Various Radioactive Exposure Pathways Determination for TiO_2 Production - Case Study

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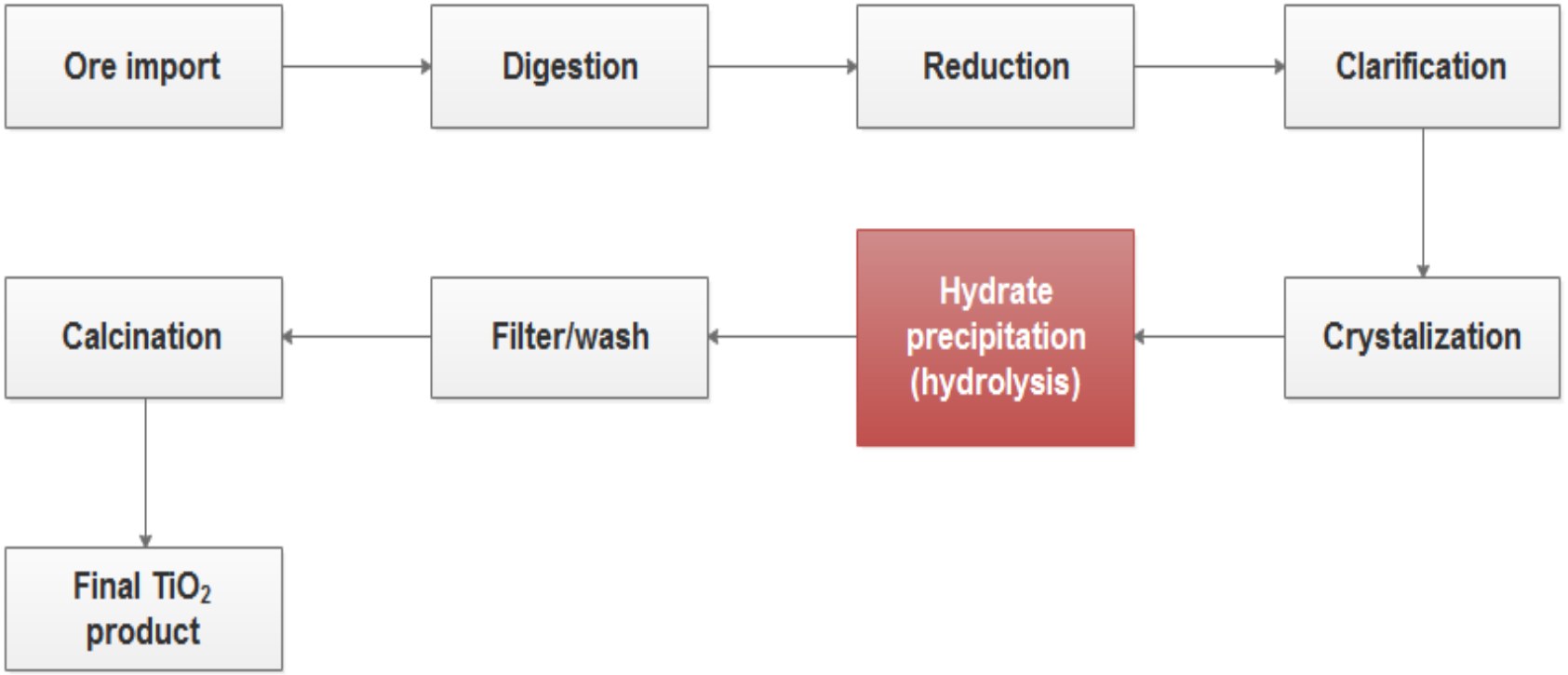
Production of TiO_2 by the Sulphate Process



Hydrolysis process

Radionuclides concentration in the inner scales in the hydrolysis vessels in the normal condition:

- ^{226}Ra 64 kBq/kg
- ^{228}Th 40 kBq/kg
- ^{222}Rn concentration - maximum 5400 Bq/m^3
- ^{220}Rn concentration - median 12 000 Bq/m^3
- external exposure - 10 – 60 µSv/h

Description:

- Modernization of the TiO_2 production process.
- Removing of three hydrate precipitation vessels.
- All work couldn't last more than two months.
- The demolition work had to have a minimal impact on the rest of the factory.
- No dispersion of the radioactive dust to the other parts of the factory hall.

