



## Individual external dosimetry during various phases/conditions of an R/N emergency: engaging citizens in their RP

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*RRADEW Workshop, Lisbon, 24-25 March, 2025*



# Overview

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- **Our small group**
  - Medical Radiation Physics, ITM, LU
- **The salt**
  - Individualized dosimetry in R/N emergency situations - household NaCl as a “folk dosemeter”
- **NaCl + RRADEW = True**
- **Practical implementation**
  - Step-by-step procedure for achieving individualised external NaCl dosimetry on a large scale
- **Alternatives for citizen R/N sciences**



# Medical Radiation Physics group (MRPG), 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
- **~42 employees/co-workers (LUCRIS)**
  - PhD students, postdoc, docenter/assoc. Prof., lektor/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)



# EPR: MRGP as SWE expert support organisation to SSM

- **Medical Radiation Physics at LU is one of several similar (but unique) labs in the organisation**

## → 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 laboratoriemätningar
- Basresurser för fältmätningar

## → Göteborgs universitet

- Stationär helkroppsmätare
- Basresurser för laboratoriemätningar
- Fordon för strålningsmätning

## → Lunds universitet (Malmö)

- Stationär helkroppsmätare
- Resurser för laboratoriemätningar
- Fordon för strålningsmätning

## → Totalförsvarets forskningsinstitut i Umeå

- Mobil och stationär helkroppsmätare
- Omfattande resurser för laboratoriemätningar
- Fordon för strålningsmätning

## → Sveriges lantbruksuniversitet i Uppsala

- Basresurser för laboratoriemätningar

## → Sveriges geologiska undersökning, SGU, Uppsala

- Mätningar med flygplan

## → Totalförsvarets forskningsinstitut i Stockholm

- Basresurser för laboratoriemätningar
- Fordon för strålningsmätning

## → Studsvik AB i Nyköping

- Stationär helkroppsmätare
- Resurser för att omhänderta och lagra strålkällor
- Omfattande resurser för laboratoriemätningar
- Basresurser för fältmätningar



**Support the government and SSM in connection with R/N emergencies by:**

- Maintain and lead a local expert support organisation
- Validation of data, dos calculations etc.
- Common methods and development within the organisation
- Common training and exercises



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# EPR: MRGP as SWE expert support organisation to SSM

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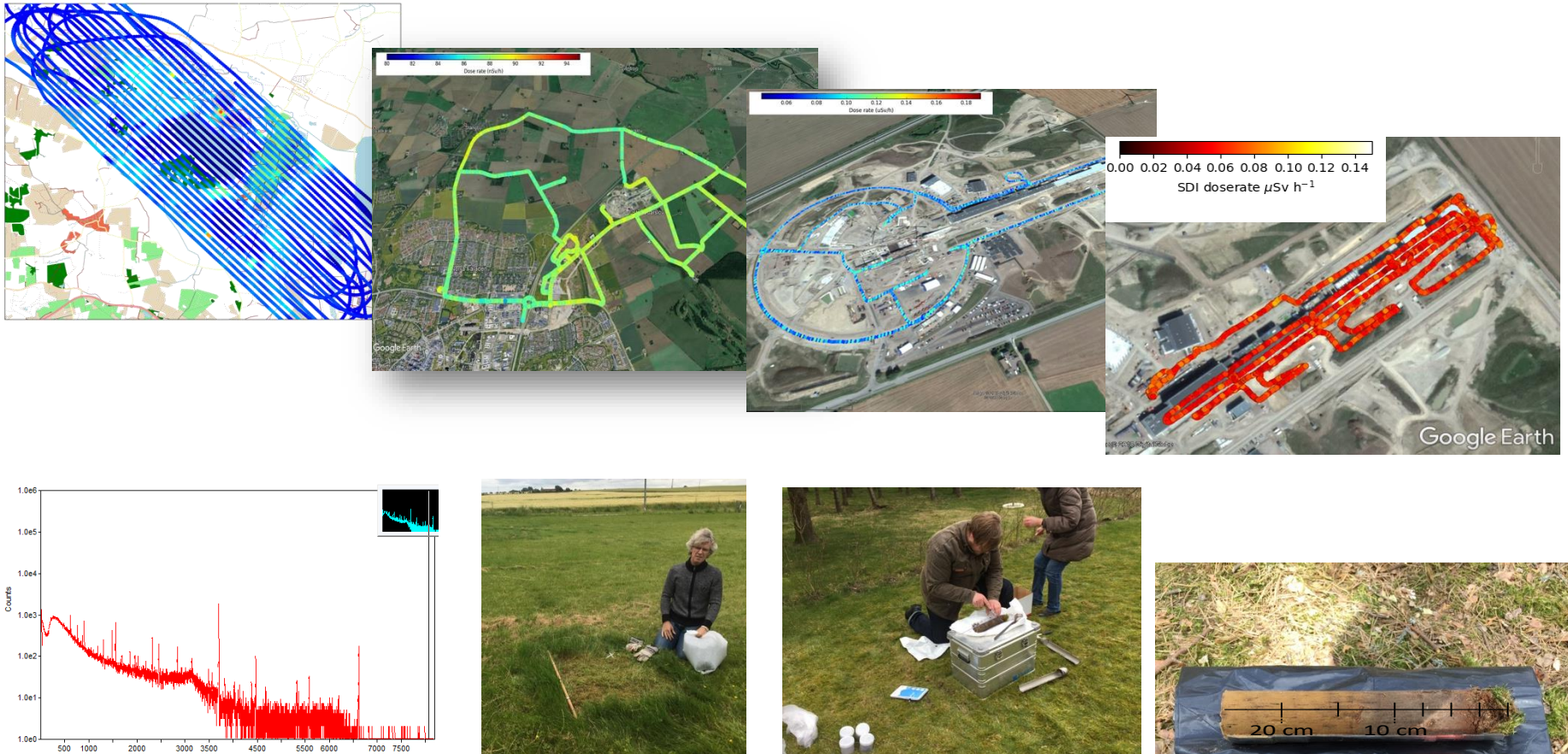
- Maintain, develop, train, educate, improve resources/functions and staff (incl. external)





