Proceedings of the 2006 International Radon Symposium
September 17 – 20, 2006

DESIGN AND PERFORMANCE OF A PASSIVE RADON DECAY PRODUCTS MONITOR

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ABSTRACT

Electret-based passive air samplers have been used in United Kingdom and elsewhere for quantitative sampling for airborne dust. Alpha electret ion chambers (EIC) have been used for quantitative measurement of deposited alpha emitting isotopes. These two well documented principles are combined to create a passive radon progeny monitor. Large area (50 cm^2) electret charged to 500 to 2000 volts collect airborne radon decay products and the collected sample is "viewed" and measured by an alpha EIC. Such collection and measurement continues for the entire period of sampling, providing an integrated signal to the electret in alpha EIC. The present work is of exploratory nature and provides the responses of three different sizes of collection electrets. Results are also compared with a simple passive device with no collecting electret. The study provides data for optimization of the design depending upon the requirement. Study is limited to a typical home with equilibrium ratios from 40 to 60%. This method can be used for both short term and long term monitoring of RDP in working level units.

INTRODUCTION

It is known that radon decay product (RDP) measurement is more accurate method of characterization of radon risk compared to measuring radon gas. However, most measurements carried out to date are radon gas, because of simplicity and lower cost.

RDP measurements are needed for more precise correlation with health effects. There are several instruments available for measuring RDP concentration in air. In these instruments, air is sampled through a filter paper and alpha activity collected on the filter is counted to determine the RDP concentration in WL units. These require a pump and electrical power to operate. It is not practical to use these devices for extended periods. This is because of several reasons such as dust loading and the cost of running the unit for extended time. Hence these are used for short term (ST) measurements extending from 2 to 7 days only. There has been a need for a device that can be used without a pump or power and usable for extended periods.

ELECTRET PASSIVE SAMPLERS

Recently electret-based passive air samplers have been used in United Kingdom and elsewhere for quantitative sampling for airborne dust. This works like a pump (1). This work proved the feasibility and demonstrated the integrating capability of the passive electret sampler. The original design is not widely used because of the limitations of stability of electrets used in those devices. It is now practical to manufacture very stable electrets which can be used for extended period.

PASSIVE SAMPLERS FOR RADON DECAY PRODUCTS

Alpha electret ion chambers (EIC) have been used for quantitative measurement of deposited alpha emitting isotopes (2, 3). These two well documented principles are combined to create a passive radon progeny monitor.

Electrets charged to 500 to 2000 volts collect airborne radon decay products by the principle similar to the published version (1) and the collected sample is "viewed" and measured by an alpha EIC. Such collection and measurement continues for the entire period of sampling, providing an integrated signal to the electret in alpha EIC.

Figure 1 gives an exploded as well as assembled view of this device. The parameters used in the study are similar to those used in published version (1). The diffusion cell is made up of 8 cm diameter Al disk with1 cm separation. The cell is positioned on the top of Aluminized Mylar foil (also 8 cm diameter) of alpha EIC (2,3),with three separation pedestals.

Under normal circumstances, the concentration of RDP inside the cell is the same as that in the room. However these see surfaces available to deposit and get deposited. There is equal probability of collection on top Aluminum disk and on to the aluminized Mylar on top of the alpha EIC. More enter the cell from room air for further deposition. This is the well know principle of passive diffusion deposition.

It is well known that the aerosols get collected preferentially on charged surfaces. If the bottom side of the top aluminum disk is lined with an electret, the passive diffusion deposition gets amplified. This works like an aerosol pump (1) and hence RDP collector.

The alpha particles emitted by the collected RDP penetrate through the Aluminized Mylar and cause ionization inside the alpha EIC and get registered by an electret of the alpha EIC. The process continues providing integrated signal just as in EIC used for radon monitoring.

The rate of discharge of electret in the alpha EIC is caused by two sources, the progeny collected in the cell and the ionization caused by radon and gamma radiation inside alpha EIC. A background alpha EIC (Aluminized Mylar window covered) provides the signal from radon and gamma radiation. The difference between the combined signal and that due to radon and gamma provides the signal uniquely relatable to progeny concentration.

The signal from alpha EIC is measured in terms of volts per day, obtained by measuring total discharge and dividing it by the period of collection in days.

