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Assessment of radiological impact from nuclear installations

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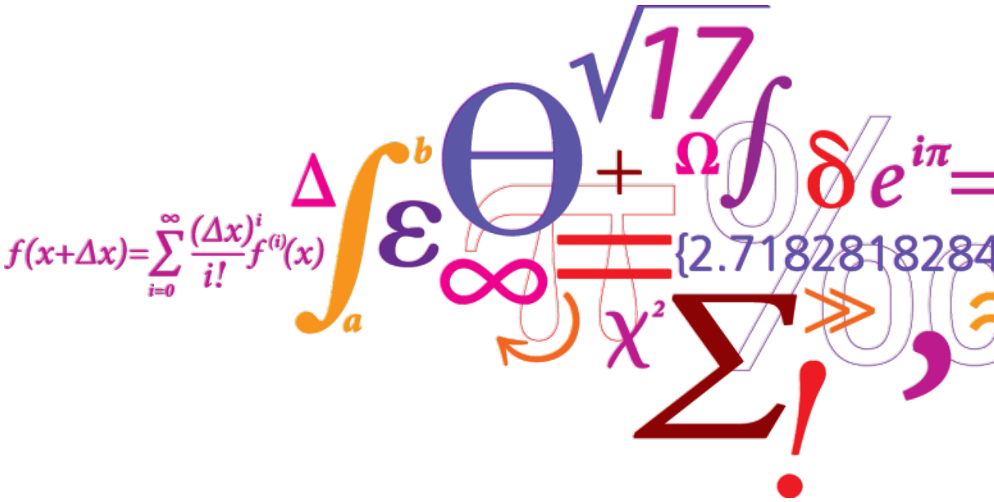
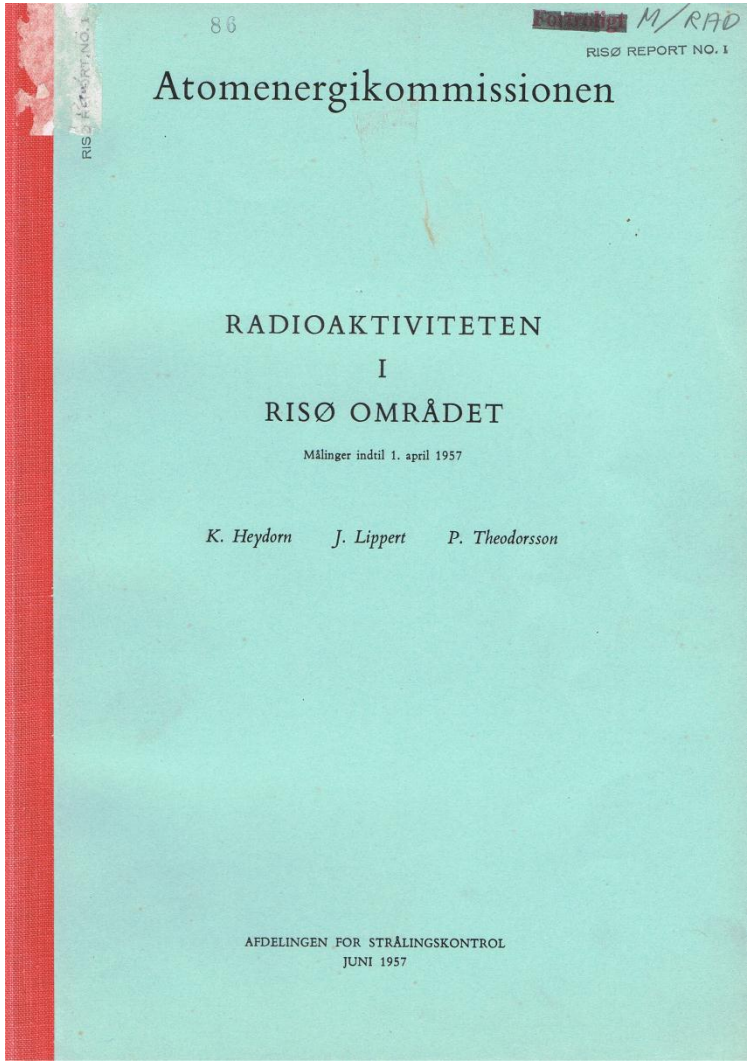
Assessment of radiological impact from nuclear installations

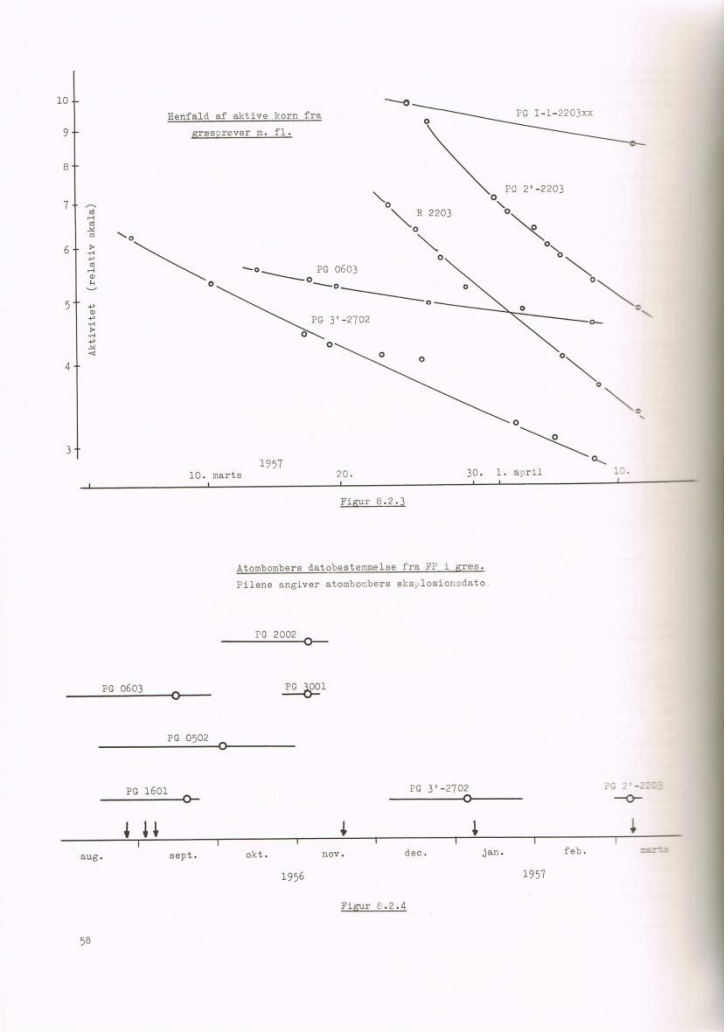
Sven P. Nielsen



DTU Nutech
Center for Nuclear Technologies

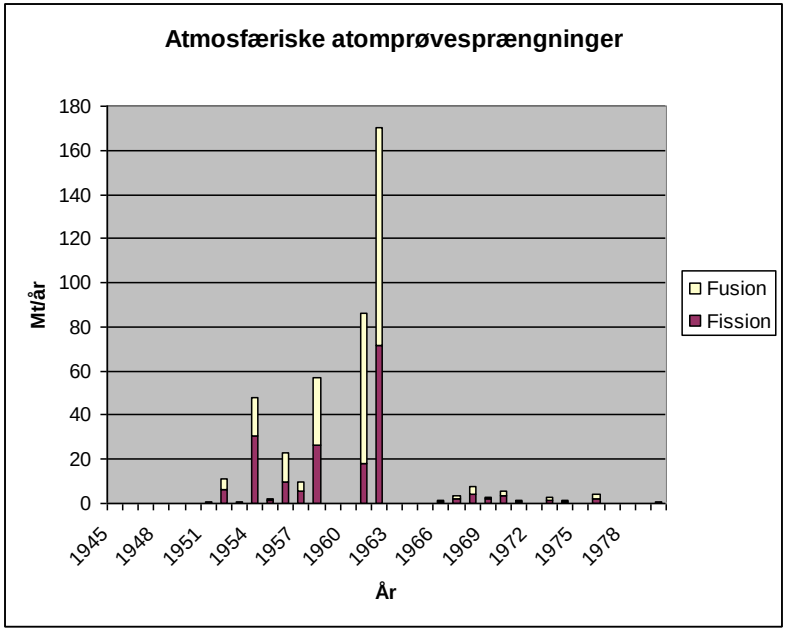
Investigations of man-made radioactivity in the Danish environment from 1957

