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^{220}Rn ACTIVITY CONCENTRATION LEVELS IN LARGE U/Th SUBTERRANEAN ENCLOSURES

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ABSTRACT - Concurrent measurements of ^{220}Rn and ^{220}Rn progeny were conducted in an underground uranium mine. The ^{220}Rn measurements represent the first accurate source of data for Canadian mines. Furthermore, a study of the ratio between ^{220}Rn and its progeny under varying airflow conditions was conducted in order to determine its usefulness to derive ^{220}Rn activity concentration levels from experimentally simpler ^{220}Rn progeny measurements. The data obtained suggest that the relationship between these two variables, although approximate, can be used for practical applications when no great accuracy is required.

Key words: Thoron; Thoron progeny; Radioactivity; Uranium mines.

INTRODUCTION

Measurements of ^{220}Rn are of interest from the theoretical and practical standpoints. Knowledge of the ^{220}Rn concentration at a given cross-section of an enclosure of known geometry enables the determination of the ^{220}Rn progeny concentration within the enclosure as a function of time and of space coordinates. These calculations are useful for airborne radioactivity modelling of living and working environments, and for the estimation of occupational exposure of working personnel.

Determination of ^{220}Rn concentrations is, however, time-consuming and difficult, particularly in the presence of other airborne radioactive contaminants, such as ^{222}Rn and its progeny. There are several methods available for the measurement of ^{220}Rn such as the activated carbon (charcoal) method(1), the scintillation cell method, in conjunction with solid-state detectors(2), and the track-etch detector method using selective gas barriers. In any case, however, measurements are not straightforward. By comparison, measurements of ^{220}Rn progeny are relatively simple.

This paper presents data on ^{220}Rn and ^{220}Rn progeny measurements carried out in an underground (UG) U mine. The relationship (ratio) between these two variables was calculated and related to airflow conditions in the mine locations where measurements were made in order to determine whether this ratio was suitable for approximate estimations of ^{220}Rn activity concentration levels from experimental measurement of ^{220}Rn progeny concentrations.

EXPERIMENTAL PROCEDURE

Several UG locations of different ore grades and under varying airflow (ventilation) conditions were selected for the measurement of ^{220}Rn activity concentration levels, i.e., $[^{220}Rn]$, and of ^{220}Rn progeny concentration levels, e.g., Potential Alpha Energy Concentration, PAEC(Tn), and Working Level, WL(Tn). (It should be noted that the relationship between WL(Tn) and

PAEC(Tn) is a simple one, namely, 1 WL(Tn) = 20.8 $\mu J/m^3$, where $\mu J/m^3$ is the unit of the PAEC. The symbol Tn in round brackets stands for ^{220}Rn progeny.)

Measurements were conducted for a period of several days at different sections of each mine location. Radon-220 measurements were carried out using the Two Filter Method (2FT)[3]. Radon-220 progeny measurements were conducted using standard grab-sampling techniques[4,5]. Parallel, i.e., concurrent, measurements of both ^{220}Rn and ^{220}Rn progeny were made at each UG mine section so that these two variables could be related unambiguously at each sampling station. Ventilation conditions, i.e., airflow rate (Q) at each sampling station, were carefully monitored and noted. Although a number of mine locations were investigated, only two main locations are reported here, namely, airway/travelway, and an exhaust airway. As previously indicated, each mine location was subdivided into several mine sections, i.e., sampling stations, in order to obtain a representative average value for each variable measured.

Because, in general, ^{220}Rn progeny measurements are far less complicated and less labour intensive than ^{220}Rn measurements, and because ^{220}Rn progeny measurements are routinely conducted in some Canadian UG U mines, it is of great practical interest to determine whether a simple relationship between these two variables exists that is suitable for practical application. This, as stated above, was the purpose of this investigation where simplicity in determining ^{220}Rn was a major consideration even at the expense of some tolerable lack in accuracy.

EXPERIMENTAL RESULTS AND DISCUSSION

A summary of some of the experimental data obtained is given in Table 1, where the tabulated values of concurrent measurements of ^{220}Rn activity concentration, ^{220}Rn progeny concentration, and ventilation conditions for several UG sampling stations and dates are shown. The data of Table 1 are given in SI units, and also in the more historical units, i.e., Bqm^{-3} and $pCiL^{-1}$ for [^{220}Rn], and μJm^{-3} and WL for ^{220}Rn progeny, respectively.

