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Intercomparison Of North American Radon Progeny Measurement Methods And Equipment

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BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

CN cm^{-3}	condensation nuclei per cubic centimeter
cpm	count per minute
dpm	disintegration per minute
h	hour
Lm^{-1}	liter per minute
m^3	cubic meter
min	minute
nm	namometer
pct	percent
WL	working level

INTERCOMPARISON OF NORTH AMERICAN RADON PROGENY MEASUREMENT METHODS AND EQUIPMENT

By T. H. Davis[1] and R. F. Holub[2]

ABSTRACT

Twelve laboratories from the Western United States and Canada participated in radon progeny intercomparison measurements at the U.S. Bureau of Mines radon calibration facility in March 1987. The participants intercompared grab-sampling and automated equipment methods at high and low concentrations of radon progeny and condensation nuclei (CN). The objective of this intercomparison was to determine if the measurement procedures and equipment of the North American facilities are equivalent.

The sampling results showed good agreement among all participants. The standard deviation for the working level measurements was less than 3.5% for 1.70 working level (WL) and less than 8.8% for 0.21 WL. This relatively good agreement was achieved by using alpha standards calibrated by National Bureau of Standards (NBS) and by closely checking and monitoring airflows.

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INTRODUCTION

The accurate assessment of the occupational and general public exposure to radon and radon progeny requires instruments and methods that are properly calibrated and compared under controlled conditions. Since calibration standards are not available for the seradio nuclides, intercomparison among laboratories is necessary to verify quality assurance and comparability of the methods and equipment. Recognizing this need, the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD), in cooperation with the Commission of European Communities (CEC), established an International Intercalibration and Intercomparison Program (IIIP) in 1983. The U.S. Bureau of Mines Radiation Hazards Research Facility was designated as a reference laboratory to serve as a center for occupational exposure measurements in North America.

Part I of the IIIP, dealing with radon measurements has been completed.[3] This reference also contains the justification and a brief history of the program. Part II, radon progeny measurements, phase I, and intercalibration and intercomparison of methods and equipment used by the four designated regional reference laboratories, has also been completed and reports are in preparation.This report covers part II, phase II, intercalibration and intercomparison among a larger number of laboratories within North America. Three laboratories from Canada and nine from the United States participated in this exercise (table 1). Other laboratories from North America participated in a similar exercise at the Department of Energy Environmental Measurements Laboratory, New York, NY.

The objective of this intercomparison was to evaluate the present state of the methods and equipment used in North America for the assessment of occupational exposure to radon progeny and to improve the comparability of measurements within North America and other international laboratories.

Although the main purpose of this exercise was to compare grab-sampling methods, also included were one continuous working level monitor (CWLM) and one thermoluminesent dosimeter (TLD). All of the alpha radiation counting standards were checked by the Bureau's gas proportional counter converter.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Jamie Stewart and Wade Cooper, Safety and Health Technology Center, Mine Safety and Health Administration, Department of Labor, Denver, CO, for assisting in the organization, scheduling, and conducting the intercomparison.

EXPOSURE FACILITY AND MEASUREMENT METHODS

The controlled environment sampled was the Bureau of Mines radon chamber of approximately 4 m^3.[4] Test conditions for the intercomparison were specified at an OECD workshop in 1985. Two different radon progeny and CN concentrations were selected to simulate, as closely as possible, various occupational conditions. Radon progeny size distributions and CN were measured during the intercomparison.

Grab sampling was performed by inserting sampling filter holders into the test chamber through sampling ports. The participants sampled simultaneously, with some repetition to obtain an adequate number of samples to ensure valid comparisons. During the grab-sampling exercise, the Bureau operated its automated chamber monitoring systems. Established protocol required the participants to bring their own equipment as if they were going to sample at a field site. Their measuring equipment included pump and flow measuring device, filter holder and filters, alpha radiation detector, and alpha counting standard. Table 2 lists results of determination of alpha standards activity in the Bureau proportional counter converter.

All grab sampling was performed using the modified Tsivoglou, Kusnetz, or Rolle method. The coefficients used in the Tsivoglou method varied slightly from the original ones[5] because the half-life of ^{218}Po used by the participants was 3.11 min instead of 3.05 min. The accuracy of the measurements was calculated based on counting statistics only (one standard deviation).

The CN concentrations were set for typical ventilated occupational sites (high–70,000 CN cm^{-3}; low–18,000 CN cm^{-3}). The particle size distribution of radon progeny at high CN concentrations was a single mode with a peak at 42 nm. At low CN concentrations, the particle size distribution was bimodal with peaks at 4 and 42 nm.

Table 3 is a list of the laboratories along with equipment and method used.