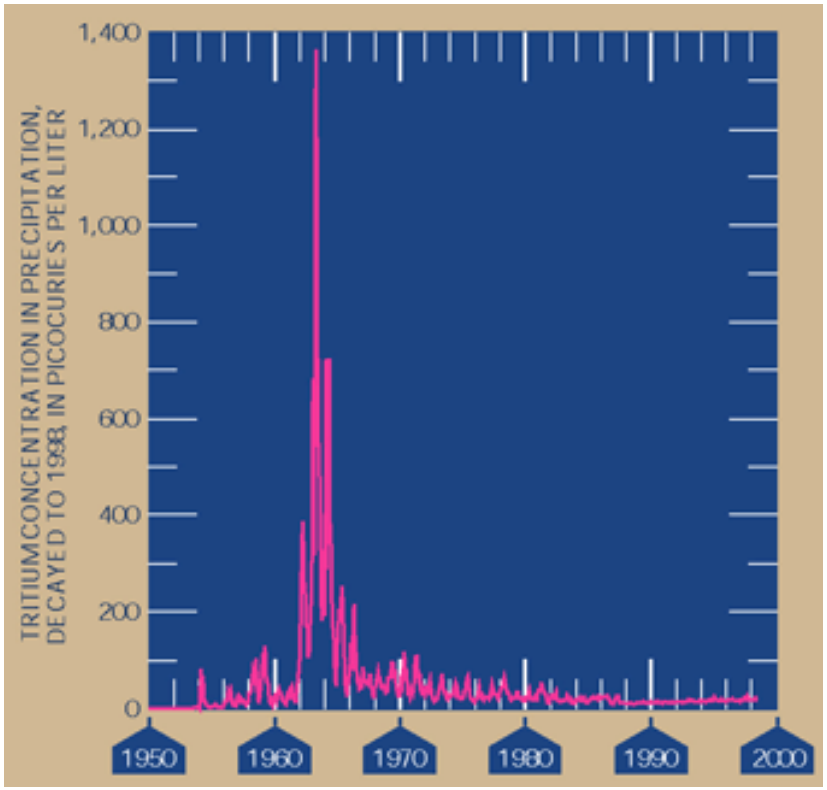


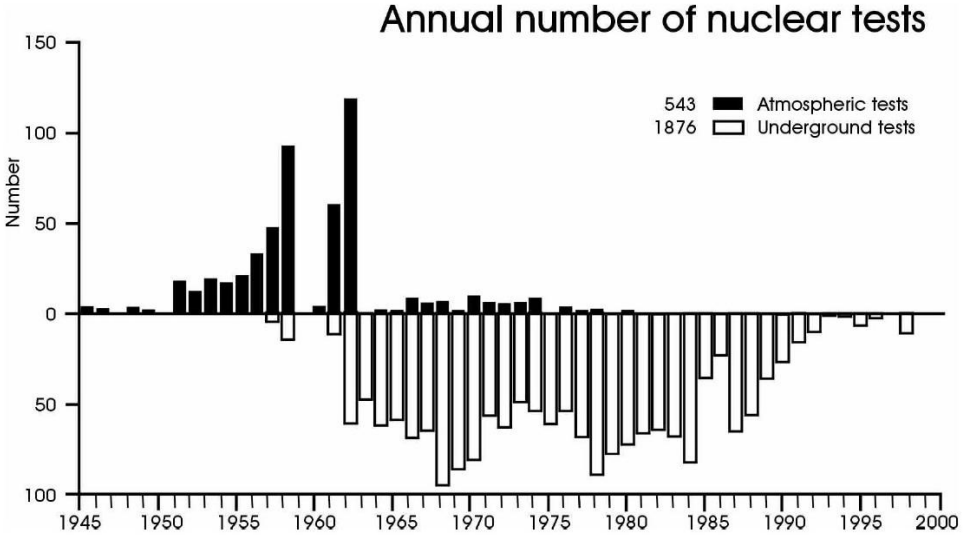


Atmospheric nuclear weapons tests

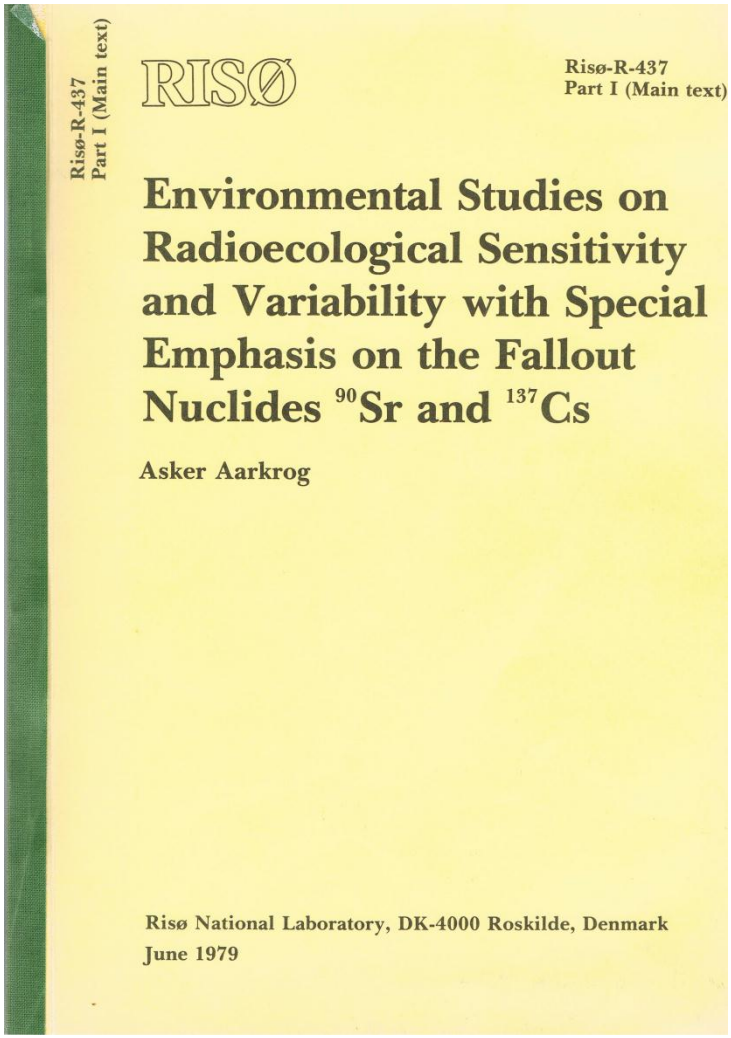
Global pollution from atmospheric nuclear weapons tests: fission products, activation products, fissile material and tritium.







Radioecological sensitivity



- Studies covering
  - Air, water, soil
  - Grain, bread
  - Grass
  - Vegetables and fruit
  - Sea plants
  - Milk, meat, fish
  - Total diet
  - Human body, bone
- Radioecological sensitivity of a sample type is the infinite time integral of appropriate quantities of the sample type from an appropriate quantity of the radionuclide deposited
- Example for Cs-137 in Danish cow's milk
  - 2.0 Bq/L d per Bq/m^2

