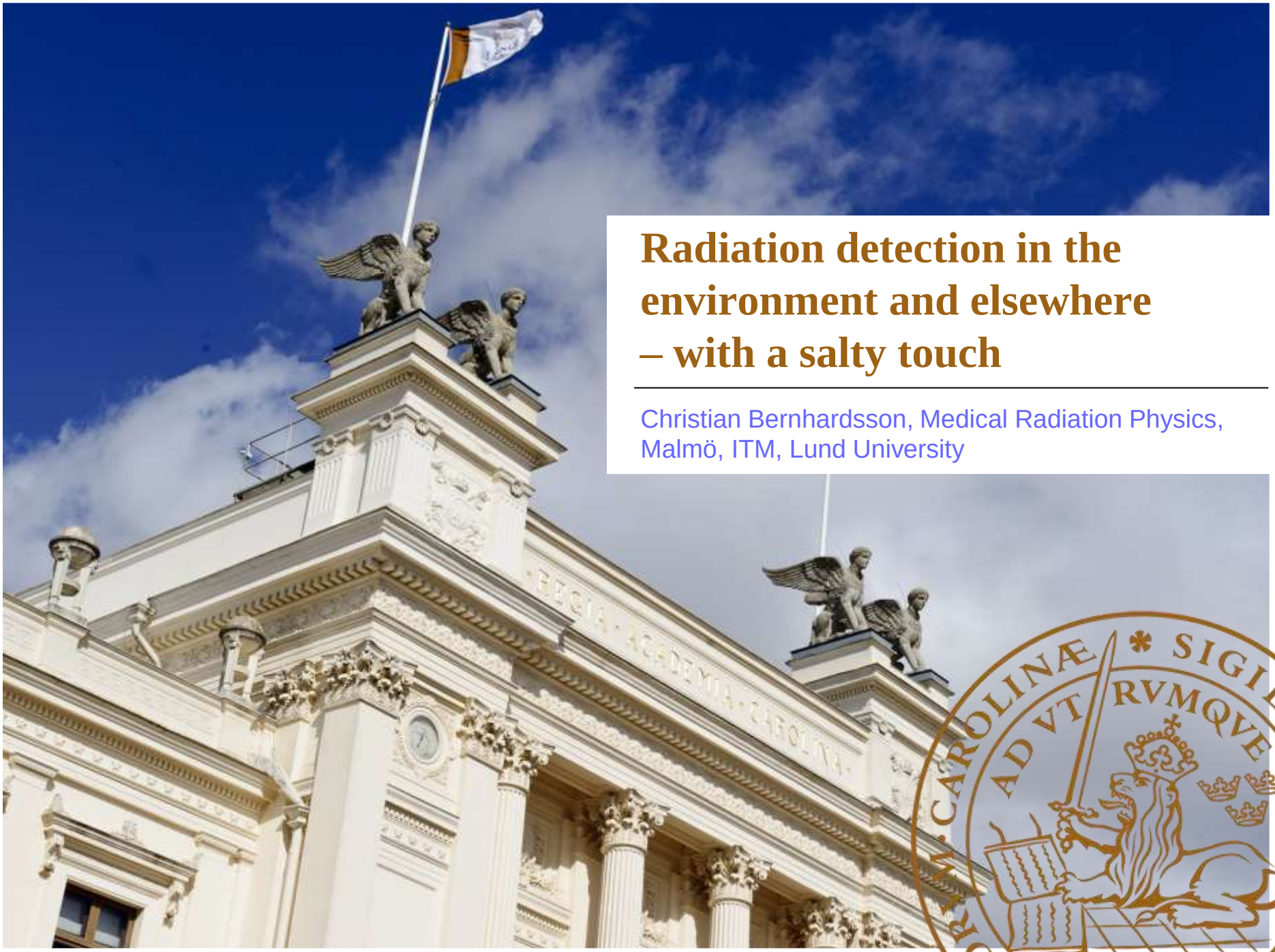


Radiation detection in the environment and elsewhere – with a salty touch

Christian Bernhardsson, Medical Radiation Physics, Malmö, ITM, Lund University

Overview

- **Medical Radiation Physics, ITM, LU**
- **Environmental monitoring programs**
  - ESS (Lund) – zero point assessments
  - Astravet NPP (Belarus) – zero point assessments
- **Expert support to the Swedish Radiation Safety Authority (SSM)**
- **Individualized dosimetry in R/N emergency situations household NaCl as a "folk dosemeter"**

LUND UNIVERSITY

Medical Radiation Physics, Department of Translational Medicine, LU

- **Medical Radiation Physics, Malmö**
- **Research and education within**
  - MR
  - Nuclear medicine and internal dosimetry
  - Environmental radiology
  - Radiology and CT
  - Mammography and tomosynthesis
  - Radiation protection
- **39 employees/co-workers (LUCRIS)**
  - PhD students, postdoc, docenter/assoc. Prof., lektorer/senior lecturer, professors, senior researchers and admin. And technical staff
  - 2x affiliated medical physics staff
  - BSc, MSc, and other students

Some of us at MSF (2018)

PhD theses (1981-2022)

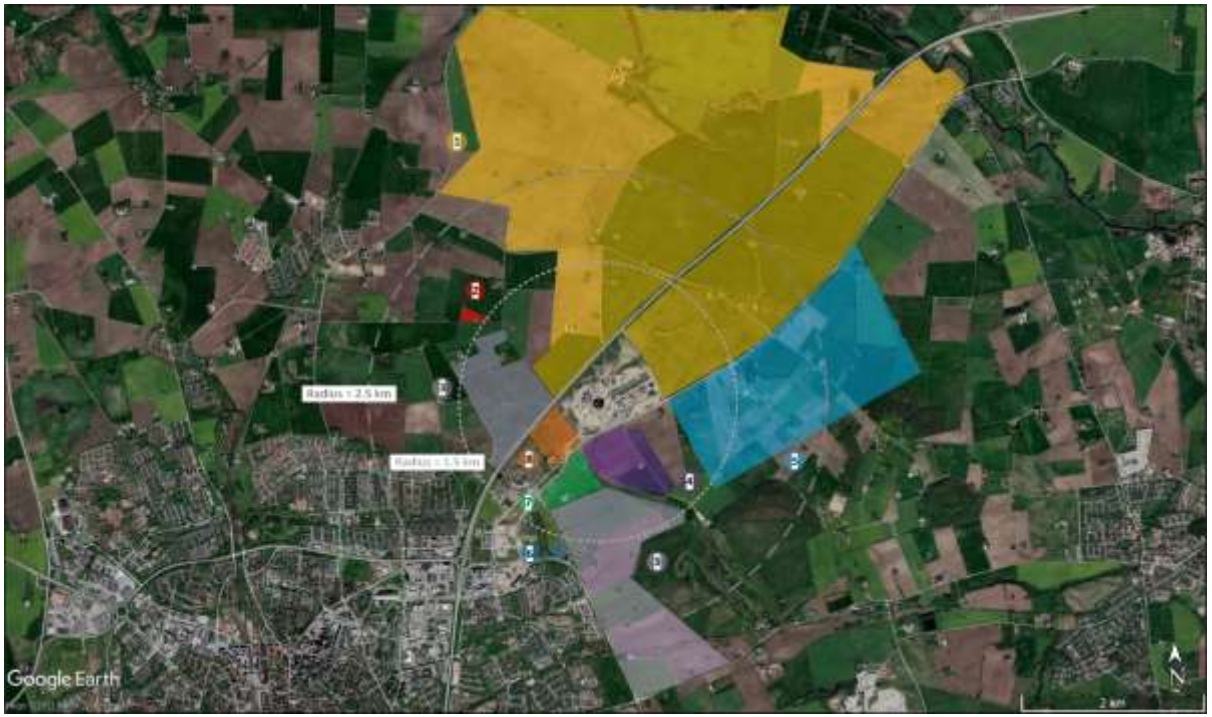
Mapping of the radiation environment around ESS (prior to operation)