# EPR: MRGP as SWE expert support organisation to SSM

- As an example: determine the radiation environment in a designated area using a combination of mobile/stationary systems and sampling



# Workers with ionising radiation vs the public

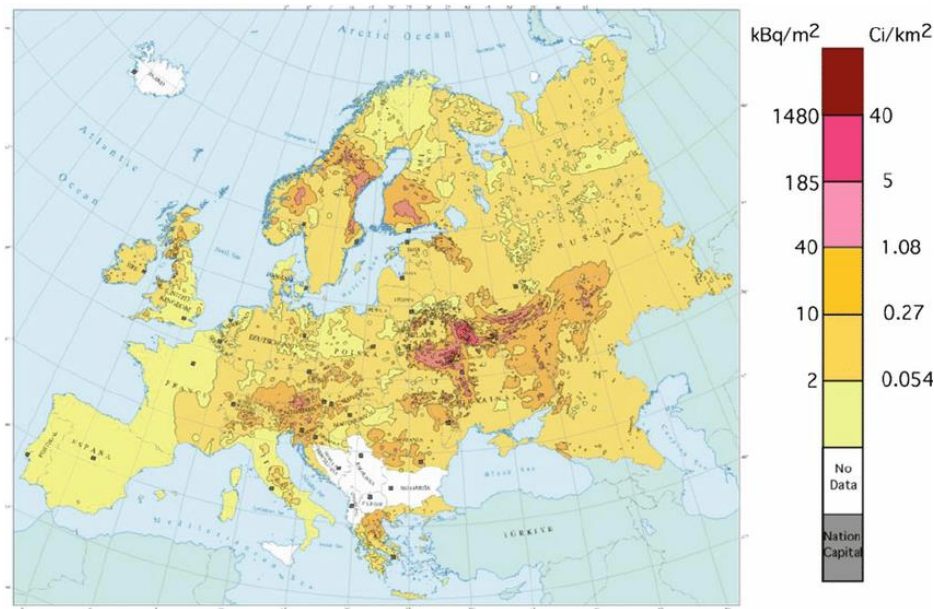
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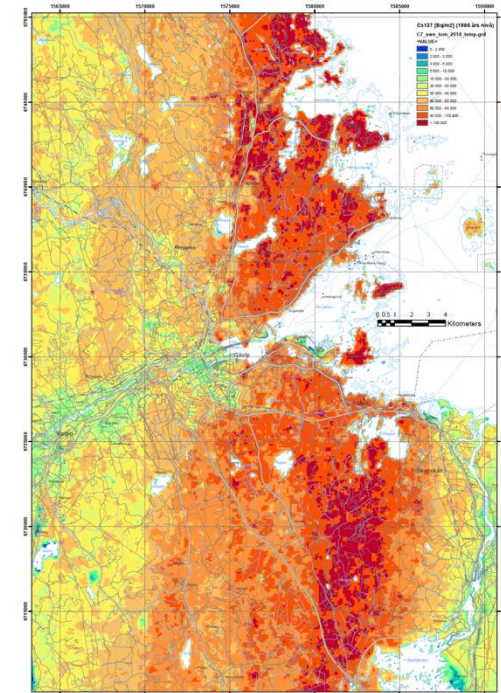
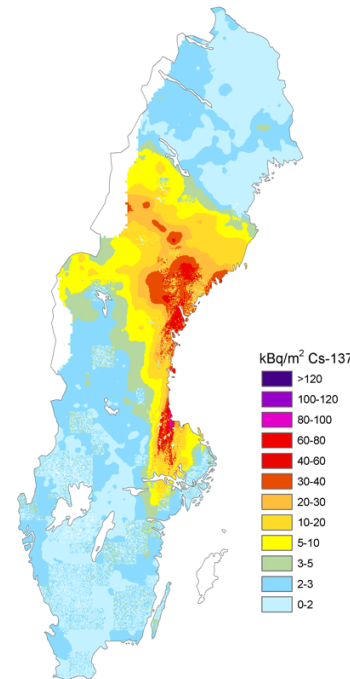


# Complex dose estimation: inhomogeneity in radionuclides deposited, residence times, decay

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



*De Cort et al. 1998*



SGU



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→ Justification for individualised (external) dosimetry