The data shown in Table 1 are valid under airflow conditions in the range 12 m^3s^{-1} to 66 m^3s^{-1} which are typical for this UG U mine. The average value for the ratios of interest, namely, PAEC(Tn)/[^{220}Rn] and WL(Tn)/[^{220}Rn] are, approximately:

PAEC(Tn)/[^{220}Rn] = (1.184 ± 0.380) x 10^{-3} μJBq^{-1} for SI units, and

WL(Tn)/[^{220}Rn] = (2.057 ± 0.733) x 10^{-3} WL/$pCiL^{-1}$ in 'historical' units.

Figure 1 shows a normalized frequency histogram of ^{220}Rn progeny measurements conducted in a variety of mine locations in the same UG U mine. Most of these locations were areas of lower activity than the areas chosen for the measurements indicated in Table 1. The shape of the histogram shown in Figure 1 is consistent with direct ^{220}Rn data measured elsewhere.

CONCLUSIONS

The ratio of ^{220}Rn progeny concentration to ^{220}Rn concentration given above is of practical interest in U/G U-mines with significant amounts of ^{232}Th in the orebody, and hence, significant contribution of ^{220}Rn and its progeny to mine air, because in enables calculation of [^{220}Rn], which measurement is rather complex and time consuming, from far simpler measurements of WL(Tn) or PAEC(Tn). Radon-220 concentration data can then be used to determine the ^{220}Rn flux density across mine walls as described elsewhere(6). The data so obtained are expected to be sufficiently approximate for engineering purposes and radiation control applications where no great degree of accuracy is required.

Because the ratio PAEC(Tn)/[^{220}Rn] depends on the airflow rate, the ratio can also be used as an index of ventilation conditions in U/G U mines. Furthermore, knowledge of [^{220}Rn] and PAEC(Tn) is important from the health physics standpoint for radiation exposure calculation purposes.

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Table 1 - Thoron and thoron progeny concentration for two underground mine locations and several sampling stations.

Date	Location	[^{220}Rn] pCi/L (Bq/m^3)	WL(Tn) (PAEC(Tn)) (μJ/m^3)	Q (m^3/s)	Remarks
16/11/87	Exhaust airway	194.4 (7193)	0.462 (9.61)	-	
		192.1 (7108)	0.454 (9.44)	-	
		203.6 (7533)	0.482 (10.03)	-	
19/11/87		217.1 (8033)	0.473 (9.84)	-	
		222.4 (8229)	0.490 (10.19)	-	
		202.9 (7507)	0.504 (10.48)	-	
17/12/87		209.4 (7748)	0.458 (9.53)	-	
		236.7 (8758)	0.458 (9.53)	-	
		225.4 (8340)	0.455 (9.46)	-	
04/11/87	Airway/travelway	82.5 (3053)	0.081 (1.68)	37.8	
		67.1 (2483)	0.074 (1.54)	37.8	
		75.1 (2779)	0.091 (1.89)	37.8	
30/12/87		39.1 (1447)	0.101 (2.10)	23.6	
		32.2 (1191)	0.110 (2.29)	23.6	
		28.5 (1055)	0.106 (2.20)	23.6	
07/01/88		43.8 (1621)	0.063 (1.31)	20.3	
		42.0 (1554)	0.065 (1.35)	20.3	
		37.5 (1388)	0.061 (1.27)	20.3	
26/01/88	Exhaust airway	191.8 (7097)	0.439 (9.13)	63.5	A
		251.6 (9309)	0.482 (10.03)	62.7	B
		197.2 (7296)	0.437 (9.09)	64.5	A
		167.0 (6179)	0.459 (9.54)	58.8	B
27/01/88		230.6 (8532)	0.419 (8.72)	62.5	A
		245.2 (9072)	0.456 (9.48)	63.7	B
		217.7 (8055)	0.428 (8.90)	66.4	A
		163.0 (6031)	0.444 (9.23)	60.7	B
28/01/88	Airway/travelway	65.4 (2420)	0.083 (1.73)	17.0	C
		224.0 ?	0.095 (1.97)	16.3	D
		51.8 (1917)	0.074 (1.54)	14.5	C
		59.7 (2209)	0.089 (1.85)	17.1	D
29/01/88		70.4 (2605)	0.089 (1.85)	17.0	C
		45.7 (1691)	0.132 (2.75)	14.8	D
		46.7 (1728)	0.110 (2.29)	12.5	C
		43.0 (1591)	0.152 (3.16)	14.4	D

Note: The letters A, B, C and D refer to sampling stations.