- **MSF Malmö/NP Lund & ESS collaboration**
  - Start 2017-2019, FA 2020-2025
- **Mapping of gamma emitting radionuclides, ^{3}H and ^{14}C in ground, air, waters and biota**
  - Base line of the radiation environment and its variation, data for identifying diffuse long-term discharges, reporting to authorities, information to the public, etc.
- **Annual reports***
- **Research projects related to ESS, mainly through SSM**

LUND UNIVERSITY

*e.g. https://portal.research.lu.se/sv/publications/radiological-environmental-monitoring-at-the-ess-facility-annual--2

Mapping of the radiation environment around ESS (prior to operation)



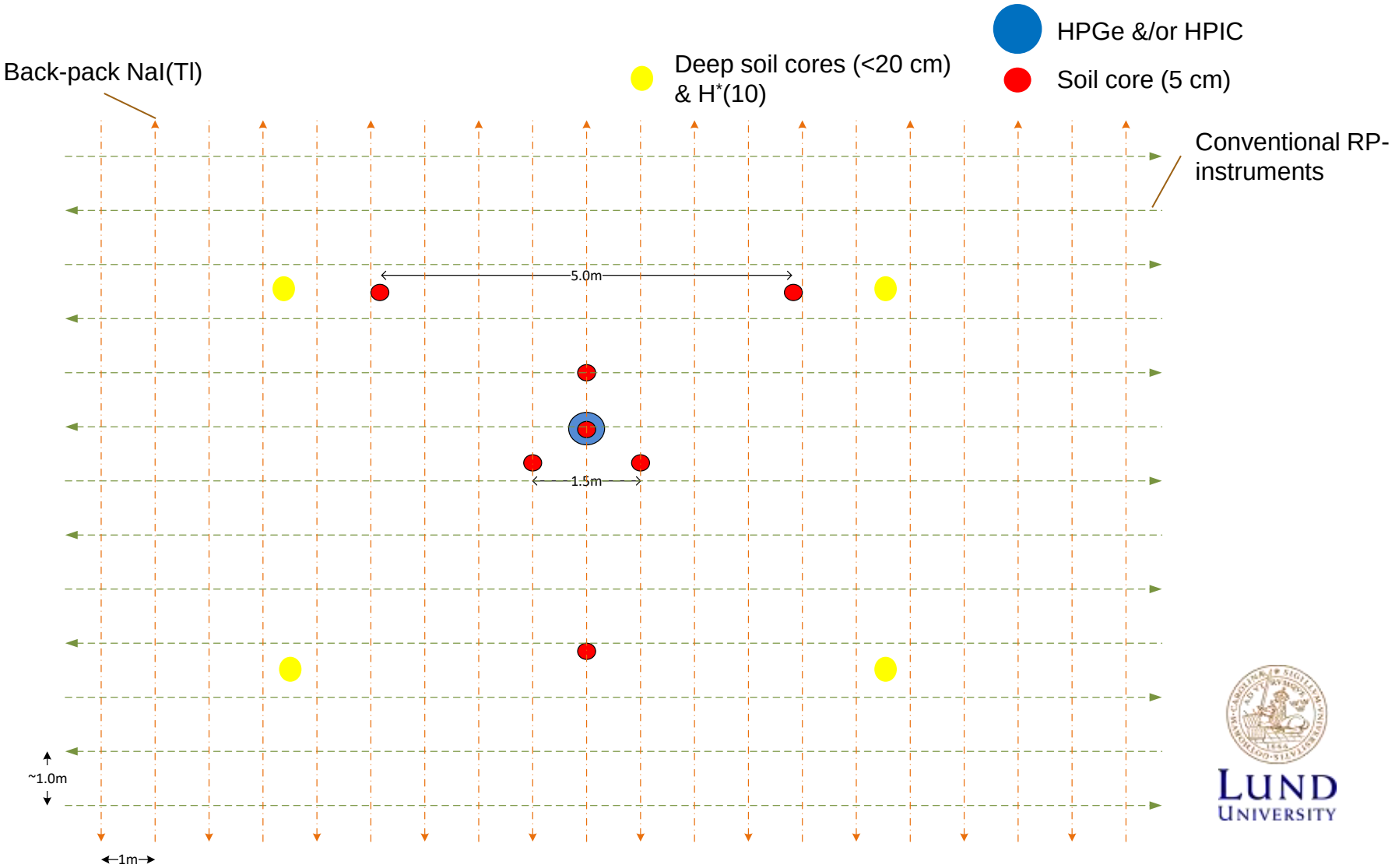
Foodstuff grown near ESS
Wheat
Barley
Rapeseed
Corn
Apples
Honey
Green peas
Sugar beet
Potatoes

Radiation measurements *in situ* – and in-between

Sampling and measurements *ex situ*: plats, animals, bioindicators, water, sewage sludge, etc.

LUND UNIVERSITY

Mapping of the radiation environment around ESS (prior to operation)



LUND UNIVERSITY

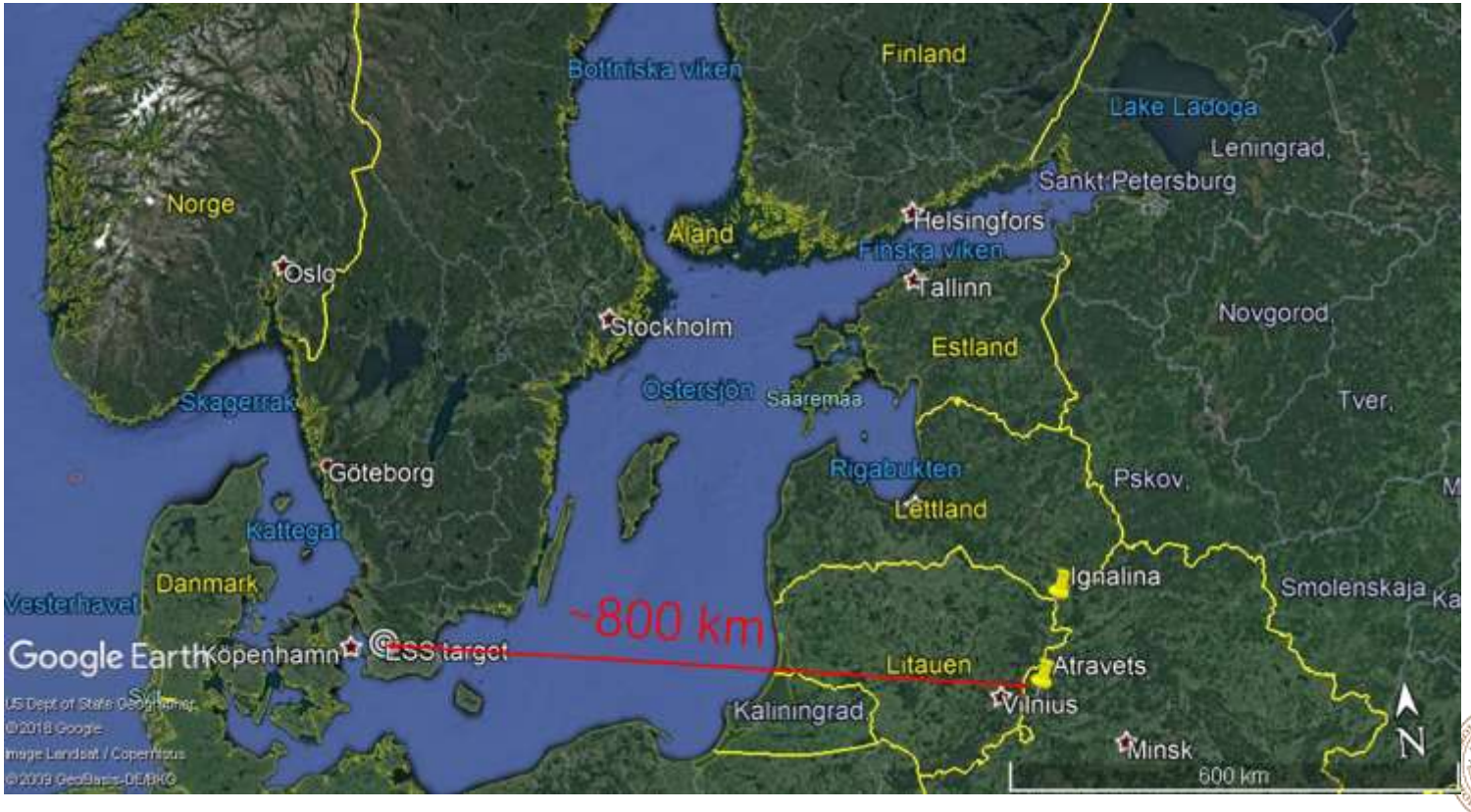
Mapping of the radiation environment around ESS (prior to operation)

Figure 1. Map of the north-eastern part of Lund where the red circles indicate sites for measurements of ambient dose rate, *in situ* gamma spectrometry and soil sampling.

