Dosimetry and epidemiological studies in Sweden after the Chernobyl accident

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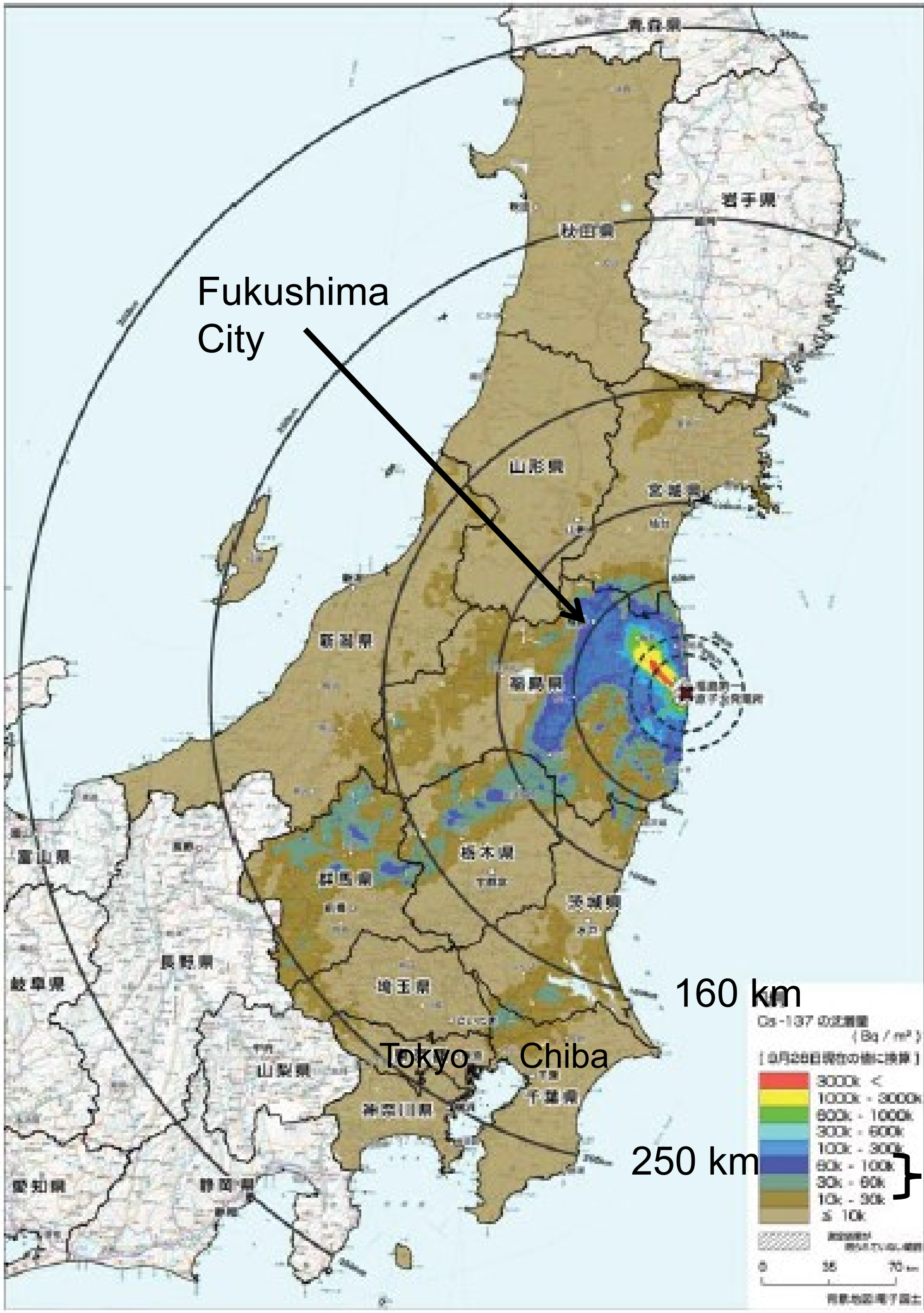
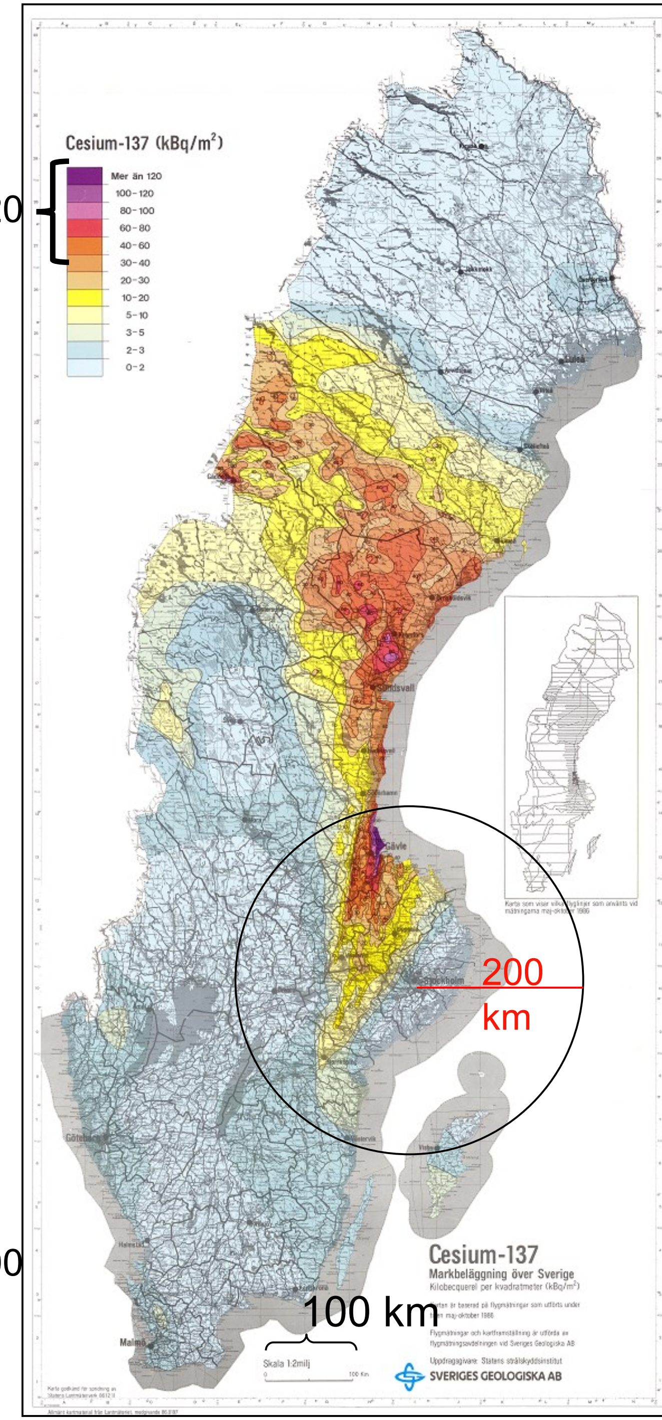
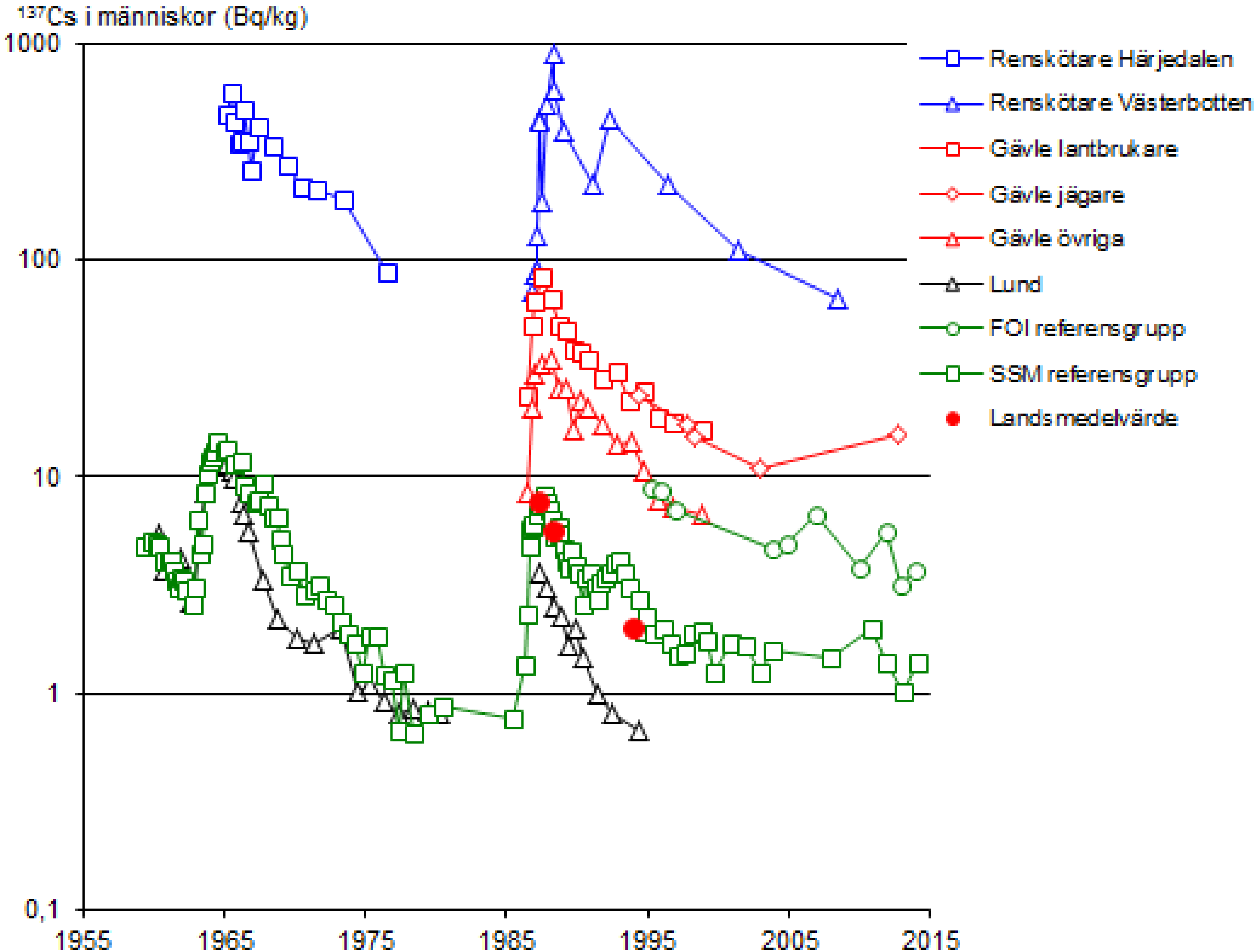
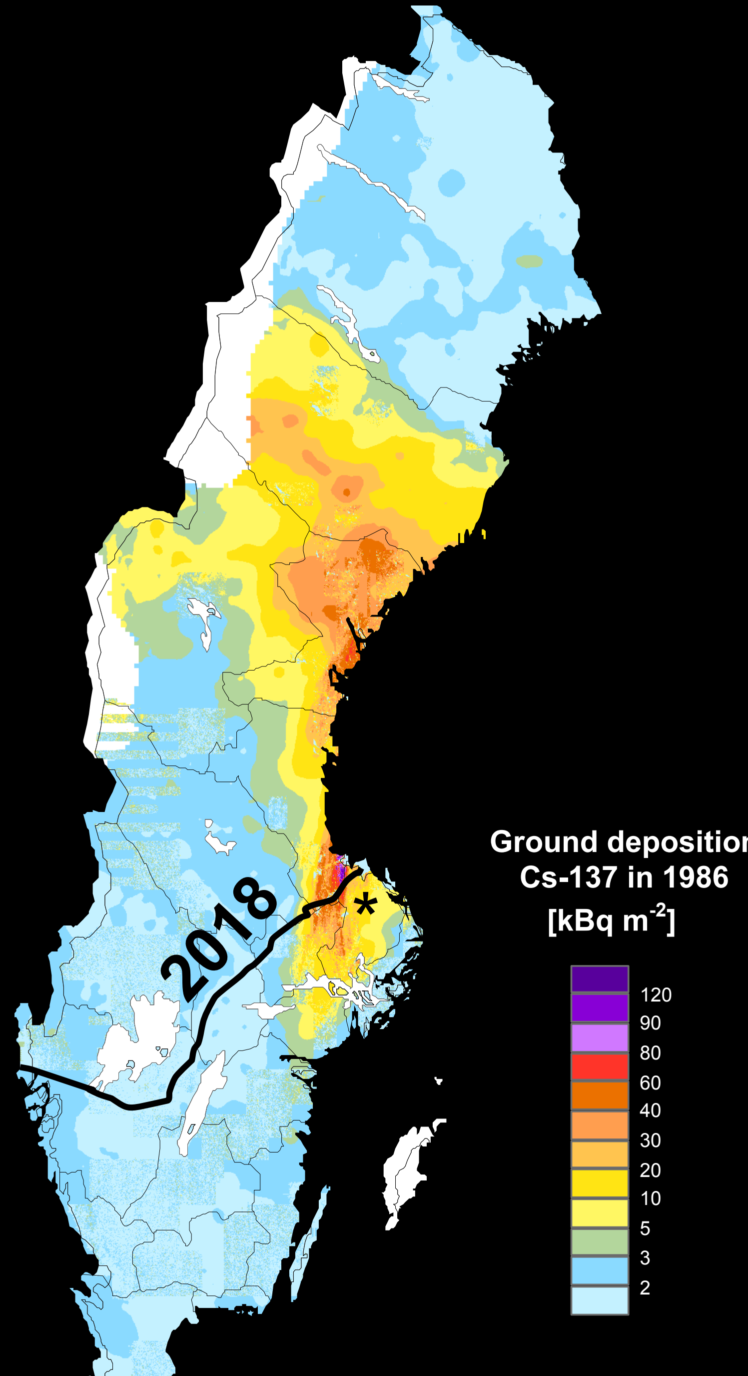