# Retrospective dosimetry methods

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

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

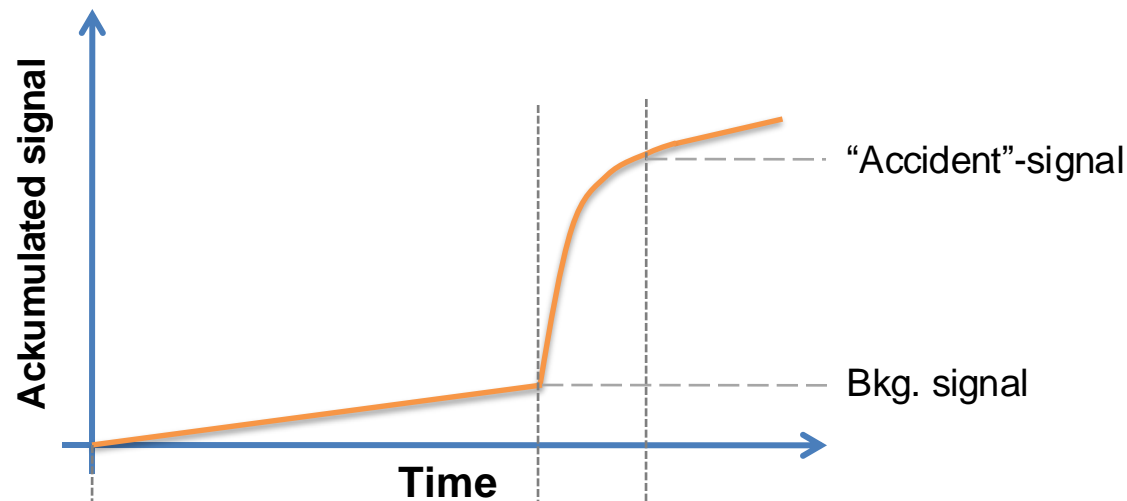


# Optically stimulated luminescence dosimetry

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## 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) = problematic/good!



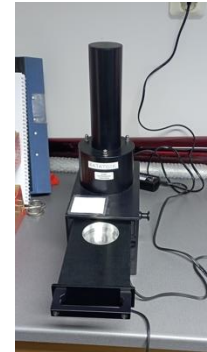
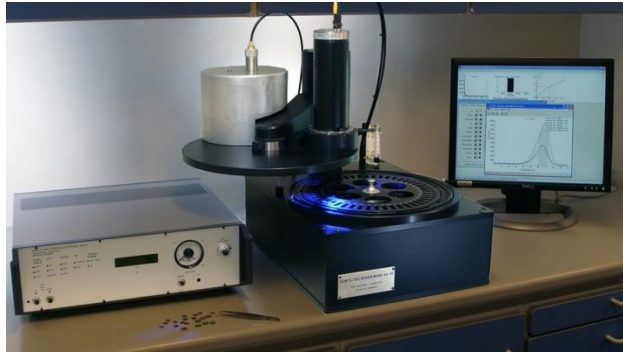


# Concept of retrospective OSL dosimetry with fortuitous materials

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)

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



10 PLN sedel



Collection of personal materials

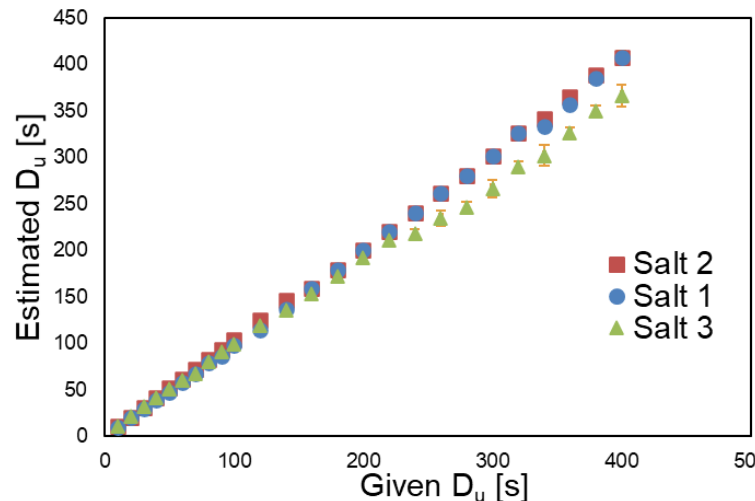
<https://doi.org/10.1016/j.ra-dmeas.2017.04.012>



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# Salt (NaCl) for OSL dosimetry

- **Dosimetric properties of (NaCl pellets)**
  - Minimum detectable dose  $\sim 10 \mu\text{Gy}$  (normal bkg. radiation ca.  $3 \mu\text{Gy}$  per 24 h)
  - Reproducibility: ca. 2%
  - Dose-response:



Bernhardsson et al. Household salt (NaCl) for optically stimulated luminescence dosimetry: an overview. Medical Physics in the Baltic States 2021: Proceedings of the 15th International Conference on Medical Physics. Adliene, D. (red.). Kaunas University Of Technology Press, s. 90-94

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





# Salt as an OSL dosimeter

- 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 [ $\mu\text{Gy}$ ]		$C_{\text{spec}}$ [counts/mGy·mg]		Reproducibility Dose [%]		Sensitisation [%]		Dose est. Eq. slope	
	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	463	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 (2021) for the full list of salts investigated:  
<https://portal.research.lu.se/en/publications/optically-stimulated-luminescence-dosimetry-with-nacl-pellets-dos>



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# Salt as a prospective OSL dosimeter

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



+



€1

€1000



=



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# NaCl pellets – outside of the lab (Belarus)



