Radiological monitoring of groundwater and discharge water from NORM sites in Belgium

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Overview

1) NORM sites in Belgium
2) Water matrices
3) Reference levels
4) Screening measurements: gross α / β
5) Results: DCP production, FeNb production legacy, landfills
6) Conclusions

NORM sites in Belgium

- Sites in **operation**: phosphate industry (DCP + fertilizers production), TiO_2 production, steel industry, landfills for hazardous and non hazardous waste,...

- **Legacy** sites: phosphogypsum stacks, FeNb production + all of the above,...

Water matrices

Discharge waters

⇒ DCP production, TiO_2 production, landfills

Surface water

⇒ DCP production

Groundwater

⇒ former FeNb production, phosphate production, TiO_2 site, landfills

Leachate

⇒ Landfills

Reference levels

Discharge: generic discharge limits defined in Belgian RP regulations (Royal Decree 20/07/2001) (not applicable to NORM but may serve as reference)

Groundwater: site-specific background values (if available) or reference levels for *drinking water* (draft EU directive 2012/074)

	Discharge limit - Bq/l	Drinking water (Detection Limit) - Bq/l
U-238	22	3 (0,02)
U-234	20	2,8 (0,02)
Ra-226	3,6	0,5 (0,04)
Ra-228	1,4	0,2 (0,08)
Pb-210	1,4	0,2 (0,02)
Po-210	0,83	0,1 (0,01)
K-40	160	-

Methodology

Need for **cost-optimization**: one measurement of all natural nuclides potentially of concern (U, Ra-226, Ra-228, Pb-210, Po-210) ~ 1000 Eur/ sample

Focus the measurements:

Identify relevant nuclides on basis of literature or analysis of the process

Screening methods (gross α / β) if applicable

Gross alpha > 0,1 Bq/l => nuclide-specific analysis

Gross beta > 1 Bq/l => potassium (1g K = 27,6 Bq β K-40

=> residual beta (gross $\beta - \beta_{K\text{-}40}$)

Gross α / β measurements

Draft EU directive drinking water: DL gross α < 0,04 Bq/l / gross β < 0,4 Bq/l

High content in salt => self-absorption => DL up

<u>EPA method 900.0</u> (US Safe Drinking Water Act)

$\Rightarrow$ solids density on counting planchet < 5 mg/cm^2 (gross α) or 10 mg/cm^2 (gross β)

