Radon Emanation into Water

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Materials submerged in the SNO detector and materials used in the water purification system emanate radon (Rn) at a very small, yet significant level. It is necessary to identify potentially troublesome materials and take mitigative measures (substitution, elimination, cleaning, etc.)

The most technically straightforward procedure is to look at the radon emanation rate of a material placed inside a vacuum chamber. This work has been described in a Queen's M.Sc thesis [1], by the group at Guelph [2] and Bigu [3]. Measurements of radon emanation rate from various materials are given in references 4-7.

In order to compare the rate of radon emanation into vacuum to the more relevant rate of a material submerged in water, the equipment used to study radium leaching [8] was modified. This equipment consisted of a 100 liter PVDF flat-bottomed tank sealed at the top with a clear lexan cover. An O-ring gasket ensures that it is air tight. The tank is filled with 35 liters of distilled water. At the bottom of the tank is a bubbler consisting of a 15 cm diameter 0.1 micron filter paper sandwiched inside an acrylic holder. This produces a column of bubbles which start off about 2 mm in diameter.

External to the tank is a Metal Bellows diaphragm pump (Model 155, Sharon Mass.), an Omega FL 114 flowmeter, Matheson 2.5" Bourdon gauge, two stainless steel water vapor traps and the Rn board (for trapping Rn and transferring to a ZnS scintillation cell).

Nitrogen gas from the outlet side of the diaphragm pump passes by the Matheson gauge, through the Omega flowmeter and into the bubbler at the bottom of the leaching tank (see attached figure). The pressure and flowmeter is controlled by a Nupro ball valve on the inlet side of the diaphragm pump. When the nitrogen bubble pass through the water, they pick up ("strip") Rn atoms and dissolved gases (N_2, traces of O_2, CO_2 etc).

Coming out of the tank, the nitrogen gas stream water vapor contains a lot of water vapor. This water vapor is frozen out by two traps in series cooled with a methanol bath at -50 °C. Typically there are 2-3 ml of water trapped in the first trap less than 0.1 ml in the second. The nitrogen then passes into the radon-board large-radon trap (Trap A) cooled to -196 °C (liquid nitrogen). The radon is trapped and nitrogen then goes to the inlet side of the diaphragm pump (thus completing the closed loop).

A run starts by having the water traps cooled to -50 °C and the radon board Trap A bypassed. The diaphragm pump is turned on and the throttle valve adjusted for the proper pressure and flow. Once the nitrogen gas is flowing steady in the loop, Trap A is valved into the loop and the extraction begins. Typically a one hour extraction is done and the radon is transferred to a cell. Then a second one hour extraction is done and the radon transferred to a second cell. By comparing the radon in the first and second cell, we can infer an efficiency for the extraction of radon. The efficiency is typically 55-70%.

The background radon in the system is due to radon in the air which permeates through the connecting tubing (flexible teflon) and the tank walls. There is also a small contribution from radon emanated by the bubbler, tank walls and the Metal Bellows pump. Measurements of the background (without any sample underwater) gives a rate of 514 $\pm$ 24 Rn/day. We can see 48 Rn/day (two sigma) above this background so this is the sensitivity for measuring radon emanation into water. For a material with an emanation into vacuum of 20 Rn m^{-2} hr^{-1}, we could require at least 0.1 m^2 to put underwater.

Four pieces of ^{226}Ra spiked (equivalent to 80 ppm U) glass pucks were placed underwater on top of the bubbler. Each puck was 107 grams weight and about 7.5 cm in diameter, 0.9 cm thick (giving total area of 0.044 m^2). They were made at a local glass company near Oxford (UK).

A series of extractions over 8 weeks were performed. The averaged result is listed in Table 1. After the extractions the glass was taken out and emanation into vacuum was done. The result is also listed in Table 1.

The second sample loaded into the water tank was Pharmed flexible tubing (from Cole

Table 1 Summary of radon emanation results

Material	Emanation into water (Rn $m^{-2}h^{-1}$)	Emanation into vacuum (Rn $m^{-2}h^{-1}$)	$Rn_{water}/Rn_{vac.}$
Glass Pucks	357 ± 18	105 ± 15	3.4
Pharmed tubing	2800 ± 400	6070 ± 23	0.5

Parmer). Five lengths of tubing, each 0.24" I.D., 0.45" O.D., 24 inches long were tied down with stainless steel wire. The total exposed area was 0.22 m^2. A series of four extractions were done and the averaged result along with the vacuum emanation result is listed in Table 1.

On the basis of two physically different samples (glass and tubing), we concluded the rate of radon emanation into water is within a factor of 3 (higher or lower) than the rate into vacuum. The emanation rate for a sample will depend on the size of the micropores on the surface, the location of the parent ^{226}Ra with respect to the pores and the diffusion constant of radon near the surface.

References:

[1] Manqing Liu, M.Sc. thesis, Department of Physics, Queen's University (1991)

[2] Jianxiong Wang, (Physics) has constructed large chambers to eletrostatically collect the radon daughter on a large area silicon photodiode. The design is based on work by Howard et al (Nucl. Instru. Meth. A293, 589(1990) and Amer. J. Phys. 59 544(1991).