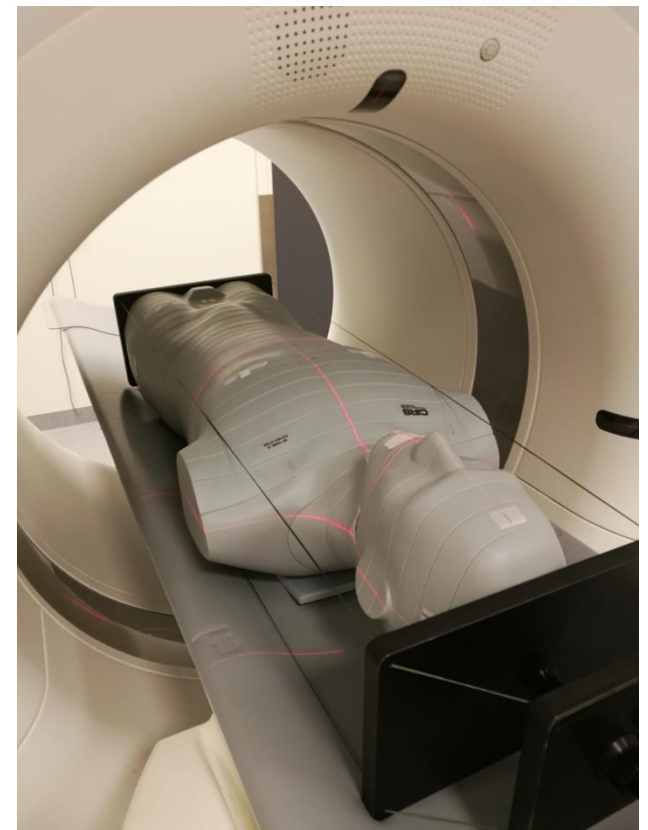
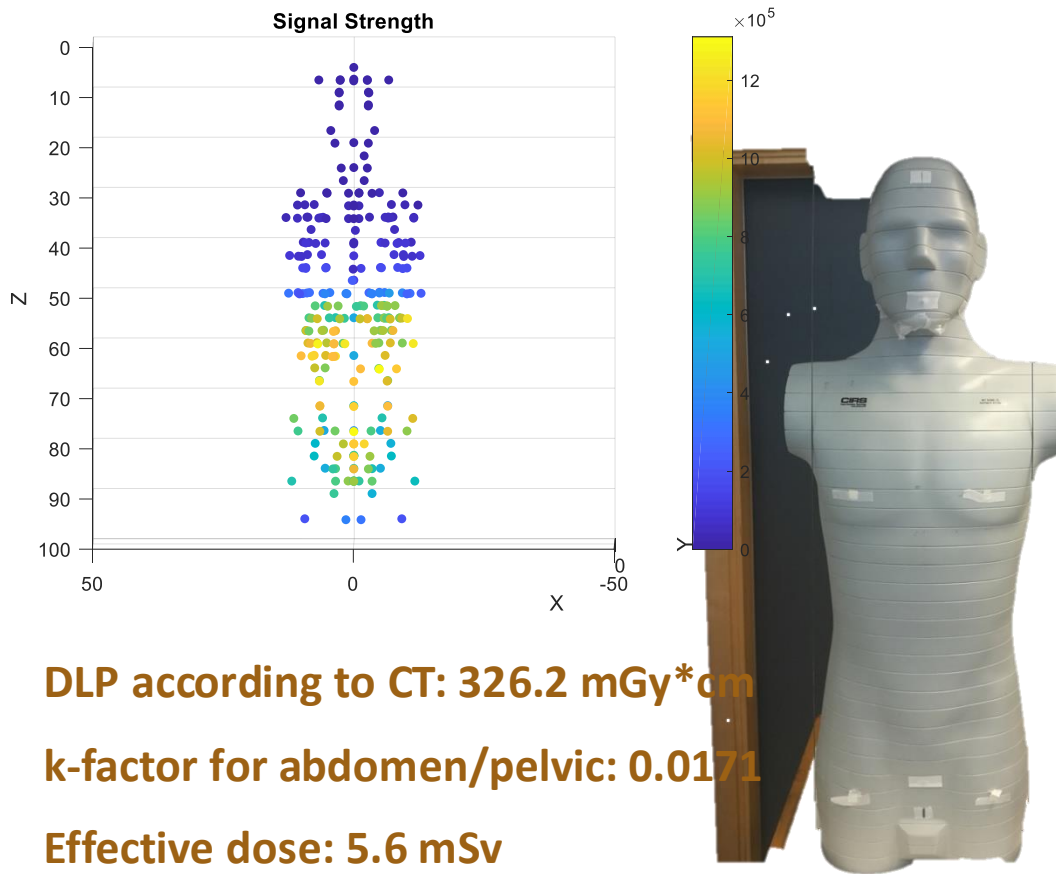
**Table 2.** Average external dose rates (mean value  $\pm 1$  SD of the mean value for each type of house) inside the houses and outside in the gardens as registered by the different dosimeters and detectors. The following house types represent the majority of the houses in the village: 1) wooden house, 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 ( $\mu\text{Gy h}^{-1}$ )				Average dose rate ( $\mu\text{Sv h}^{-1}$ )			
	Inside		Outside		Inside		Outside	
	NaCl	LiF	NaCl	LiF	Nal(Tl)	HPIC	Nal(Tl)	HPIC
1.	0.13 $\pm$ 0.03	0.13 $\pm$ 0.03	0.20 $\pm$ 0.04	0.18 $\pm$ 0.05	0.14 $\pm$ 0.02	0.13 $\pm$ 0.02	0.21 $\pm$ 0.04	0.28 $\pm$ 0.10
2.	0.14 $\pm$ 0.02	0.12 $\pm$ 0.03	0.19 $\pm$ 0.06	0.16 $\pm$ 0.01	0.15 $\pm$ 0.04	0.12 $\pm$ 0.02	0.21 $\pm$ 0.05	0.17 $\pm$ 0.02
3.	0.09 $\pm$ 0.00	0.11 $\pm$ 0.00	0.23 $\pm$ 0.01	0.25 $\pm$ 0.03	0.10 $\pm$ 0.00	—	0.26 $\pm$ 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