[3]OECD Nuclear Energy Agency. International Intercalibration and Intercomparison of Radon, Thoron and Progeny Measuring Equipment. Part I—Radon Measurement. Paris, France, 1986, pp. 14-15.

[4]Droullard, R. F., T. H. Davis, E. E. Smith, and R. F. Holub. Radiation Hazard Test Facilities at the Denver Research Center. BuMines IC 8965, 1984, 22 pp.

[5]Thomas, J. W. Measurement of Radon Daughters in Air. Health Phys., v. 23, 1972, pp. 779-783.

TABLE 1.—List of Participants

Organization	Abbreviation	Principal investigator
New Mexico Institute of Mining and Technology Socorro, NM, 87801, USA	(NMIMT)	Dr. Stephen Schery Mr. Paul Sisson
Environmental Protection Agency Office of Radiation Programs 4220 S. Maryland Parkway Las Vegas, NV, 89109, USA	(EPA-LV)	Mr. Richard Hopper
United Nuclear Technical Services (DOE Technical Measurements Center) P.O. Box 1569 Grand Junction, CO, 81502, USA	(UNC)	Mr. G. Harold Langner, Jr. Mr. Mark Pearson
Atomic Energy Control Board Uranium Mine Division 151 Ontario Ave. Elliot Lake, Ontario, Canada P5A 2T2	(AECB)	Mr. Jack W. Hore
Atomic Energy Control Board Health Effects and Regulatory Documents Section P.O. Box 1046 Ottawa, Ontario, Canada KIP 559	(AECB)	Dr. Phillip Duport
CANMET Department of Energy, Mines and Resources P.O. Box 100 Elliot Lake, Ontario, Canada P5A 2J6	(CANMET)	Dr. Jaime Bigu
Eberline Instrument Co. P.O. Box 2108 Santa Fe, NM, 87501, USA	(EBE)	Mr. T. Richard Downard
Ludlum Measurements Inc. P.O. Box 517 1219 E. Broadway Sweetwater, TX, 78556, USA	(LUD)	Mr. Paul Fritz
Barringer Geoservices, Inc. 15000 W. 6th Ave., Suite 300 Golden, CO, 80401, USA	(BDM)	Dr. B. E. Sabels
Environmental Protection Agency 160 Lincoln St. Denver, CO, 80295, USA	(EPA-DEN)	Mr. Phil Nyberg
Department of Labor Mine Safety and Health Administration Denver Federal Center Denver, CO, 80225, USA	(MSHA)	Mr. Robert T. Beckman Mr. Wade Cooper Mr. Jamie Stewart
Department of Interior Bureau of Mines Bldg. 20, Denver Federal Center Denver, CO 80225, USA	(BOM)	Dr. Robert F. Holub Mr. Ted H. Davis

TABLE 2.—Alpha source standards

(Sources counted using Nuclear Measurements Corp. Model PCC-IITL Gas Proportional Counter (Background = 2.5 cpm))

Participants[1]	Nuclide	Serial number	Activity, dpm	
			Stated	Measured
AECB	Am^{241}	36A	2,540	2,323
UNC	Am^{241}	G53	85,980	86,527
UNC	Am^{241}	F79	9,168	8,485
UNC	Am^{241}	F17	10,083	10,231
BOM	Am^{241}	NBS-6	12,530	12,387
CANMET ..	Am^{241}	87-103	40,770	41,011
CANMET ..	Am^{241}	87-101	3,170	3,200
CANMET ..	Am^{241}	87-102	570	561
EBE	Th^{230}	S-3239	19,000	17,000
MSHA	Am^{241}	S-413	11,891	11,993
MSHA	Am^{241}	S-412	7,742	7,932
MSHA	Am^{241}	S-411	4,288	4,265
EPA-DEN ..	Am^{241}	LV-6	731	717
EPA-DEN ..	Th^{230}	10377	2,550	2,561
EPA-DEN ..	Th^{230}	10376	19,400	19,172
EPA-LV ...	Am^{241}	4904LF-11	3,801	3,790
LUD	Th^{230}	None	[2]12,185	[3]22,832
NMIMT	Th^{230}	10212	[2]1,040	(4)

[1]See table 1.
[2]Counts per minute.
[3]11,590 cpm.
[4]Source was too large (4-in diam) to count in proportional counter. By using other sources, the efficiency of the detector used by NMIMT agreed with its stated efficiency.

