Radon (^{222}Rn) Emanation Results

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A summary of results of radon (^{222}Rn) emanation into vacuum up to December 1991 was given in SNO-STR-91-083. A summary of the procedure used to reduce the apparatus background, a description of the analysis of the results and a table of results on sample up to August 1993 is given in SNO-STR-93-045. This report is a summary of results for materials measured from September 1993 to August 1994.

Recent work on the radon emanation setup has included:

1. Measuring the efficiency of removing radon from the 40 liter emanation chamber and trapping it into the first (big) radon trap.

Radon was extracted from the emanation chamber and transferred into a ZnS cell. Then a second extraction was immediately performed and the radon transferred to a second ZnS cell. By comparing the counts after one day of counting for the first and second ZnS cell, the efficiency for removal from the emanation chamber is determined. The removal efficiency was found to be around 75% (assuming the big radon trap freezes all the radon which enters it).

2. Fitting of the cumulative counts from a ZnS cell

The counts from a ZnS cell originate from the decay of radon atoms originally from the sample in the emanation chamber and from the decay of background radionuclides in the ZnS cell. The cumulative counts from background increases linearly with time while the count rate from the decay of sample-radon atoms decreases with a half-life of 3.8 days. An EXCEL (spreadsheet) least-squares fit program has been written to fit the cumulative counts from a ZnS cell to these two components.

3. Automated Data Recording

The ORTEC Multi-Tasker 2.20 program has been installed. Multi-Tasker manages simultaneous acquisition of up to 128 detectors using user- written application specific "procedures". For our application, Multi- Tasker manages eight ZnS-cell-PMT segments. It records the cumulative counts (in the ROI) and live time every four hours and can record the cumulative spectra as often as once an hour. This is very useful to recover from overnight power failures or monitor counts over weekend.

4. Emanation of radon from a Material Underwater

A PVDF tank with airtight cover is filled with 42 liters of distilled water and a sample is submerged. Nitrogen gas is circulated through a bubbler at the bottom of the tank, through the radon board and back to the bubbler. Emanated radon is swept out of the water by the nitrogen gas bubbles and is trapped in the large radon trap.

Preliminary results indicate that the radon emanation rate in water and in vacuum for spiked glass discs and for flexible tubing are comparable. A detailed report is in preparation.

Detailed reports exists on the polypropylene beads/piping (SNO-STR-93- 065) and black acrylic sheets (SNO-STR-93-059) listed in the table below.

Table 1 Summary of radon emanation results

Material	Emanation rate in vacuum	Comments
Grey Polypropylene Piping	23.2 ±1.3 Rn $m^{-2}h^{-1}$ 18.3 ± 1.0 3.9 ± 0.6 16.1 ± 1.1 15.0 ± 0.9	Third extraction anomalously low
White Polypropylene Piping 2 " I.D.	1.1 ± 0.6 Rn $m^{-2}h^{-1}$ 1.4 ± 0.5 0.7 ± 0.4 1.1 ± 0.4	
White Polypropylene Piping 7/8" I.D.	4.6 ± 0.6 Rn $m^{-2}h^{-1}$ 2.4 ± 0.4 1.4 ± 0.4 1.6 ± 0.3	

Material	Emanation rate in vacuum	Comments
PVDF Piping	< 1.1 Rn $m^{-2}h^{-1}$	
Black Acrylic Sheets	6 ± 1Rn $m^{-2}h^{-1}$ 8 ± 1 6.9 ± 0.8	
Flexible Pharmed Tubing	6000 Rn $m^{-2}h^{-1}$	
Kynar PVDF Beads	< 0.2 Rn $m^{-2}h^{-1}$	
Himont SV956 Beads	4.4 ± 0.3 Rn $m^{-2}h^{-1}$ 0.9 ± 0.1 0.6 ± 0.2	
Himont SV258 Beads	< 0.2 Rn $m^{-2}h^{-1}$	
Teflon Coated Tonkaflow Parts	82 ± 2 Rn $m^{-2}h^{-1}$ 69 ± 2 0.6 ± 0.2	
Huge American Pump	291 ± 12 Rn $m^{-2}h^{-1}$ 147 ± 10 212 ± 9	291 Rn $m^{-2}h^{-1}$ corresponds to 24 Rn h^{-1} for the pump
3 Chemkor SuperBloc II Valves	32 ± 4 Rn $m^{-2}h^{-1}$ 11 ± 2 < 4 < 3.5 13 ± 3	
Small American Pump	292 ± 23 Rn $m^{-2}h^{-1}$	or 9.0 ± 0.7 Rn h^{-1} for the pump
Short Tonkaflow Cylinder	60 ± 4 Rn $m^{-2}h^{-1}$ 56 ± 2 43 ± 2	Radon is assumed to come from outside and inside surface
Long Tonkaflow Cylinder	227 ± 7 Rn $m^{-2}h^{-1}$ 106 ± 3 127 ± 4	Radon is assumed to come from inside surface only
Welded Aluminium 3" Angles	7.8 ± 0.8 Rn $m^{-2}h^{-1}$	
Welded Covered Aluminium	3.7 ± 0.7 Rn $m^{-2}h^{-1}$ 1.7 ± 0.4 2.0 ± 0.4 2.2 ± 0.4	