Total discharge divided by the exposure period provides the discharge rate in units of volts per day.

CALIBRATION

Calibration of these new passive RDP monitors is simple and straight forward. A typical home basement was chosen that has radon concentration between that ranges from 3 to 10 pCi/L. Reference device used was a calibrated E-RPISU. The E-RPISU and the passive devices with associated blanks (for radon and gamma signal measurement) are deployed as per EPA protocols. These were operated for the desired sampling period.

The calibration factor (CF) is defined as the net signal (volts per day, VPD) divided by the RDP concentration in units of mWL. The discharge rate is normalized to the mid point voltage of 400 volts by using the published equations for alpha EIC (2,3).

The calibration factors were determined for electrets of different areas (large, medium and small area) and for the device that did not have collection electrets.

RESULTS

Preliminary experiments proved that there is no significant change in response when electret voltages are in the range of 500 to 2000 volts. Because of the small gap width, the electret field is large enough to collect the particles.

Table-1 gives the calibration factors for large area electrets.

Table-2 gives the results for medium area electrets and Table-3 gives the results for small area electrets.

Table-4 gives results for the collection cell when no electret was present.

Table-5 gives the summary of all the results, including collection areas, calibration factors, and relative calibration factors, relative to large area collection electret and relative areas, relative to large area electret.

DISCUSSION OF RESULTS

There is some collection of RDP in Aluminum surfaces as seen by the response of 0.25 VPD per mWL (Table-4). This may be a right choice for long term sampling. Expected volts drop for 180 day sampling is 45 volts for 1 mWL or 900 volts for 20 mWL (.02 WL). When expected levels are in excess of 10 mWL, long term electret has to be used.

Wider standard deviations in the calibration factors may be due to several factors. These include the expected non uniformity of RDP levels in the room, finer dependence of responses on the electret voltages. Large area electret samples at a rate which is nearly 14 times that of passive sampling with out a collecting electret. These samplers are a right choice for short term sampling. Medium and small area collection electrets behave in between.

It is expected, that larger the area of the electret, higher is the collection and higher is the response as seen in Table-5.

In these studies, negative electrets were used because of the ease of making and handling negative electrets of high surface potential. Current studies are limited to equilibrium ratios in the range of 40 to 60 %, usually found in typical homes. It is worth noting that the standard deviation in the responses of simple diffusion sampler with no collecting electret. Future studies are needed to cover wider range of equilibrium ratios. These studies are planned in the next phase of the study.

USEFUL CONCLUSIONS

Simple diffusion sampler with no electret collector promises to be a practical device for both short and long term monitoring of RDP.

ACKNOWLEDGEMENTS

Authors are grateful for the useful discussions with Dr. Dan Steck and Mr.Doug Kladder.

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Table1
Large Area Electret Collector
Calibration Data

Days	I	F	G	H	NVPD(P)	NVPD(B)	Net NVPD	mWL	CF	pCi/L	ER %
2.083	504	348	504	492	77.76	5.73	72.03	19.13	3.7650	4.58	41.5
2.083	565	428	504	492	65.49	5.73	59.76	19.13	3.1238		
2.083	517	333	504	492	91.77	5.73	86.03	19.13	4.4974		
2	505	343	492	481	84.21	5.51	78.70	20.4	3.8577	3.66	55.6
2	514	389	492	481	63.94	5.51	58.43	20.4	2.8641		
2	310	191	492	481	68.08	5.51	62.57	20.4	3.0673		
2	348	209	492	481	78.35	5.51	72.84	20.4	3.5707		
2	428	312	492	481	62.19	5.51	56.68	20.4	2.7782		
2	333	180	492	481	87.26	5.51	81.75	20.4	4.0073		
4	567	539	483	465	84.16	4.54	84.16	21.1	3.9884	3.81	55.4
4	444	422	483	465	71.10	4.54	66.56	21.1	3.1544		
4	618	592	483	465	75.60	4.54	71.05	21.1	3.3674		
4	516	483	483	465	102.51	4.54	96.78	21.1	4.5868		
4	459	432	483	465	86.62	4.54	80.89	21.1	3.8337		
4	566	538	483	465	84.21	4.54	78.48	21.1	3.7193		
							Grand Avg.		**3.6121**		
							Grand SD		**15.2000**		