Strontium-90 in ground-level air at Risø

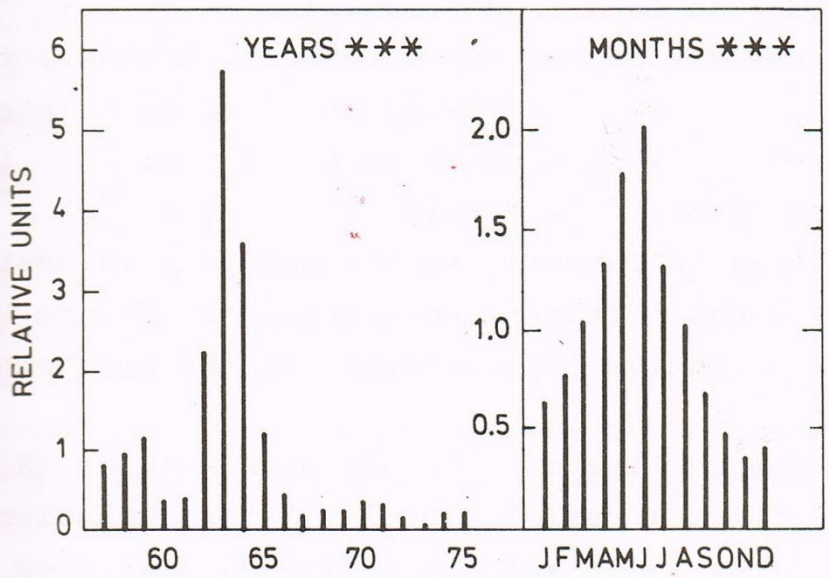
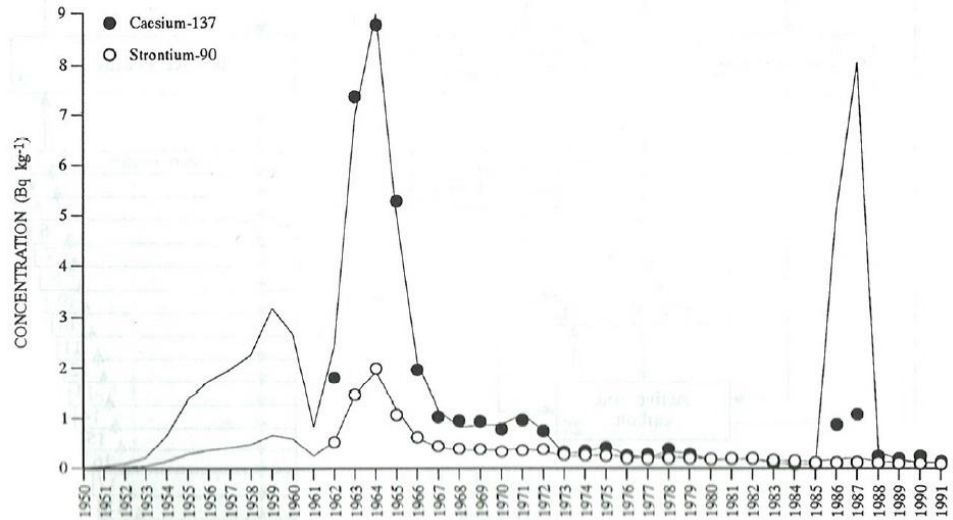


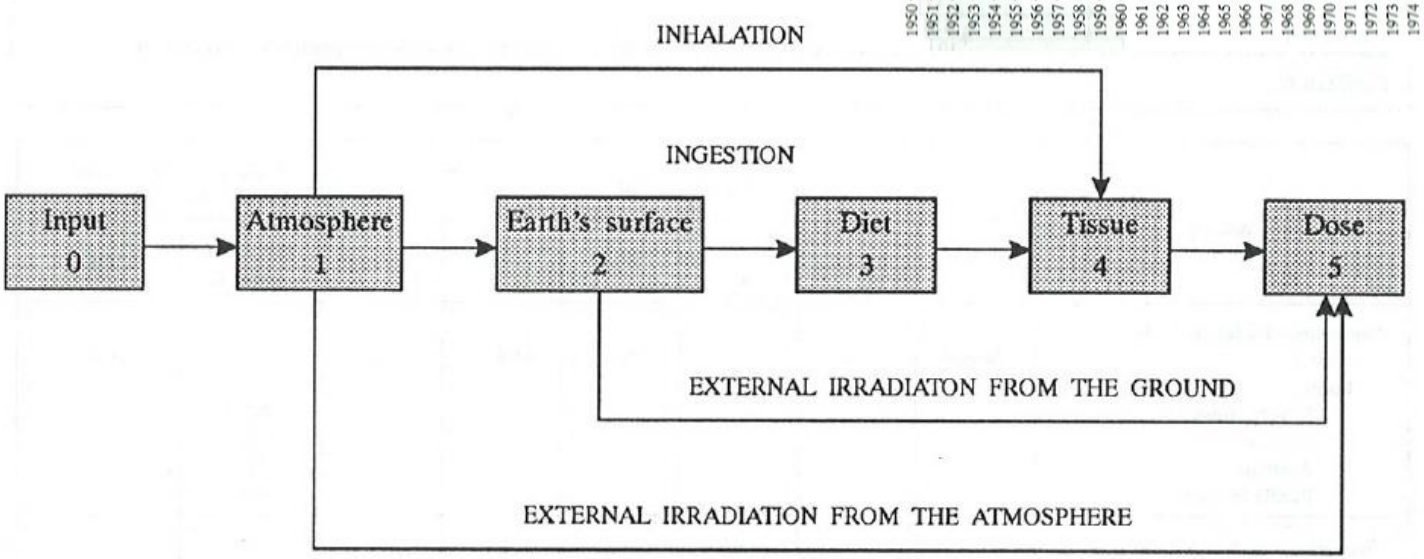
Fig. 1.2.1. The annual and monthly variation of ^{90}Sr in ground-level air collected at Risø 1957-1975. The bars indicate the air concentrations relative to the grand mean: 5.31 fCi m^{-3} (= 1 at the relative scales).

- Maximum concentrations in 1963 following the 1962 test series before moratorium
- Maximum within year occurring in May-June and minimum in November-December

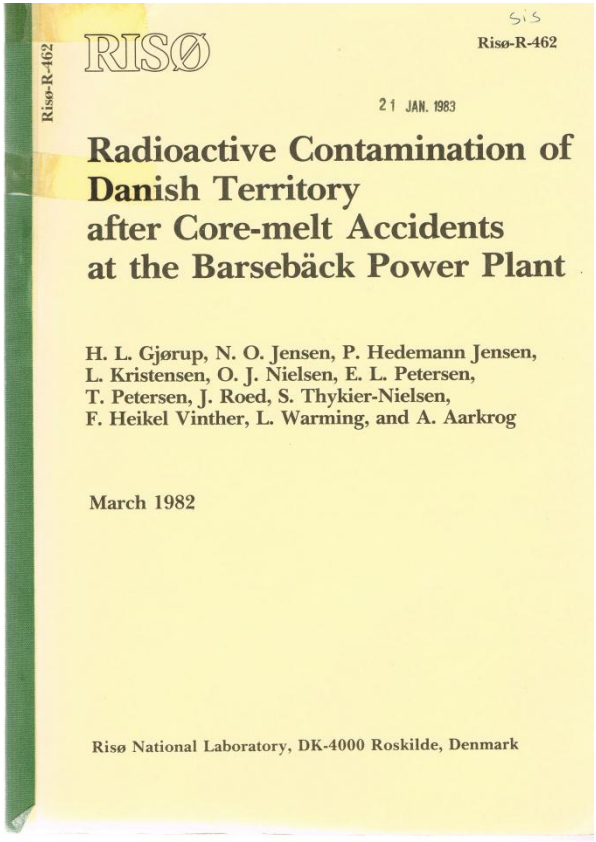
Radioecological models

- Nuclear weapons fallout of Cs-137 in Denmark
  - Time-integrated air concentration during 1957-1975: 3 Bq/m^3 d
  - Ingestion dose: 0.3 mSv
  - External dose: 0.5 mSv
  - Total 0.8 mSv





Radioactive contamination in Denmark after accidents at Barsebäck nuclear power plant



Risø-R-462

RISØ

Risø-R-462

21 JAN. 1983

Radioactive Contamination of Danish Territory after Core-melt Accidents at the Barsebäck Power Plant

H. L. Gjørup, N. O. Jensen, P. Hedemann Jensen, L. Kristensen, O. J. Nielsen, E. L. Petersen, T. Petersen, J. Roed, S. Thykier-Nielsen, F. Heikel Vinther, L. Warming, and A. Aarkrog