Figure 4 Mobile (car) gamma spectroscopy (NaI(Tl)) around ESS in August 2020. The colour scale shows the average dose rate (μSv h^{-1}) as detected by the NaI(Tl) detectors, averaged over one second, from blue (0.06 μSv h^{-1}) to red (0.17 μSv h^{-1}). Although within normal background levels for the area, the highest values observed are due to naturally occurring radionuclides in nearby soil piles and buildings.

Mapping of the radiation environment around BelNPP (first NPP in Belarus)

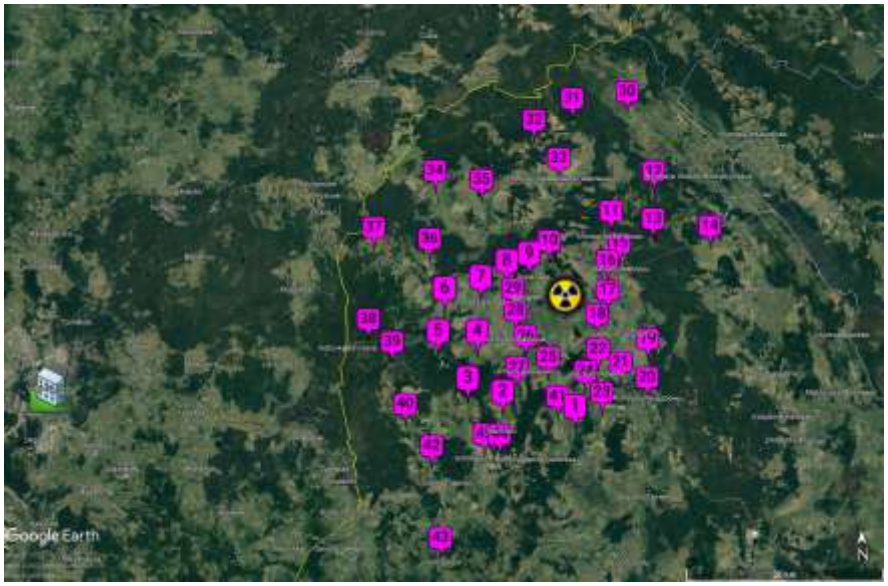
BelNPP1 was commissioned 2021-05 and BelNPP2 2023-06



First independent assessment of the preoperational radiation environment in Belarus

Mapping of the radiation environment around BelNPP in 2019 (+2022)

Mapping of the radiation environment around BelNPP



In Belarus: 45 sites within 30 km from BelNPP

In Lithuania: 17 sites along the boarder to Belarus, from Ignalina in the north to south of Vilnius

Ramzaev V. et al. *Ambient dose equivalent rates of gamma radiation from natural radionuclides and ^{137}Cs at grasslands and forests in the area of the Belarusian NPP in the pre-commissioning period (2019).* Radiation Protection Dosimetry 2024; 200(5):496-503.
Bernhardsson C. et al. *Environmental radiation baseline around the Belarussian nuclear power plant – assessments in Belarus and Lithuania. Proceedings of the 16th International Conference on Medical Physics in the Baltic States, Kaunas, Lithuania, 2023 pp. 121-125.*

SSM expert support for radiological and nuclear emergencies

Purpose

- To support the State and SSM during smaller or larger R/N emergency situations
    - Measurements & analysis, competence support, equipment and methods
    - Common methods and reporting systems

- Ex. NPP accidents, industrial- and transport accidents, lost sources, radioactive depositions from abroad, antagonistic acts with radiation

LUND UNIVERSITY

SSM expert support organisation for radiological and nuclear emergencies

→ **Strålsäkerhetsmyndigheten, Stockholm**
- Nationell samordning av expertstöd
- Stationär helkroppsmätare
- Resurser för laboratoriemätningar
- Fordon för strålningsmätning
- Mätningar med helikopter

→ **Sveriges meteorologiska och hydrologiska institut i Norrköping**
- Väderprognoser
- Spridningsberäkningar

→ **Linköpings universitet**
- Retrospektiv dosimetri
- Resurser för laboratorie-mätningar
- Basresurser för fältmätningar

→ **Göteborgs universitet**
- Stationär helkroppsmätare
- Basresurser för laboratoriemät-ningar
- Fordon för strålningsmätning

→ **Lunds universitet (Malmö)**
- Stationär helkroppsmätare
- Resurser för laboratorie-mätningar
- Fordon för strålningsmät-ning

→ **Totalförsvarets forsknings-institut i Umeå**
- Mobil och stationär helkroppsmätare
- Omfattande resurser för laboratoriemätningar
- Fordon för strålningsmätning

→ **Sveriges lantbruks-universitet i Uppsala**
- Basresurser för laboratorie-mätningar

→ **Sveriges geologiska under-sökning, SGU, Uppsala**
- Mätningar med flygplan

→ **Totalförsvarets forsknings-institut i Stockholm**
- Basresurser för laboratorie-mätningar
- Fordon för strålningsmätning

→ **Studsvik AB i Nyköping**
- Stationär helkroppsmätare
- Resuser för att omhänderta och lagra strålkällor
- Omfattande resurser för laboratoriemätningar
- Basresurser för fältmätningar