TABLE 3.—Measurement methods, efficiencies, and flow rates

Participants[1]	Method detector	Detector efficiency, %	Flow rate, Lm^{-1}
NMIMT	Modified Tsivoglou scintillation ..	35.0	[2]451
EPA-LV ...	.. do	47.5	6.0
UNC	.. do	49.0	14.0
AECB	Kusnetz scintillation	44.6	4.3
AECB	Rolle scintillation	44.6	3.6
CANMET ..	Modified Tsivoglou scintillation ..	45.7	4.0
EBE	Kusnetz scintillation	NA	3.0
LUD	Modified Tsivoglou scintillation ..	36.9	12.1
MSHA	.. do	49.2	2.7
BDM	.. do	49.1	2.7
EPA-DEN ..	.. do	49.0	6.0

NA Not available.
[1]See table 1.
[2]No samples taken during intercomparison because high flow rate would have disturbed chamber environment.

RESULTS AND DISCUSSION

The measurement results are listed in tables 4 through 7 along with the results of the Eberline WLM-IA[6] CWLM and TLD exposures. The good agreement with the average of the CWLM at low concentrations would indicate the instrument had been calibrated for environmental measurements. At high concentrations the CWLM results were about 10% high. The TLD results were in good agreement at the low concentrations, also indicating they were calibrated for environmental measurements.

The grab-sampling radon daughter and working level (WL) results listed in tables 4 through 7 show very good agreement among all intercomparison participants, both at high and low WL concentrations and CN. The standard deviation at low concentration and CN was about 8% while at high levels it was about 3%.

[6]Reference to specific products does not imply endorsement by the Bureau of Mines.

TABLE 4.—Morning session, March 10, 1987

Participants[1]	Time[2]	RaA	RaB	RaC	WL
UNC	0854	397.7	168.1	83.4	1.600
EPA-LV	0854	406.5	175.7	92.7	1.656
BOM	0854	378.0	170.7	88.3	1.592
LUD	0854	NAp	NAp	NAp	(3)
EBE	0912	NAp	NAp	NAp	1.704
EPA-DEN	0912	418.6	175.2	89.9	1.655
AECB	0912	NAp	NAp	NAp	1.660
MSHA	0912	NAp	NAp	NAp	(4)
CANMET	0925	429.4	167.5	84.9	1.617
AEBC	0946	NAp	NAp	NAp	1.660
EPA-LV	0946	401.2	169.9	87.9	1.608
BOM	0946	361.7	158.1	92.8	1.528
CANMET	1011	398.1	170.4	95.2	1.638
BOM	1012	407.4	175.5	84.1	1.632
EPA-DEN	1012	382.7	159.6	98.9	1.573
UNC	1012	369.1	159.1	89.0	1.529
Mean	NAp	395.5	168.2	89.8	1.618
Std. Dev. .. % ..	NAp	±5.2	±3.9	±5.4	±3.2

NAp Not applicable.
[1]See table 1.
[2]Based on 24-h clock.
[3]No results—filter problem.
[4]No results—counter problem.

TABLE 5.—Afternoon session, March 10, 1987

Participants[1]	Time[2]	RaA	RaB	RaC	WL
MSHA	1221	411.8	173.6	95.6	1.689
CANMET	1247	437.2	180.3	99.9	1.746
BOM	1247	431.5	189.0	82.9	1.722
EPA-DEN	1247	446.2	179.9	97.6	1.737
AECB	1247	NAp	NAp	NAp	1.750
EPA-LV	1319	413.7	174.2	93.3	1.663
LUD	1335	433.4	194.8	93.5	1.813
BOM	1338	395.9	187.5	98.4	1.734
UNC	1348	392.4	169.7	91.0	1.631
MSHA	1348	388.6	160.0	93.0	1.583
BOM	1418	411.5	178.6	87.8	1.666
CANMET	1419	410.2	175.4	99.2	1.691
AECB	1419	NAp	NAp	NAp	1.680
LUD	1440	440.5	194.2	87.6	1.795
MSHA	1441	393.7	168.7	94.0	1.639
CANMET	1459	443.7	175.2	96.0	1.713
BOM	1459	424.2	173.0	90.7	1.662
Mean	NAp	418.3	178.3	93.4	1.701
Std. Dev. .. % ..	NAp	±4.8	±5.4	±5.1	±3.5

NAp Not applicable.
[1]See table 1.
[2]Based on 24-h clock.

NOTE.—Results of Eberling WLM-IA CWLM for March 10 were reported as 1.838 WL.

