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EFFECT OF SELECTED VARIABLES ON AIRBORNE THORON PROGENY CONCENTRATIONS

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INTRODUCTION

The effect of mixing fans on ^{222}Rn progeny, under laboratory-controlled and field conditions, has been investigated by several authors (Ab82; Bi83; Hi83; Ho79a; Ho79b; Ru83; Sh72; Wr69). The effect of mixing fans and ion-generators on ^{220}Rn progeny has been studied by the author and the results have been reported elsewhere (Bi84a).

Experiments on ^{220}Rn progeny were carried out by the author in the past in a small (3 m^3) $^{222}Rn/^{220}Rn$ chamber under conditions of low aerosol concentration (~1.0 x 10^3 cm^{-3}) and low relative humidity (30-40%) in order to investigate plate-out phenomena. Furthermore, the effect of an ion-generator on aerosol concentration using NaCl was also studied (Bi84a). In all cases, the effect of the ion-generator was to lower ^{220}Rn progeny and aerosol concentration. The operation of a mixing fan had the effect of lowering the ^{220}Rn progeny concentration.

In this paper, the above experiments have been extended to other environmental conditions such as higher aerosol concentration and humidity. Furthermore, these experiments were conducted in a large Radon/ Thoron Test Facility (RTTF) of the walk-in type (~26 m^3) (Bi84b). More specifically, the effect of aerosol concentration, relative humidity, mixing fans, negative ion-generators and a small electrostatic dust precipitator, on ^{220}Rn progeny concentration were investigated.

EXPERIMENTAL APPARATUS AND MEASUREMENTS

Aerosol consisting of an aqueous solution of NaCl (1 gL^{-1}) was injected into the RTTF by means of an aerosol atomizer in conjunction with its corresponding air supply system, desiccator column and ^{85}Kr electrical charge neutralizer unit[1].

Rn-220/^{220}Rn progeny atmospheres were produced using commercially available ^{228}Th dry-sources of the flow-through type[2].

Commercially available, modestly priced ion-generators, some purchased in a large department store, were used. Up to four ion-generators were used[3]. Experiments with mixing fans were conducted using the fan of some of the ion-generators with the filament off. The effect of the ion-generators alone was carried out with ion-generators which had either no fan or ion-generators in which the filament and fan could be operated independently.

Because experiments were conducted this time in a much larger chamber than before, up to four ion-generators were, at times, used simultaneously to ensure an adequate supply of ions in the RTTF. Unfortunately, because it was not possible at the time of the experiment to obtain all the ion-generators of the same kind, ion-generators of different characteristics had to be used. Hence, certain experiments were partly aimed at differentiating the effect of the ion-generator fans from the ion-generator filaments (see Tables 3, 4 and 5). (It should be noted that the ion output rate of some ion generators was considerably less than that specified by the manufacturers. The ion output rate for the other ion-generator(s) was not specified in the instruction manuals.)

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[1]System available from Thermo-Systems Inc. (T.S.I), P.O. Box 43394, St. Paul, MN 55164, U.S.A., model 3075/3076.

[2]Available from Pylon Electronic Development Ltd. (147 Colonnade Rd., Ottawa, Ont. K2E 7L9, Canada) under the commercial name Th-1025.

[3]Models Bionaire 100 (filament only, no fan), Bionaire 2000 filament and two-speed fan), Bionaire 500S (filament and fan; filament will not operate without the fan), and Pollenex 1599C (same as Bionaire 500S). Bionaire models are available from Bionaire Corporation, 565A Commerce St., Franklin Lakes, NJ 07417, U.S.A. Pollenex model is available from Associated Mills Inc., 111 North Canal St., Chicago, IL 60606, U.S.A.

A small electrostatic dust precipitator[1] was used in the experiments. Aerosol concentration was measured with two condensation nuclei counters[2]. Environmental variables such as air temperature, relative humidity and barometric pressure were measured by means of a meteorological package[3].

Rn-220 progeny levels, i.e., WL(Tn), ^{212}Pb concentration, [^{212}Pb], and ^{212}Bi concentration, [^{212}Bi], where the square brackets are used to denote activity concentration (mBq m^{-3}), were measured using a two gross α-count method.

RESULTS AND DISCUSSION

The results of the experimental tests are given in Tables 1 to 6 and Figure 1.