LUND UNIVERSITY

SSM expert support for R/N situations

Education, exercises, intercomparisons



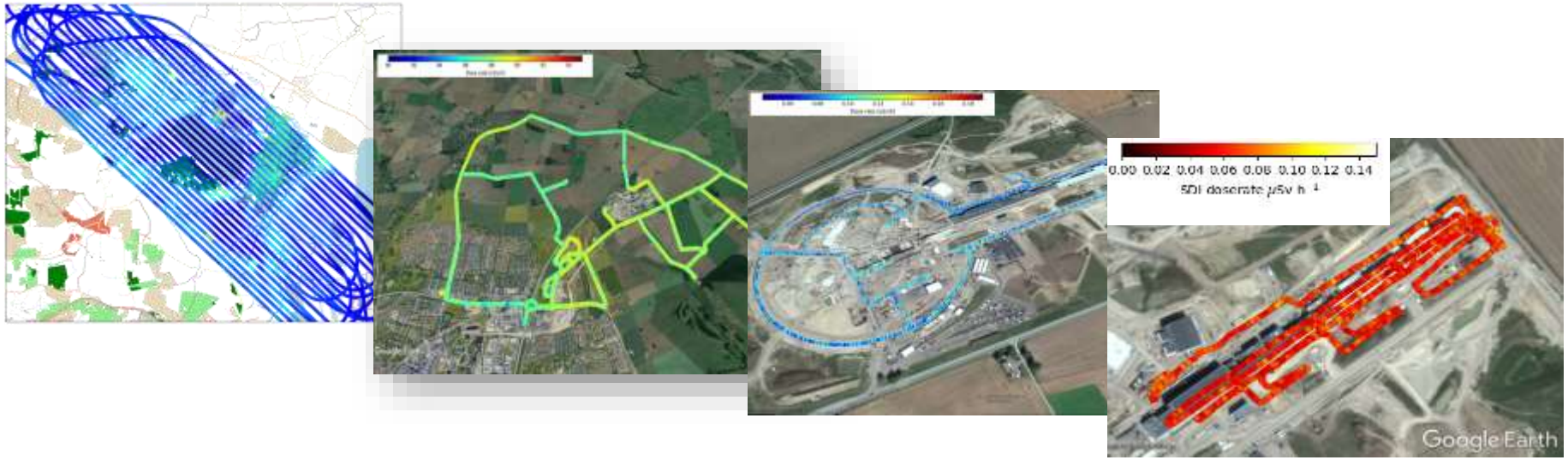


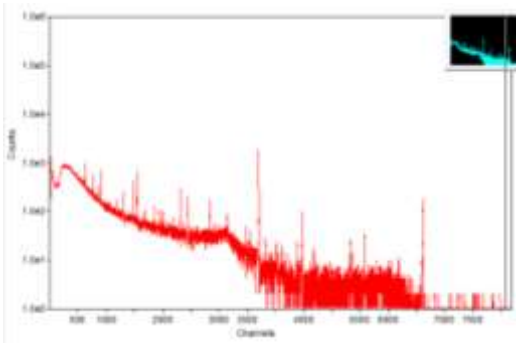


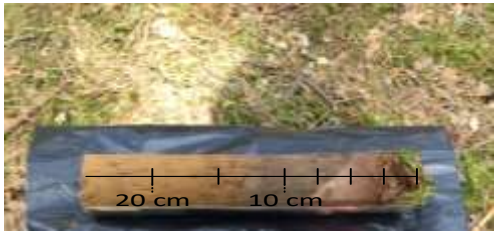


SSM expert support for R/N situations

Education, exercises, intercomparison



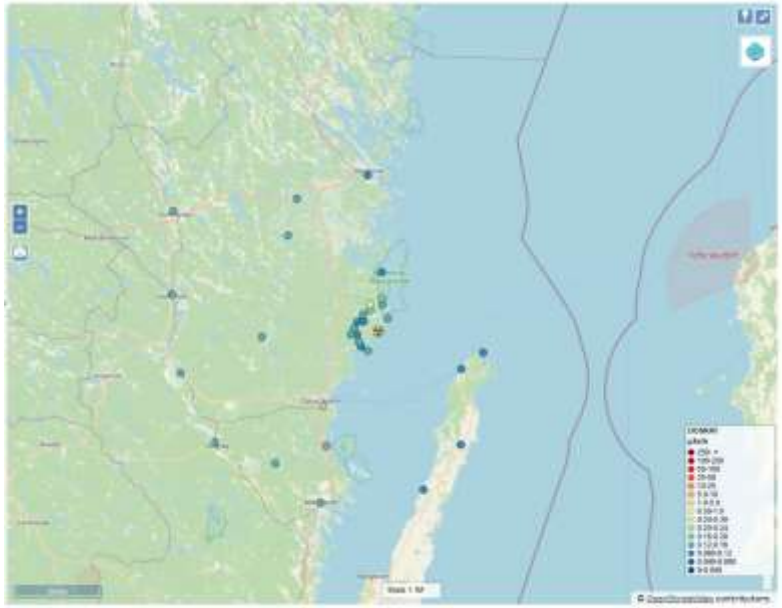


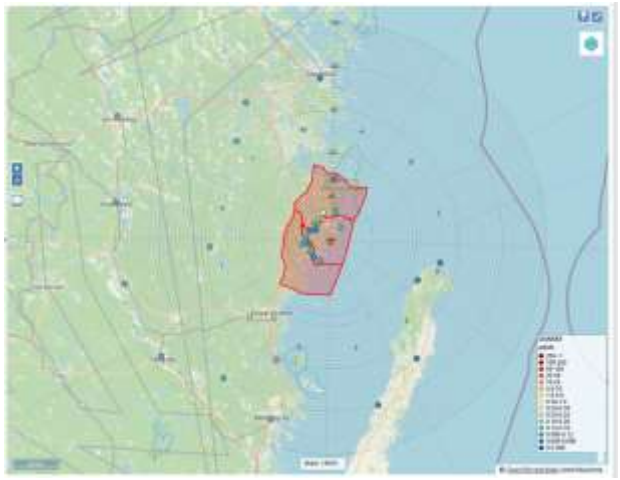


Annual exercises in the nuclear power plant counties – KKÖ24 (21-25 Oct.)

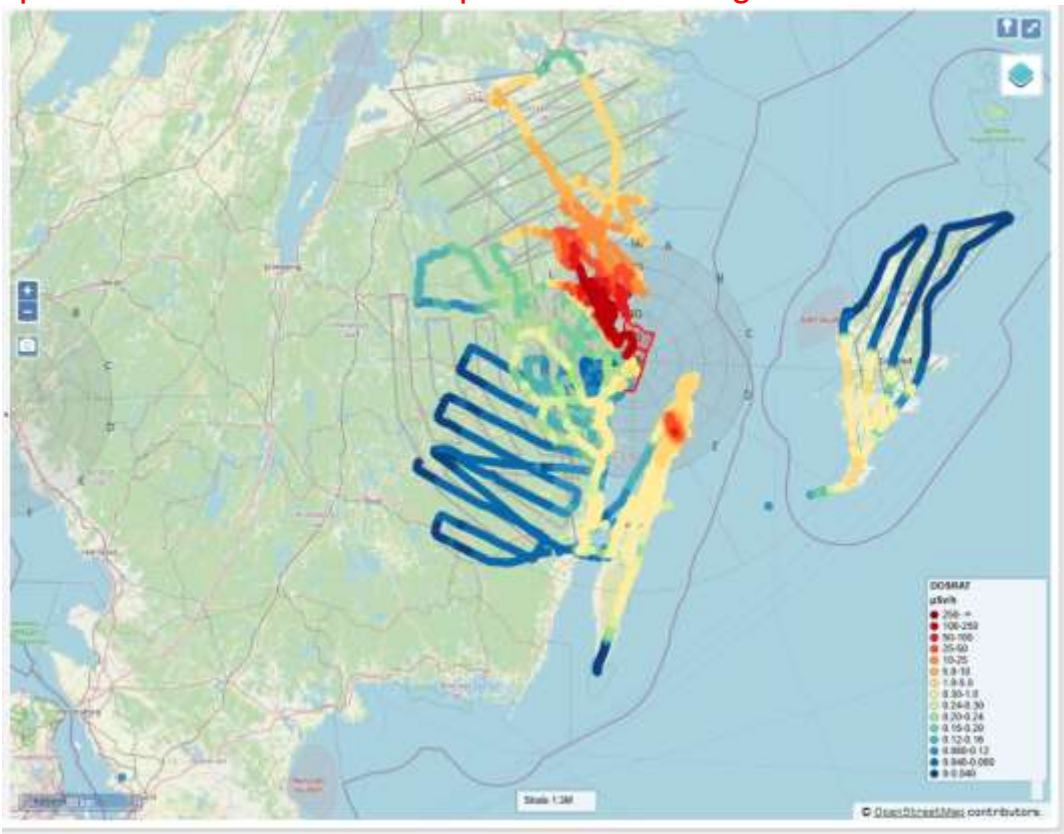
LUND UNIVERSITY

Annual exercises in the nuclear power plant counties – KKÖ24 (21-25 Oct.)





Contaminated areas are revealed by gamma stations, weather data, mobile teams (car, airplane, helicopter), *in situ* assessments, sampling (air, grass, soil, etc), coordinated by a stab from the county board and SSM, and others. The focus here was to make decision from the simulated data on people protection from external exposure to ionising radiation.



Annual exercises in the nuclear power plant counties – KKÖ24 (21-25 Oct.)

Example of one task for the LU team (+SSM). Map the deposition (kBq/m^2) and H*(10) on a defined surface on the ground (farmland) for the SGU airplane to calibrate their 16 l NaI(Tl) and HPGe detectors.

Annual exercises in the nuclear power plant counties – KKÖ24 (21-25 Oct.)

