SYSTEM OF RADIATION PROTECTION AND SAFETY IN COAL MINING INDUSTRY IN POLAND

Silesian Centre for Environmental Radioactivity

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Radon and radon progeny
the source of direct radiation risk to miners due to inhalation

Formation water with abnormal concentration of radium
the carrier of pollution and the source of sediments with enhanced concentration of radium isotopes
OCCUPATIONAL EXPOSURE

Decree of Ministry of Economy from 23rd November 2016

on work safety and hygiene, exploration technology and fire safety and security equipment in underground mines.

Establishes, for radiation risk caused by natural radioactivity:

- Monitoring methods
- Monitored places
- Monitoring frequency
- QA and QC
- Qualification of personnel involved
Obligatory measurements

Due to regulations, following sources of radiation hazard must be monitored in mines:

➢ The concentration of radium isotopes ($^{226}$Ra and $^{228}$Ra) in brines,
➢ The concentration of $^{226}$Ra, $^{224}$Ra, $^{228}$Ra, and $^{210}$Pb in sediments
➢ Exposure to gamma radiation,
➢ Potential alpha energy concentration of radon decay products.

All measurement methods have been used under control of the QA/QC system and accreditation for radiation measurements since 1992.
## Frequency of area monitoring at workplaces

<table>
<thead>
<tr>
<th>Exposure source</th>
<th>Measured quantity</th>
<th>Criterion</th>
<th>Exposure source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-lived radon daughters</td>
<td>Potential alpha energy concentration, $\mu$J/m$^3$</td>
<td>$C_\alpha \leq 0.5$</td>
<td>once per three months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_\alpha &gt; 0.5$</td>
<td>once per month</td>
</tr>
<tr>
<td>External gamma radiation</td>
<td>Kerma rate free in air, $\mu$Gy/h</td>
<td>$K \leq 0.6$</td>
<td>once a year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$K &gt; 0.6$</td>
<td>once per three month</td>
</tr>
<tr>
<td>Radium waters</td>
<td>$C_{RaW} - ^{226}\text{Ra and } ^{228}\text{Ra concentration}$</td>
<td>-</td>
<td>once a year</td>
</tr>
<tr>
<td>Sediments</td>
<td>$C_{RaO} - ^{226}\text{Ra, } ^{228}\text{Ra and } ^{224}\text{Ra concentration}$</td>
<td>$C_{Ra-226w} + C_{ra-228w} &gt; 1 \text{kBq/m}^3$</td>
<td>once a year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_{Ra-226w} + C_{ra-228w} \leq 1 \text{kBq/m}^3$ and $C_{Ra-226o} + 2C_{Ra-28o} \leq 1 \text{kBq/kg}$</td>
<td>no monitoring</td>
</tr>
</tbody>
</table>
EFFECTIVE DOSE CORRESPONDING TO EXPOSURE TO RADON PROGENY (PAEC)

\[ E_\alpha = 0.0014 \times (C_\alpha + \Delta C_\alpha - C_{\alpha Tlo}) \times t \]

- \( E_\alpha \): effective dose corresponding to PAEC, mSv
- \( C_\alpha, \Delta C_\alpha, C_{\alpha Tlo} \): PAEC, PAEC total uncertainty and PAEC background respectively, \( \mu J \text{ m}^{-3} \)

When \( C_\alpha \leq 0.1 \mu J/m^3 \), it is assumed that \( E_\alpha = 0 \)
ALFA-2000 probe

Cross section A-A

- Top cover
- Divider
- Elastic fixing
- O-ring gasket
- TL detector (γ)
- TL detector (α)
- Protective foil
- Filter
- Air flow direction

ALPHA probe top view

TL detectors: CaSO₄ : Dy detection of alpha particles
Monitoring of potential alpha energy concentration including also dust concentration measurements

Every measuring device has to be approved by the Polish State Mining Authority before use in underground mines therefore the best solution was to apply common dust samplers

Barbara-3A

PCEX8 (SKC)