Dismantling of vessel

Protection of the environment

Removal of hydrolysis vessels

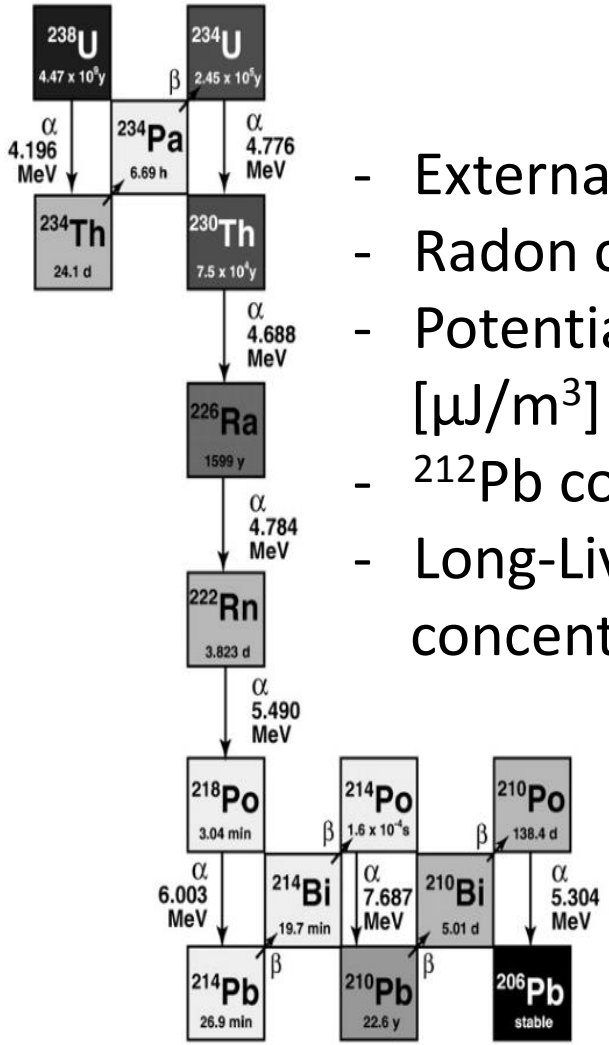
Main exposure pathways

- Exposure to gamma radiation
- Inhalation of radionuclides in dust

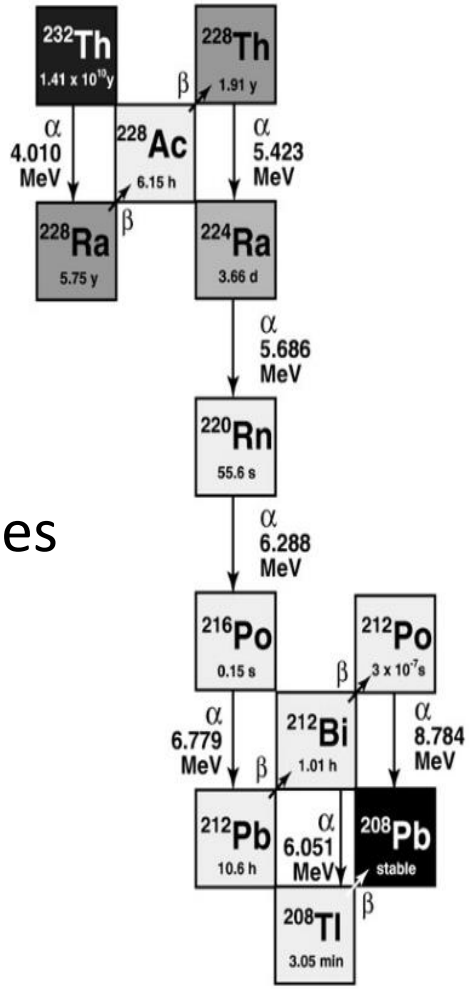
Ensuring of radiation protection during the removal of hydrolysis vessels

