THE NATURAL RADIOACTIVITY OF NONURANIFEROUS MINES FROM ROMANIA

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ABSTRACT

Between 1970 - 1990 were investigated 267 mining and exploration non-uranium units at 104 (39.0%) being exceeded the maximum permissible radon concentration (MPC) for public (110 Bq/m^3) and at 15 (5.6%) the MPC for occupational exposure (1100 Bq/m^3)[1], so being necessary the recommendation of limiting measures.

Were clarified the causes of appearance and accumulation of radioactive gases, the main source being the natural radioactive elements from rocks and minerals and the cause of accumulation the inefficiency of ventilation.

INTRODUCTION

In 1974 by a governmental programme, initiated by the Department of Mines and Geology, on the basis of measurements previously carried out by our laboratory[2], has been started the investigation of non-uranium mining and exploration units from the point of view of natural radioactivity.

The aim of this programme was to clarify the causes of appearance and accumulation of radioactive gases in the underground atmosphere and to estimate the workers' exposure.

The implied investigation methods have been those presented in Table 1.

TABLE 1. Investigation methods

Nature of samples Radioelement	Method	Sensitivity
Solid		
U natural	Fluorimetry	0.06 g/t
Th natural	Spectrophotometry	0.2 g/t
Ra-226	Scintillation	$0.1\cdot10^{-6}$ g/t
Water		
U natural	Fluorimetry	$0.1\cdot10^{-6}$ g/t
Ra-226	Scintillation	0.004 Bq/L
Rn-222	Scintillation	0.4 Bq/L
Air		
Rn-222	Scintillation	200 Bq/m^3
Rn daughters	Modified Kusnetz	40 Bq/m^3

To clarify the causes of appearance and accumulation were determined the concentrations of natural uranium and thorium and of Ra-226 in rocks, minerals and mine waters and those of Rn-222 in waters. The geological environment, the mining methods and the ventilating conditions were also investigated.

As thoron was found only in two mines, this paper will refere only to Rn-222.

The exposure to radiation was estimated by measuring the gamma dose rates and the concentrations of radon and its daughters.

EXPERIMENTAL RESULTS

Between 1970 and 1990 were investigated 267 underground non-uranium units. Were collected over 6,000 geological samples and were made determinations of gamma dose rate, radon and its daughters at over 7,000 underground sites.

In Table 2 are given some results of natural uranium and thorium content of geological samples analysed by our laboratory[3].

TABLE 2. Uranium and thorium content of rocks (mean values)

Rock type	No. of samples	U g/t	Th g/t	Th:U
Igneous rocks	416	2.2	9.2	4.1
Metamorphic rocks	89	2.2	11.1	5.0
Sedimentary rocks	107	1.5	-	-

From the igneous rocks the highest radioactive element content is presented by the acid ones, from the metamorphic rocks by porphirogenic schists and from sedimentary rocks by clays. The geological samples have an uranium and thorium content comparable to the mean content of upper lithosphere. The mean values for Ra-226 content vary from $1.4 \cdot 10^{-6}$ g/t in acid igneous rocks to under $0.1 \cdot 10^{-6}$ g/t in ultrabasic igneous ones.

The mean uranium and Ra-226 contents of mine waters are shown in Table 3.

TABLE 3. Uranium and radium 226 content of mine waters

Water source	No. of samples	U 10^{-6} g/L	Ra-226 mBq/L
Infiltration waters	102	12.94	32
Drainage channel waters	233	13.10	58

The radon content of mine waters is frequently between 15 and 110 Bq/L and in some cases over 550 Bq/L.

The gamma dose rates varied between 0.02 µSv/h and 7 µSv/h, with mean values of 0.04 µSv/h in salt mines and 0.33 µSv/h in iron mines.

It can be said that the external radiation by gamma rays is not important for the exposure of workers from non-uranium mines.

The most important factor that contribues to the radiation exposure of workers in non-uranium mines is radon and its short-lived daughters. The results of determinations of equilibrum equivalent radon concentrations are given in Table 4[4].

It can be seen from Table 4 that in 104 (39.0%) from the investigated units was exceeded the MPC for public and in 15 (5.6%) ones the MPC for occupational exposure.

The limiting measures concerned first of all the improvement of ventilation, primary and/or secondary, by increasing of air changes/min, distribution of air, maintenance of tubing and continuous operation of fans. The increasing of air changes/min, can be obtained either by increasing of air flow rates or by reducing the volume of underground workings necessary to ventilate. For an underground working or a mine area it was used the following formula[5]:

$$Q=\left(\frac{C}{MPC}\right)^{0.56}\cdot Q_1 \quad (m^3/min) \qquad (1)$$

where

Q - required air flow rate (m^3/min)

Q_1 - provided air flow rate (m^3/min)

C - equilibrum equivalent concentration of radon in that environment (Bq/m^3)

MPC - 110 Bq/m^3 - maximun permissible concentration for public.

For the general ventilation it was used the formula[6]:

$$Q = \frac{D}{MPC} = \frac{Q_1\cdot C}{MPC} \quad (m^3/min) \qquad (2)$$

where Q,Q , C and MPC have the meaning from (1) and D is the radon flow rate (Bq/m^3). As it can be seen, relation (2) is more restrictive than relation(1), the resistance of the whole mine being higher than that of a working or a mine area. Both relations were used with success.

TABLE 4. Equilibrum equivalent concentration of radon vs. useful mineral (mean values)

Mining and exploration units	No. of units	Equilibrum equivalent concentration Bq/m^3		
		≤110	110-1100	>1100
Iron	26	13(50.0%)	10(38.5%)	3(11.5%)
Non-ferous	98	57(58.2%)	34(34.7%)	7(7.1%)
Gold-silver	22	10(45.5%)	12(54.5%)	-
Bauxite	8	1(12.5%)	7(87.5%)	-
Pegmatite	9	5(55.6%)	4(44.4%)	-
Talc, clay, caolin or bentonite	15	10(66.7%)	5(33.3%)	-
Barytine	4	1(25.0%)	1(25.0%)	2(50.0%)
Salt	6	6(100.0%)	-	-
Coal	67	36(53.7%)	28(41.8%)	3(4.5%)
Bituminous shale	6	3(50.0%)	3(50.0%)	-
Total	267	148(55.5%)	104(39.0%)	15(5.6%)

An epidemiological study[7] proved that, in a gold mine having a mean cumulative exposure to radon of over 60 WLM, the frequency of death by respiratory cancer, in the period 1960-1985, was 1.9 times greater for miners than for the public from the same region, supposing the same smokink habitudes.

CONCLUSIONS

Responsible for the appearance of radon 222 in the atmosphere of underground non-uranium mines is the presence of Ra-226 in rocks, minerals and mine waters.

There is no linear relationship between the level of the radon and the natural radioelement content of geological environment, respectively the gamma dose rate, but it strongly depends upon the ventilating conditions.

From the 267 investigated units in 119 (44.6%) ones was necessary the application of limiting measures, concerning first of all the improvement of ventilation.

Responsible for the cumulative exposure of non-uranium workers are radon and its daughters, the contribution of external dose by gamma radiation being insignificant.

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