Ra Content in the Carleton Ultrapure Water (WET Lab)

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Ultrapure water from the Carleton Biolab plant was flowed through a large acrylic column containing 265 grams of MnO_2 coated acrylic beads and the radium in the water was adsorbed on the beads. The radon board in the WET lab was then used to determine how much ^{222}Rn emanated from the radium absorbed on the beads.

We performed two radon measurements. The first one was done after 10 tonnes of water was passed through the column. The second one was done after an additional 5 tonnes of water was flowed through the same MnO_2 coated acrylic beads. We did not measure the radon before the first 10 tonnes of water was passed through the acrylic beads, but according to data from Guelph (see J.X. Wang et al, July 1991 report), MnO_2 coated acrylic beads have a very low background — 1.8 ^{222}Rn/hr/kg, which means that for 265 g of beads the emanation background is about 11 Rn/day which is negligible.

The measurement procedure is as follows:

1. The empty emanation chamber is pumped for 1 to 2 days with a trapped oil roughing pump.

2. The emanation chamber is sealed for 1 day and then connected to the radon board.

3. Radon in the emanation chamber is extracted, transferred into a Lucas cell and counted according to the steps as specified in M.Q. Liu's thesis.

4. Dried MnO_2 coated acrylic beads from the acrylic column is put into the emanation chamber and the chamber is pumped for two days.

5. The chamber is sealed for one day and then connected to the radon board.

6. Radon in the emanation chamber is extracted, transferred into a Lucas cell and counted according to the steps as specified in M.Q. Liu's thesis.

7. The MnO_2 coated acrylic beads are taken out of the emanation chamber and steps 1 to 3 are repeated.

All measurements were repeated several times to determine the size of the radon memory in the apparatus and any air leaks. All emanation times were 1 day.

The data are listed below and in the figure 1:

First one: (after 10 tonnes of water)

background	measurement	background again
(79±9)/day	(150±12)/day	(94±10)/day
(75±9)/day	(161±13)/day	(125±11)/day†
	(162±13)/day	(95±10)/day
		(93±10)/day

† this data point is abnormally high and is rejected

The average of background = (87±4)/day
The average of measurement = (158±7)/day
The net count rate = (71±8)/day

If N_0 is Rn number in the filter after emanation then

$$71/3 = N_0 \times [1\text{-}\exp(-2.1\times10^{-6}\times86400)]\times0.75(E_{trans})\times0.70(E_{pump})\times0.63(E_{detect})$$

$$N_0 = 425 = N_{Ra}\lambda_{Ra}/(\lambda_{Rn}\times[1\text{-}\exp(-2.1\times10^{-6}\times86400)])$$

$N_{Ra}\lambda_{Ra} = 5.38\times10^{-3}$/second (which equals the disintegration rate of each nuclide in the U chain if we assume secular equilibrium).

Now if UC is the equivalent U content in the water then

$$UC \times 10 \times 10^6 \times 6.02 \times 10^{23} \times \ln 2/(238 \times 4.5 \times 10^9 \times 365 \times 86400) = 5.38 \times 10^{-3}$$

$$UC = 4.3 \pm 0.5 \times 10^{-14} gU/g \quad \text{(stat. error only*)}$$

* The systematic errors in E_{tras}, E_{pump} and E_{detc} have not been estimated.

second one: (another 5 tonnes of water)

background	measurement	background again
(68±8)/day	(170±13)/day	(66±8)/day
(80±9)/day	(181±13)/day	(73±9)/day

the average of background	=	(72±4)/day
the average of measurement	=	(176±9)/day
the net count rate	=	(104±10)/day
subtract the first 10 tonnes water Ra count rate	=	(104-71)=(33±13)/day

$UC \times 5 \times 10^6 \times 6.02 \times 10^{23} \times \ln 2/(238 \times 4.5 \times 10^9 \times 365 \times 86400) = 2.53 \times 10^{-3}$

$UC = 4.1 \pm 1.6 \times 10^{-14}$ gU/g (stat. error only)

This preliminary result is encouraging. For future measurements we suggest that a new acrylic column be built at Carleton which can withstand vacuum. Then after drying the acrylic beads, the column can be directly connected to Rn board thus minimizing the background. Alternatively we could use another emanation chamber. We have two emanation chambers, the other one having a teflon O-ring and a lower background (20-30/day). It is now filled with water and being used for another study.

The U content in water has been previously studied by ultra-sensitive mass spectrometry. The present measurements provided radioactive data near the end of U chain.