# NaCl pellets – diagnostic radiology



**DLP according to CT: 326.2 mGy\*cm**

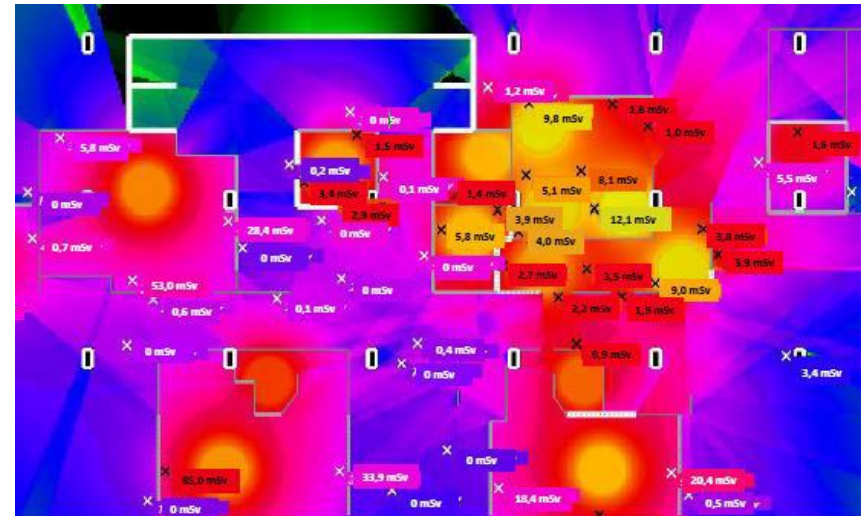
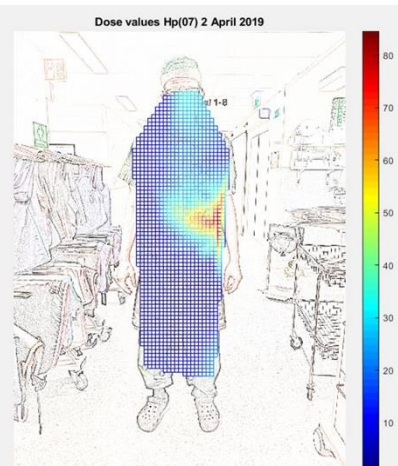
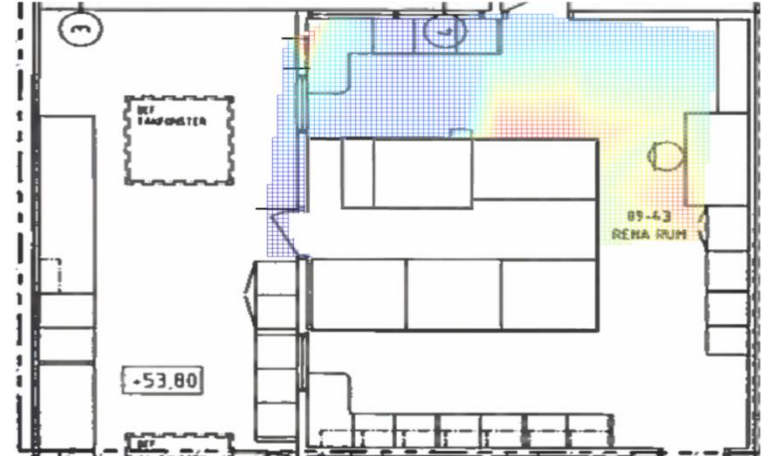
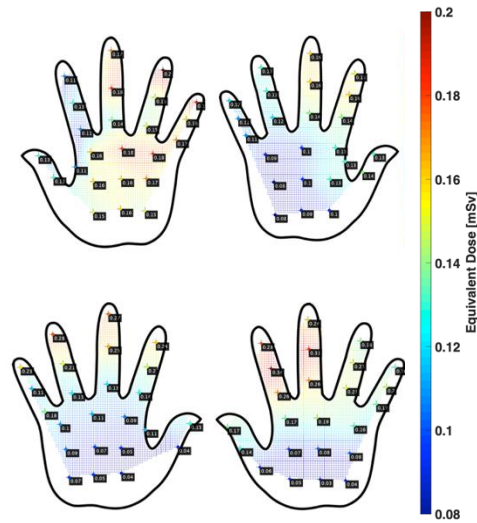
**k-factor for abdomen/pelvic: 0.0171**

