

Estimation of annual doses of outside workers from maintenance of multiple facilities

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Take home messages

- Implementation of Directive 2013/59/Euratom in national law requires a system for individual radiological monitoring of outside workers equivalent to that for exposed workers employed on a permanent basis. This is a challenge for regulators and the undertakings.
- Many 'dirty' practices in NORM industries are maintenance activities and executed by outside workers.
- For single commitments doses are usually $\ll 1$ mSv.
- Monitoring of doses for outside workers requires registration on daily or weekly basis.
- Outside workers are active in different countries with diverging positive lists for NORM practices.
- Harmonization within European organizations would be useful.

- Extraction of rare earths from monazite
- Production of thorium compounds and manufacture of thorium-containing products
- Processing of niobium/tantalum ore
- Oil and gas production
- Geothermal energy production
- TiO_2 pigment production
- Thermal phosphorus production
- Zircon and zirconium industry
- Production of phosphate fertilisers
- Cement production, maintenance of clinker ovens
- Coal-fired power plants, maintenance of boilers
- Phosphoric acid production
- Primary iron production
- Tin/lead/copper smelting
- Ground water filtration facilities
- Mining of ores other than uranium ore

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According to our experience
operated mainly with
outside workers

NORM practices with outside workers

- Cleaning, maintenance and repair of NORM scales:
 - Oil and gas production facilities
 - Geothermal power stations
- Maintenance and repair of refractories:
 - Clinker ovens in cement industry
 - Coal-fired power plants
 - Glass kilns (not on the list of BSS)
 - Iron melting furnace (not on the list of BSS)
- Cleaning, maintenance and removal of residues:
 - Water treatment/filtration facilities

... to be completed...



- Dose from external exposure:
 - Working activities in vicinity of materials with enhanced radioactivity emitting γ -radiation.

- Dose from inhalation of dust:
 - Inspection and service works with access to dust particles containing materials with enhanced radioactivity.
 - Maintenance and repair measures where dust with enhanced radioactivity is set free.

- Dose from inhalation of Radon:
 - Working activities in badly aerated rooms where Radon can reach higher concentrations.

External exposure

External exposure E_A of person „j“ by γ -radiation

measured ADR $H^*(10)$
and registered exposure time t_{Exp}
of person „j“ at workplace „s“

$$E_{A,j} = f \cdot \sum_s \dot{H}^*(10)_s t_{Exp,j,s}$$

f – Conversion factor (0.6, 0.7, 1)
depending on the geometry



Internal exposure from dust inhalation

Internal exposure by inhalation of dust
 E^{inh}

Measuring activity concentration c
(nuclide specific or total alpha activity)
registration of working time T_j of
person „j“

$$E_j^{inh} = 1.2 \cdot e \cdot c \cdot T_j$$

1.2 m³/h – respiration rate

e – dose coefficient (Sv/Bq) referred
to a nuclide vector



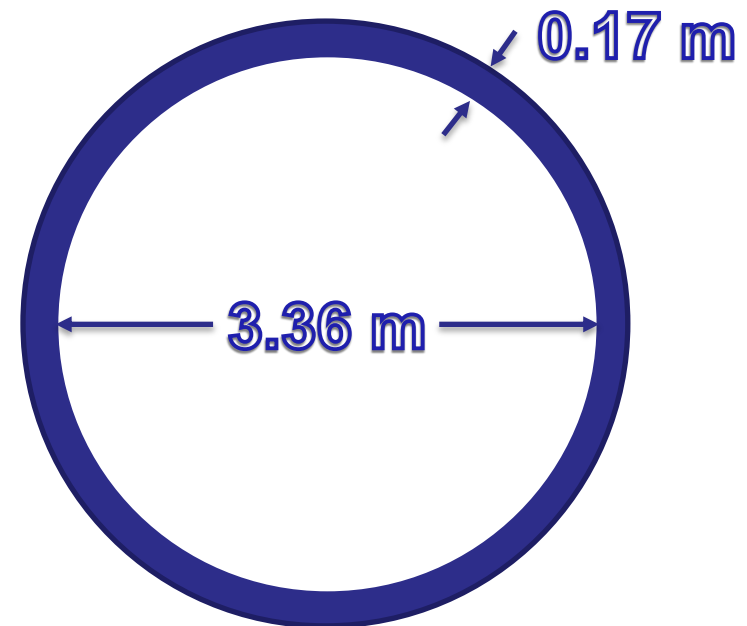
Dust sampling device

Example: Rotary kiln repair, cement production



Dimensions of rotary kiln

- Length: 56 m, Ø 3.36 m (inner), 0.17 m refractory lining
- Renewal of 26.8 m
- Repaired surface of refractory lining: 283 m²
- Volume of refractories renewed: 50.5 m³