Star dune: Scientists solve mystery behind Earth's largest desert sands

4 March

The Lala Lallia star dune in Morocco is 100m high

By Georgina Rannard

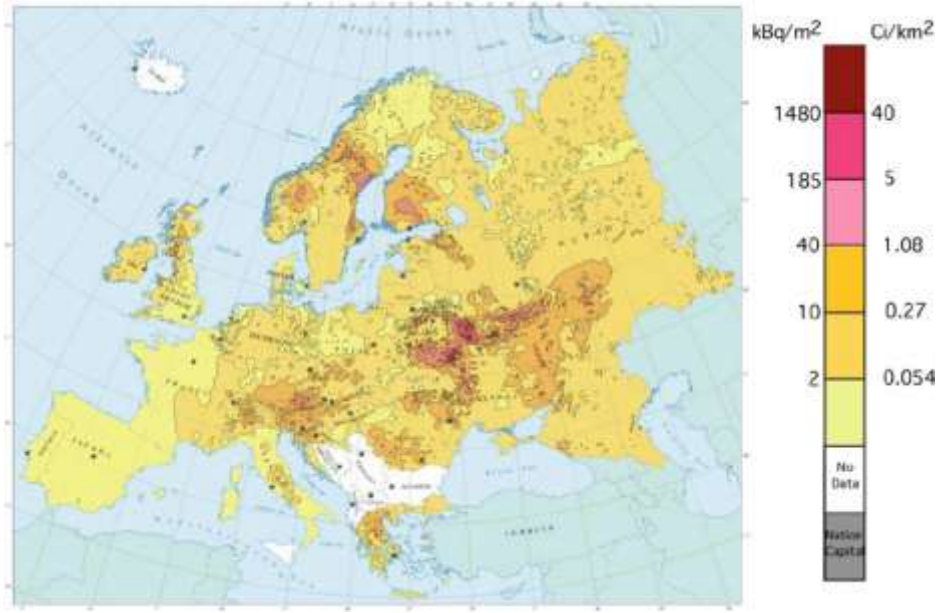
Science reporter

Workers with ionising radiation vs the public

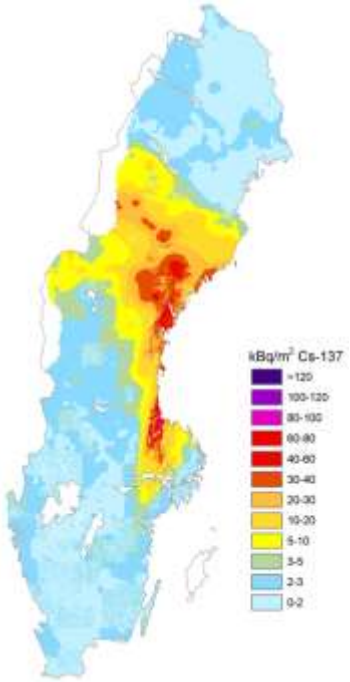
LUND UNIVERSITY

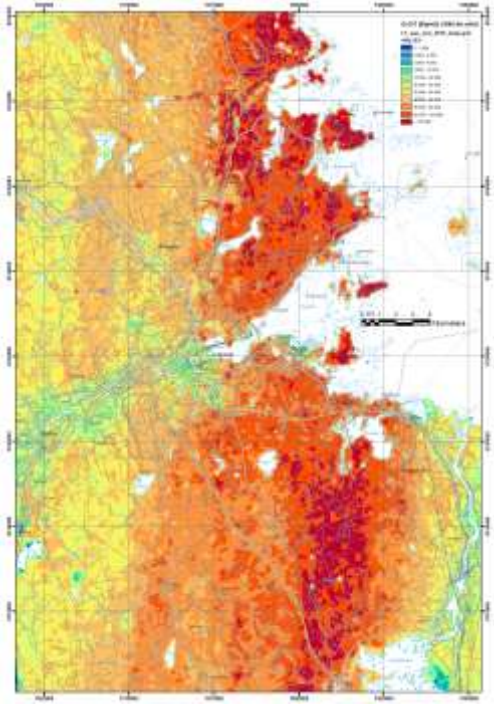
Complex dose estimation: inhomogeneity in radionuclides deposited, residence times, decay

Cs-137 from Chornobyl deposited over Europe, Sweden, and Gävle area in Sweden



De Cort et al. 1998





SGU

→Justification for individualised (external) dosimetry

LUND UNIVERSITY

Retrospective dosimetry methods

- **Biological**
  - chromosomal aberrations, lymphocytes, radionuclides in the body, etc.
- **Physical**
  - TL*- and OSL** materials, EPR***, radionuclides in the body.
- **Mathematical**
  - Monte Carlo calculations (based on *in situ* measurements).

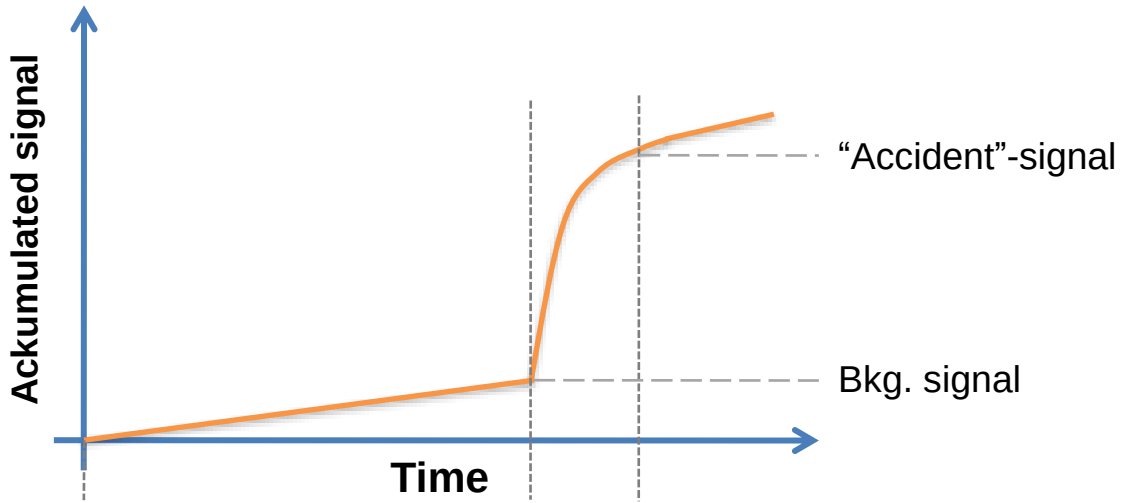
**Thermoluminescence; **Optically Stimulated Luminescence; ***Electron paramagnetic resonance*

LUND UNIVERSITY

Optically stimulated luminescence dosimetry

Retrospective- and prospective dose determinations on an individual level

- Energy is stored in crystalline defects (quartz, feldspar, salt, and others) when exposed to ionising radiation
- Energy is released, as luminescence, when the material is stimulated by heat (TL) or light (OSL)

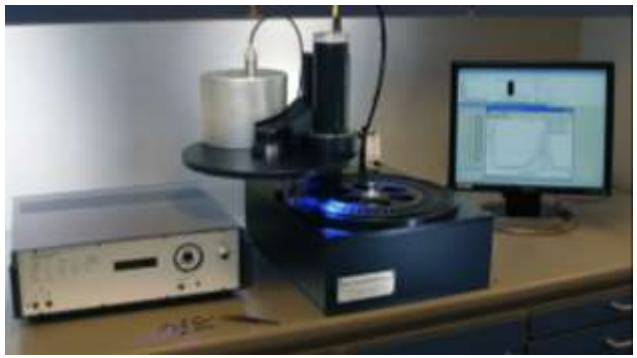


LUND UNIVERSITY

OSL dosimetry with fortuitous materials

Unintentional exposure (OR NOT) to ionising radiation

In situ or *ex situ* read-out (+calibration/pre-determined curve)



Reporting of estimated doses (if *in situ* – potential for triage support)