Fukushima City
青森県
岩手県
秋田県
山形県
宮城県
新潟県
福島県
栃木県
群馬県
茨城県
富山県
長野県
岐阜県
埼玉県
山梨県
千葉県
神奈川県
愛知県
静岡県
160 km
250 km
Tokyo
Chiba
Cs-137 の沈着量 (Bq / m²)
3000k <
1000k - 3000k
600k - 1000k
300k - 600k
100k - 300k
60k - 100k
30k - 60k
10k - 30k
≦ 10k
30-100

Cesium-137 (kBq/m²)
Mer än 120
100-120
80-100
60-80
40-60
30-40
20-30
10-20
5-10
3-5
2-3
0-2
30-120
200 km
100 km
Cesium-137
Markbeläggning över Sverige
Kilobecquerel per kvadratmeter (kBq/m²)
SVERIGES GEOLOGISKA AB



http://www.stralsakerhetsmyndigheten.se/Yrkesverksam/Miljoovervakning/Radioaktiva-amnen/Helkroppsmatning/

* Wildboar 13,000 Bq/kg
August 2017



Increase of regional total cancer incidence in north Sweden due to the Chernobyl accident?

J Epidemiol Community Health 2004 Dec;58(12):1011-6

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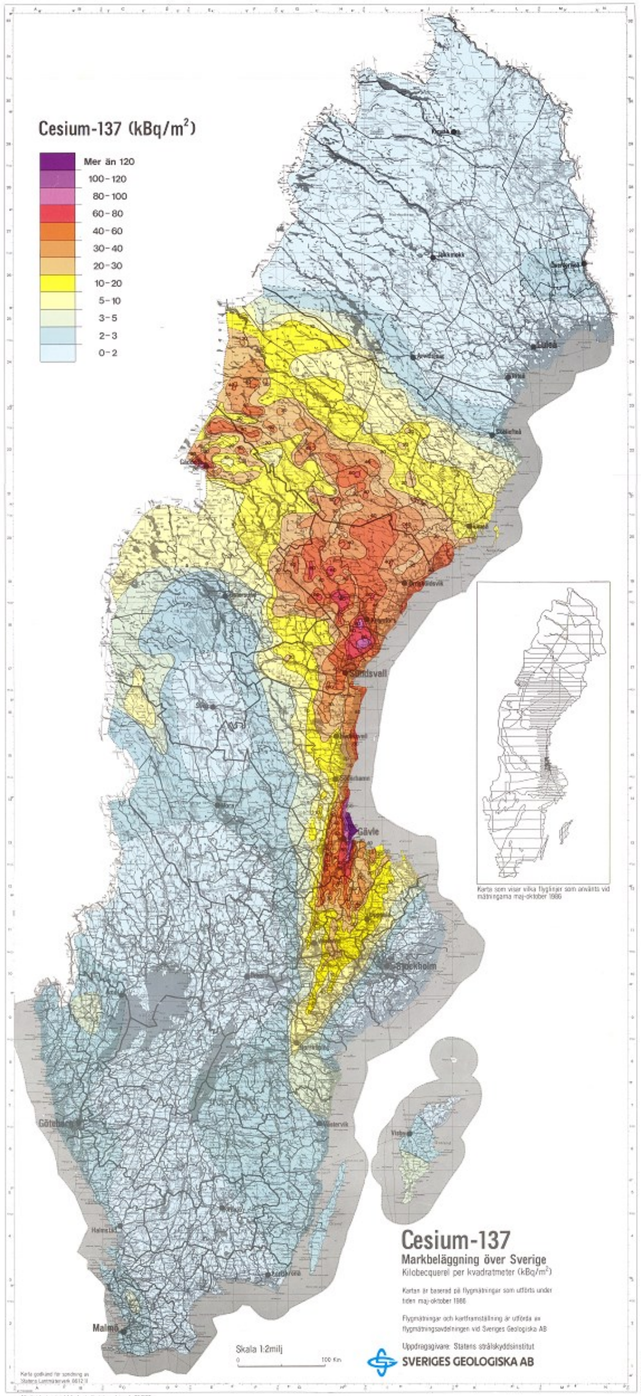
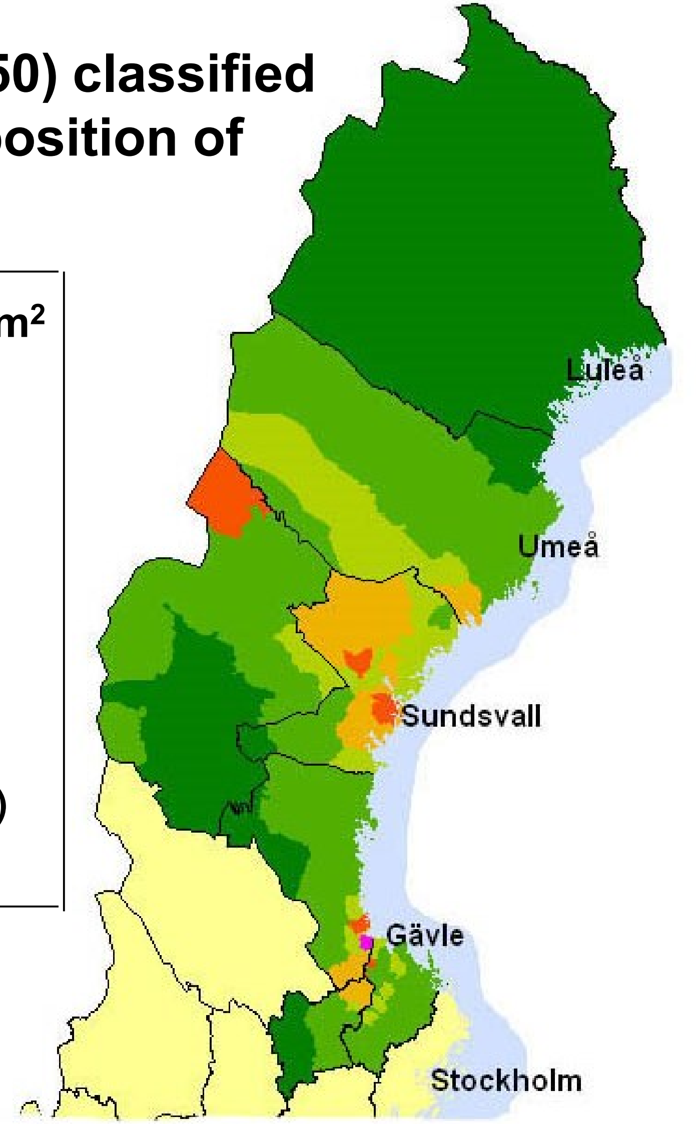
- Inhabitants in 7 out of 21 counties in Sweden
- 0-60 years old 1986
- Same address, Dec 31, 1985 and Dec 31, 1987