Table-2
Medium Area Electret Collector
Calibration Data

Days	I	F	G	H	NVPD(P)	NVPD(B)	Net NVPD	mWL	CF	pCi/L	ER %
1.0625	419	350	462	452	69.06	9.60	63.55	43.7	1.4542	3.62	38.6
1.0625	460	397	462	452	61.48	9.60	51.88	43.7	1.1873		
1.0625	327	266	462	452	64.10	9.60	54.50	43.7	1.2472		
1.0625	396	338	462	452	58.63	9.60	49.03	43.7	1.1220		
1.0625	366	303	462	452	64.84	9.60	55.25	43.7	1.2642		
0.8958	350	289	472	462	75.09	11.32	63.77	39.3	1.6226		
0.8958	357	289	472	462	83.54	11.32	72.23	39.3	1.8378		
0.8958	320	255	472	462	81.41	11.32	70.09	39.3	1.7836		
0.8958	372	285	472	462	106.56	11.32	95.25	39.3	2.4236		
0.8958	303	246	472	462	71.89	11.32	60.57	39.3	1.5413		
								Average	1.5484		
								STDEV	0.3948		
								% STDEV	25.5002		

Table-3
Small Area
Electret
Calibration Data

Days	I	F	G	H	NVPD(P)	NVPD(B)	Net NVPD	mWL	CF	pCi/L	ER %
2.04	546	507	497	487	18.69	4.89	13.80	20.4	0.6763	3.62	38.6
2.04	267	230	497	487	20.78	4.89	15.88	20.4	0.7785		
2.04	298	257	497	487	22.67	4.89	17.78	20.4	0.8713		
2.04	535	488	497	487	22.74	4.89	17.84	20.4	0.8745		
2.04	430	396	497	487	17.44	4.89	12.54	20.4	0.6148		
4	507	417	473	465	22.88	2.02	11.56	21.1	0.5478	3.81	55.39
4	230	156	473	465	21.81	2.02	19.79	21.1	0.9377		
4	257	199	473	465	16.79	2.02	14.76	21.1	0.6997		
4	488	391	473	465	24.98	2.02	22.96	21.1	1.0881		
4	396	341	473	465	14.75	2.02	12.73	21.1	0.6033		
1.0625	566	546	496	492	18.07	3.75	14.32	19.25	0.7436		
1.0625	285	267	496	492	19.12	3.75	15.37	19.25	0.7984	3.75	52
1.0625	315	298	496	492	17.77	3.75	14.01	19.25	0.7279		
1.0625	560	535	496	492	22.71	3.75	18.95	19.25	0.9846		
1.0625	446	430	496	492	15.53	3.75	11.77	19.25	0.6116		
								Average	0.7706		
								STDEV %	0.1558		

Table-4
No Electret
Calibration Data

Days	I	F	G	H	NVPD(P)	NVPD(B)	Net NVPD	mWL	CF	pCi/L	ER %
4	396	361	483	465	9.336696	4.542461	4.794235	21.1	0.227215	3.81	55.39
1.75	279	259	306	297	12.94985	5.726597	7.223257	28.1	0.257055	5.11	55%
0.8958	357	339	472	462	21.81082	11.31568	10.49513	41.1	0.255356	8.88	45%
1.104	323	306	443	434	17.02559	8.403693	8.621902	33	0.26127	8.1	41%
								Average	0.250224		
								STDEV	0.0155		
								% STDEV	6.210255		

Table-5
Relative resonses of Large, Medium and Small Area Collecting electrets

	Area (cm2)	Response	Rel Resp.	Rel Area
Large E	59.5	**3.6121**	1.00	1.00
Medium E	38.5	1.5484	0.43	0.65
Small E	21.2	0.7706	0.21	0.36
No E	59.5	0.2502	0.16	1.00

