Główny Instytut Górnictwa

System of radiation protection and safety in coal mining industry in Poland

Silesian Centre for Environmental Radioactivity

Bogusław Michalik, Małgorzata Wysocka, Skubacz & Stanisław Chałupnik
bmichalik@gig.eu

NORM IX - The 9th International Symposium on NORM,
September 22 – 27, 2019
Denver, Colorado

SOURCES AND PATHWAYS OF EXPOSURE TO NATURAL RADIATION IN A COAL MINE

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 23th 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 radioactivty:

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

GIG

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 mesurement methods have been used under control of the QA/QC system and accreditation for radiation measurements since 1992.

GIG

Frequency of area monitoring at workplaces

Exposure source	Measured quantity	Criterion	Exposure source
Short-lived radon daughters	Potential alpha energy concentration, $\mu J/m^3$	$C_\alpha \leq 0.5$	once per three months
		$C_\alpha > 0.5$	once per month
External gamma radiation	Kerma rate free in air, $\mu Gy/h$	$K \leq 0.6$	once a year
		$K > 0.6$	once per three month
Radium waters	C_{RaW} – ^{226}Ra and ^{228}Ra concentration	-	once a year
Sediments	C_{RaO} – ^{226}Ra, ^{228}Ra and ^{224}Ra concentration	$C_{Ra\text{-}226w} + C_{ra\text{-}228w} > 1\ kBq/m^3$	once a year
		$C_{Ra\text{-}226w} + C_{Ra\text{-}228w} \leq 1\ kBq/m^3$ and $C_{Ra\text{-}226o} + 2C_{Ra\text{-}28o} \leq 1 kBq/kg$	no monitoring

GIG

EFFECTIVE DOSE CORRESPONDING TO EXPOSURE TO RADON PROGENY (PAEC)

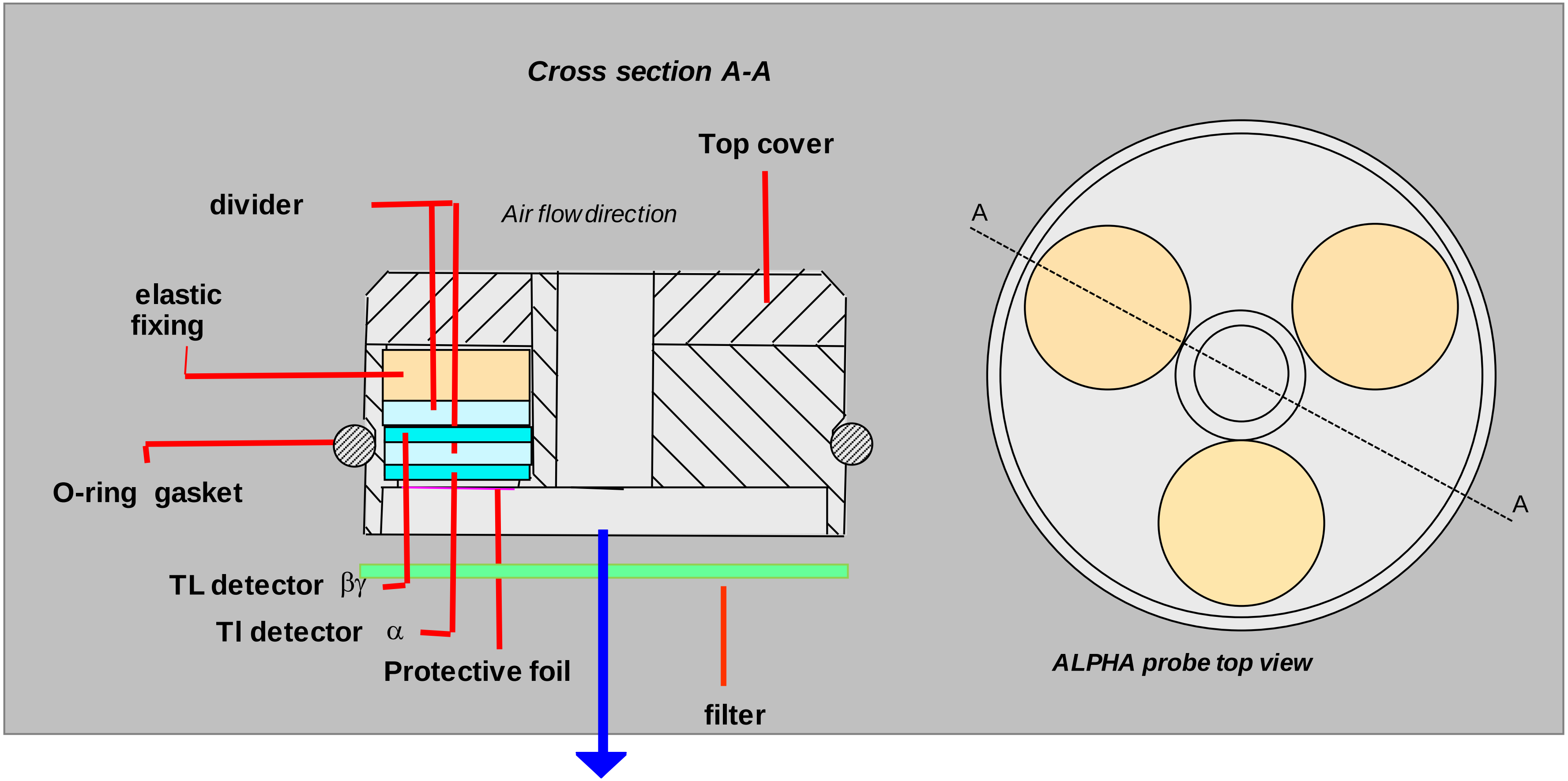
$$E_\alpha = 0{,}0014 \times (\mathrm{C}_\alpha + \Delta C_\alpha - \mathrm{C}_{\alpha \mathrm{Tlo}}) \times t$$