Parishes (n=450) classified by ground deposition of Caesium-137

Caesium-137 kBq/m^2	(parishes)
80-120	(1)
60-79	(9)
40-59	(42)
30-39	(41)
3-29	(240)
< 3	(117)



MH-IRR and ERR adjusted for:

A. Population density by parish

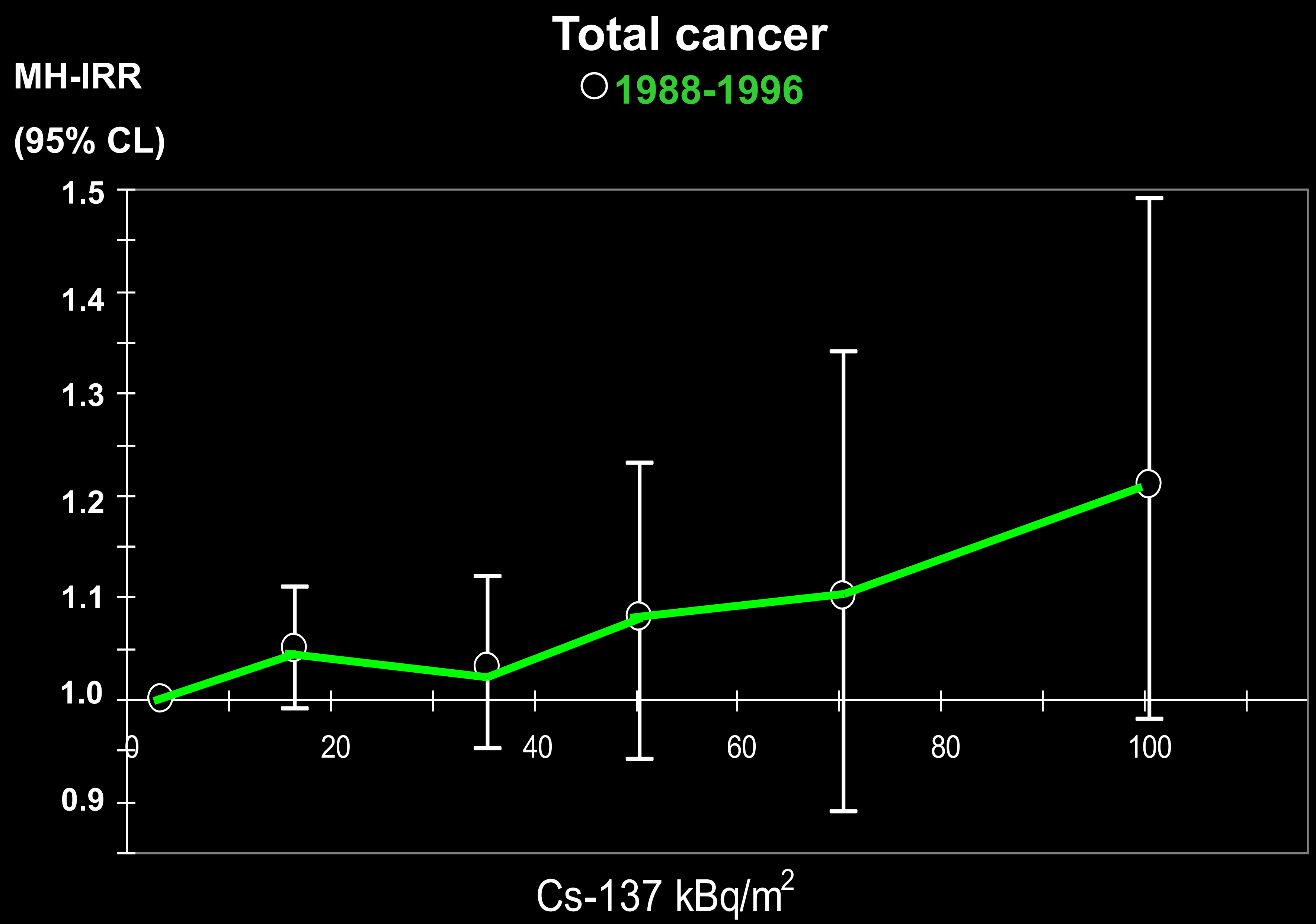
B. Population density by municipality (H-regions)

C. Lungcancer 1988-1996 by municipality (proxy for smoking)

D. Total cancer incidence 1986-1987 (geographic difference)

Population and cancer cases by parish exposure

Cs-137 kBq/m^2 (parishes)	Population 1988 (%)	Cancer cases 1988-1996
< 3 (117)	359,509 (31.4)	6,691
3-29 (240)	527,812 (46.2)	10,378
30-39 (41)	92,323 (8.1)	1,827
40-59 (42)	124,862 (10.9)	2,744
60-79 (9)	21,625 (1.9)	401
80-120 (1)	17,051 (1.5)	368
Total	1,143,182 (100.0)	22,409



Total cancer
1988-1996
MH-IRR
(95% CL)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0
20
40
60
80
100
Cs-137 kBq/m2

Conclusion

- Unless attributable to chance or remaining uncontrolled confounding, a slight exposure related increase in total cancer incidence has occurred in northern Sweden after the Chernobyl accident.

Increased incidence of malignancies in Sweden after the Chernobyl accident–a promoting effect?

Am J Ind Med 2006 Mar;49(3):159-68

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Lennart Hardell
Department of Oncology, University Hospital, Örebro, Sweden

- Inhabitants in 8 out of 21 counties in Sweden
- 0-60 years old 1986
- Same address, Dec 31, 1985 and Dec 31, 1987