March 1982

Risø National Laboratory, DK-4000 Roskilde, Denmark

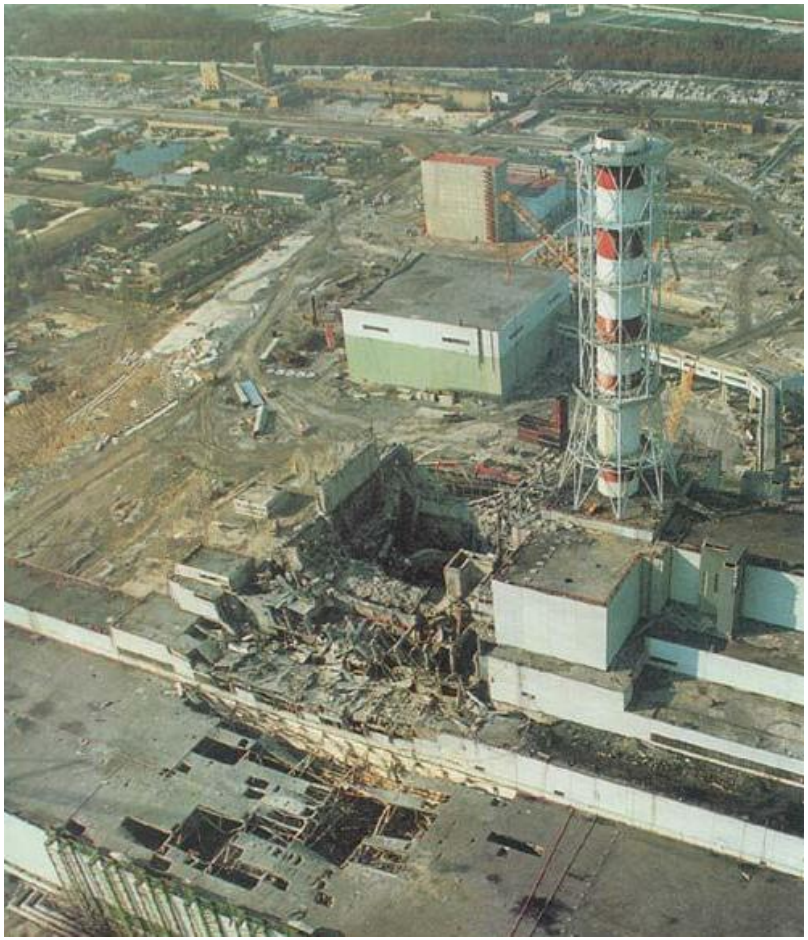
Table 10.20. Collective committed effective dose equivalents from foodstuffs contaminated in the BWR-2 case and the BWR-3 case

Mmanrem

	Agricultural products on Zealand		Marine products		Total	
	BWR-2	BWR-3	BWR-2	BWR-3	BWR-2	BWR-3
No foodstuffs destroyed	196	22.5	1	0.2	197	22.7
Foodstuffs produced on the soil during year "0" are destroyed	28	3.5	1	0.2	29	3.7
Foodstuffs produced on the soil during year "0" and "1" are destroyed	8	0.8	1	0.2	9	1.0
Agricultural production limited to barley and pigs	0.7	0.02	1	0.2	1.7	0.2
Agricultural production limited to seed-growing, sugar beet and potatoes	0.4	0	1	0.2	1.4	0.2

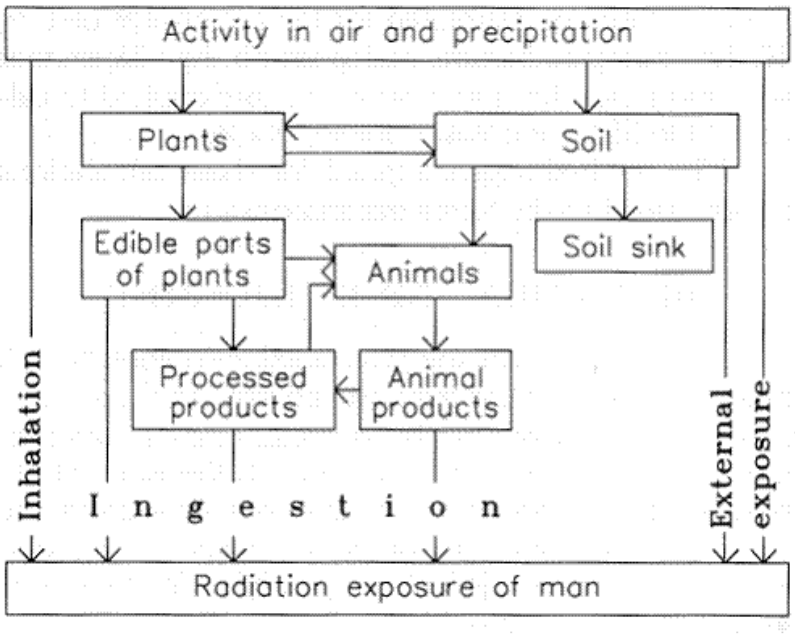
Chernobyl accident, 26 April 1986

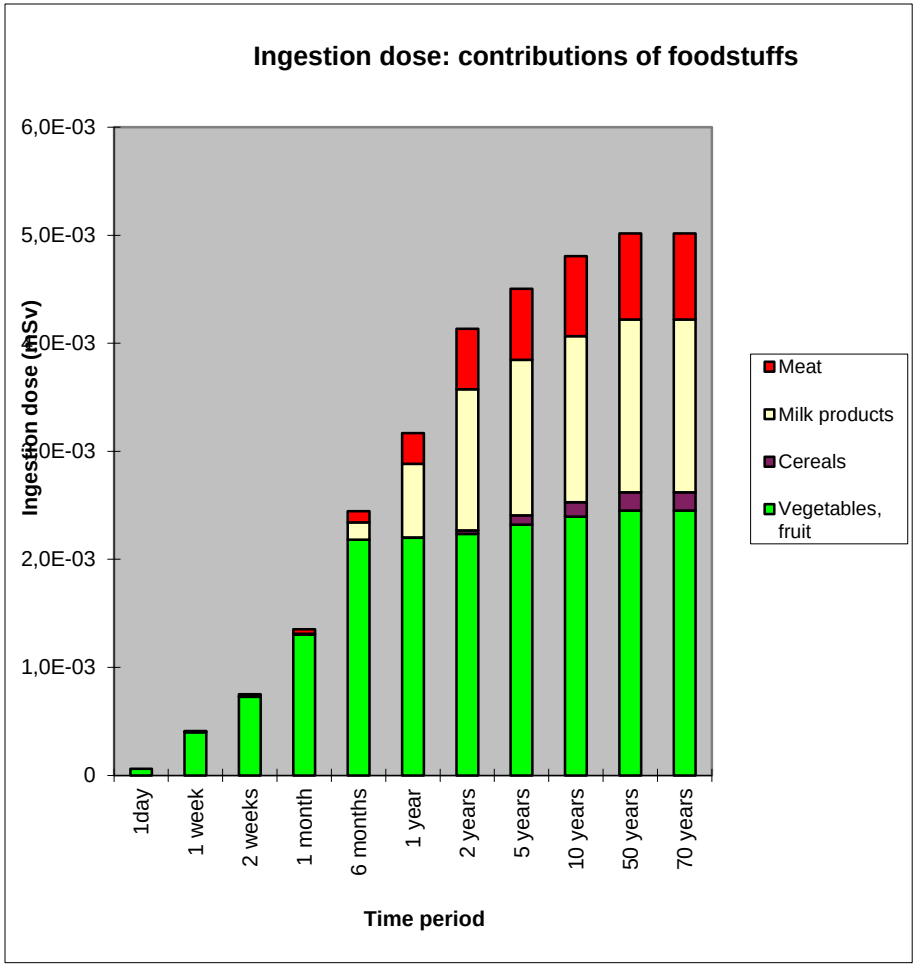
- Time-integrated concentration in air of Cs-137 in Denmark from Chernobyl was 0.3 Bq/m^3 d
- Rapid estimate of average doses to individuals based on experience from nuclear weapons fallout
  - 0.03 mSv from ingestion
  - 0.05 mSv from external exposure
  - 0.08 mSv in total
- However, this estimate turned out to be too large (about 5 times) due to Chernobyl fallout occurring in May early in the growing season while nuclear weapons fallout occurred more evenly over the year, effect of seasonality



Foodchain modelling after Chernobyl accident

ECOSYS, Food and Dose Module
Dynamic modelling of radionuclide transfer through foodchains taking seasonality into account, site-specific parameters etc.