Workplaces rotary kiln, basic characterisation

	Dimensions	Period [h]	Mean ADR [μSv/h]	Range Dust conc. [mg/m ³]
Removal of depositions	600 m ²	48 [*]	0.25	1.36-98.79 [#]
Refractory demolition	50 m ³	80 [*]	0.25	1.36-98.79 [#]
Transport of debris	50 m ³	10 [*]	0.25	1.36-98.79 [#]
Refractory construction	26.8 m	187 [*]	0.20	11.3-19.3 [#]
Refractory sawing	900 cuts [*]	45 [*]	0.07	0.42-21.1 [#]

^{*}) Estimates on basis of information given by staff members and own surveys.

[#]) Range of dust concentrations from TRGS 559 (technical guideline for occupational safety)
some approved with own measurements or adjusted to situations on site.

Further workplaces at other parts of the cement clinker production facility:

- Cyclone unit, preheater
- Calcliner

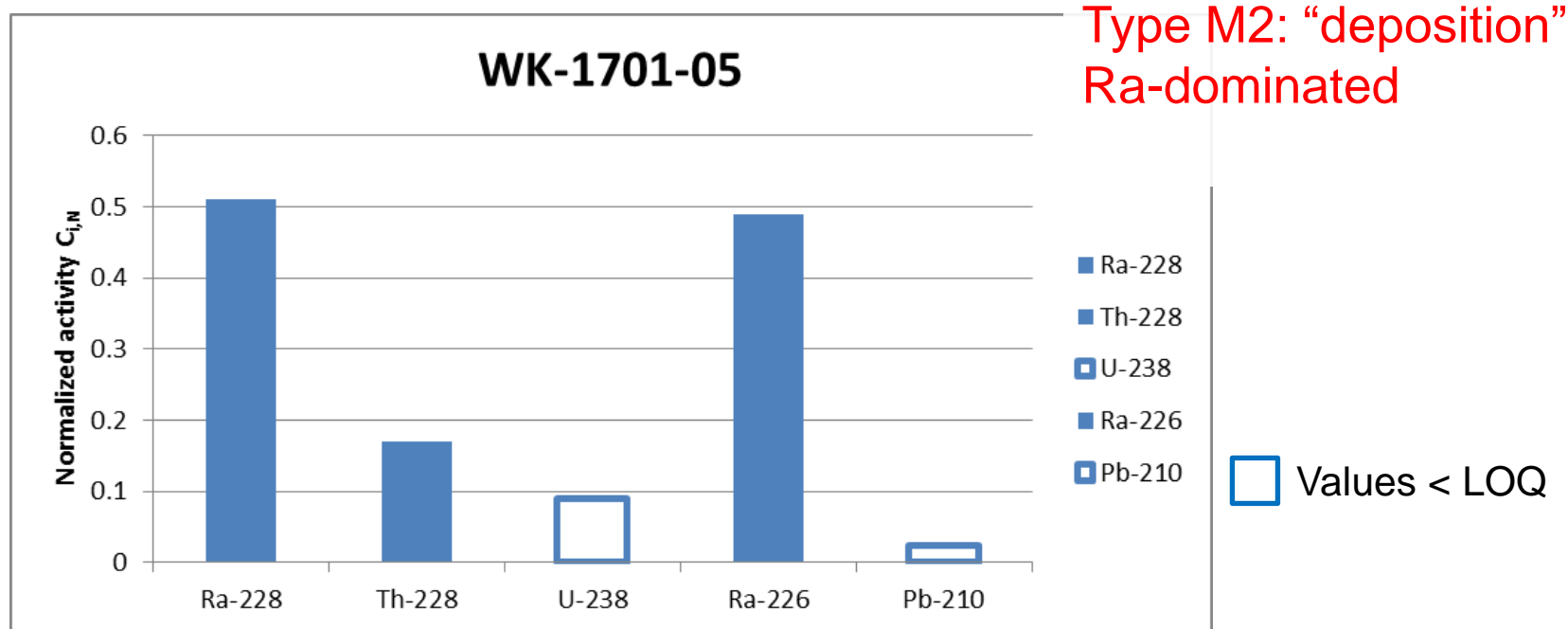
Refractory demolition work



Internal exposure is dominating, high dust concentrations ($3\text{-}25 \text{ mg/m}^3$)