Material	Emanation rate in vacuum	Comments
Diakon MnO_2 Beads	0.026 ± 0.003 Rn $h^{-1}g^{-1}$ 0.037 ± 0.006 0.030 ± 0.008	
Norel Plastic RO Inserts	8.2 ± 0.4 Rn $m^{-2}h^{-1}$ 6.2 ± 0.3 8.7 ± 0.3	
Fabco SV-258 Poly-propylene Resin (1.4 Kg)	3.1 ± 0.2 Rn $m^{-2}h^{-1}$ 0.7 ± 0.2 0.4 ± 0.2	
Fabco SV-258 Poly-propylene Resin (9.2 Kg)	4.0 ± 0.1 Rn $m^{-2}h^{-1}$ 1.14 ± 0.05 0.65 ± 0.04 0.24 ± 0.02 0.10 ± 0.02 0.15 ± 0.02 0.13 ± 0.02	The emanation rate drops with a 4 day half-life. This indicates the presence of absorbed room air radon in the beads
American 1" Pump (with urethane diaphragms)	7.8 ± 0.6 Rn h^{-1} 2.7 ± 0.4 1.5 ± 0.5 3.6 ± 0.5 1.9 ± 0.3 2.7 ± 0.3 3.0 ± 0.3 2.8 ± 0.3	For extraction 3 to 8 the pump was bagged in plastic and filled with nitrogen gas
Yellow Kevlar Rope	< 0.001 Rn $m^{-1}h^{-1}$	The rope acts like a vacuum pump and does not emanate its radon into the chamber
Clear PVC Tubing	61.8 ± 1.9 Rn $m^{-2}h^{-1}$ 29.1 ± 0.9 33.0 ± 0.9	
Plast-O-Matic Valve Pieces	3 ± 1 Rn $m^{-2}h^{-1}$ < 1.125 3 ± 1 < 0.936	
Aluminium Laminated Foil	1.8 ± 0.2 Rn $m^{-2}h^{-1}$ 2.3 ± 0.1 1.9 ± 0.2	

Material	Emanation rate in vacuum	Comments
Simona DWST PP Sheets	4.2 ± 0.6Rn $m^{-2}h^{-1}$ 2.1 ± 0.6 3.0 ± 0.6 1.9 ± 0.6 0.7 ± 0.5	
^{226}Ra Spiked Glass Pucks	83 ± 13 Rn $m^{-2}h^{-1}$ 93 ± 11 107 ± 12 127 ± 10	
Vacuum Research Gate Valve (dirty O-ring)	Opened: 41 ± 3 Rn $m^{-2}h^{-1}$ Closed: 17 ± 3 16 ± 3	
Vacuum Research Gate Valve (cleaned O-ring)	Opened: 48 ± 4 Rn $m^{-2}h^{-1}$ Closed: 13 ± 3 18 ± 3 15 ± 2	
Silicone Tubing	1.4 ± 0.8 Rn $m^{-2}h^{-1}$ 1.4 ± 0.6 1.6 ± 0.7 1.5 ± 0.5	
SV - 258 Packing Balls (2015 balls)	33 ± 1 Rn h^{-1} 7.4 ± 0.5 3.1 ± 0.4 3.0 ± 0.4	
Polyurethane Tubing	1.4 ± 0.4 Rn $m^{-2}h^{-1}$ 1.6 ± 0.4 < 0.3 < 0.2 < 0.2	

Description of Samples

Grey Polypropylene Piping

From Chemline Plastics Limited, Thornhill, Ontario; Chemline A/AM PP-R PRO 1 pipes.

Load 4 pieces of polypropylene piping, $22\frac{15}{16}$" long, $1\frac{1}{2}$" internal diameter, 7/32" thick in chamber.

White Polypropylene Piping (2 " I.D.)

Cut Chemkor schedule 80 tube in half with clean hacksaw blade.

Load 6 pieces of polypropylene piping, 2" internal diameter , 1/4" thick (4 pieces $18\frac{1}{4}$" long and 2 pieces $20\frac{1}{4}$" long) in chamber; total surface area 0.421 m^2.

White Polypropylene Piping (7/8 " I.D.)

Cut CP Inc schedule 80 tube in half with clean hacksaw blade.