Dwelling coordinate (100 m) National Land Survey of Sweden

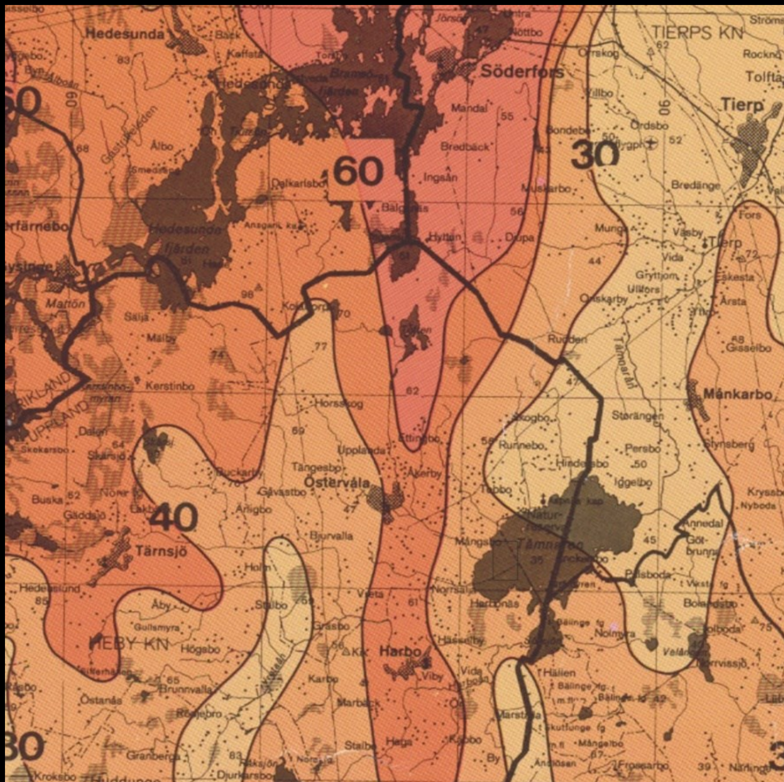
Digital maps (200 x 200 m) Geological Survey of Sweden (TGR) and Swedish Radiation Protection Authority (Cs-137)

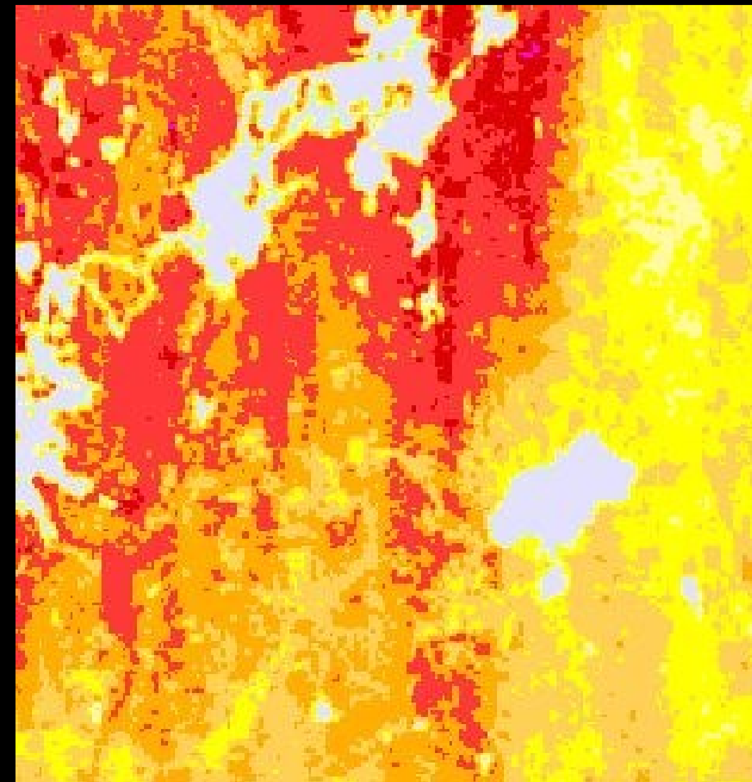
GIS-technique to match dwelling coordinate with TGR and Cs-137

Categories for TGR and Cs-137 with the same proportions of population (30-25-20-15-5-5%)

Analogue map with isolines

Digital map 200 x 200 m





5-10 | 11-20 | 21-30 | 31-40 | 41-60 | 61-80 | 81-200

Cs-137 kBq/m^2

MH-IRR and ERR adjusted for:

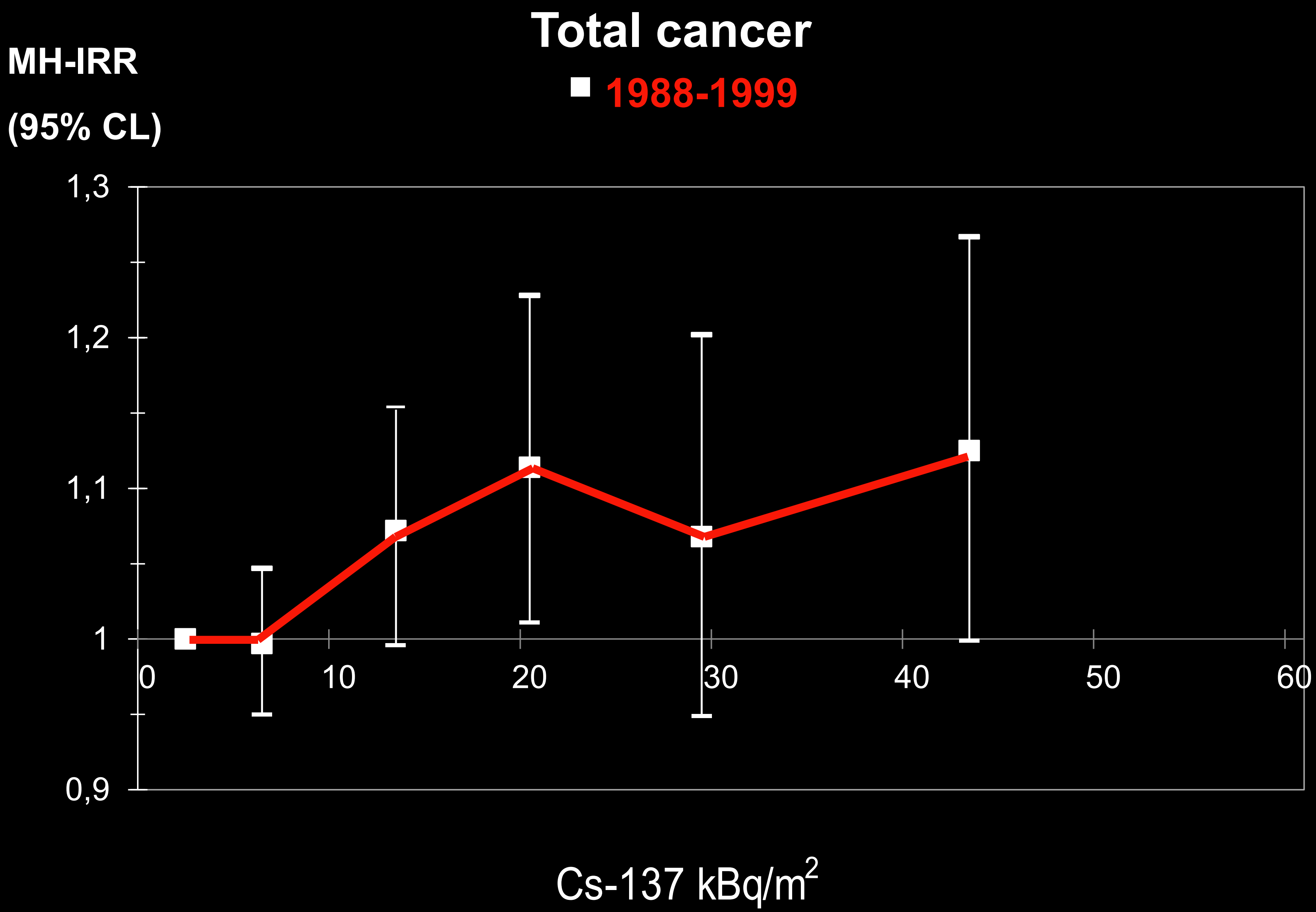
A. Population density by parish

B. Population density by municipality (H-regions)

C. Lungcancer 1988-1999 by municipality (proxy for smoking)

D. Total cancer incidence 1986-1987 (geographic difference)

E. Terrestrial Gamma Radiation (TGR)



Total cancer
1988-1999
MH-IRR
(95% CL)
1,3
1,2
1,1
1
0,9
0
10
20
30
40
50
60
Cs-137 kBq/m2

Conclusion

- Increase in the incidence of total malignancies related to increasing caesium radiation in the time period 1988-1991 which contributes to the increase in the follow-up period 1988-1999.