- Workplace monitoring
- Personal monitoring
- Discharge monitoring
- Environmental monitoring

Main monitored radiation protection variables



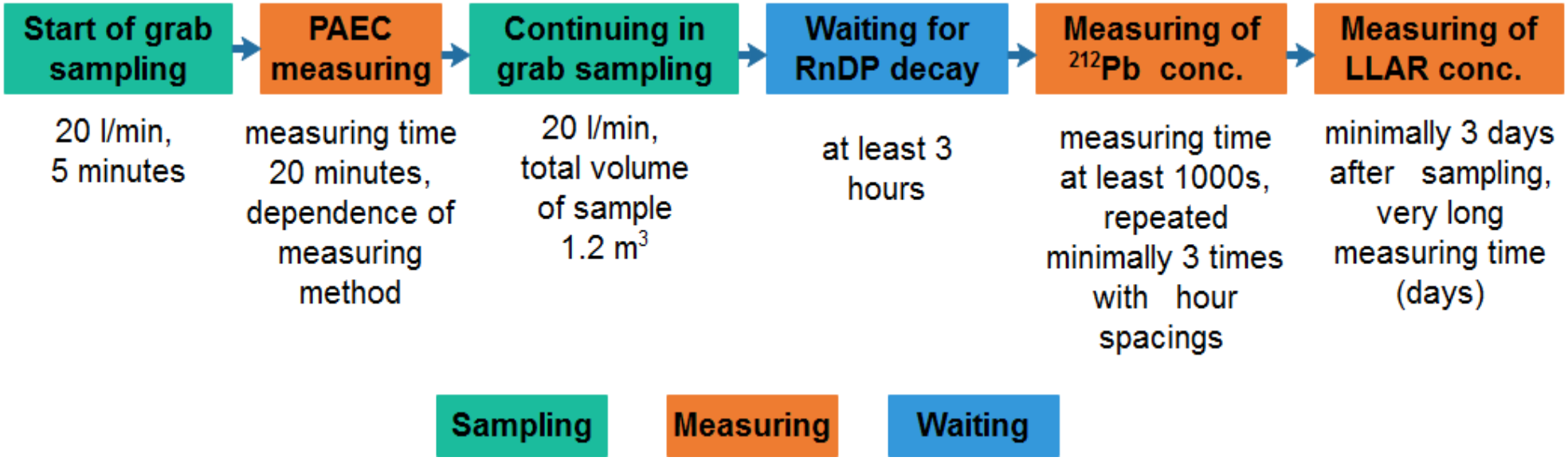
- External dose rate [µGy/h]
- Radon concentration [Bq/m^3]
- Potential Alpha Energy Concentration [µJ/m^3]
- ^{212}Pb concentration [Bq/m^3]
- Long-Lived Alpha-emitting Radionuclides concentration [Bq/m^3]