Collection of personal materials

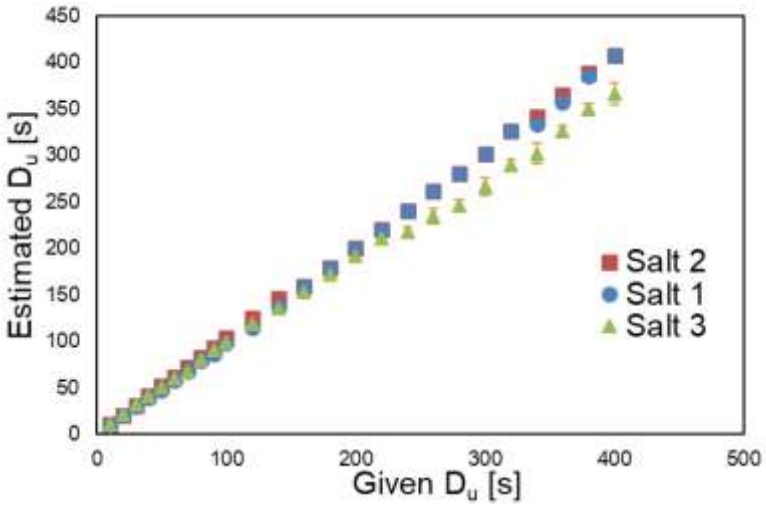
Analysis of OSL signal vs absorbed (whole-body) dose – estimation of effective dose

https://doi.org/10.1016/j.radmeas.2017.04.012

LUND UNIVERSITY

Salt (NaCl) for OSL dosimetry

- **Dosimetric properties of (NaCl pellets)**
  - Minimum detectable dose ~10 µGy (normal bkg. radiation ca. 3 µGy per 24 h)
  - Reproducibility: ca. 2%
  - Dose-response:



- **Pros./cons.: must be kept shielded from light**

LUND UNIVERSITY

Salt as a prospective OSL dosemeter

- A cost-effective and available alternative to conventional detectors and methods for radiation dose determinations

+

=

€1

€1000

LUND UNIVERSITY

Salt as an OSL dosemeter

- 102 different salts from 47 countries and 6 continents

Table 1. The 102 salts investigated with information on country where the salt was bought, the type (Sea salt (S), Rock salt (R), Pure salt (P)), iodine and anti-caking agent (yes/no (Y/N)) and the grain size fraction used in this study. The table is sorted alphabetically according to country of purchase.

Country of purchase	Type	Iodine	Anti-caking	Grain size	Country of purchase	Type	Iodine	Anti-caking	Grain size
Australia 1	S	Y	Y	100-250	Morocco 2	-	Y	Y	100-250
Australia 2	S	N	Y	100-400	Morocco 3	-	Y	N	100-250
Austria 1	R	Y	Y	100-250	Netherlands 1	R	N	Y	100-250
Austria 2	R	Y	-	100-250	Netherlands 2	R	Y	Y	100-250
Bangladesh 1	S	Y	N	100-250**	Norway 1	S	N	Y	100-250
Belarus 1	R	Y	Y	100-250	Peru 1	R	Y	Y	100-250

Table 3. The dosimetric properties of all 102 salts, both for grains and for pellets. Also shown are the categorisations of type of salt and iodine and anti-caking agent content.

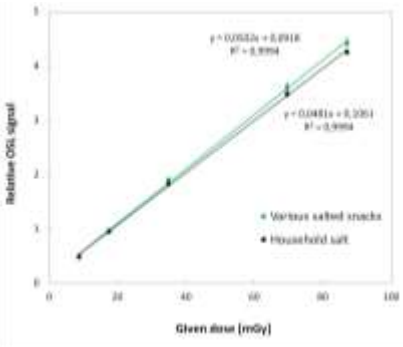
	MDD [μGy]		c_{pm} [counts/mGy·mg]		Reproducibility Dose [%]		Sensitization [%]		Dose est. Eq. slope	
Country	Grain	Pellet	Grain	Pellet	Grain	Pellet	Grain	Pellet	Grain	Pellet
Australia 1	13	6.1	869	961	0.96	0.13	57	1.4	0.79	0.99
Australia 2	9.2	13	954	1043	0.20	0.48	86	1.7	0.76	0.98
Austria 1	36	16	133	385	0.77	0.30	25	4.6	0.91	1
Austria 2	17	31	154	525	1.12	0.24	38	3.1	0.83	1
Bangladesh 1	121	17	41	277	2.05	0.26	28	1.7	0.84	1
Belarus 1	35	22	107	393	0.26	0.49	63	9.1	0.75	1
Belarus 2	76	23	201	335	1.18	0.85	51	7.5	0.8	0.99
Belarus 3	26	14	344	501	1.21	0.67	60	2.3	0.73	1.03
Belgium 1	7.3	16	847	906	0.46	0.38	42	8.1	0.88	0.98
Canada 1	23	6.3	253	1653	0.75	0.13	69	-0.2	0.8	1
China 1	7.3	29	465	212	0.48	0.46	133	4.9	0.67	1.03
China 2	56	19	90	569	0.80	0.40	35	2.3	0.84	1
Croatia 1	37	20	90	1041	0.84	0.19	26	1.7	0.9	1
Croatia 2	27	8.7	152	661	0.89	0.30	41	8.2	0.84	0.99
Czech republic 1	106	230	581	766	0.67	0.27	34	2.6	0.81	1.03
Denmark 1	12	11	336	537	0.37	0.16	128	6.5	0.67	0.99

See Waldner L. thesis (2020) for the full list of salts investigated: https://portal.research.lu.se/en/publications/optically-stimulated-luminescence-dosimetry-with-nacl-pellets-dos

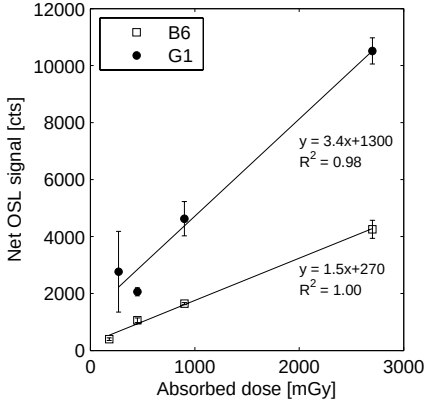
LUND UNIVERSITY

OSL dose response in some materials

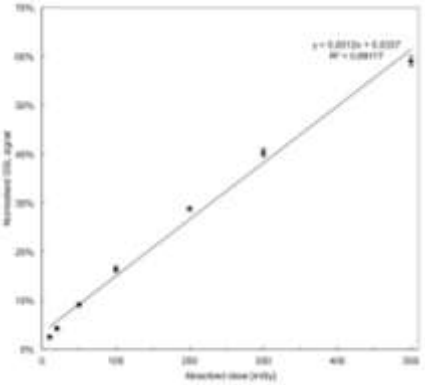
Snacks

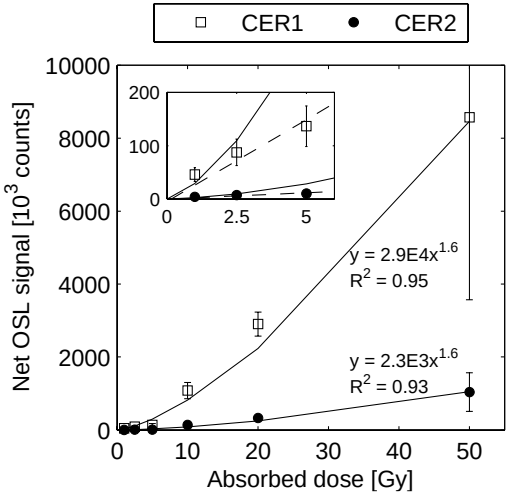


Silica gel



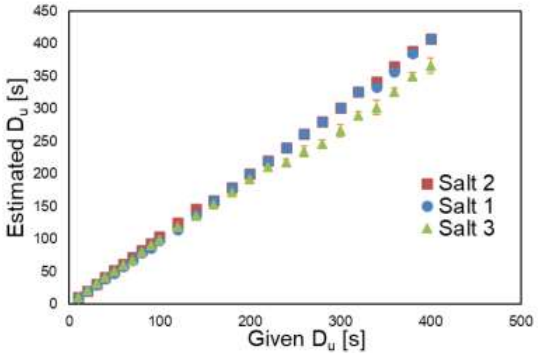
Mobile phone comp.