  After control for confounding factors this increase can be seen in MH-IRR, EAR and ERR.

Total cancer incidence in relation to ^{137}Cs fallout in the most contaminated counties in Sweden after the Chernobyl nuclear power plant accident: a register-based study

BMJ Open. 2016;6:e011924

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[1] Occupational and Environmental Medicine, Department of Medical Sciences, Uppsala University, Uppsala, Sweden

BMJ Open. 2016;6:e011924

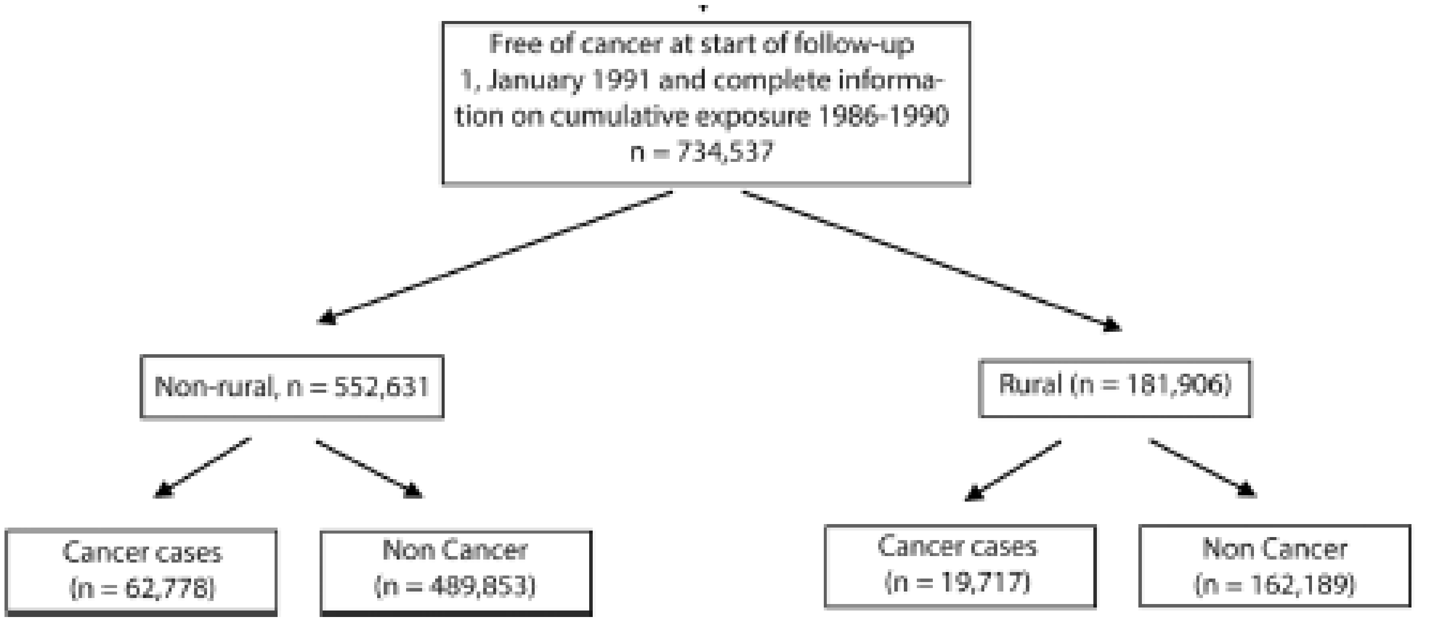

Figure 1 Sample selection in a study of the effect of cumulative caesium-137 exposure from the 1986 Chernobyl nuclear accident on cancer rates in three counties in Sweden, 1991–2010.

BMJ Open. 2016;6:e011924

Cumulative exposure 1986-1990	^{137}Cs kBq/m^2	Cancer 1991-2010 (n)	Adjusted HR* (95% CI)
Q1	0.00 - 45.40	19,772	1.00 (ref)
Q2-3	45.41 - 118.80	41,257	1.03 (1.01 - 1.05)
Q4	118.81 - 564.71	21,466	1.05 (1.03 - 1.07)

*age, sex, residence, pre-Chernobyl incidence 1980-1985

Conclusion

- a small overall exposure – response pattern of the total cancer incidence related to a 5-year cumulative ^{137}Cs exposure based on the place of residence

- given the limitations in our exposure assessment, small risk estimates and overlapping CIs, we cannot claim causal inference

	JECH 2004	AJIM 2006	BMJ Open 2016
Counties	7	8	3
Individuals Follow-up (years) Malignancies Person-years	1,143,182 1988-96 (9 y) 22,409 10,115,849	1,137,106 1988-99 (12 y) 33,851 13,391,362	734,537 1991-2010 (20 y) 82,495 12,672,699
Exposure by Exp to Cs-137	Parish 1986-87 kBq/m^2	Coordinate 1986-87 nGy/h	Coordinate 1986-90 kBq y/m^2
Confounding factors	Age, pop density x 2, lung cancer, cancer pre-Chernobyl	as JECH + TGR	Age, sex, urban/rural, cancer pre-Chernobyl
Risk estimates Time periods ERR per 100 kBq/m^2 (95% CL)	MH-IRR, Poisson regression-RR, EAR, ERR one 0.11 (0.03;0.20)	MH-IRR, ERR, EAR three 0.10 (0.00;0.23)	HR one --
Exp related cases	849 (3.79%)	1,278 (3.78%)	2,401 (2.91%)

Estimated lifetime effective dose to hunters and their families in the three most contaminated counties in Sweden after the Chernobyl nuclear power plant accident in 1986 - A pilot study

J Environ Radioact 2017;177:241-249

Tondel Martin[1], Rääf Christopher[2], Wålinder Robert[1], Mamour Afrah[3], Isaksson Mats[3]

[1] Occupational and Environmental Medicine, Department of Medical Sciences, Uppsala University, Uppsala, Sweden

[2] Radiation Physics, Department of Translational medicine, Lund University, Malmö, Sweden

[3] Department of Radiation Physics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