Figure 1 shows WL(Tn) and the aerosol concentration, N, versus time. There is a dramatic increase in WL(Tn) with increasing N. However, the rate of increase for WL(Tn) was substantially lower than that corresponding to N. Constant aerosol concentration conditions were attained in about 3 hours after continuous aerosol injection. Figure 1 shows that 65% of the final value of N was reached in less than 1 hour, whereas it took more than 2 hours for WL(Tn) to attain 65% of its final value. These times depended, of course, on air flow conditions in the RTTF. A time lag between N and WL(Tn) suggests itself from the above data.

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[1] MSA electrostatic sampler model F manufactured by Mine Safety Appliances Co., Pittsburgh, PA, U.S.A.

[2] TSI Inc. Model 3020 and a Rich model 200, the latter manufactured by Environment One, 2733 Balltown Rd., Schenectady, NY 12309, U.S.A.

[3] The meteorological system consisted of probe models 602 (air temperature), 604 (relative humidity), and SD 001 (barometric pressure) in conjunction with a data logger model 650. The system is available from alpha-NUCLEAR, 1125 Derry Road East, Mississauga, Ont., L5T 1P3, Canada.

Table 1 shows ^{220}Rn progeny data, some of which have been used in Figure 1. Experiments were conducted at 26-27^{o}C, with a relative humidity of 52%. The aerosol concentration before aerosol injection was $\lesssim 1.0 \times 10^3$ cm^{-3}. Under steady-state conditions N reached a value of ~2.8 x 10^4 cm^{-3} after about 3 hours of continuous injection. As the RTTF was operated at a low air exchange rate, i.e., long air residence time, N only decreased slowly after aerosol injection was terminated. Table 1 shows the following interesting features:

1. WL(Tn), [^{212}Pb] and [^{212}Bi] increased markedly after aerosol injection. The ^{220}Rn progeny increased in a similar fashion and rate as that of WL(Tn), see Figure 1;
2. The ratio [^{212}Bi]/[^{212}Pb] decreased significantly shortly after aerosol injection and then increased again reaching values slightly larger than before aerosol injection. This appears to be a transient effect; and
3. As expected, the ratio [^{212}Pb]/WL(Tn) remains essentially constant, with a maximum variation of less than 2.5%, as ^{212}Pb contributes about 90% to WL(Tn).

Table 2 shows the effect of relative humidity on WL(Tn) and the ^{220}Rn progeny. Also shown in the Table are the aerosol concentration and the temperature, T, in the RTTF. There is a significant increase in WL(Tn), i.e., ~36%, with increasing relative humidity from 34% to 70%. This effect cannot be attributed to the aerosol concentration because N did not follow the same pattern as WL(Tn). The ^{220}Rn progeny ratio remained essentially constant with a variation within $\pm$5% of its mean value.

Table 3 shows the effect of two ion-generators on WL(Tn), and the ^{220}Rn progeny concentration. Also shown is the aerosol concentration. Tests were conducted at 25^{o}C and at a relative humidity of 31 to 34%. One of the ion-generators, i.e., the larger one, had a fan whereas the smaller ion-generator had a filament only and no fan. The data shown were obtained when the filaments were on but the fan was not operating.

The following effects induced by the ion-generators are worth mentioning:

a) WL(Tn) and the ^{220}Rn progeny concentration were reduced when the ion generators were operated;

b) Operation of the ion-generators caused a decrease in the aerosol concentration;

c) The effect of the two ion-generators operating simultaneously was larger than the effect of only one; and

d) The converse of items a) and b) is also true, i.e., the effects are reversible.

For the cases presented here, a decrease in WL(Tn) of 29% was caused by turning the small ion-generator on for a few hours. An increase in WL(Tn) of 77% was caused when the ion-generators were turned off. The smaller starting values for WL(Tn), [^{212}Pb] and [^{212}Bi] on Table 3 are due to the fact that the ion-generators were turned on the previous evening and left on until 09:00 next day.

Table 4 shows the effect of two ion-generators when only the fans were turned on and the filaments were turned off. One of the two generators was the same as the one used the previous day (Bionaire 2000); the other generator was a different one (Bionaire 500S). The effect brought about by the ion generator fans was greater than the effect with the filaments on and fans off. As previously reported (Bi84a) the effect of the fans was to decrease WL(Tn) and the ^{220}Rn progeny concentration. A 5-fold reduction was observed in these tests. Furthermore, the fans had an effect on the ^{220}Rn progeny concentration ratio; it decreased when the fans were operating. The experiments were carried out at 24.5^{o}C and at a relative humidity of 35%. The aerosol concentration was in the range $1.3 \times 10^3 - 1.75 \times 10^3\ cm^{-3}$.

