25 YEARS OF RADIOLOGICAL PROTECTION IN POLISH COAL MINES

Silesian Centre for Environmental Radioactivity
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Introduction

The radiation hazard is one of the natural hazards in underground mines, like methane, tremors and other ones.

Main sources of natural radiation in Polish coal mines are short-lived radon progeny, radioactive waters and deposits precipitated out of radium-bearing waters.
The history

- Investigation of that specific problem has been started in hard coal underground mines in Poland in early 1970’s.
- At the end of 1980’s first regulations were issued: the national standard of radiation protection in mining have been prepared, in which dose limits and requirements of the radiation monitoring have been established.
- In following years in some branches of underground mining (mainly in hard coal mining industry) internal regulations for monitoring and mitigation measures were developed on the basis of the Polish Standard.
The history

- At the end of 1980’s there were 70 coal mines in Poland, several lead and zinc ore mines, and copper mines.
- The environmental monitoring of the sources of radiation hazard was proposed:
  - Potential Alpha Energy Concentration (PAEC) of radon decay products
  - Radioactivity of mine waters (radium isotopes)
  - Radioactivity of deposits, precipitated out from radium-bearing waters
  - Gamma radiation exposure, due to emission from deposits with enhanced radium content
The legal system

• The first legal acts, related to radiation protection in mines were issued by Ministry of Mining and Energy in 1989.
• Since that time there were several changes in the radiation protection system, mostly due to implementation of European Union legislation.
• The General Manager (GM) of the underground mine is responsible for the radiation protection in the mine.
• The person, having required qualification and appointed by GM as the Radiation Protection Officer is responsible for radiation protection measures in this mine (surveillance, designation of measurement locations if necessary, limiting of working time and so on).
The legal system

• The most important act, on which the radiation protection system in mines is based that is the Polish Atomic Law – the latest version from August 2019, to include requirements of Euratom/59/2013 EU Directive.

• Another legal act is Geological and Mining Law, focused on different aspects related to these issues, also radioactivity and radiation protection.

• In Decrees of Ministry of Economy and Ministry of Energy there are requirements given how to assess the radiation hazard in mines
Radiation protection system in mining industry

The system of monitoring of radiation hazard in Polish coal mines is a part of the system of monitoring of natural and technical hazards.

It is based on the following assumptions:

• monitoring of radiation exposure should be carried out by existing mine services, preferably together with the monitoring of other hazards.

• a primary goal of the system is a preventive action;
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

However, if the total concentration of $^{226}$Ra and $^{228}$Ra in water is not higher than 1 kBq/m$^3$, and the sum of $^{226}$Ra concentration and doubled $^{228}$Ra concentration in sediments is not higher than 1 kBq/kg, the further monitoring of nuclide concentration in sediments is not obligatory.
## 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, µJ/m³</td>
<td>$C_\alpha \leq 0.5$</td>
<td>once per three months</td>
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<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, µGy/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>$C_{RaW} - ^{226}$Ra and $^{228}$Ra concentration</td>
<td>-</td>
<td>once a year</td>
</tr>
<tr>
<td>Sediments</td>
<td>$C_{RaO} - ^{226}$Ra, $^{228}$Ra and $^{224}$Ra concentration</td>
<td>$C_{Ra-226w} + C_{ra-228w} &gt; 1$ kBq/m³</td>
<td>once a year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_{Ra-226w} + C_{Ra-228w} \leq 1$ kBq/m³  and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_{Ra-226o} + 2C_{Ra-28o} \leq 1$ kBq/kg</td>
<td>no monitoring</td>
</tr>
</tbody>
</table>
Central Mining Institute

Since very beginning the Silesian Centre for Environmental Radioactivity has been involved in creation and implementation of the radiation protection system in Polish mining industry.

Centre collected, within last 25 years, data related to all radiation hazard sources, including PAEC, area and personal monitoring of gamma radiation exposure, radium concentration in brines and deposits from all mines in Poland.

