Radon and equivalent gamma dose rate variations at different types of anthropogenic inhomogeneities in Erzgebirge and its piedmont area (NW Bohemia)

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Introduction

The variations of radon concentrations (Rn, in kBq.m^{-3}) and equivalent gamma dose rate (H´ in μSv.h^{-1}) were measured at profiles situated across the anthropogenic inhomogeneities, which, in the studied areas, are represented mostly by remnants of old and subrecent mining activities.

The investigated areas are situated about 100 km NW from Prague between cities Teplice and Chomutov. This area is known by mining activities starting up at the Celtic and medieval time with continuation of mining activities until the 20th century. The mining in the mountain ridge formations of Erzgebirge (N from Teplice – Cínovec=Zinnwald) was focused mainly on Sn and W ores with polymetals. At present the interest on Li minealization starts to develop. In piedmont areas near Chomutov (SE direction) the anthropogenic inhomogeneities are represented by remediated remnants of backfilled brown coal (Miocene age) small shafts (20-100 m depth) (Fig.1). On the contrary to the forested landscape of Erzgebirge mountains the coal shafts are situated in agriculture land (fields and meadows) and they are detectable by coordinates of old mining works only (map server of Czech Geological Survey, CGS). All of these activities left its traces in the landscape in the form of small pits and small size waste dumps, adits, and sinked shafts, namely in Cínovec area. The radiometric characteristic of the crystalline and granitoid Cínovec area is discussed in Gnojek et al. 2018, further petrological information is given in Romer et al. 2012, or Hoffmann et al. 2013. The overall geological information on the former coal mining area Chomutov are gathered from historical unpublished reports on map server of CGS – old mining works.

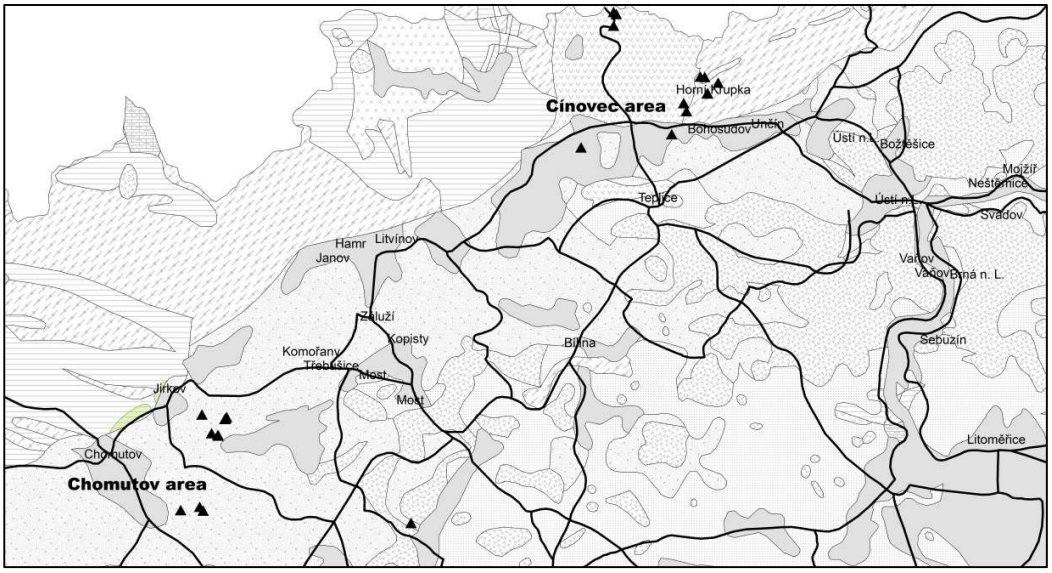

Fig.1 Position of Cínovec and Chomutov areas (NW Bohemia, distance of areas 35 km)

Due to the long history of mining in this region it is difficult to find out the areas which were not (partly at least) influenced by mining activities. On the other hand, the spatial development of settlements starts to reach these areas. Also the touristic outdoor activities often cross these undermined areas, however the securing of old mining works is under a permanent control of the Ministry of Environment. The obligatory measurements of radon index at the building sites do not need to correspond to the statistically prevailing radon index for a specific rock type, but local differences in radon concentrations and equivalent gamma dose rate can be strongly influenced by presence of faults, fragmentation of waste dumps´material and type of mined raw material.