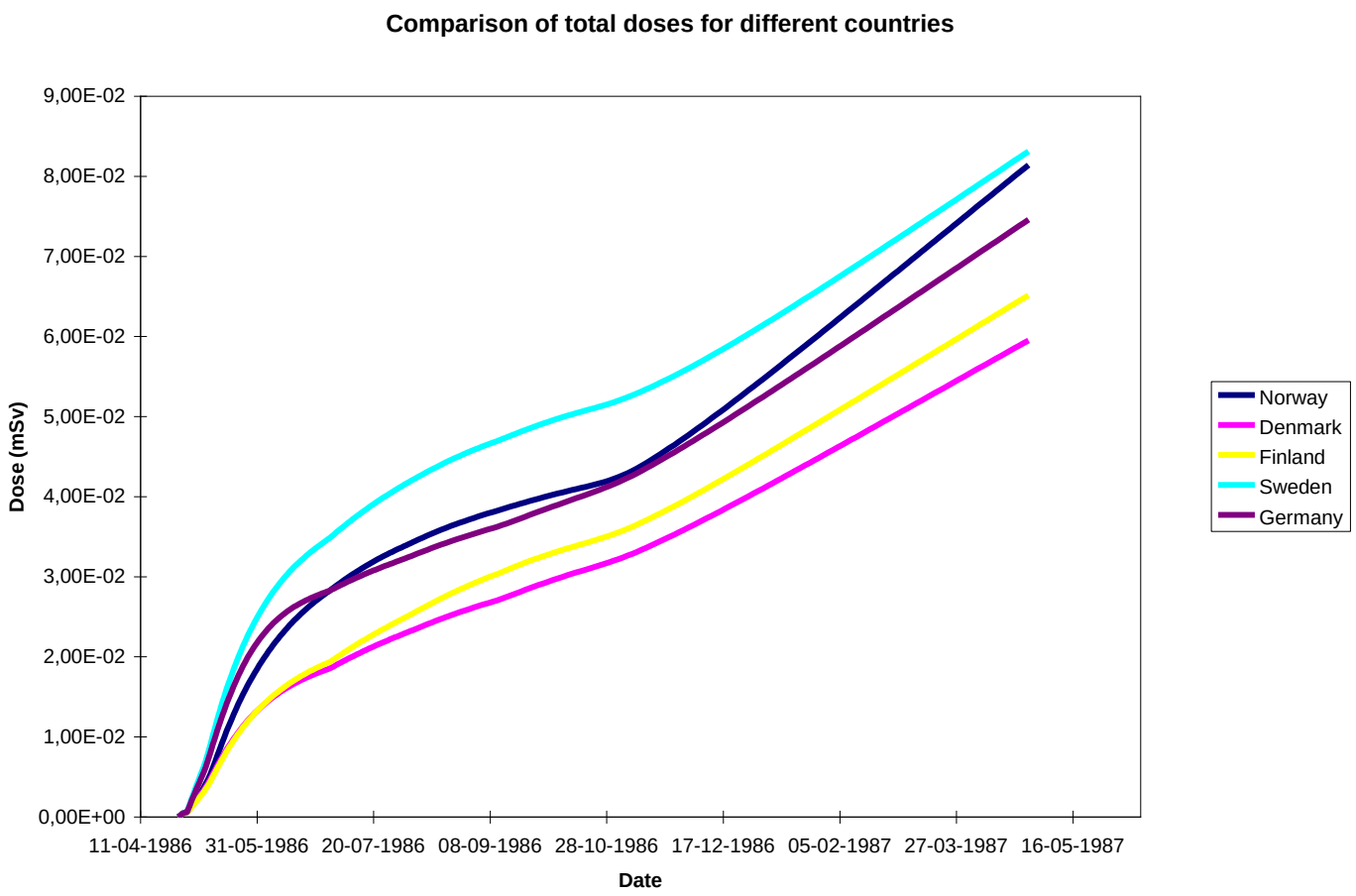




ECOSYS used in decision support systems

- ECOSYS foodchain model used in RODOS and ARGOS decision support systems applied by national authorities to predict consequences of potential accidents at nuclear facilities from releases of radioactivity to air
- Model predictions used as input for decisions on possible countermeasures such as evacuation, food ban, etc.
- ECOSYS model parameters examined in projects identifying values valid for Nordic and general conditions, e.g. dry and wet deposition, weathering, growing season, soil-to-plant transfer, human diet, animal feeding regime

Estimates of accumulated individual ingestion doses for the average adult population in each of the Nordic countries, using nation-specific dietary information: ECOSYS runs based on the ^{137}Cs air concentrations, rainfall and wet deposition recorded at Tranvik (Sweden) in the first month after the Chernobyl accident.



Radiological impact on public from ESS

- ECOSYS model applied to predict radiological impact on representative persons near ESS from routine operation and accidents
- Representative persons (critical group) assumed to live 330 m from ESS and consume locally produced foodstuffs and drink local well water
- Atmospheric dispersion estimated with Gaussian plume model
- Challenging spectrum of radionuclides from ESS requiring data not known from nuclear power plants, transfer estimated based on chemical analogues

Table 1. Calculated external doses from the contaminated plume from exposure to 1 Bqs m^{-3} of various radionuclides to the atmosphere from the ESS facility, shown together with calculated external doses to people living at a distance of 330 m south of the ESS facility from each Bq released to the atmosphere.

Radionuclide	$T_{½}$, s	Sv per Bq s /m^3	Sv per Bq released
H-3	3.90E+08	0	0
Be-7	4.60E+06	2.36E-15	1.11E-19
Ar-41	6.60E+03	6.50E-14	3.06E-18
I-120	4.86E+03	1.38E-13	6.49E-18
I-121	7.63E+03	1.94E-14	9.12E-19
I-123	4.75E+04	7.28E-15	3.42E-19
I-124	3.61E+05	5.38E-14	2.53E-18
I-125	5.20E+06	5.22E-16	2.45E-20
I-126	1.12E+06	2.15E-14	1.01E-18
I-130	4.45E+04	1.04E-13	4.89E-18
I-131	6.93E+05	1.82E-14	8.55E-19
I-132	8.26E+03	1.12E-13	5.26E-18
I-133	7.49E+04	2.94E-14	1.38E-18
Gd-146	4.17E+06	9.95E-15	4.68E-19
Gd-148	2.35E+09	0	0
Tb-149	1.49E+04	8.02E-14	3.77E-18
Tm-167	7.98E+05	6.06E-15	2.85E-19
Tm-170	1.11E+07	2.23E-16	1.05E-20
Yb-169	2.77E+06	1.29E-14	6.06E-19
Lu-170	1.73E+05	1.28E-13	6.02E-18
Lu-171	7.12E+05	3.25E-14	1.53E-18
Lu-172	5.79E+05	9.25E-14	4.35E-18
Lu-173	4.32E+07	5.10E-15	2.40E-19
Hf-172	5.90E+07	4.06E-15	1.91E-19
Hf-175	6.05E+06	1.69E-14	7.94E-19
Ta-179	5.75E+07	1.09E-15	5.12E-20
Ta-182	9.89E+06	6.40E-14	3.01E-18
Ta-183	4.41E+05	1.31E-14	6.16E-19
W-185	6.49E+06	5.37E-18	1.07E-18
W-187	8.54E+04	2.28E-14	2.52E-22
Re-186	3.26E+05	9.19E-16	4.32E-20
Re-188	6.12E+04	2.87E-15	1.35E-19

Doses estimated from ESS Design Basis Accident

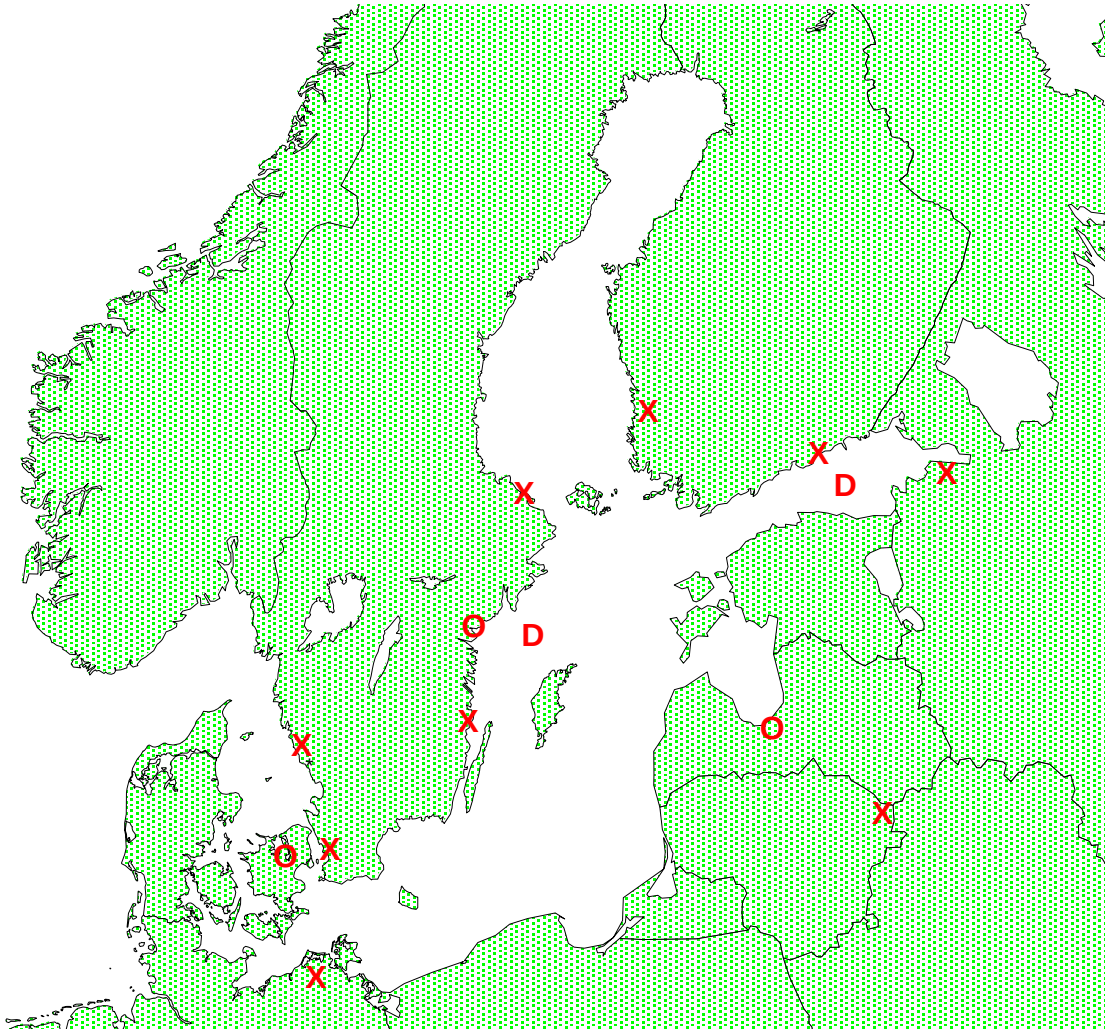
Table 2. Estimated doses received through different pathways from a range of particularly important radionuclides in connection with atmospheric releases following a DBA with a volatile release fraction of 0.001 %. Doses given in units of Sv.