Aims

Develop algorithms for calculating projected lifetime effective dose for hunters and their family members (internal and external doses)

Method

County	Total population (n=803,702)		Licence for a hunting weapon (n=15,689)		Hunter sample (n=30)		Family members to hunters (n=55)	
	(n)	Mean age	(n)	Mean age	(n)	Mean age	(n)	Mean age
Västernorrland	261,081	40.65	5,999	49.10	10	51.00	18	28.56
Uppsala	254,932	37.40	3,782	49.28	10	46.80	15	35.00
Gävleborg	287,689	40.74	5,908	48.01	10	42.70	22	27.91

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Method

External dose:

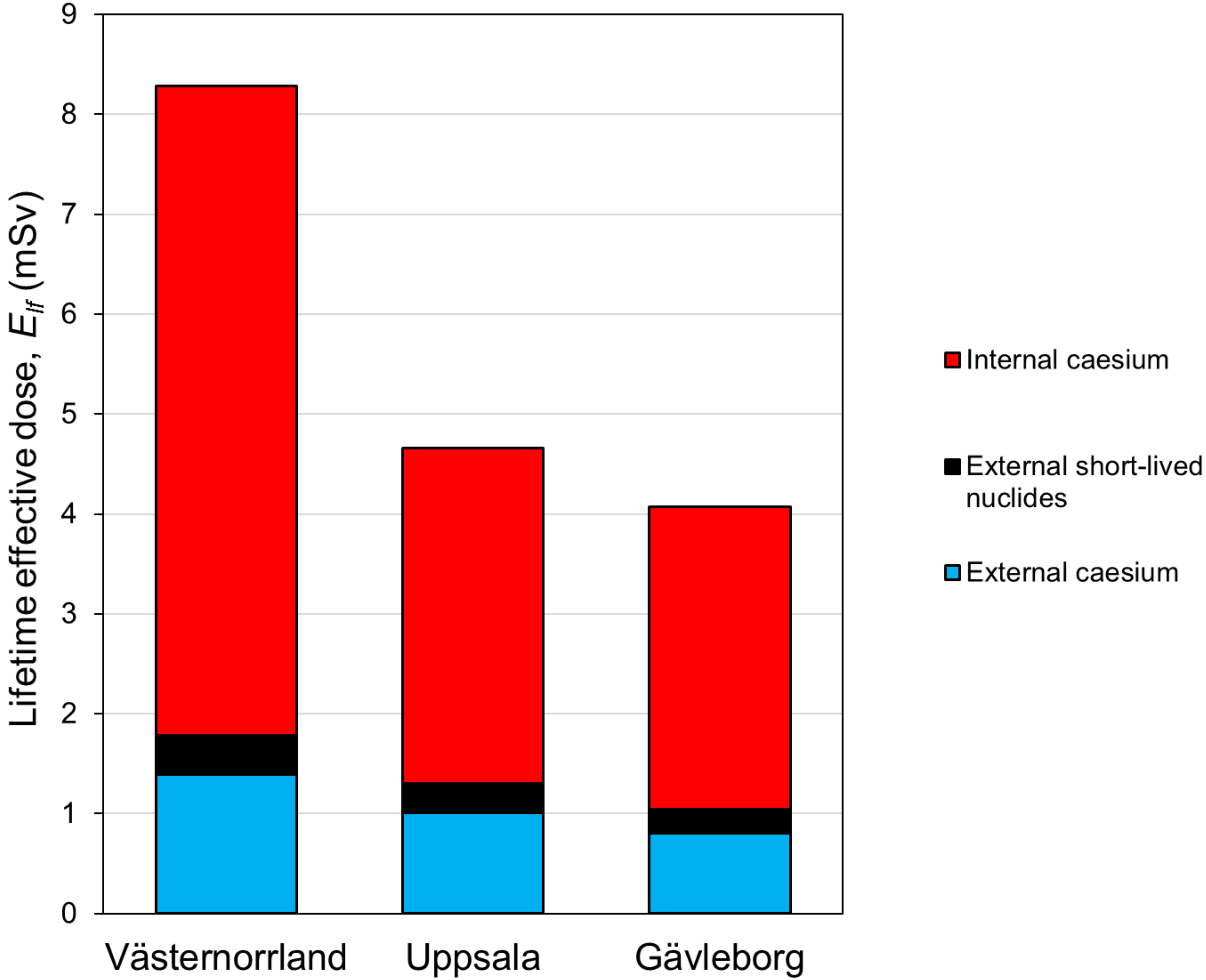
- 134Cs, 137Cs, short-lived
- Occupancy factor
- Shielding snow, building
- Physical decay
- Migration and weathering

Internal dose:

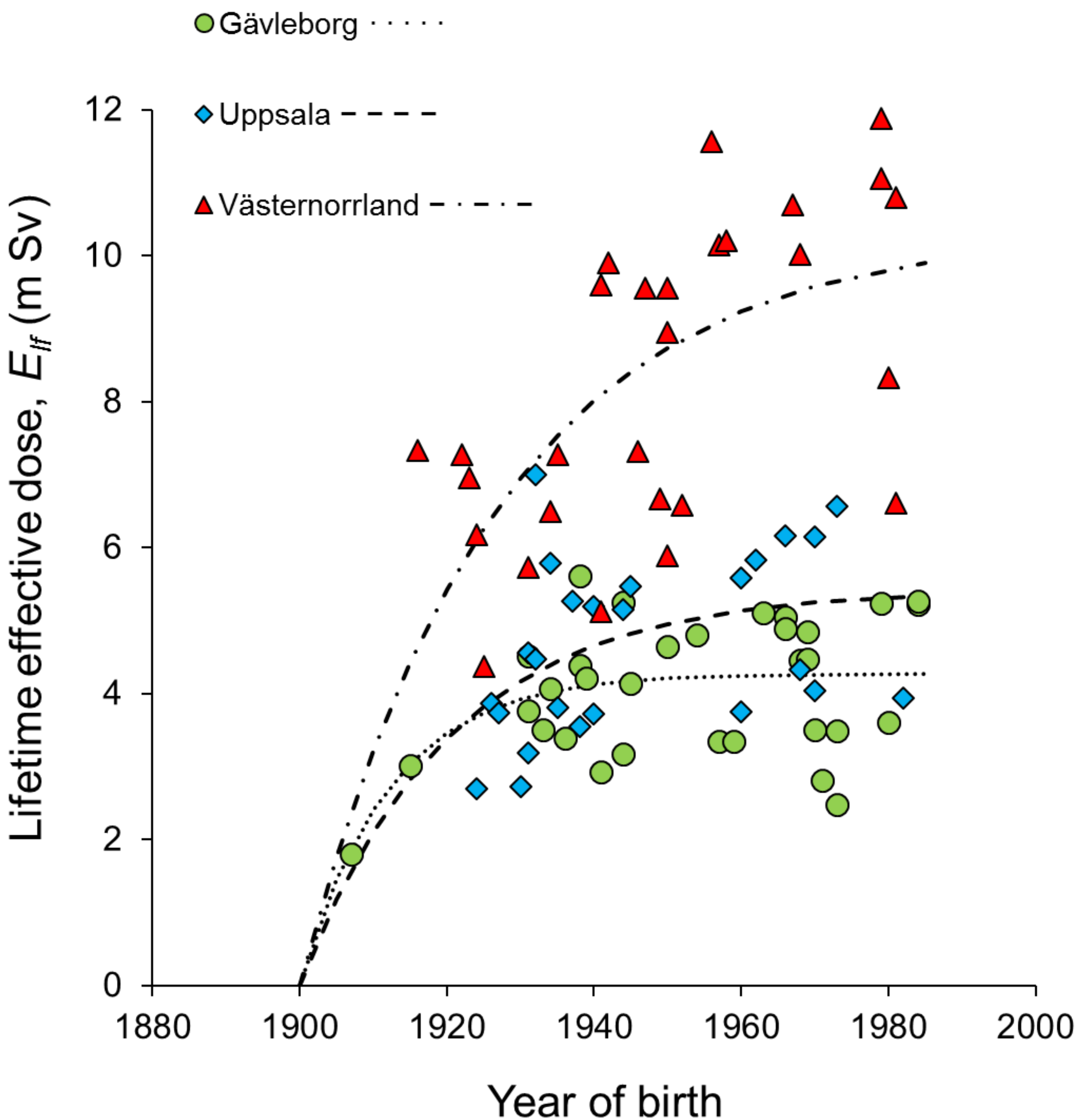
- 134Cs, 137Cs
- Transfer to internal dose
- age
- Sex
- Weight