Table 5 shows the combined effect of four ion-generators operating simultaneously, with fans and filaments on, on WL(Tn) and the ^{220}Rn progeny concentration. Also shown is the aerosol concentration. Experiments were conducted at 27.0-29.0^oC and at a relative humidity of about 48%. Quite a dramatic effect was observed in this case, i.e., a 30-fold reduction in WL(Tn) and [^{212}Pb] after about 3 hours of ion-generation operation. The ^{220}Rn progeny concentration ratio was also dramatically affected. As indicated above, the aerosol concentration decreased as the ion-generators were in operation, and vice versa.

Table 6 shows the effect of a small, and rather old, electrostatic dust precipitator on WL(Tn), and the thoron progeny concentration. The effect observed in this case was rather low because of the relatively large dimensions of the RTTF and the limited capacity of the precipitator. In contrast to other designs, however, this precipitator had no protective barrier material at the air intake, e.g., thin layer of 'foamlike' material which acts as an effective 'filter' for entering radon and thoron progeny.

CONCLUSIONS

As expected, ^{220}Rn progeny levels increased markedly with increasing aerosol concentration. The operation of mixing fans and ion-generators had a substantial and opposite effect to aerosol concentration on ^{220}Rn progeny levels. Furthermore, the operation of ion-generators significantly decreased the aerosol concentration in the RTTF. It is suspected that the ions produced by the generators may act as nucleation sites with the formation of larger particles. A lowering of the aerosol concentration may, in turn, reduce airborne ^{220}Rn progeny concentration, and increase plate-out of these products on large surfaces, e.g., walls. In general, the data presented here are qualitatively consistent with data for ^{222}Rn progeny reported previously by the author elsewhere (Bi83).

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Table 1 - Thoron progeny and aerosol concentration data in the Radon/Thoron Test Facility (RTTF). Operating conditions were: 26-27°C (temperature) and 52% (relative humidity).

Time	WL(Tn)	$[^{212}Pb]$ $(Bq\ m^{-3})$	$[^{212}Bi]$ $(Bq\ m^{-3})$	$\frac{[^{212}Bi]}{[^{212}Pb]}$	$\frac{[^{212}Pb]}{WL(Tn)}$ $(Bq\ m^{-3}\ WL^{-1})$	$\frac{[^{212}Bi]}{WL(Tn)}$ $(Bq\ m^{-3}\ WL^{-1})$	N (cm^{-3})
8:00	1.13	323.1	148.4	0.46	285.9	131.3	875
8:40	1.03	296.7	130.8	0.44	288.1	127.0	942
9:00	1.44	420.5	131.8	0.31	292.0	91.5	7.3×10^{3}
10:00	5.52	1610.5	473.4	0.29	291.7	85.8	1.95×10^{4}
11:00	8.33	2402.6	968.9	0.40	288.6	116.3	2.35×10^{4}
12:00	10.48	3010.4	1340.2	0.44	287.2	127.9	2.60×10^{4}
13:00	11.18	3193.2	1590.5	0.50	285.6	142.3	2.69×10^{4}
14:00	11.51	3284.8	1685.9	0.51	285.4	146.5	2.75×10^{4}
15:00	12.38	3530.7	1815.3	0.51	285.2	146.6	2.78×10^{4}

Notes: Aerosol was injected at 8:41.
N stands for aerosol concentration.

Table 2 - Radon-220 progeny concentration, aerosol concentration, and relative humidity data from the Radon/Thoron Test Facility (RTTF).

Time	WL(Tn)	[^{212}Pb] (Bq m^{-3})	[^{212}Bi] (Bq m^{-3})	[^{212}Bi]/[^{212}Pb]	[^{212}Pb]/WL(Tn) (Bq m^{-3} WL^{-1})	[^{212}Bi]/[WL(Tn) (Bq m^{-3} WL^{-1}	N (10 cm^{-3})	Relative Humidity %
8:30	-	-	-	-	-	-	-	34
8:50	4.14	1184.0	589.8	0.50	286.0	142.5	2.65	34
9:50	4.17	1195.1	583.1	0.49	286.6	139.8	3.0	38
10:50	4.43	1269.1	614.6	0.48	286.5	138.7	2.4	59
11:50	-	-	-	-	-	-	2.3	64
12:50	5.33	1517.0	788.1	0.52	284.6	147.9	2.0	66
13:50	5.21	1483.7	785.5	0.53	284.8	150.8	2.1	68
14:50	5.58	-	-	-	-	-	2.0	69
15:50	5.50	-	-	-	-	-	2.1	70

Notes: Experiments were conducted at 24-25°C.

