slopes of the graphs, noting drum head space volume (depth = 35 cm), and found J = 1.9 and 3.2 $Bq/m^2/s$, normalized to 1000 ppmU, for sand and lignite ores respectively.

Wetting and Clay capping tests:

Subsequent to these 'bare ore' runs, the drums of ore were saturated with water (sand: 123L+20L water added, lignite: 118L+28L water added), and re-tested using both charcoal cans and the Rad-7. The sand emanation rates were reduced to average 0.024 $Bq/m^2/s$; and the lignite emanation rates were reduced to average 0.067 $Bq/m^2/s$, a reduction factor of approximately fifty-fold!!

Finally, a clay cap of thickness 25 cm was applied. Retest then gave a further reduction to essentially zero in both cases.

	Raw results ($Bq.m^2/s$)	**Normalized 1000 ppmU**
Dry sand ore	0.46 (CC); 0.52 (RAD-7)	1.7 (CC); 1.9 (RAD-7)
Dry lignite ore	1.48 (CC); 2.24 (RAD-7)	2.1 (CC); 3.2 (RAD-7)
Wet sand	0.024	
Wet lignite	0.067	
Clay capped sand	0.00	0.00
Clay capped lignite	0.00	0.00

These general agreements between the charcoal can results and the Durridge Rad-7 results were most gratifying, as were the results from the wetting test and clay capping.

References

Gan, T.H., Peggie, J.R., Wilson, O.J., 1983, Increasing the counting efficiency of activated charcoal canisters used for radon emanation measurements, Radiation Protection in Australia, Vol. 1, N.3, p117-119.

Spehr, W., Johnston, A., 1983, The measurement of radon emanation rates using activated charcoal, Radiation Protection in Australia, Vol. 1, N.3, p113-116.

Countess RJ, "Radon 222 Flux Measurements with a Charcoal Canister", Health Physics 31, p455ff 1976