On this basis annual reports are prepared each year for State Mining Authority and Polish National Atomic Energy Agency.
Silesian Centre for Environmental Radioactivity

We have a QA/QC system and accreditation for radiation measurements since 1992.

Specific techniques and methods were developed and implemented in the mining industry.

Most important methods of monitoring are based on thermoluminescent dosimetry (TLD), high resolution and low background gamma spectrometry, and liquid scintillation spectrometry (LSC).
Methods of measurements

Brines: Liquid scintillator counter

Sediments: Gamma spectrometry
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)
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
Monitoring of radium concentration in waters

![Graph showing radium isotopes concentration in water over years](image)
Monitoring of potential alpha energy concentration

![Bar graph showing potential alpha energy concentration from 1993 to 2018. The x-axis represents years (1993 to 2018), and the y-axis represents potential alpha energy concentration in μJ/m³. The graph shows a peak around 1995 and another peak around 2017-2018.](image-url)
Results of monitoring of gamma exposure

Kerma rate free in air, $\mu$Gy/h

Years

Results of monitoring – radium in sediments

<table>
<thead>
<tr>
<th>Years</th>
<th>maxRa-226</th>
<th>maxRa-228</th>
<th>Suma</th>
</tr>
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<tbody>
<tr>
<td>1993</td>
<td>100</td>
<td>80</td>
<td>150</td>
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<td>2017</td>
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<tr>
<td>2018</td>
<td>600</td>
<td>560</td>
<td>1350</td>
</tr>
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The dose estimation

Specific techniques and methods of measurement were developed and implemented by Silesian Centre for Environmental Radioactivity for monitoring of natural radioactivity in the mining industry.

The most important methods of monitoring are based on thermoluminescent dosimetry (TLD), high resolution, low background gamma spectrometry and liquid scintillation spectrometry (LSC).

We have a QA/QC system and accreditation for radiation measurements since 1992.

On the basis of all results the annual dose estimation is done, when needed.
The radiation hazard classes of workplaces

**Underground workings of A class (controlled area):** workers are likely to receive more than $E > 6$ mSv (whole body dose)

- surveillance of the working environment and personal dosimetry for workers, appropriate warning signs, access for external persons only by permission of general manager, medical care by authorized physicians.

**Underground workings of B class (supervised area):** workers are likely to receive more than 1 mSv and equal or less than 6 mSv (whole body dose)

- surveillance of the working environment, assessment of the individual radiation exposure, appropriate warning signs, access of external persons shall be recorded.
Results of the annual dose estimations
Work places divided into radiation hazard classes

Percentage of miners in different risk classes

- Risk class A: 0.18%
- Risk class B: 0.51%
- Potential risk: 7.23%
- No risk: 92.02%

Number of miners in different risk classes in 2018

- Risk class A: 300
- Risk class B: 1,260
- Potential risk: 8,952
- No risk: 74,000
Comparison of number of miners in different risk classes between 1994 and 2018
Conclusions

- Implementation of different methods of the monitoring and prevention has been started in Polish coal mines many years ago. The effect of the implementation of the system was the decrease of the radiation hazard since beginning of 90’s of XX century. Also the level of environmental pollution, caused by mining, became less significant.

- The system of the monitoring of radiation hazard in Polish mining industry was a unique, complete system, implemented in non-uranium industry (1989). This system permits not only the assessment of miners exposure but provides data necessary for preventive measures, when necessary.
Conclusions

- It can be seen, that despite the significant decrease of the number of miners in last decades, there was no congruent changes of radiation hazard level. The hazard, related to PAEC was diminished due to improvement of ventilation systems, while inflows of radium-bearing waters and precipitation of radium-rich sediments was leading to the increase of gamma radiation doses.

- Important part of the system is the training of miners, managers, the staff of different services (ventilation specialists, hydrogeologists, geologists etc.). The training makes the co-operation easier and useful for all partners (i.e. mine services and units, providing radiation monitoring).

- The key issue is the reliability of results of the monitoring. Therefore in any laboratory, dealing with monitoring of radiation hazard, the quality assurance system should be implemented.
Many thanks for your attention