Radio-nuclide	Ingestion	Inhalation	External fr. plume	Ext. from deposition	Ext. from skin dep.	Tritium
H-3	-	-	-	-	-	6.77E-04
I-120	2.00E-13	2.33E-09	1.95E-08	3.21E-09	2.40E-10	-
I-123	1.49E-08	1.69E-09	1.03E-09	2.05E-09	2.54E-10	-
I-125	4.05E-05	1.36E-07	8.34E-11	1.88E-08	8.79E-11	-
I-126	1.37E-06	6.17E-09	8.29E-11	2.80E-09	3.04E-10	-
Xe-121	0.00E+00	0.00E+00	5.58E-04	0.00E+00	0.00E+00	-

Marine modelling: EU Marina-Balt Project 1992

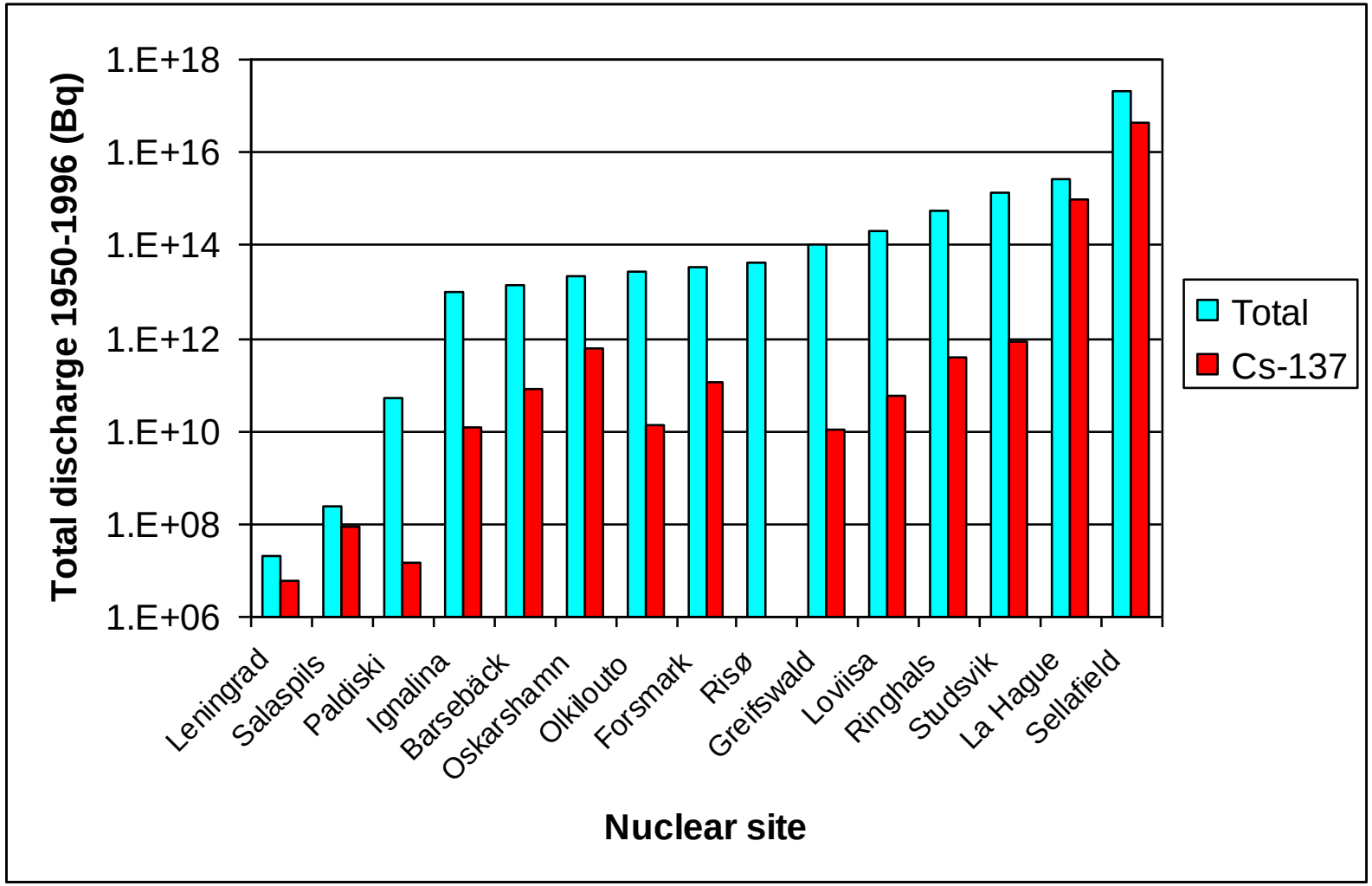
- Information on source terms
- Data on environmental radioactivity in the Baltic Sea
- Data on fishery statistics
- Doses to man from nuclear discharges, atmospheric nuclear-weapons fallout, Chernobyl fallout and natural radioactivity