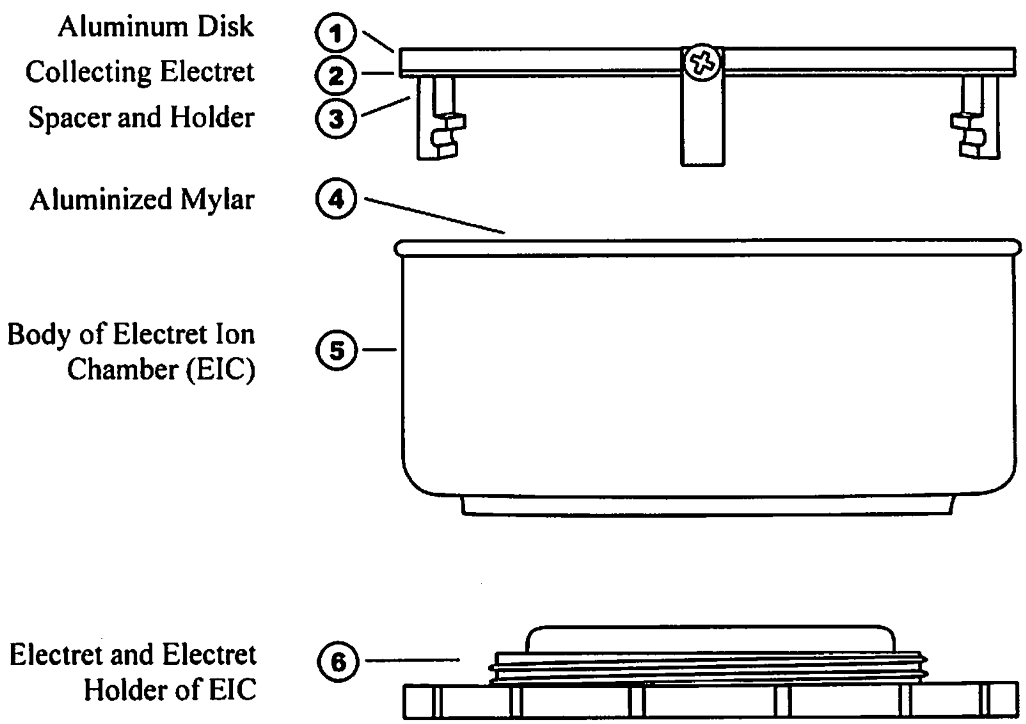

Fig 1A

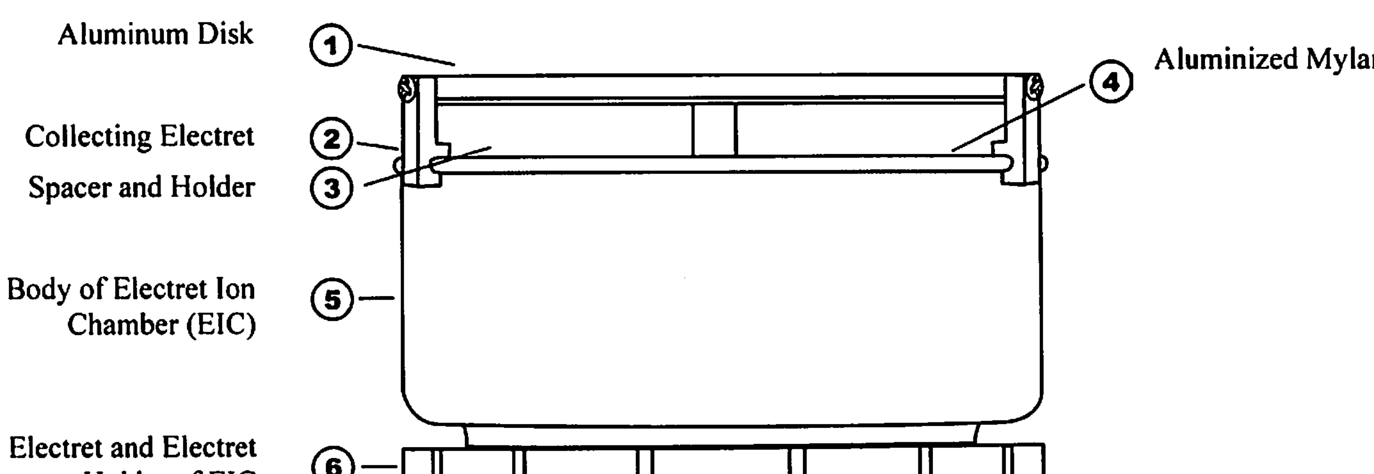

Fig 1B

Passive Radon Progeny Monitor (Passive R-RPISU)
Fig 1A Exploded View and Fig 1B Assembled View