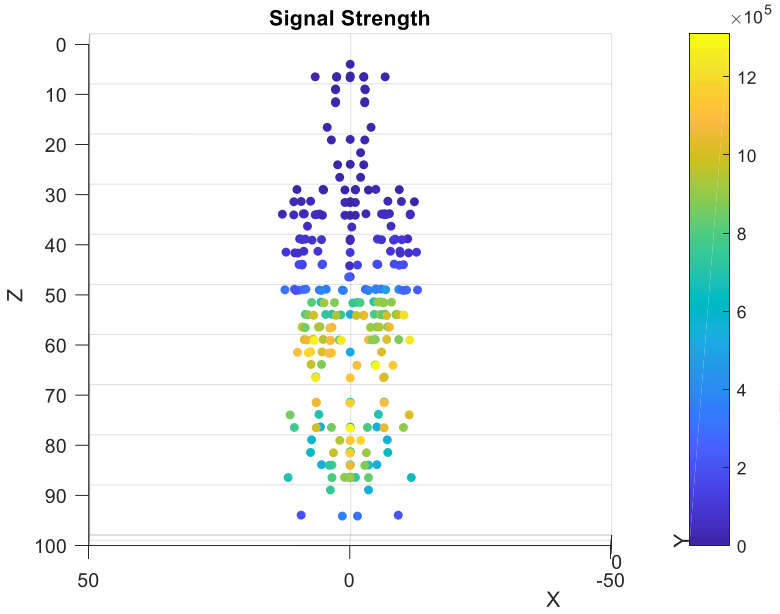


Dental repair materials

Household salt



NaCl pellets – applications for CT



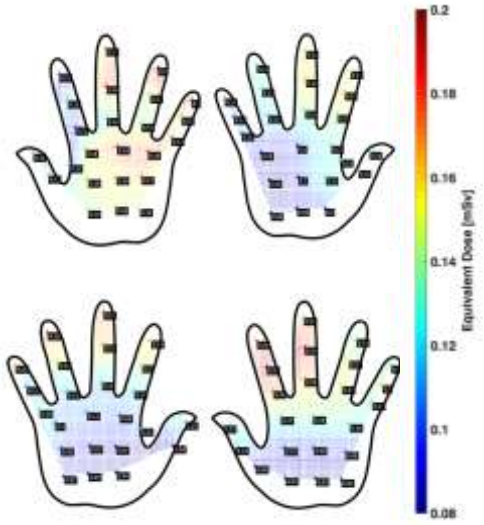
DLP according to CT: 326.2 mGy*cm

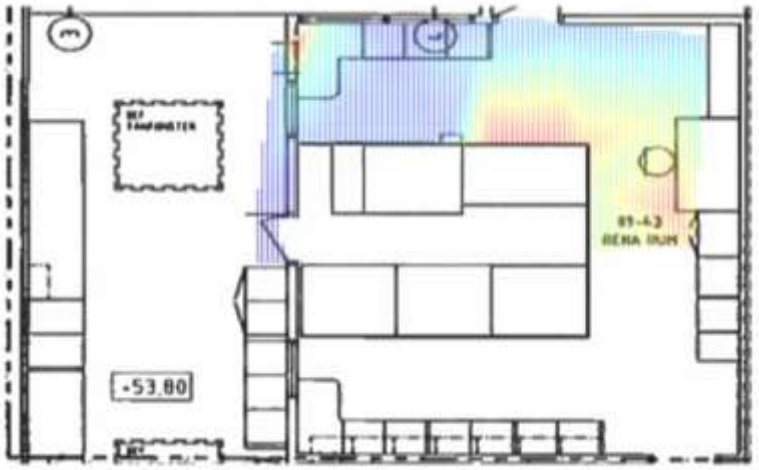
k-factor for abdomen/pelvic: 0.0171

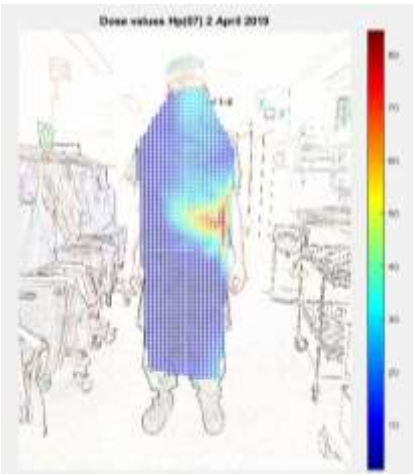
Effective dose: 5.6 mSv

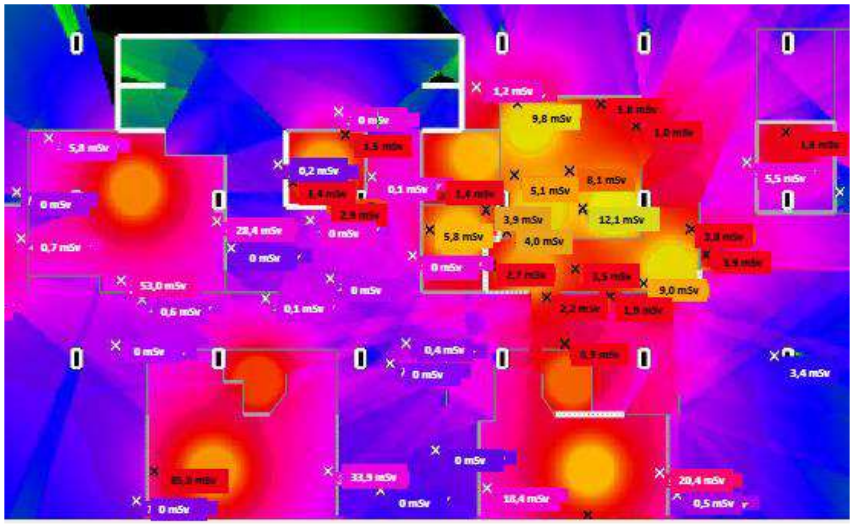
Estimated effective: 3.7-4.9 mSv

NaCl pellets – clinical applications









NaCl pellets – applications within environmental radiology

Table 2. Average external dose rates (mean value ±1 SD of the mean value for each type of house) inside the houses and outside in the gardens as registered by the different dosimeters and detectors. The following house types represent the majority of the houses in the village: 1) wooden house, not decontaminated; 2) wooden house, decontaminated; 3) brick house, not decontaminated; 4) brick house, partly decontaminated. The indicated values refer to averages over several measurements inside and outside the houses. Note that the dosimeter signals are given as absorbed dose rate.

House type	Average dose rate (μGy h^{-1})				Average dose rate (μSv h^{-1})			
	Inside		Outside		Inside		Outside	
	NaCl	LiF	NaCl	LiF	NaI(Tl)	HPIC	NaI(Tl)	HPIC
1.	0.13±0.03	0.13±0.03	0.20±0.04	0.18±0.05	0.14±0.02	0.13±0.02	0.21±0.04	0.28±0.10
2.	0.14±0.02	0.12±0.03	0.19±0.06	0.16±0.01	0.15±0.04	0.12±0.02	0.21±0.05	0.17±0.02
3.	0.09±0.00	0.11±0.00	0.23±0.01	0.25±0.03	0.10±0.00	—	0.26±0.03	—
4.	0.12	0.11	0.22	0.16	0.14	0.11	0.27	0.28

Health Phys. 103(6):740Y749; 2012

OSL dosimetry with household salt – how its done in practice

- **Retrospective OSL(NaCl) dosimetry**
  - Initially in connection with an R/N event the affected population is informed on how to pack their own NaCl dosemeter kits (part of an ongoing EU PIANOFORTE project ”Resilience to RADiological Events in Wartime”)
    - » Collection, read-out and *in situ* (Triage) or *ex situ*, reporting of doses
    - » Other personal items may be of interest (for example when arriving to a hospital)
- **Prospective OSL(NaCl) dosimetry**
  - NaCl pellets are distributed to the concerned population when first responders arrive
    - » Collection, read-out (*in situ* or *ex situ*), reporting of doses
  - May be used in other applications for control, optimisation of existing or new exposure situations

LUND UNIVERSITY

Thank you for your attention!