Dust sampling and analysis

- Air volume total 31.1 m³, Sampling period 01:53 h
- Mean dust conc. 9.0 mg/m³, range dust conc.: 3 – 25 mg/m³



Ra-228	Th-228	U-238	Ra-226	Pb-210
5,08 ± 5%	1,68 ± 4%	< 0,89	4,86 ± 15,3%	< 0,23
0,51	0,17	0,09	0,49	0,02

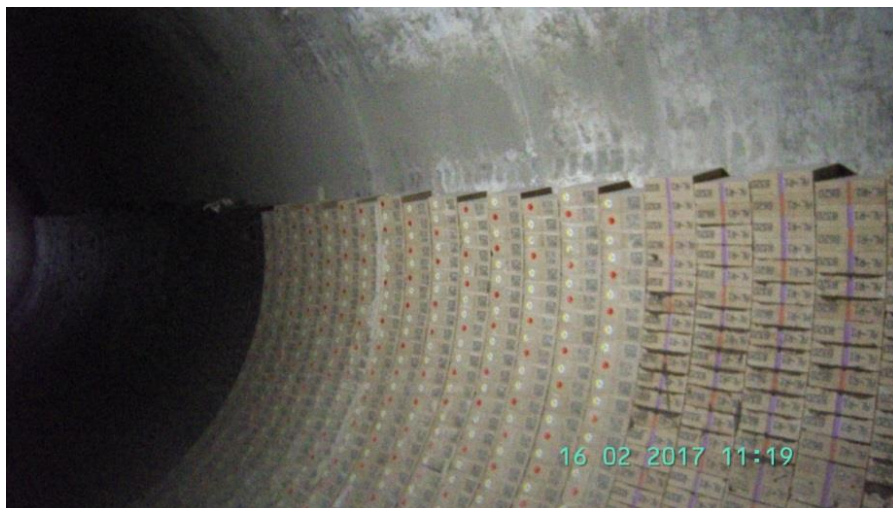
Dose estimate ,refractory demolition work‘

- Respiration rate: 1.2 m³/h
- Exposure time: 80 h
- Mean dust conc.: 9.0 mg/m³
- Dose coefficient: 1.28E-05 Sv/Bq
- $C_{U-238,max} + C_{Th-232,max}$: 9.94 Bq/g
- External exposure: 0.25 μSv/h



- $E_A = 20 \mu\text{Sv}$ distributed on 3 employees ~ 7 μSv each
- $E_{inh} = 110 \mu\text{Sv}$ distributed on 3 employees ~ 40 μSv each
- $E_A + E_{inh} \sim 0.047 \text{ mSv}$
- Radon < 33 Bq/m³

Refractory construction



Closer look to external exposure. Assumption of higher dust exposition.

Ambient dose rates of refractories

Results obtained from measuring stock-piles (case study):

Refractories	ADR [$\mu\text{Sv/h}$]
‚Kronex 85s‘	0,55
‚Forma 88p‘	0,126
‚Resistal B75Z‘	0,44
‚Ankral ZE‘	0,085
‚Almag 85p‘	0,076
‚Ankral R1‘	0,074
‚Resistal B75Z‘	0,48
‚Almag A1‘	0,076
‚Resistal B50Z‘	0,281