Locations of Nuclear Sites



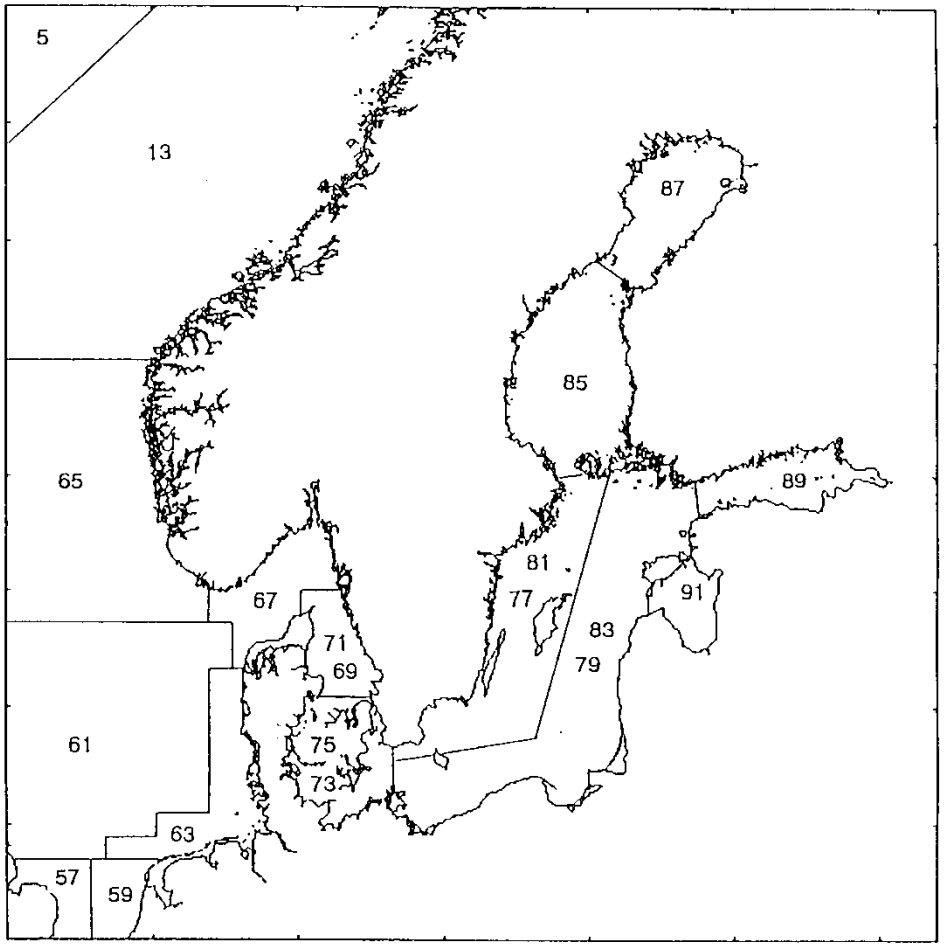
X - NPP
O - Nuc.centre
D - Dump site

Discharges to Sea

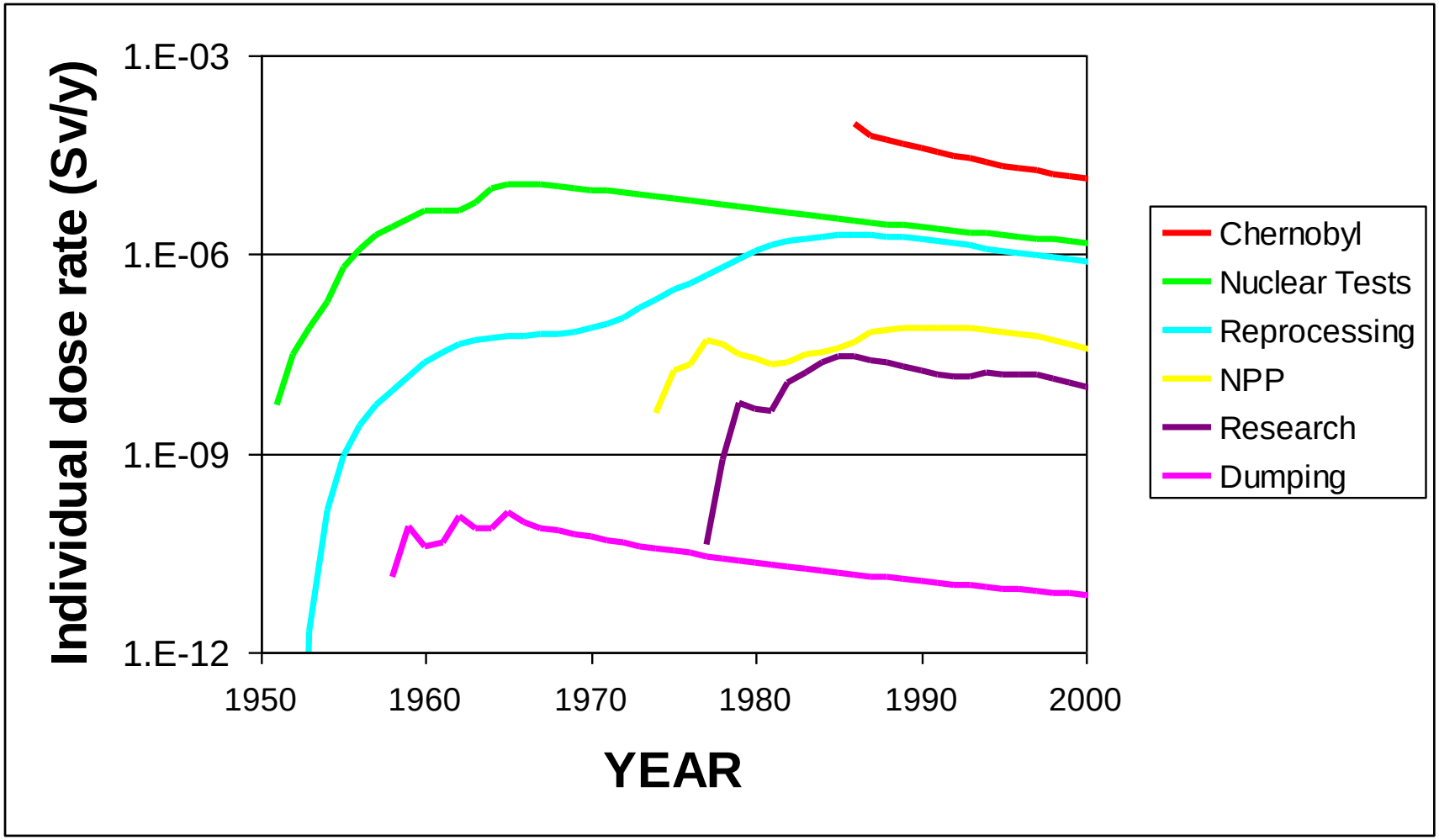


Environmental Modelling

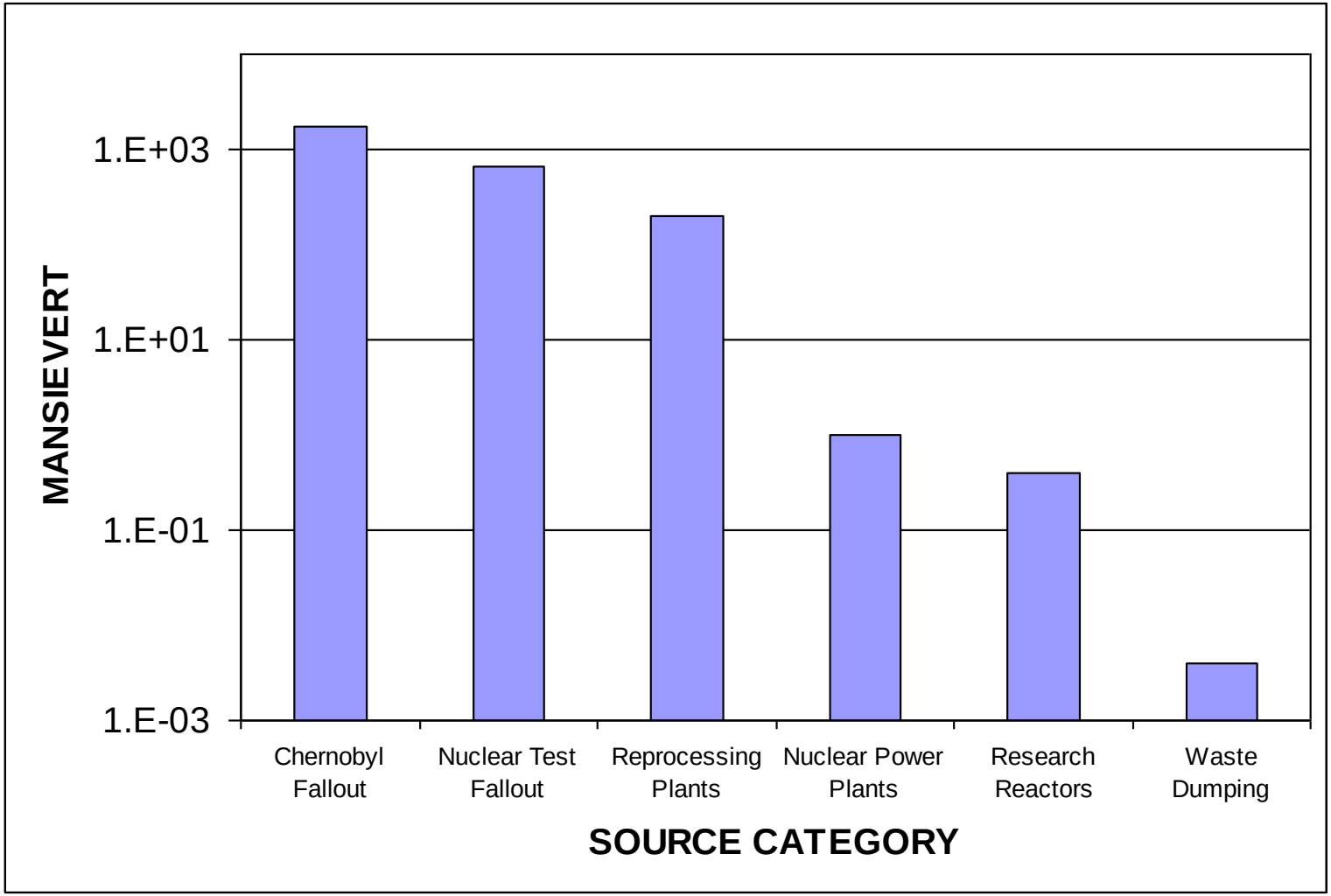
- Box model
  - transport of dissolved and particulate matter
- Processes considered
  - advection and mixing of water between adjacent boxes
  - sedimentation from the water column
  - resuspension from sediment
  - sediment burial
  - surface-sediment mixing
  - bio-concentration and doses to man