Instrumentation and method

Rn concentration was measured by lost tip method in depth 80 cm using radonmeter RM 2 (producer Dr. Froňka, NUCLEAR TECHNOLOGY, Czech Rep.) and H´ was measured 1 m above soil surface by radiometer Gamma-Scout®. The profiles usually covered both rims of unaffected mother rock and the central part of profile was situated over the old mining work. The profiles with 10 points, 3 m apart, were oriented across the mining remnants.

Sources of data

The position of profiles across the anthropogenic inhomogeneities was derived from the digitized geological maps and old mining works available at the map server of the Czech Geological Survey (CGS) – www.geology.cz. The detailed location of profiles during the field works was specified after the coordinates from topographical maps at a scale 1 : 10 000 (State Administration of Land Surveying and Cadastre www.cuzk.cz) or more detailed Lidar imaging data, which are licensed in CGS for GIS applications from the same source.

Results

In Cínovec area 13 profiles were measured. With the exception of profiles 1 and 13, situated on the remediated coal shafts in piedmont area all of them are situtated in small depressions after the Sn – W mining. Most of the mining traces are situated in the orthogneiss complexes of the main Erzgebirge ridge, the magmatic and volcanic bedrock is represented by the granites, granodiorites and rhyolites. The smaller pits (Pinge in German) have usually diameter in first meters and they are usually filled with the collapsed local material from the walls. The bigger pits were backfilled with fragmented local material from the surrounding waste dumps, as the transport from the remote sources would be financially unefficient.

For each profile the graphs of Rn an H' values were drawn and the variation of them was studied. The rise of measured quantities Rn and H' over the old miming work in its position (center of profile) is marked by 1, the decline is marked by 0 in tabs. 1 (Cínovec) and 2 (Chomutov).

ID	profile	locality	Rn	H’
1	1	Košťany	0	1
2	2	Cínovec 2	1	1
3	3	Cínovec 3	0	1
4	4	Cínovec 4	1	1
5	5	Vrchoslav 1	0	1
6	6	Vrchoslav 2	0	1
7	7	Horní Krupka 1	0	1
8	8	Horní Krupka 2	0	1
9	9	Horní Krupka 3	0	1
10	10	Horní Krupka 4	0	1
11	11	Sedmihůrská cesta 1	0	0
12	12	Sedmihůrská cesta 2	0	1
13	13	Přítkov	0	0
		total rise	**2**	**11**

Tab. 1 Variations of Rn concentrations and equivalent gamma dose rate H’ at profiles of area Cínovec.

The common feature was discovered for profiles in Cínovec area situated in crystalline and magmatic – volcanic rocks. Nearly all profiles are characterised by the decline of Rn concentration in the center of profile and rise of H’ values, which can be explained by presence of unpermeable weathered clayey material in the collapsed pits, preventing the radon release to the surface. Rise of H’ values may be caused both by the presence of clayey material or by the radiation influence of the walls, as the centers of pits are situated often in shallow depressions. The profiles 2 and 4 are situated on the collapsed shafts backfilled by a coarse fragmented boulders (up to 30 cm) of local origin, which can cause the ascent route for Rn from deeper levels. Fig. 2 illustrates the influence of thick concrete cover (points 3 – 6) of the former ventilation shaft Cínovec (profile 4), where the Rn concentration rises only on one side of cover at point 6 (possible inhomogeneities of backfill ?).