Load 10 pieces of polypropylene piping, 7/8" internal diameter , 3/16" thick (7 pieces $18\frac{3}{8}$" long, 2 pieces $17\frac{1}{4}$" long and 1 piece $11\frac{7}{8}$") in chamber;

PVDF Piping

Stock pieces of FIP piping from CRPP were welded together and the ends capped.

Total inside area is about 0.25 m^2.

Black Acrylic Sheets

0.25" thick piece of black acrylic from Canada Plastics, Toronto, cut into two pieces: 17 cm × 57.8 cm and 20 cm × 57.8 cm. All edge were carved with razor blade and all faces were wiped clean with alcohol.

Total surface area 0.44 m^2.

Flexible Pharmed Tubing

Masterflex 6485-24 from Cole Parmer.

Load 9 pieces 24" long and 13 pieces 23" long in chamber. All pieces have a 6 mm internal diameter and a 11 mm outer diameter. All printing was removed with ethanol.

Kynar PVDF beads

From Fabco (Toronto)

Put 18060 beads in chamber; total mass 1320.7 g.

Total surface area 14,267 cm^2.

<u>Himont SV956 beads</u>

From Fabco (Toronto) (Originally from Himont Canasa, Varennes, Québec).

Load 48,790 ± 10 % beads into Chemkor polypropylene pipe.

Total mass 1369.4 ± 0.2 g, total volume 2380 ± 10 % mL, total surface area 2.2 m^2.

<u>Himont SV258 beads</u>

Received from Himont Canasa, Varennes, Québec.

Cylindrical in shape, 3 mm × 3 mm.

Load 38,570 ± 3.5 % beads into Chemkor polypropylene pipe,

Total mass 976.68 ± 1.00 g, total volume 1800 ± 100 mL, total surface area 1.47 m^2.

<u>3 Chemkor Valves</u>

The valves are called The Super Bloc II.

Three valves $6\frac{3}{8}$" long, joined together with 1.5" internal diameter polypropylene piping.

Whole unit is 29.5" long.

Total inner surface area of unit 917 cm^2, surface area of each valve 193 cm^2

<u>Teflon coated Tonkaflow pump parts</u>

Black teflon coated stainless steel 316, wiped down with ethyl alcohol.

Load the following in chamber:

One 56.6 cm long, 1.5 mm thick cylinder, 13.5 cm outer diameter, surface area 0.48 m^2.

One 46.7 cm long, 1.5 mm thick cylinder, 13.5 cm outer diameter, surface area 0.4 m^2.

One 6.4 cm long threaded union, 13 cm outer diameter, 7 cm internal diameter, surface area 0.06 m^2.

One 10 cm long inlet, 13.1 outer diameter, 7.3 inner diameter, surface area 0.08 m^2.

Total surface area 1.02 m^2.

Short Tonkaflow Cylinder

After removing all the other teflon coated Tonkaflow parts, leave the short cylinder (46.7 cm long) in acrylic chamber and perform extraction.

Total surface area 0.40 m^2.

Long Tonkaflow Cylinder

Seal both end of cylinder with polypropylene caps. Connect long cylinder to radon board and perform extraction.

Total surface area 0.23 m^2.

Huge American Diaphragm Pump

American polypropylene pump, model 1532, serial 5294.

Retrofitted with O-rings at CRPP; blank off ports and put a Swagelok B-6P4T valve on end.

Surface area 0.08 m^2.

Welded Aluminium 3" Angles

Three Al channels, 8.2 cm $\times$ 7.6 cm, 24.3 cm, 27.5 cm and 46.2 cm long, 6 mm thick. Each channel, made up of two right angles welded together at Queen's Physics workshop, were wiped clean with ethanol and Kimwipe.

Total surface area 0.57 m^2.

Weld Covered Aluminium

Welded at Queen's University with new welder by Chuck Hearns.

Made from 2 square tube pieces: the two smaller Al channel welded together and the longer Al channel (see Welded Aluminium 3" Angles above). All pieces were wiped clean with ethanol and Kimwipe.

Total surface area 0.58 m^2.

Diakon MnO_2 beads

Load 75g of Diakon MnO_2 beads (2nd CRPP batch, Nov 26) in mini acrylic chamber.

Norel RO Plastics Inserts

Shipped from CRPP. Used inside RO filter cartridges. Inserts were wiped clean with ethanol and Kimwipe.

Put 14 large inserts and 6 small inserts in chamber:

Large insert: 19.7 cm outer diameter and 16.8 inner diameter; flange 4 cm wide; 12 spokes 2.2 cm wide, 6.3 cm long and 0.6cm thick; 275.2 ± 0.5 g each;

Small insert: 9.9 cm outer diameter and 8.1 inner diameter; flange 3.2 cm wide; 6 spokes 1.0 cm wide, 2.6 cm long and 0.5cm thick; 41.3 ± 0.5 g each;

Total surface area 1.75 ± 20% m^2; Total mass 4100.6 ± 20% g.