AP-2000 EX
PAEC GRAB SAMPLING

RGR 40 – working in Markov cycle
EXPOSURE TO EXTERNAL GAMMA RADIATION

\[ E_\gamma = 0.0011 \times (\dot{K} + \Delta \dot{K} - \dot{K}_{Tlo}) \times t \]

- \( E_\gamma \): effective dose derived from exposure to external radiation, mSv
- \( K, \Delta K, K_{Tlo} \): kerma, kerma uncertainty and background, respectively, \( \mu \text{Gy/h} \)
- \( t \): exposure time, h

when \( K \leq 0.1 \, \mu\text{Gy/h} \), it is assumed that \( E_\gamma = 0 \)
Methods of measurements

PAEC and gamma radiation
Thermoluminescence dosimetry

Detection of alpha radiation:
TLD: CaSO$_4$ : Dy or Tm

Detection of gamma radiation:
TLD LiF: Mg, Cu, P (MCPN)
EFFECTIVE COMMITTED DOSE CAUSED BY INADVARENT INTAKE OF WATER AND SEDIMENTS

\[ E_{Ra} = \sum_j e(g)_{j,p} \cdot J_{j,p} + \sum_j e(g)_{j,o} \cdot J_{j,o} \]

- \( e(g)_{j,p} \) and \( e(g)_{j,o} \) – dose conversion factors for intake by ingestion and inhalation, respectively
- \( J_{j,p} \) and \( J_{j,o} \) – intake of radionuclides by ingestion and inhalation, respectively
EFFECTIVE COMMITTED DOSE CAUSED BY INADVORENT INTAKE OF WATER AND SEDIMENTS

Evaluated on base of 5 typical risk scenarios, taking in to account:

- Dust concentration in air,
- Air relative humidity,
- Breath rate,
- Application of respiratory tract protection means (PPE),
- Radium activity concentration in water and sediment.
### Work conditions

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Total dust, mg/m³</td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2. Inhalable dust, mg/m³</td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>3. Humidity, %</td>
<td></td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>4. PPE</td>
<td>Yes/not</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Type of activity**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Roczny czas pracy w godzinach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>rest</td>
</tr>
<tr>
<td>movement in endangered zone</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Sediment transport/loading/uploading</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>dewatering system cleaning (mine sewer system)</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>water galleries cleaning</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>other activities carried out in the endangered zone</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

5. Type of activity and work on yearly base

6. remarks
GRADED APPROACH

\[ E_c = E_\gamma + E_\alpha + E_{Ra} \]

- Nominal working time (1880 h/year) – heavy work (highest breath rate)
- Maximal radium activity concentration in water and sediments
- High dust concentration,
- 100% humidity
- No PPE
- Registered working time – work intensity identification
- Current radium activity concentration in water and sediments (at work places)
- Measured, current dust concentration,
- Measured, current humidity
- PPE applied
Ventgraph
a tool for modeling of radon hazards in underground mine workings

- Model includes losses due to radioactive decay, sedimentation and diffusion
- Model predicts concentration of radon and its progeny in mine workings and gobs
- Good compliance of modelling results and field measurements was observed
- Developed software is a practical tool to control radon risk in underground mines

**Underground work places classification**

**Category A** – underground work places where miners are exposed to effective dose higher than 6 mSv per year

*Corresponding to restricted area in the meaning of Atomic Law*

**Category B** – underground work places where miners are exposed to effective dose higher than 1 mSv per year

*Corresponding to supervised area in the meaning of Atomic Law*
Conclusions

- The system of the monitoring of radiation hazard in Polish mining industry is an unique, complete system, has been implemented in non-uranium industry since 1989. This system permits not only the assessment of miners exposure but provides data necessary for preventive measures, when necessary.

- In spite of the fact that the existing system of regulation, monitoring and risk evaluation in underground mines was developed 30 years ago it meets specific and generic requirements set by recently published IAEA SAFETY STANDARDS SERIES No. GSG-7 OCCUPATIONAL RADIATION PROTECTION (2018) and IAEA SAFETY STANDARDS SERIES No. GSR Part 3 RADIATION PROTECTION AND SAFETY OF RADIATION SOURCES: INTERNATIONAL BASIC SAFETY STANDARDS (2014), respectively
Thanks for your attention