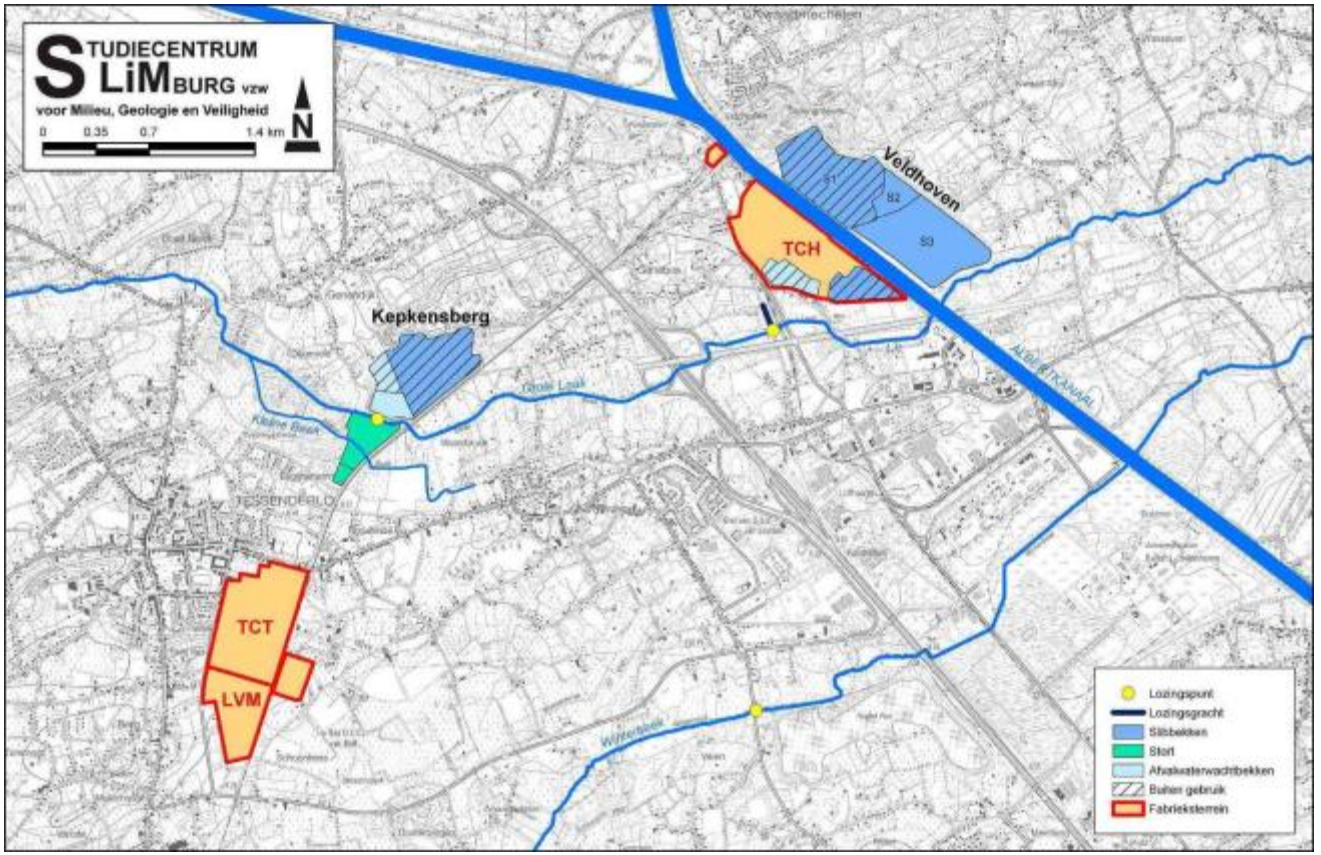
Watch out calibration standard

Gross β: if calibrated on nuclide with energy lower than K-40 residual β must take into account efficiency curve

Results: DCP production

Dicalciumphosphate (DCP) production:

Several sites of concern: CaF_2 sludge basin, waste water retention pond, discharge river



Results – discharge water and river

Up to the 90s, **20 – 30** Bq/l in discharge water

Now, addition of $BaCl_2$ => co-precipitation of Ra

Weekly measurements of waste water and discharge river

Gross α / β DL > 0.1 / 1 Bq/l (high concentration of hygroscopic salt)