TABLE 6.—Morning session, March 11, 1987

Participants[1]	Time[2]	RaA	RaB	RaC	WL
UNC	0836	115.9	14.2	5.7	0.216
MSHA	0836	117.5	13.7	4.4	.210
EBE	0836	NAp	NAp	NAp	.205
AECB	0836	NAp	NAp	NAp	.221
EPA-LV	0845	122.0	13.9	5.04	.216
BOM	0845	139.6	19.9	6.09	.273
EPA-DEN	0845	120.3	15.6	7.28	.230
LUD	0845	110.7	15.3	6.45	.219
CANMET	0855	121.1	14.2	4.5	.218
MSHA	0855	128.0	13.5	5.8	.226
AECB	0855	NAp	NAp	NAp	.272
BOM	0930	130.3	14.3	3.2	.221
UNC	0930	108.5	11.2	7.69	.201
AECB	0939	NAp	NAp	NAp	.220
MSHA	0939	127.3	14.7	3.2	.216
CANMET	0939	122.9	12.8	6.5	.218
BOM	0949	132.1	16.6	3.5	.225
MSHA	0958	121.2	14.7	3.7	.217
BOM	1018	116.6	11.9	5.6	.204
AECB	1018	NAp	NAp	NAp	.191
UNC	1028	110.3	12.4	6.3	.203
MSHA	1028	116.8	14.3	3.8	.210
LUD	1028	103.4	12.9	10.0	.212
Mean	NAp	120.3	14.2	5.5	0.219
Std. Dev. .. % ..	NAp	±7.5	±13.6	±32.3	±8.8

NAp Not applicable.
[1]See table 1.
[2]Based on 24-h clock.

TABLE 7.—Afternoon session, March 11, 1987

Participants[1]	Time[2]	RaA	RaB	RaC	WL
CANMET	1247	142.64	15.51	8.16	0.259
BOM	1247	142.8	18.7	5.82	.267
LUD	1247	129.8	14.6	8.7	.244
MSHA	1302	110.9	10.3	11.3	.212
AECB	1302	NAp	NAp	NAp	.263
EPA-LV	1302	126.9	15.3	6.4	.232
EPA-DEN	1302	144.9	14.8	6.3	.248
BOM	1342	133.4	17.7	4.09	.245
CANMET	1342	141.0	15.6	4.84	.245
EBE	1342	NAp	NAp	NAp	.228
MSHA	1357	139.3	18.6	3.1	.253
EPA-DEN	1357	101.7	13.0	10.5	.210
EPA-LV	1420	126.0	14.9	6.4	.231
UNC	1420	133.2	17.6	5.1	.256
MSHA	1420	NAp	NAp	NAp	.206
AECB	1420	NAp	NAp	NAp	.253
UNC	1454	136.7	15.9	5.1	.244
MSHA	1454	130.9	12.5	7.1	.228
Mean	NAp	131.4	15.4	6.6	0.240
Std. Dev. .. % ..	NAp	±9.4	±15.4	±35.3	±7.6

NAp Not applicable.
[1]See table 1.
[2]Based on 24-h clock.

NOTE.—TLD results for March 11 exposure from Barringer Resources were reported as 0.23 WL; results of Eberline WLM-1A CWLM for March 11 were reported as 0.225 WL.

Table 8 shows the results taken in an underground structure (quonset) whose volume is 444 m^3 to accommodate NMIMT 451 Lm^{-1} flow. The agreement is also very good, which justified the expectation that there would be such agreement. The assumption is, of course, that this agreement is not fortuitous.

TABLE 8.—Quonset, March 10-11, 1987

Participants[1]	Time[2]	RaA	RaB	RaC	WL
DOOR OPENED					
NMIMT[3]	1115	0.272 ± 0.055	0.257 ± 0.013	0.224 ± 0.017	2.42 ± 0.05
NMIMT[3]	1158	.441 ± .065	.315 ± .015	.244 ± .02	2.96 ± .06
DOOR CLOSED					
NMIMT[3]	1006	4.49 ± 0.221	3.73 ± 0.053	3.60 ± 0.066	37.0 ± 0.21
EPA-LV	1010	NAp	NAp	NAp	35.1 ± 3.1
UNC	1307	NAp	NAp	NAp	55.7 ± 1.4
NMIMT[3]	1310	6.01 ± .26	5.77 ± .07	5.01 ± .08	54.1 ± .3

NAp Not applicable.
[1]See table 1.
[2]Based on 24-h clock.
[3]Counting error (overall systematic error ±8%, additional).

CONCLUSIONS

The results of this intercomparison for radon progeny measurement indicate the methods, equipment, and personnel taking part are capable of accurately measuring radon progeny in occupational areas. All equipment observed was maintained in a ready condition for field use.

Along with the good intercomparison results, as always, emphasis should be placed on further improvements. This can only be accomplished through continued exchange of information and further intercomparisons. Acquisition by all laboratories, as was previously done by a few, of similar alpha counting standards would aid all concerned.

The continuous working level monitor (CWLM) and the thermoluminiscent dosimeter (TLD), used in the intercomparison, are considered satisfactory for occupational measurements.

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