**Effective dose: 5.6 mSv**

**Estimated effective: 3.7-4.9 mSv**



# NaCl pellets – nuclear medicine



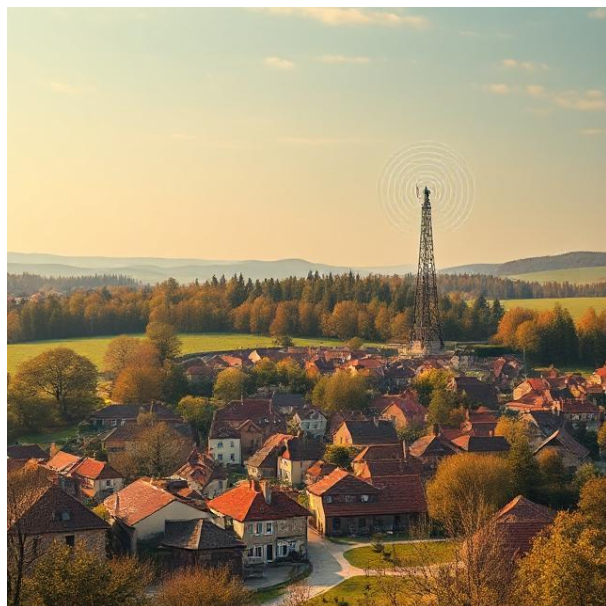


From the concept of *retrospective OSL dosimetry* to improved dosimetry as “*prospective*” *OSL dosimetry* with salt –  
**improving the conditions for accurate individual dose determinations and calculation of risk related quantities**



# RRADEW – individual NaCl dosimetry

- **Transmit the message to make the population aware**
- **Homemade dosimeter kits based on household salt + common materials**



Gamma.app



## Instructions

Information transmitted with radio-waves, local representatives, (first responders), or other warning system, internet etc.

Instructions on “how to prepare dosimeter kits” and where to find this information.

General procedure information will also be provided e.g. why, how, when – from packing of kits to receiving information on individual dose.

# RRADEW – individual NaCl dosimetry

- Clear instructions on how to prepare the kits



1



2



3

## Instructions

**Step 1:** take 1-2 teaspoons of household salt and put onto a sheet of plastic foil. Fold 1-2 times with the salt evenly distributed on the foil. Put this sheet onto a doubly folded sheet of aluminium foil. Fold to an envelope and secure the edges.

**Step 2:** Mark each kit with an individual number (1,2,3...) for each family member and not these numbers on a paper. On the same paper, write down the date/time for the preparation of the kits and salt type..



# RRADEW – individual NaCl dosimetry

- Information on procedure for handling the kits
  - Storage, protection, replacing, not sharing, etc.



Deepai.org



Deepai.org

## Instructions

**Step 3:** Each person wears one dosimeter, the same kit. Position it on the front-side of the body, e.g. pocket of a shirt. Alternatively, put it on a string and wear it as a necklace.

- Always keep the same position of the dosimeter when wearing it.
- When at home the dosimeter can be stored in the persons room.

If the dosimeter kit is broken or lost, create a new one and note the new name, date/time on the paper.

# RRADEW – individual NaCl dosimetry

- **Collect dosimeter kits and distribute kits with NaCl pellets**



Gamma.app



Gamma.app



Gamma.app

## Instructions

**Step 4:** When informed by designated local authorities, collect all dosimeters, the paper with information and bring them in one bag to the collection point (e.g. community center).

- During the collection you will be provided with a unique QR code for your family to follow your dosimeter results.
- Dedicated NaCl dosimeters may be provided as well to follow the exposure during the later phase.

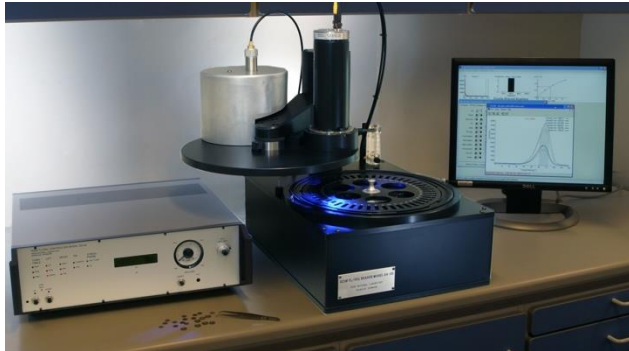
## “Workshop” with Q&A

*At this point, a limited amount of reference dosimeters may be distributed in parallel.*

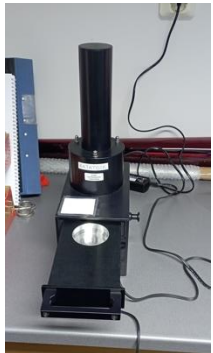


# RRADEW – individual NaCl dosimetry

- Reporting back on individual results/doses



OSL lab *ex situ*



OSL lab *in situ*

## Instructions

**Step 5:** The dosimeter can be screened *in situ*, and later analysed more careful in a lab. Or sent directly to a lab or network of labs for dose assessment.

**Step 6:** When the doses are calculated they are registered in a database. To view your individual family member doses you visit the page that is linked with the QR code.