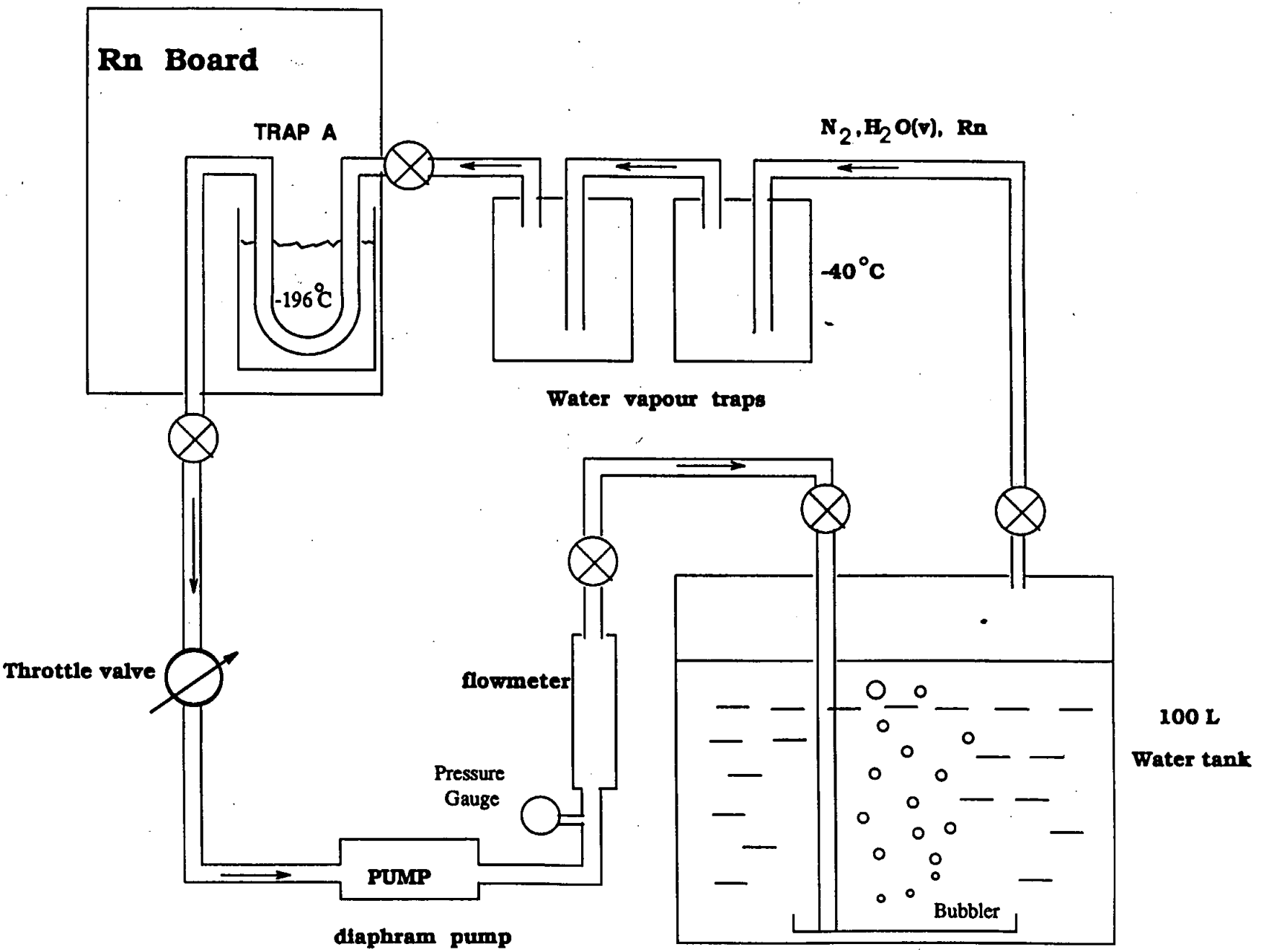
[3] J. Bigu, E.D. Hallman, L. Kendrick, Division Report MRL 91-152(TR), Canada Center for Mineral and Energy Technology (CANMET), Energy, Mines and Resources Canada.

[4] Manqing Liu et al, Sudbury Neutrino Observatory, SNO-STR-91-083, Queen's University (1991)

[5] V.S. Uras et al, Sudbury Neutrino Observatory, SNO-STR-93-045, Queen's University (1993)

[6] V.S. Uras et al, Sudbury Neutrino Observatory, SNO-STR-94-024, Queen's University (1994)

[7] J. Bigu et al, Appl. Radiat. Isotop.


Rn Board
TRAP A
-196°C
N_2, H_2O(v), Rn
-40°C
Water vapour traps
Throttle valve
flowmeter
Pressure Gauge
PUMP
diaphram pump
Bubbler
100 L
Water tank