N stands for aerosol concentration.

Table 3 - Effect of ion-generators on ^{220}Rn progeny (filaments only).

Time	WL(Tn)	[^{212}Pb] (Bq m^{-3})	[^{212}Bi] (Bq m^{-3})	[^{212}Bi]/[^{212}Pb]	N (10^3 cm^{-3})
8:10	0.73	206.8	119.9	0.58	1.0
8:50	0.80	229.0	115.8	0.51	0.70
9:00		ION-GENERATORS	TURNED OFF		0.75
9:50	0.96	275.6	132.5	0.48	1.40
10:50	1.13	324.9	141.3	0.43	1.50
12:50	1.29	370.0	170.6	0.46	1.30
13:50	1.20	344.5	169.8	0.49	1.55
14:17		ION-GENERATORS	TURNED ON		-
14:50	1.18	339.3	155.4	0.45	1.70
15:50	1.07	-	-	-	1.70

Notes: i) Radon/Thoron Test Facility (RTTF) operating conditions: 25°C and 31% relative humidity.

ii) Bionaire models 2000 and 100 were used.

iii) N stands for aerosol concentration.

Table 4 - Effect of ion-generator on ^{220}Rn progeny (Fans only).

Time	WL(Tn)	$[^{212}Pb]$ (Bq m^{-3})	$[^{212}Bi]$ (Bq m^{-3})	$[^{212}Bi]/[^{212}Pb]$	N (10^3 cm^{-3})
8:05	1.04	300.8	127.6	0.42	-
8:15		FANS TURNED ON			1.45
8:50	0.34	98.4	26.3	0.27	1.30
9:50	0.22	65.9	7.4	0.11	1.55
10:50	0.21	61.8	6.3	0.10	1.55
11:00		FANS TURNED OFF			-
11:50	0.52	152.1	27.7	0.18	1.65
12:50	0.64	185.7	74.4	0.40	1.75
13:50	1.14	329.7	112.5	0.34	1.70

Notes: i) Radon/Thoron Test Facility (RTTF) operating conditions: 24.5°C and 35% relative humidity.

ii) Bionaire models 2000 and 500S were used.

iii) N stands for aerosol concentration.

Table 5 - Effect of ion-generators on ^{220}Rn progeny (Filaments and fans).

Time	WL(Tn)	$[^{212}Pb]$ $(Bq\ m^{-3})$	$[^{212}Bi]$ $(Bq\ m^{-3})$	$\frac{[^{212}Bi]}{[^{212}Pb]}$	N $(10^3\ cm^{-3})$
8:05	9.96	2823.1	1635.4	0.58	-
8:15		ION-GENERATORS TURNED ON			-
8:30	-	-	-	-	1.30
8:50	0.95	251.6	111.0	0.44	0.60
9:50	0.32	96.2	14.8	0.15	0.55
10:50	0.29	88.8	11.1	0.12	0.42
11:50	0.31	92.5	7.4	0.08	0.55
12:00		ION-GENERATORS TURNED OFF			-
12:50	1.86	547.6	129.5	0.24	1.25
13:50	3.74	1087.8	370.0	0.34	1.75
14:50	5.06	1457.8	603.1	0.41	2.09

Notes: i) Radon/Thoron Test Facility (RTTF) operating conditions: 27-29°C, 47% relative humidity.

ii) Four ion-generators were used.