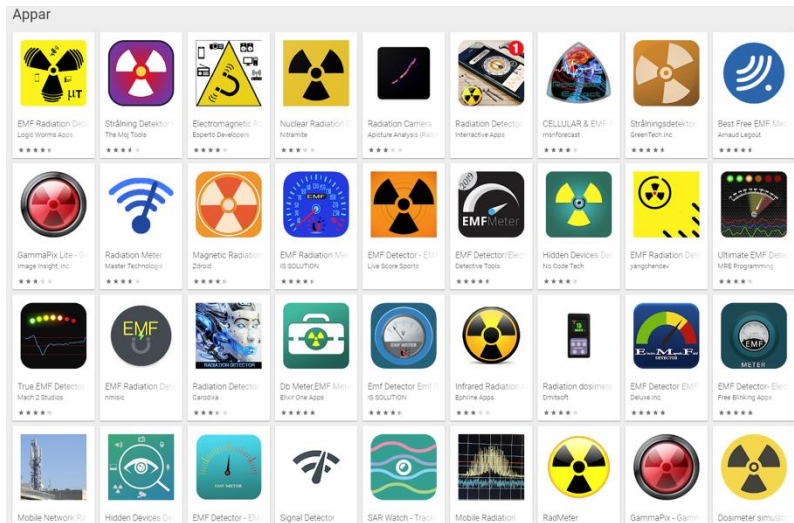
# Summary of questions to answer within RRADEW

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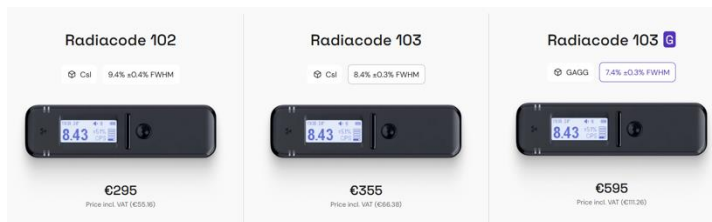
- Public opinion on the suggested tool/concept
- Develop and test the instructions on how to prepare the kits
  - *Verification by irradiating kits, exposure to light, readout*
- Survey means for optimal ways of transmitting the message
- Investigate and suggest distribution/collection mechanisms
- Suggest a methodology for readout and dose calculation in war as well as in peace
- Suggest a practically feasible workflow for implementation



# Alternatives – common tools for citizen science in R/N emergencies



<https://safecast.org/>



Radiacode.com



Temu ~€80



Amazon ~€80



From €30

**Parallel, RRADEW connected projects, at MRPG (focusing on citizen science)**  
 2025: MSc summer project  
 2025-2029: PhD project or Postdoc position (Swedish Civil Contingencies Agency)

# OSL dosimetry with household salt – how its done in practice

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- **“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 (“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, justification, optimisation of existing or new exposure situations