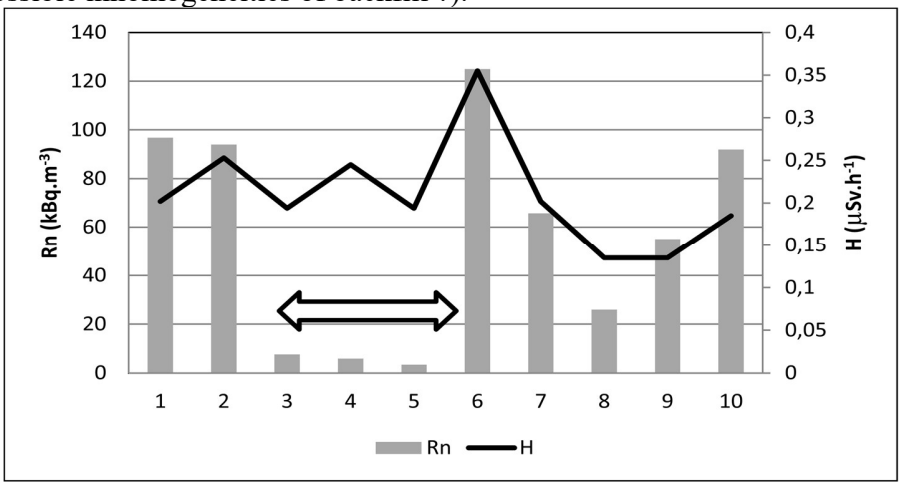

Fig.2 Profile 4 across the Cínovec ventilation shaft covered by concrete desk (points 3 – 6)

The anthropogenic inhomogeneities in the Chomutov area differ from those of Cínovec area. The 12 profiles are situated in Miocene sediments, represented by intercalations of claystones, sandstones and conglomerates. The remnants of old coal shafts are hardly visible on the surface, used as arable land and meadows at present. Nearly half of measured profiles is characterised by Rn and H‘ rise, the rest of them by their decline, but not with the common trend except of 3 – 4 cases.
This can be interpreted as the demonstration of chaotic mixing of backfill material with different lithology and permeability for gases. However the variations in the centers of profiles – aplanated mining pits can be observed on all profiles when compared to the unaffected soil surface and rocks at the rims of profile.

ID	profile	locality	Rn	H’
1	1	Polerady 1	1	1
2	2	Polerady 2	1	1
3	3	Zaječice	0	0
4	4	Vrskmaň 1	0	0
5	5	Vrskmaň 2	0	1
6	6	Vrskmaň 3	0	1
7	7	Vrskmaň 4	1	1
8	8	Vrskmaň 5	1	0
9	9	Vrskmaň 6	0	0
10	10	Údlice 1	1	0
11	11	Údlice 2	0	1
12	12	Údlice 3	0	0
		total rise	**5**	**6**

Tab. 2 Variations of Rn concentrations and equivalent gamma dose rate H’ at profiles of area Chomutov.

Conclusions

- The measurements of Rn and H’ variations on 25 profiles situated in 2 Erzgebirge areas confirmed the detectability of anthropogenic inhomogeneities – here represented by remnants of old mining works in different lithological environments.

- In crystalline and magmatic - volcanic rocks of Cínovec – Teplice area the variations are characterised by prevailing Rn decline and H’ rise at the center of profiles.. It seems that the natural or allochtonous material of their backfill is compacted enough to prevent the Rn release from deeper levels. The Rn release can be observed on the contact of backfilled depressions with parent rocks.

- The mixed sedimentary cover of Miocene area near Chomutov causes the different trend of variations at particular localities and the variations’ data cannot be interpreted as

homogeneously as in Cínovec area. This situation is probably the result of local differences in lithological composition of permeable and unpermeable rocks (sandstones, conglomerates and claystones) of the parent rock and backfill.

- The Rn and H' data from the outer rims of profile correspond to values of data statistically treated in radon database of CGS, which confirms the validity of measurement method.

Acknowledgements

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Map server CGS http://www.geology.cz/extranet/mapy/mapy-online/mapove-aplikace Geovědní mapy 1 : 50 000, Důlní díla a poddolovaná území

State Administration of Land Surveying and Cadastre www.cuzk.cz), data server