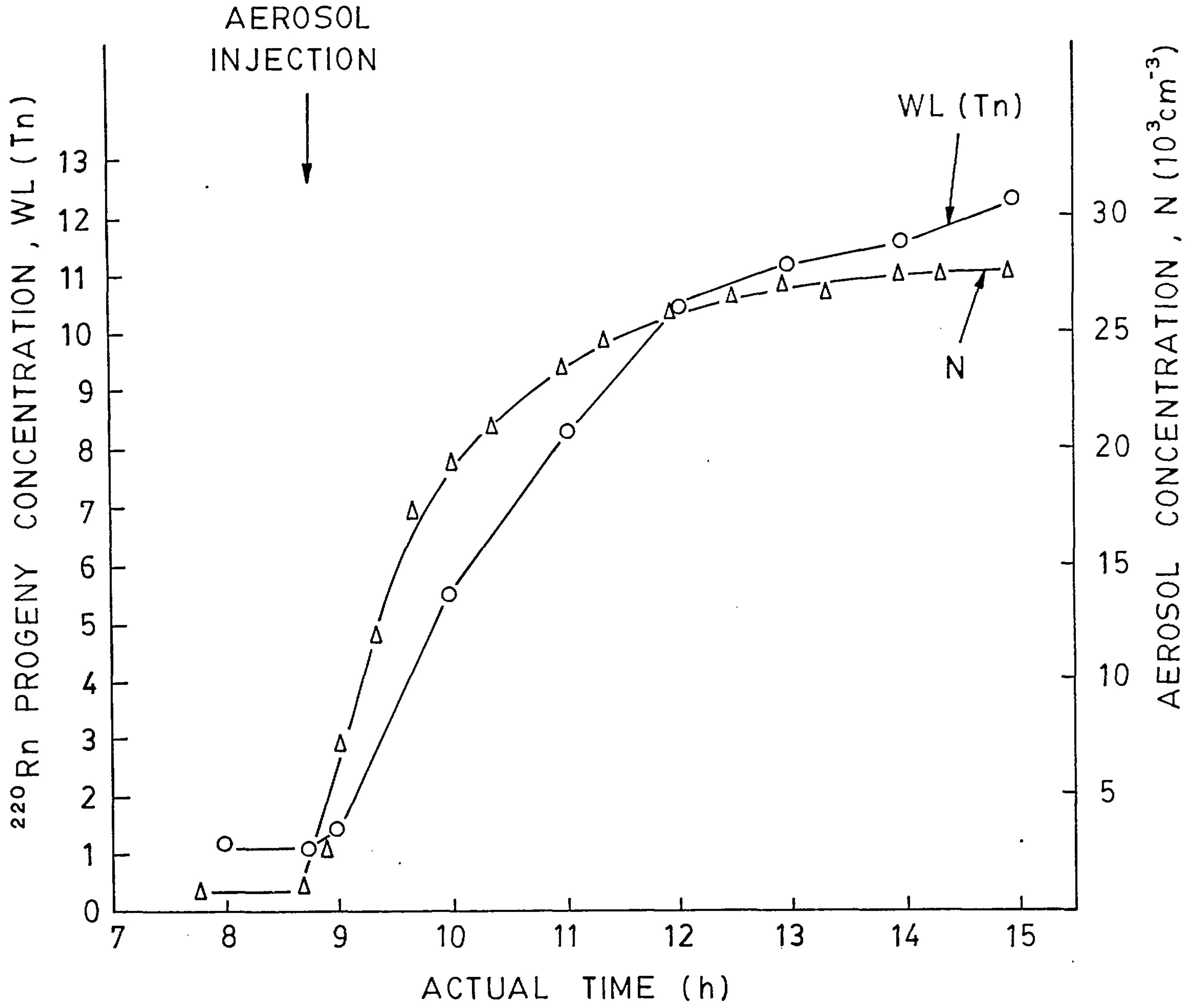
iii) N stands for aerosol concentration.

Table 6 - Effect of electrostatic precipitator (EP) on ^{220}Rn progeny.

Time	WL(Tn)	[^{212}Pb] (Bq m^{-3})	[^{212}Bi] (Bq m^{-3})	$\frac{[^{212}Bi]}{[^{212}Pb]}$	Remarks
8:10	2.94	839.9	432.2	0.51	EP off
8:40	2.97	843.6	460.3	0.54	EP off
9:20	2.96	843.6	428.8	0.51	EP fan on, filament off
9:50	1.83	521.7	262.0	0.50	EP fan and filament on
12:30	2.25	642.7	328.2	0.51	EP fan on, filament off
12:40	2.85	784.4	425.1	0.54	EP off
13:00	3.06	873.2	434.7	0.50	EP off

Note: Precipitator filament voltage: 12,500 V direct current.

LIST OF ILLUSTRATIONS



AEROSOL
INJECTION
WL (Tn)
N
^{220}Rn PROGENY CONCENTRATION, WL (Tn)
AEROSOL CONCENTRATION, N (10^3cm^{-3})
ACTUAL TIME (h)
0
1
2
3
4
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6
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Figure 1