**Thank you for your attention!**

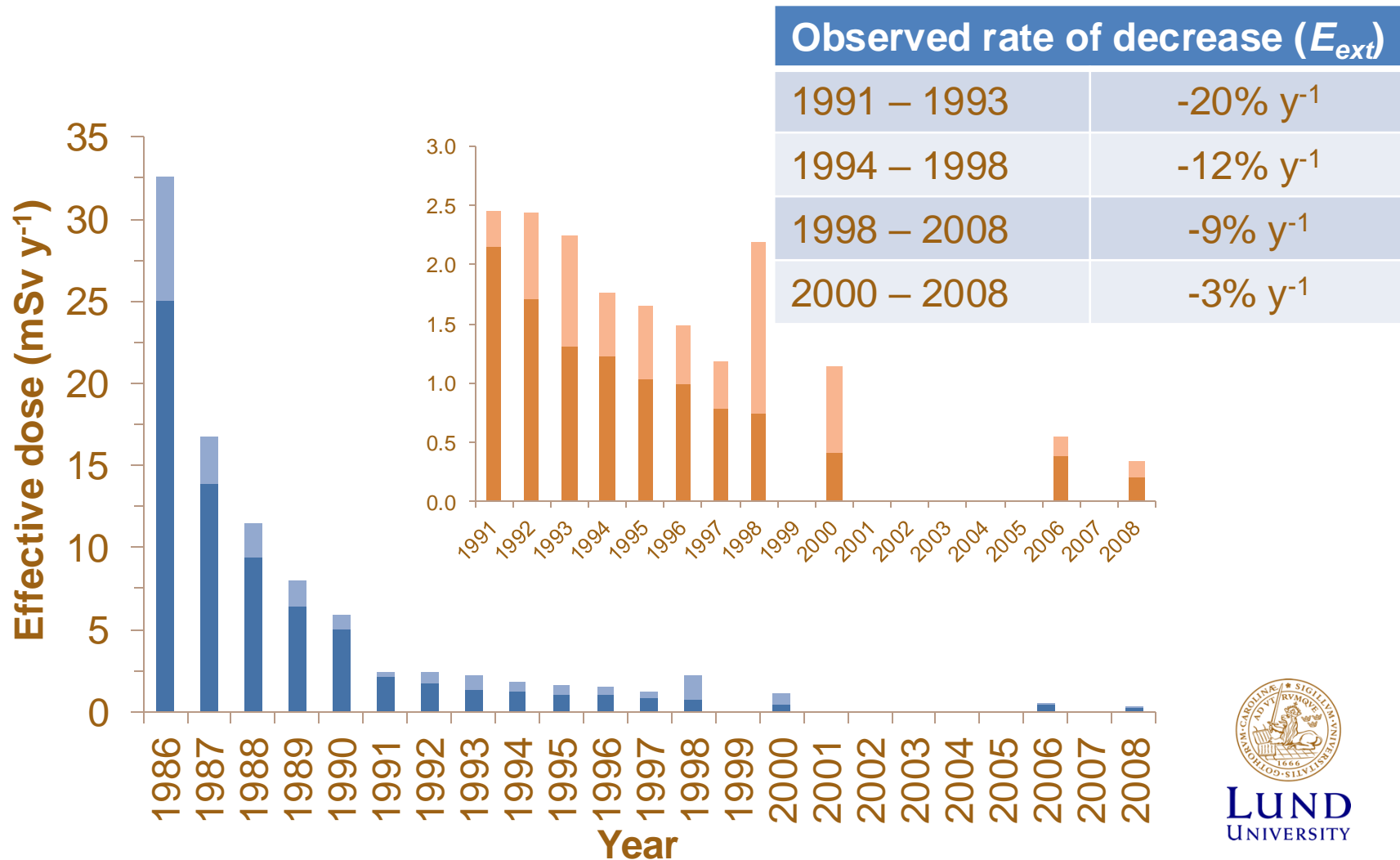


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MEDICINE**

Christian.Bernhardsson@med.lu.se

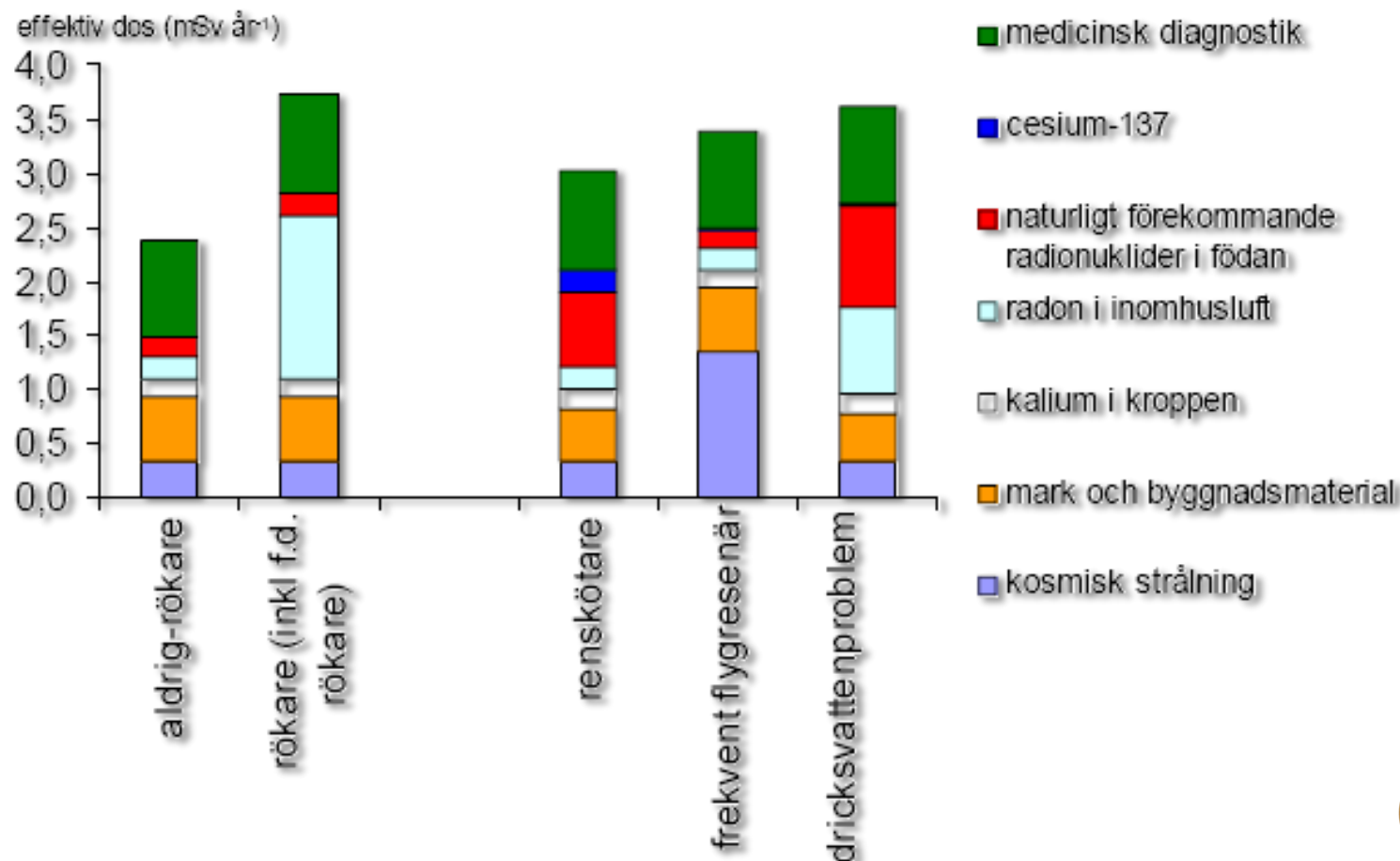
*<https://www.msf-malmo.lu.se/>*

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



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# Genomsnittlig årsdos i Sverige



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