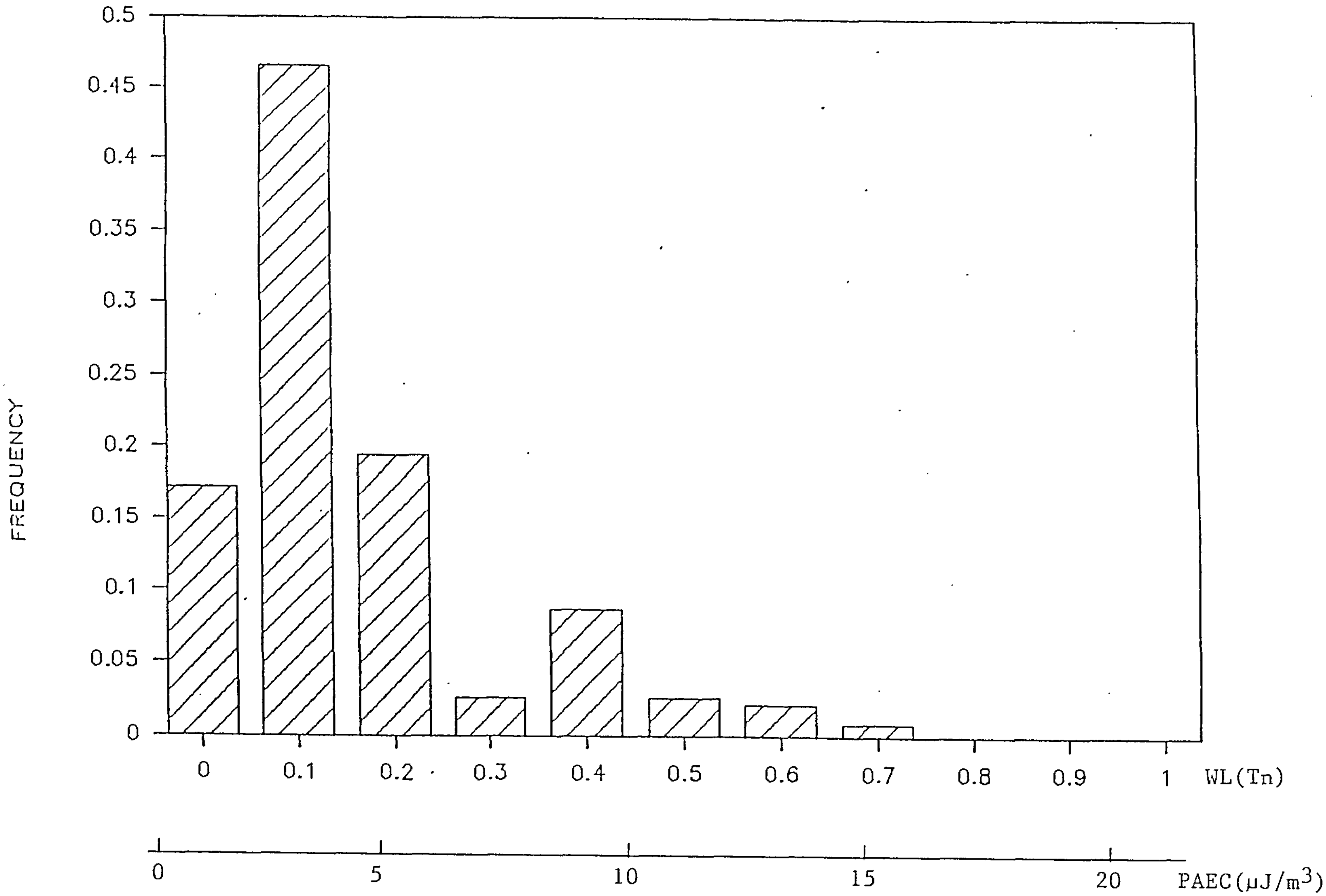

Fig. 1 Normalized frequency histogram of ^{220}Rn progeny.

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INTRODUCTION

Measurements of ^{220}Rn are of interest from the theoretical and practical standpoints. Knowledge of the ^{220}Rn concentration at a given cross section of an enclosure of known geometry enables the determination of the ^{220}Rn progeny concentration within the enclosure as a function of time and of space coordinates. These calculations are useful for airborne radioactivity modelling of living and working environments, and for the estimation of occupational exposure of working personnel.