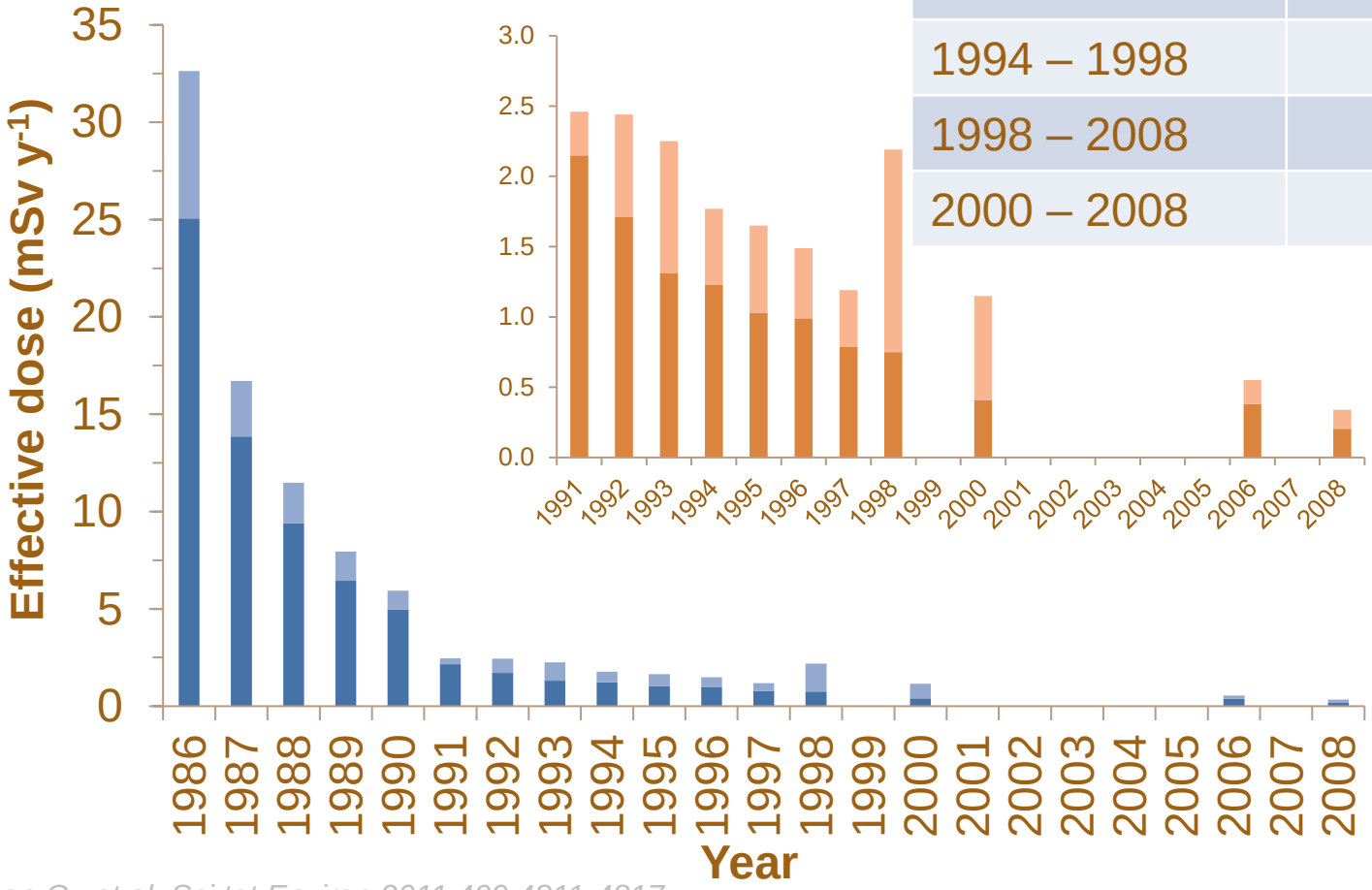
FACULTY OF MEDICINE

Christian.Bernhardsson@med.lu.se

https://www.msf-malmo.lu.se/

Annual internal- and external radiation dose to villager in Russia 1986-2008

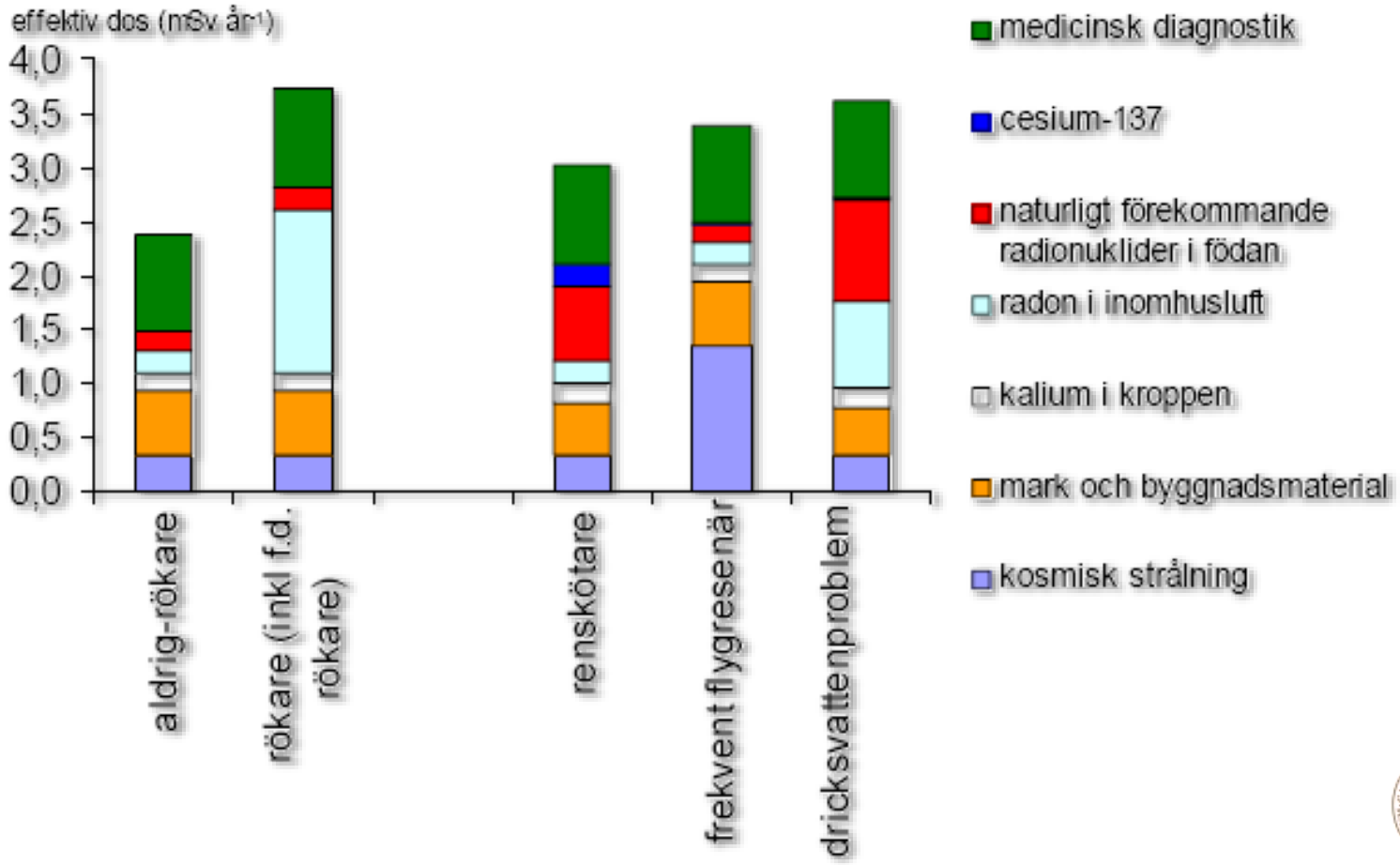
Observed rate of decrease (E_{ext})	
1991 – 1993	-20% y^{-1}
1994 – 1998	-12% y^{-1}
1998 – 2008	-9% y^{-1}
2000 – 2008	-3% y^{-1}



LUND UNIVERSITY

Bernhardsson C., et al. Sci tot Environ 2011;409:4811-4817

Genomsnittlig årsdos i Sverige



Sammanställning av strålsäkerhetsmyndigheten:
https://www.stralsakerhetsmyndigheten.se/contentassets/76e136949df04717a3940f7508ffaae0/200702-stralmiljon-i-sverige