Ambient dose rates of refractories

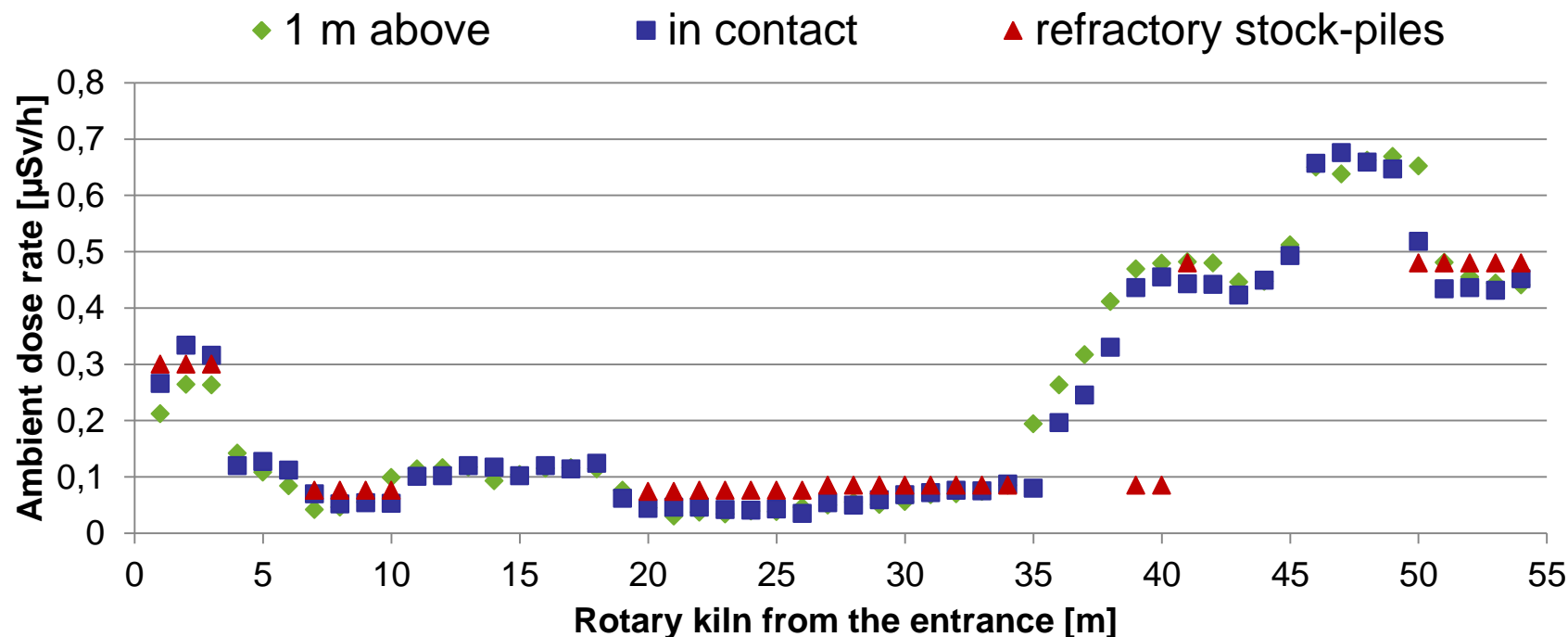
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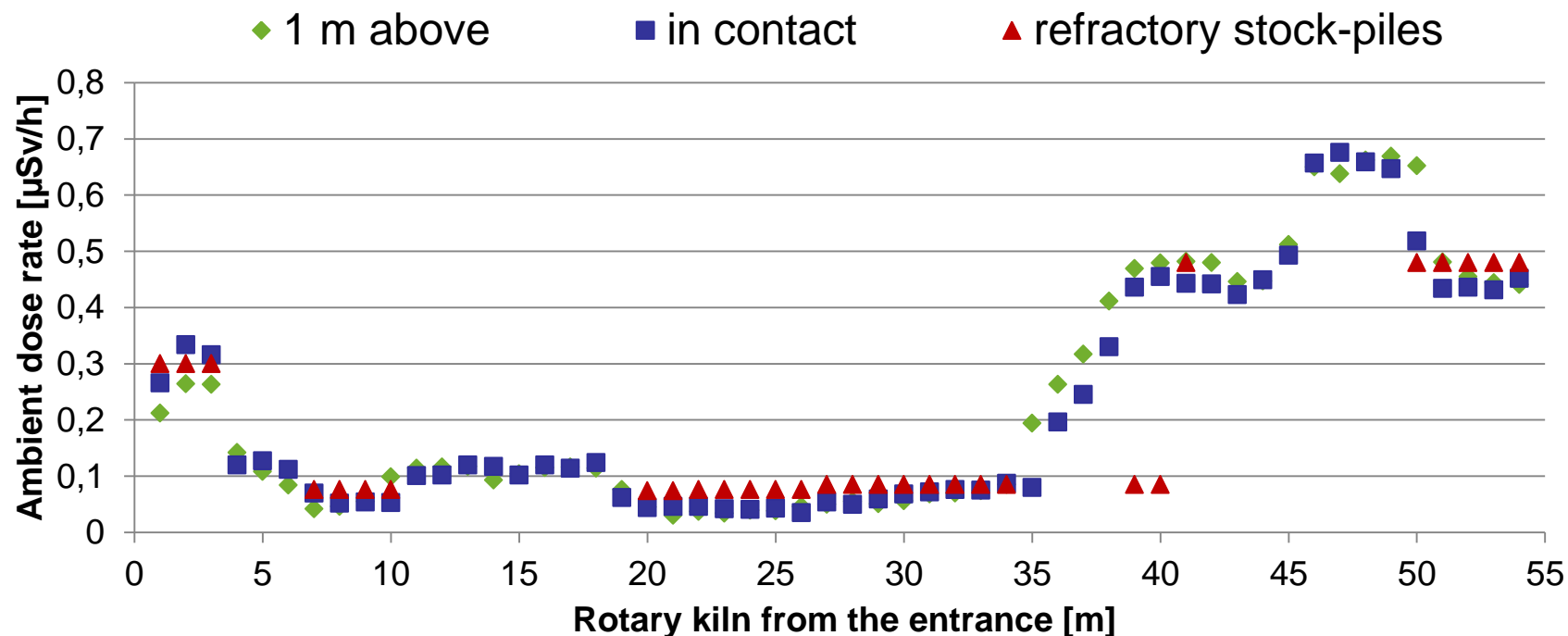
Zirconia containing refractories
on stock-piles