E_α	effective dose corresponding to PAEC, mSv
C_α, ΔC_α, $C_{\alpha Tlo}$	PAEC, PAEC total uncertainty and PAEC background respectively, $\mu J\ m^{-3}$

when $C_\alpha \leq 0{,}1\ \mu J/m^3$, it is assumed that $E_\alpha = 0$

GIG

ALFA-2000 probe



TL detectors: $CaSO_4$: 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

$$E_\gamma = 0{,}0011 \times (\dot{\mathrm{K}} + \Delta\dot{\mathrm{K}} - \dot{\mathrm{K}}_{\mathrm{Tlo}}) \times t$$

E_γ	effective dose derived from exposure to external radiation, mSv
K, ΔK, K_{Tlo}	kerma, kerma uncertainty and background, respectively, μGy/h
t	exposure time, h

when K≤ 0.1 μGy/h, it is assumed that E_γ=0

GIG

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)

GIG

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

$J_{j,p}$ i ***$J_{j,o}$*** – intake of radionuclides by ingestion and inhalation, respectively

GIG

EFFECTIVE COMMITTED DOSE CAUSED BY INADVARENT 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 .

Input data for intake and derived committed dose calculation (E_{Ra})

Work conditions						
1. Total dust, mg/m^3	20					
2. Inhalable dust , mg/m^3	30					
3. Humidity, %	92					
4. PPE	Yes/not					
5. Type of activity and work on yearly base	Type of activity	Roczny czas pracy w godzinach				
		rest	Walk/light work	Heavy work	Razem	
	• movement in endagered zone	100	50	1200	1350	
	• Sediment transport/ loading /uploading				200	
	• dewatering system cleaning (mine sewer system)				-	
	• water galleries cleaning				-	
	• other activities carried out i the endagered zone)				100	
6. remarks						

GIG

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

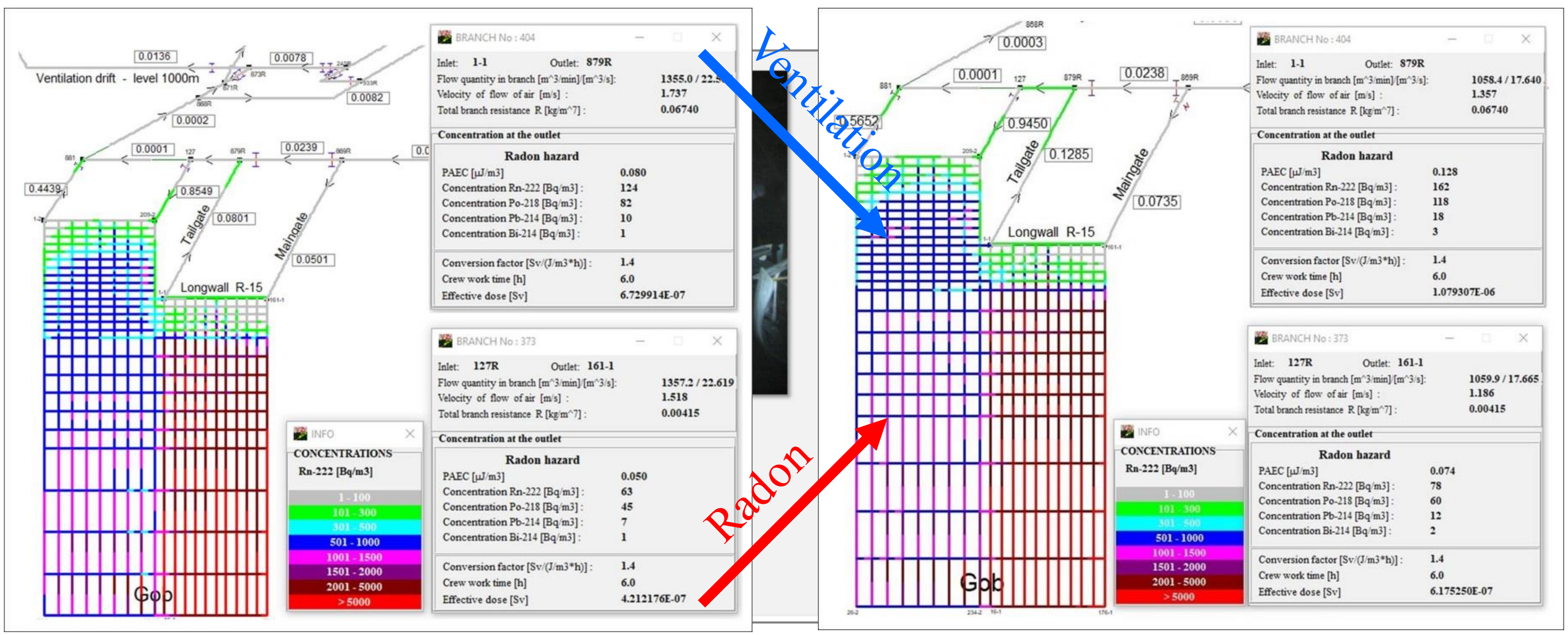
- Registered working time – work intensity identification
- Current radium activity concentration in water and sediments (at work places)
- Measured, current dust concentration,
- Measured, current humidity
- PPE applied

GIG

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



Skubacz, K., Wysocka, M., Michalik, B., Dziurzyński, W., Krach, A., Krawczyk, J., Pałka, T. 2019. Modeling of radon hazards in underground mine workings, *Science of the Total Environment*. 695, DOI: 10.1016/j.scitotenv.2019.133853

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***

GIG

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

GIG

Thanks for your attention

GIG