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Several UG locations of different ore grades and under varying airflow (ventilation) conditions were selected for the measurement of ^{220}Rn activity concentration levels, i.e. [^{220}Rn], and of ^{220}Rn progeny concentration levels, e.g. Potential Alpha Energy Concentration, PAEC(Tn), and Working Level, WL(Tn). (It should be noted that the relationship between WL(Tn) and PAEC(Tn) is a simple one, namely, 1 WL(Tn) = 20.8 $\mu J.m^{-3}$, where $\mu J.m^{-3}$ is the unit of the PAEC. The symbol Tn in round brackets stands for ^{220}Rn progeny.)

Measurements were conducted for a period of several days at different sections of each mine location. ^{220}Rn measurements were carried out using the Two Filter Method (2FT)[3]. ^{220}Rn progeny measurements were conducted using standard grab sampling techniques[4,5]. Parallel, i.e. concurrent, measurements of both ^{220}Rn and ^{220}Rn progeny were made at each UG mine section so that these two variables could be related unambiguously at each sampling station. Ventilation conditions, i.e. airflow rate (Q) at each sampling station, were carefully monitored and noted. Although a number of mine locations were investigated, only two main locations are reported here, namely, an airway/travelway, and an exhaust airway. As previously indicated, each mine location was subdivided into several mine sections, i.e. sampling stations, in order to obtain a representative average value for each variable measured.

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$$PAEC(Tn)/[^{220}Rn] = (1.184 \pm 0.380) \times 10^{-3}\ \mu J.Bq^{-1} \text{ for SI units, and}$$

$$WL(Tn)/[^{220}Rn] = (2.057 \pm 0.733) \times 10^{-3}\ \text{WL per } pCi.l^{-1} \text{ in 'historical' units.}$$

Table 1. Thoron and thoron progeny concentration for two underground mine locations and several sampling stations.

Date	Location	$[^{220}Rn]$ ($pCi.l^{-1}$)	($Bq.m^{-3}$)	WL(Tn)	(PAEC(Tn)) ($\mu J.m^{-3}$)	Q ($m^3.s^{-1}$)	Remarks
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7. 1.1988		43.8	1621	0.063	1.31	20.3	
		42.0	1554	0.065	1.35	20.3	
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Figure 1 shows a normalised frequency histogram of ^{220}Rn progeny measurements conducted in a variety of mine locations in the same UG mine. Most of these locations were areas of lower activity than the areas chosen for the measurements indicated in Table 1. The shape of the histogram shown in Figure 1 is consistent with direct ^{220}Rn data measured elsewhere.

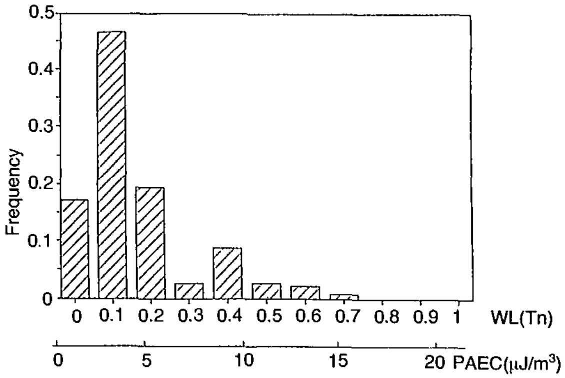

Figure 1. Normalised frequency histogram of ^{220}Rn progeny.

CONCLUSIONS

The ratio of ^{220}Rn progeny concentration to ^{220}Rn concentration given above is of practical interest in UG uranium mines with significant amounts of ^{232}Th in the ore body, and hence a significant contribution of ^{220}Rn and its progeny to mine air, because it enables calculation of [^{220}Rn], whose measurement is rather complex and time consuming, from far simpler measurements of WL(Tn) or PAEC(Tn). ^{220}Rn concentration data can then be used to determine the ^{220}Rn flux density across mine walls as described elsewhere[6]. The data so obtained are expected to be sufficiently approximate for engineering purposes and radiation control applications where no great degree of accuracy is required.

Because the ratio PAEC(Tn)/[^{220}Rn] depends on the airflow rate, this ratio can also be used as an index of ventilation conditions in UG uranium mines. Furthermore, knowledge of [^{220}Rn] and PAEC(Tn) is important from the health physics standpoint for radiation exposure calculation purposes.

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