2005 – 2011

U negligible

14 % [Ra-226] > 2 Bq/l

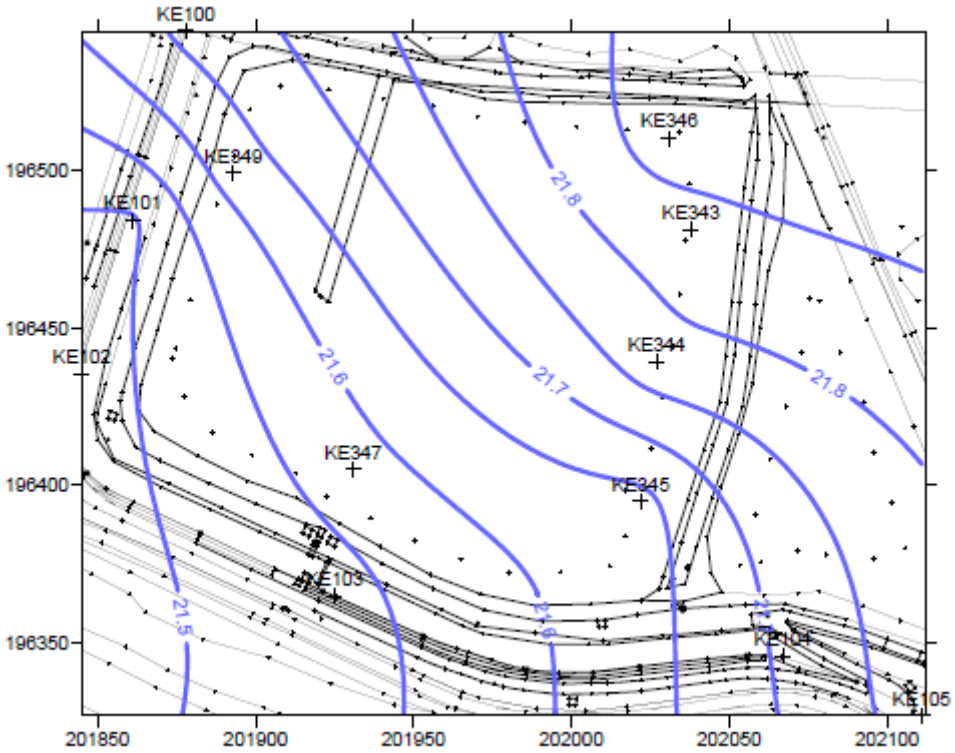
2 % [Ra-226] > 3.6 Bq/l

2011	Ra-226 (Bq/l) waste water	Ra-226 (Bq/l) river
Jan	< DL	0.05
Feb	< DL	0.033
March	0.50	0.035
April	0.55	0.085
Mai	0.46	0.118
June	0.70	0.261
July	4.07	0.354
August	1.27	1.01
Sept	0.86	0.370
Oct	1.56	0.843
Nov	0.79	0.38
Dec	0.65	0.117

Results – former waste water retention pond

Contaminated matrices: *sediments* (~ 3 Bq/g Ra-226),
Soil (up to ~ 5m deep – locally 10m) 100 – 500 Bq/kg

Shallow groundwater => flow through contaminated soil, increase of Ra concentration along flow



Pz	[Ra-226] (Bq/l)
KE346	0.076
KE343	0.034
KE344	0.5
KE345	0.45
KE347	1.26
KE349	0.104

Former ferro-niobium extraction

Extraction of FeNb in 1960s – 1970s
⇒ slag with up to 60 Bq/g Th-232 and 12 Bq/g Ra-226
⇒ patchy contamination

Next to TiO_2 production site (dump of production waste)

19 piezometers sampled (5-8 m deep)
Gross α measurements:
11 > 0.1 Bq/l
4 > 0.4 Bq/l (max. 0.9)

Gross α = 0.9 Bq/l =>
No match !

Ra-226	32 mBq/l
Th-230	0.3 mBq/l
U-234	4.5 mBq/l
U-238	3.7 mBq/l

Landfills for hazardous and non hazardous waste

Landfills regulated according to EU “landfills” directive 1999/31/CE

Some of the landfilled waste is NORM => any environmental impact ?
Measurements on **leachate, groundwater and discharge water**

	Landfill 1			Landfill 2		Landfill 3		Landfill 4		Landfill 5	
Bq/l	Leach	GW	Discharge	Leach	Discharge	Leach	Discharge	Leach	GW	Leachate	GW
Gross α	1.8	0.17	< 0.15	0.6	< 0.01	< 3.2	< 3.2	< 0.26	0.1	< 0.6	0.21
Gross β	26	0.24	14	41	0.32	36.4	36	20.5	0.09	76	2.7
K-40	18			32		32.4	29.7	18.5		63	2.13
Ra-226	0.22		< 0.6	< 5		0.18	0.24	< 2.2		0.008	
Ra-228	1		< 0.15	< 1				< 4.5		< 0.7	

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Conclusions

Screening on basis of gross α / β ?

$\Rightarrow$ Careful interpretation – watch out calibration standard, short-lived nuclides,... - not necessarily suitable for « dirty » water matrices (self-absorption) – pure screening tool

$\Rightarrow$ need for transparency

From the side of regulators, about scope of measurements (reference levels)

From the side of labs, about measurement protocol, calibration standard, efficiency curve, ...

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