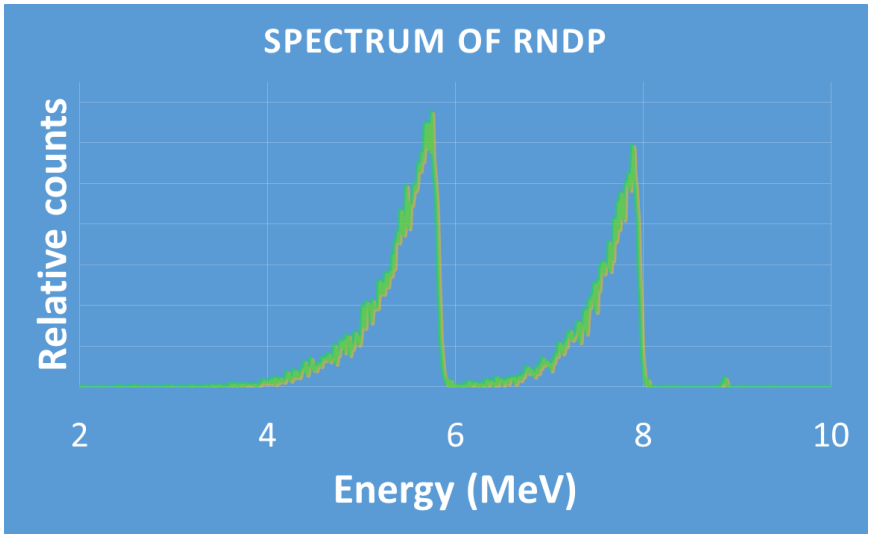
Workplace monitoring

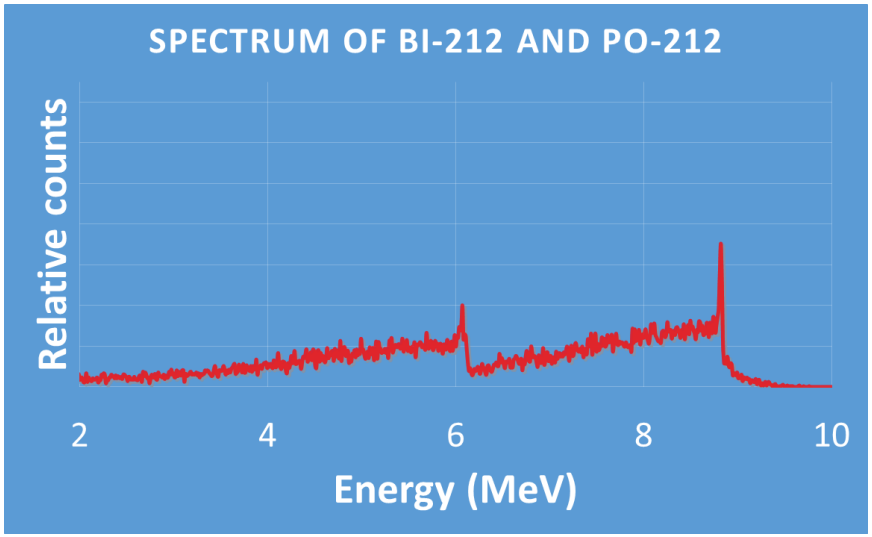
The workplace monitoring consisted of continuous monitoring of radon concentration, grab sampling for radon (^{222}Rn) and its decay products measurements, grab sampling of the dust containing Long-Lived Alpha emitting Radionuclides (LLAR) of uranium and thorium series and spot measuring of the external dose rate.

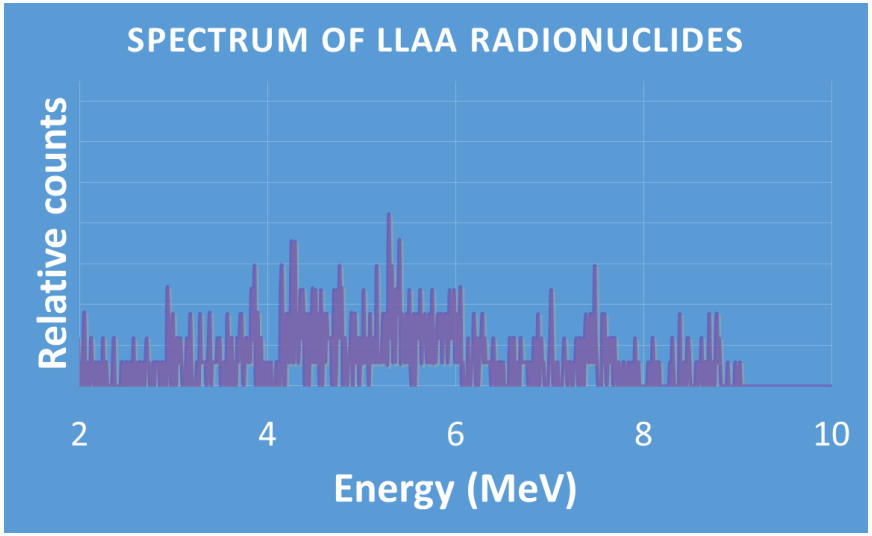
Determination of the radioactive aerosol particles concentration