Ambient dose rates in cement rotary kiln



Ambient dose rates in cement rotary kiln



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Refractory lining plan

Dose estimate ,refractory construction'

Refractories	Line [m]	Duration [h]	ADR (1m above) [μSv/h]
,Resistal B75Z'	2	14	0.21-0.26
,Ankral ZE'	9.8	70	0.05-0.08
,Almag 85p'	3.6	25	0.04-0.09
,Ankral R1'	1.2	7	0.03-0.04
,Almag A1'	3	21	0.04-0.05
,Resistal M55SICV'	7.2	50	0.44-0.65

- Estimation on basis of refractory lining plan and 7 h/m refractory lining
- $E_A = 30-45 \mu\text{Sv}$ distributed on 2 employees 15-23 μSv each
- $E_{inh} = 19-73 \mu\text{Sv}$ distributed on 2 employees 19-73 μSv each
- $E_A + E_{inh} = 0,034 - 0,096 \text{ mSv}$ (in 187/2 h \rightarrow 93,5 h \rightarrow 2 weeks)

Approach for dose registration

- Annual dose value of 1 mSv would mean **4 μ Sv** per working day as additional dose (assumed 2000 working hours per year)
- Threshold on a weekly basis would be **20 μ Sv**
- How and which PPE has to be considered?
- Has background radiation to be subtracted?
- Has Radon to be included?
- Many questions are open
- National legislation has to be implemented first
- Harmonization would be useful

Outside workers in European countries - a multifaceted phenomenon



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■ Directive 2013/59/Euratom:

- equivalent **protection** to that for exposed workers employed on a permanent basis
- **contractual agreements** with the employer of outside workers, for the operational aspects of the radiation protection of outside workers
- **training** in connection with the characteristics of the workplace and the conducted activities

■ German RP Act:

- the undertaking who carries out **practices** with outside workers has to evaluate their **effective doses**
- if there was assessed an effective dose for a workplace of an outside worker, the information has to be provided to the undertaking

Summary

- Elevated exposures often occur in maintenance services conducted by outside workers
- Awareness of exposure in concerned companies is low
- RP organisation of external workers is a challenge (dose assessment, contractual agreement etc.)
- In case of rotary kilns of cement clinker production threshold values on weekly basis could be overridden for workplaces surveyed in our assessment by assumption of higher dust exposition without PPE
- Registered single exposure for whole measure $< 0.1 \text{ mSv}$
- External workers are operating in different EU countries. Without harmonisation diverging and confusing criteria for notification may apply.

Thank you for your attention!



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