Fabco SV - 258 Polypropylene Resin

Receive approximately 10 kg From Fabco Plastics Wholesale Limited, Maple, Ontario.

Originally, load approximately 66,000 ± 1,000 beads of cylindrical shape with a diameter 3 mm and 3 mm long in chamber; Total mass 1388 ± 2 g, total surface area 2.6 m^2.

Repeat with full sample ($\sim$ 465,000 beads); Total mass 9231 ± 6 g, total surface area 17.3m^2.

Yellow Kevlar Rope

Received from C. Hearns. No cleaning done on rope.

Put 1400 ' (427 m) of rope in chamber, 1/8 " diameter.

Total mass 1424 ± 2 g, total surface area 4.3 m^2.

Clear PVC Tubing

One coil clear plastic tubing from KURI TEC KOIO BY KURIYAMA, 3/8 " inner diameter and 1/2 " outer diameter, roughly 30 m long. Wiped outside clean with ethanol and Kimwipe.

Clear Non-toxic PVC NSF-51 CANADA, K383OD3 06:17

Load 51 pieces 23 ± 1/8 " long in chamber.

Total mass 2195 ± 1 g; total surface area 2.09 m^2; total length 29.8 ± 0.2 m.

Vacuum Research Corporation Gate valve

From Vacuum Research Corporation, Pittsburgh, PA, USA.

Model LP6ASAN120BEP, serial 020794-005, certified to be less than 1×10^{-9} std cc/sec.

The valve was connected to the radon board and extractions were performed with the valve opened and closed. The valve was then disassembled and cleaned (lots of machine oil inside) and the O-rings were replaced and the extractions were repeated.

PLAST-O-MATIC Valves

From PLAST-O-MATIC Valves Inc, Totowa, NJ, USA.

One 1/2" valve (11 pieces) of total mass 105 $\pm$ 0.5 g and approximated surface area of 547.4 cm^2.

One $1\frac{1}{2}$" valve (11 pieces) of total mass 657 $\pm$ 0.5 g and approximated surface area of 2127.9 cm^2.

Put both 1/2 " and 1.5" valves in chamber; giving a total surface area 0.27 m^2.

Simona Dwst Polypropylene Sheets

Receive plastic sample from Fabco Plastics, Maple, Ontario. Plastic chalk white in colour and translucent. Wiped clean with ethanol and Kimwipe.

Load the following pieces in chamber:

Three Simona Dwst polypropylene 25.4 cm $\times$ 30.3 cm sheets, 1/2 ", 3/8 " and 1/4 " thick;

Three Simona Dwst polypropylene 4.5 cm $\times$ 30.3 cm pieces, 1/2 ", 3/8 " and 1/4 " thick;

Total surface area 0.59 cm^2.

Spiked glass

Made for Oxford by a glass manufacturer. Wiped clean with ethanol and Kimwipe.

4 pieces of glass, each disk shaped, spiked with ^{226}Ra to approximately 10 times the normal level in glass.

The 4 disks of diameter 7.5 -7.6 cm and 0.6 - 1 cm thick, giving a total surface area of 431.5 cm^2, are placed in small emanation chamber with 8 clean acrylic spacers (1.8 cm long, 0.9 cm wide and 0.6 cm thick).

Aluminized foil

From H. Evans; consist of a sandwich of nylon, aluminium and polyethylene of a total thickness of 0.0005 ". No cleaning done on the foil.

Load aluminized foil sheet 185 cm $\times$ 100 cm in chamber.

Total surface area of 3.7 m^2.

Silicone Tubing (platinum cured)

From Cole Parmer Instrument Company .

Milky translucent silicone tubing serial number #95801-12, lot # 03941903, of 1/4 " inner diameter and 3/8" outer diameter, and 1/16" thick. Wiped outside clean with ethanol and Kimwipe.

Load 13 pieces of 23" long (total length of 25') in chamber.

Total surface area 0.38 m^2.

Polyurethane tubing (ether-grade)

Translucent, slight yellow tinge, Nalgene 290, tubing from Cole Parmer Instrument Company. Wiped outside clean with ethanol and Kimwipe.

Load 26 pieces, 23" long, 3/8" in outer diameter, 1/4" in inner diameter, 1/16" thick in chamber.

total surface area 0.76 m^2.

SV - 258 Packing Balls

Manufactured by Fabco (Toronto), using SV258 resin. Packed in 8 cubic feet plastic bag and cardboard box. These 1" diameter balls have an area of 85 ft^2 per cubic foot of packing (or 2789 cm^2/liter).

The balls were not wiped before putting into emanation chamber. Loaded 2015 balls (about 26 liters volume).