Alpha spectrum of radioactive aerosol particles

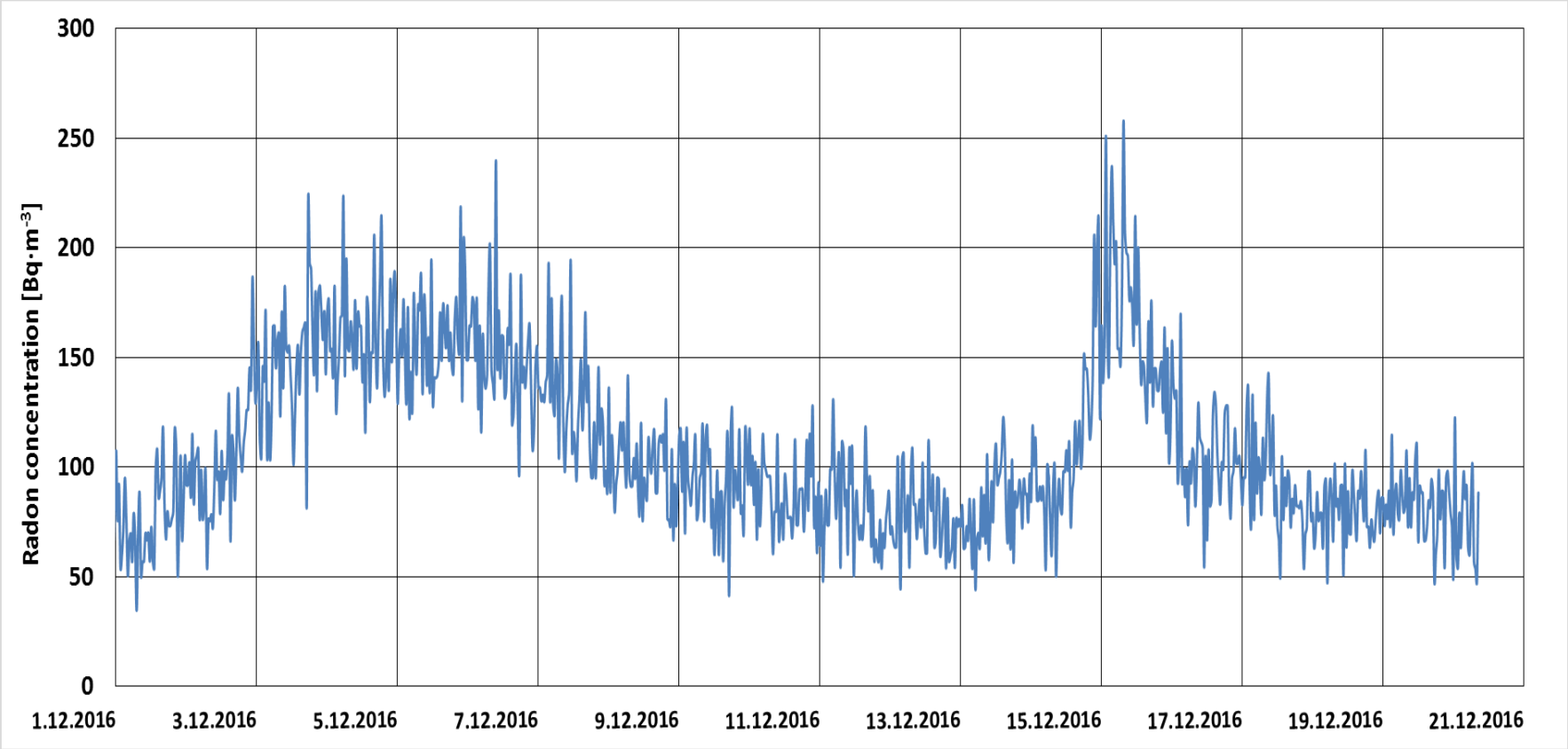






Results of the workplace monitoring

Continuously monitoring of radon concentration



Results of the workplace monitoring

Quantity	Unit	Minimum	Maximum
Dose rate of external radiation	µGy/h	< 0.1	21*
Radon concentration determined by continuous monitoring	Bq/m^3	40	260
Radon concentration determined by grab sampling	Bq/m^3	< 100	2470*
Potential Alpha Energy Concentration	$\mu J/m^3$	< 0.1	2*
^{212}Pb concentration	Bq/m^3	< 1	330*
Long-lived alpha emitting radionuclides concentration	Bq/m^3	< 0.01	0.4*

*The maximum results correspond to measuring inside in the vessels.