$$E_{lt,Cs-137} = \int_{1986.33}^{1986.33+TLife} \{A_{esd} \cdot d_{Cs} \cdot f_{Cs-137}(t) \cdot r(t) \cdot \Phi_{\Delta/H} \cdot F_{snow} \cdot F_{rot} \cdot \left[F_{out} + (1 - F_{out}) \cdot F_{sh}\right]$$
$$+ 0.0014 \cdot A_{esd}(county) \cdot T_{ag,peak} \cdot \left[\left(1 - e^{-(\ln 2/1.1)\cdot(t-1986.33)}\right) \cdot \left(0.9 \cdot e^{-(\ln 2/1.2)\cdot(t-1986.33)}\right) + 0.11 \cdot e^{-(\ln 2/30)\cdot(t-1986.33)}\right] \cdot w^{0.111} \cdot k_s\} dt \quad (14)$$

Projected lifetime effective doses, E_{lf} (mSv) cumulated for each individual to 79.9 y for men and 83.7 y for women, respectively



9
8
7
6
5
4
3
2
1
0
Lifetime effective dose, E_{lf} (mSv)
Västernorrland
Uppsala
Gävleborg
Internal caesium
External short-lived nuclides
External caesium


Gävleborg
Uppsala
Västernorrland
Lifetime effective dose, E_{lf} (m Sv)
Year of birth
0
2
4
6
8
10
12
1880
1900
1920
1940
1960
1980
2000

Conclusion

- Possible to use register data to develop algorithms for calculating projected lifetime effective dose for hunters and their family members

- The lifetime dose for the individuals is dominated by the internal-dose contribution, basically driven by county, male sex and age

References

1. Tondel M, Carlsson G, Hardell L, Eriksson M, Jakobsson S, Flodin U, Sköldestig Å, Axelson O. Incidence of neoplasms in ages 0-19 y in parts of Sweden with high ^{137}Cs fallout after the Chernobyl accident. Health Physics 1996;71:947-950
2. Tondel M, Hjalmarsson P, Hardell L, Carlsson G, Axelson O. Increase of regional total cancer incidence in north Sweden due to the Chernobyl accident? J Epidemiol Community Health 2004;58:1011-1016.
3. Tondel M, Arynchyn A, Jönsson P, Persson B, Tagesson C. Urinary 8-hydroxydeoxyguanosine in Belarussian children relates to urban living rather than radiation dose after the Chernobyl accident: a pilot study. Arch Environ Contam Toxicol 2005;48:515-519.
4. Tondel M, Lindgren P, Hjalmarsson P, Hardell L, Persson B. Increased incidence of malignancies in Sweden after the Chernobyl accident – a promoting effect? Am J Ind Med 2006;49:159-168.
5. Tondel M, Lindgren P, Garvin P, Persson B. Parish classification or dwelling coordinate for exposure assessment in environmental epidemiology - a comparative study using Geographical Information System. Sci Total Environ. 2008;405:324-329.
6. Alinaghizadeh H, Tondel M, Walinder R. Cancer incidence in northern Sweden before and after the Chernobyl nuclear power plant accident. Radiat Environ Biophys. 2014;53:495-504
7. Alinaghizadeh H, Wålinder R, Vingård E, Tondel M. Total cancer incidence in relation to 137Cs fallout in the most contaminated counties in Sweden after the Chernobyl nuclear power plant accident: a register-based study. BMJ Open. 2016;6:e011924
8. Svendsen ER, Yamaguchi I, Tsuda T, Guimaraes JR, Tondel M. Risk Communication Strategies: Lessons Learned from Previous Disasters with a Focus on the Fukushima Radiation Accident. Curr Environ Health Rep. 2016 Dec;3(4):348-359.
9. Tondel M, Rääf C, Wålinder R, Mamour A, Isaksson M. Estimated effective dose to hunters and their families in the three most contaminated counties in Sweden after the Chernobyl Nuclear Power Plant Accident in 1986 – a pilot study. J Environ Radioact 2017;177:241-249.
10. Jönsson M, Tondel M, Isaksson M, Finck R, Wålinder R, Mamour A, Rääf C. Modelling the external radiation exposure from the Chernobyl fallout using data from the Swedish municipality measurement system. J Environ Radioact. 2017;178-179:16-27.
11. Tondel M, Granath G, Wålinder R. 137Cs activity in Sweden after the Chernobyl Nuclear Power Plant accident in relation to quaternary geology and land use. Appl Geochem 2017;87:38-43
12. Rääf C, Tondel M, Isaksson M. A model for estimating the total absorbed dose to the thyroid in Swedish inhabitants following the Chernobyl Nuclear Power Plant accident: Implications for existing international estimates and future model applications. J Radiol Prot. 2019 Feb 8. [Epub ahead of print]
13. Isaksson M, Tondel M, Wålinder R, Rääf C. Modelling the effective dose to a population from fallout after a nuclear power plant accident-A scenario-based study with mitigating actions. PLoS One. 2019 Apr 9;14(4):e0215081.

Epidemiological studies after FDNPP accident?

- Which health outcomes to study
- Vulnerable groups
- Study design
- Case definition
- Confounding factors
- Exposure assessment
- Statistical power
- Ethical considerations
- Collaboration