Total effective dose determined using the maximal results of workplace monitoring

$$E[mSv] = E_{ext} + E_{int,Rn} + E_{int,LLAA} + E_{int,Pb\text{-}212}$$

E_{ext} - *effective dose belonging to external radiation*

$E_{int,Rn}$ - *effective dose estimated from exposure to RnDP*

$E_{int,LLAA}$ - *effective dose estimated from inhalation of with Long-Lived Alpha Active radionuclides (LLAA)*

$E_{int,Pb\text{-}212}$ - *effective dose estimated from inhalation of* ^{212}Pb

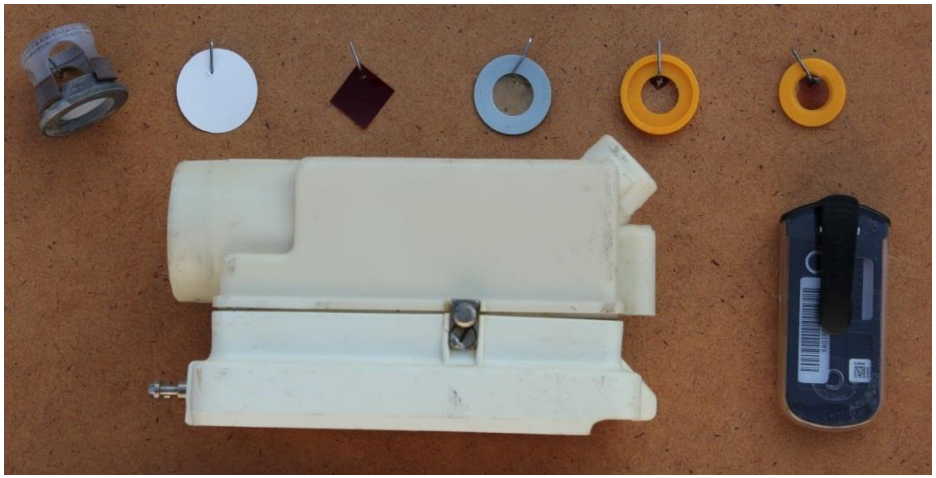
The total effective dose of imaginary worker determined by using of maximal results from workplace monitoring would be **0.32 mSv/work shift** (8 hours).

Personal monitoring

- All workers were equipped by personal dosimeters OD88a and by OSL dosimeters. The OSL dosimeter was worn during all working time. OD88a wasn't worn during the time when the workers were working in the ventilation insulating protective clothing.

- **OD88a** - personal dosimeter for evaluation of exposure from inhalation of Rn-222 daughter products and inhalation of long-lived alpha emitting radionuclides. OD88a was worn together with respirator (conservative approach).

- **OSL** – optically stimulated dosimeter for evaluation of gamma radiation exposure.



Results of personal monitoring

E_{ext}	$E_{int,Rn}$	$E_{int,LLAR}$	*E[mSv]*
0.10	0.10	0.16	0.36

The maximally effective dose of one real worker per two months exposure period determined by OD88a and OSL dosimeter. This total effective dose is a conservative estimation due to a fact that during the whole working time was the workers equipped with filtration gas mask.

Conclusion

- 0.32 mSv per work shift (maximal results of workplace monitoring),

- in the case that the maximal values would be during the whole process stable, the total effective dose would be almost 13 mSv per two months.

But the results of personal monitoring show lower realistic value:

- 0.36 mSv per two months (contribution of thoron daughters was not included, false contribution of part dose caused by inhalation at respirator use was added).

- Experience demonstrate the importance of workplace monitoring (mainly in the beginning of work activity) for determination of suitable level of personal protection equipment (the ventilation insulating protective clothing).