Doses to Critical Groups in the West Baltic Region



Collective Dose



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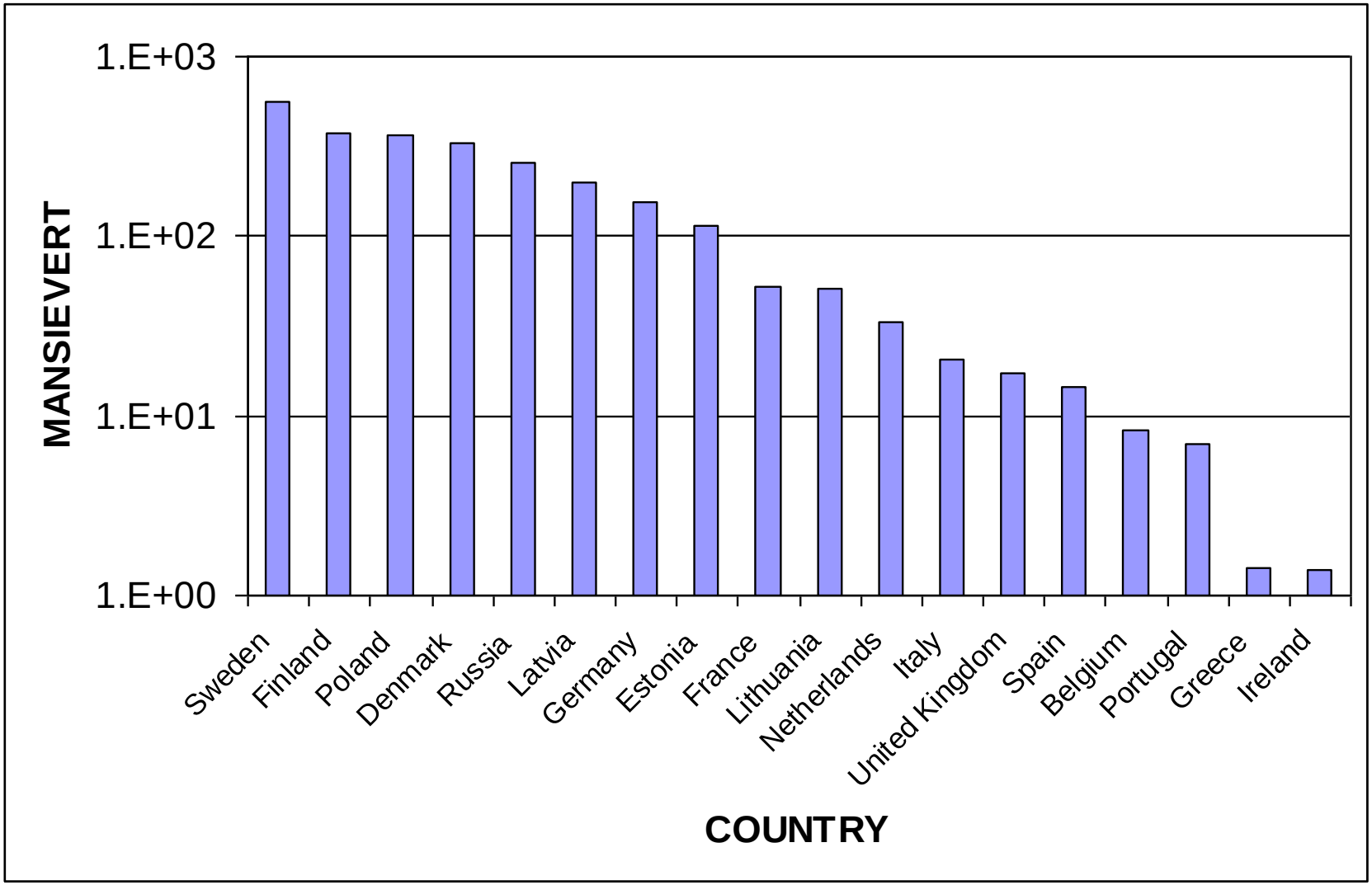
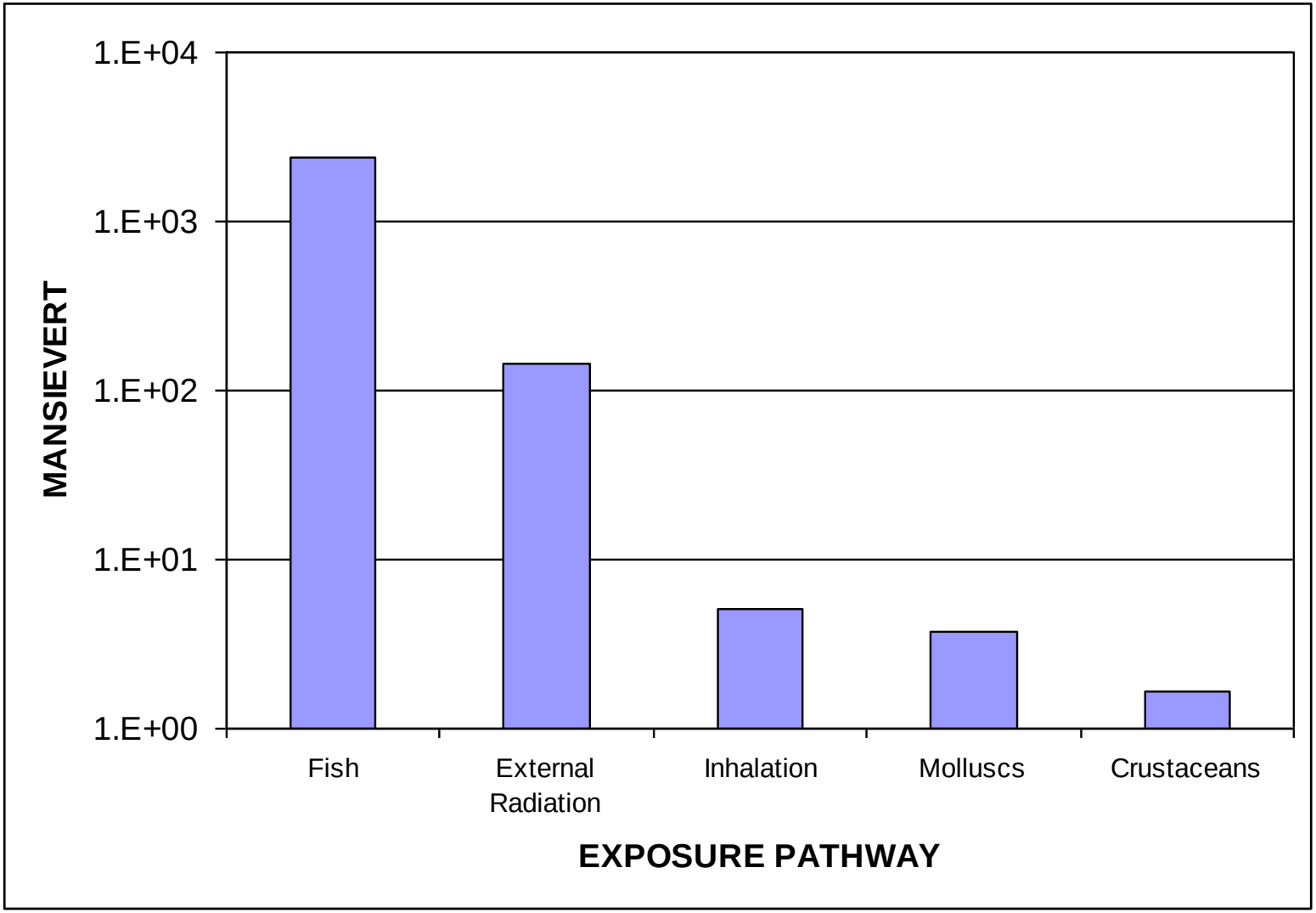
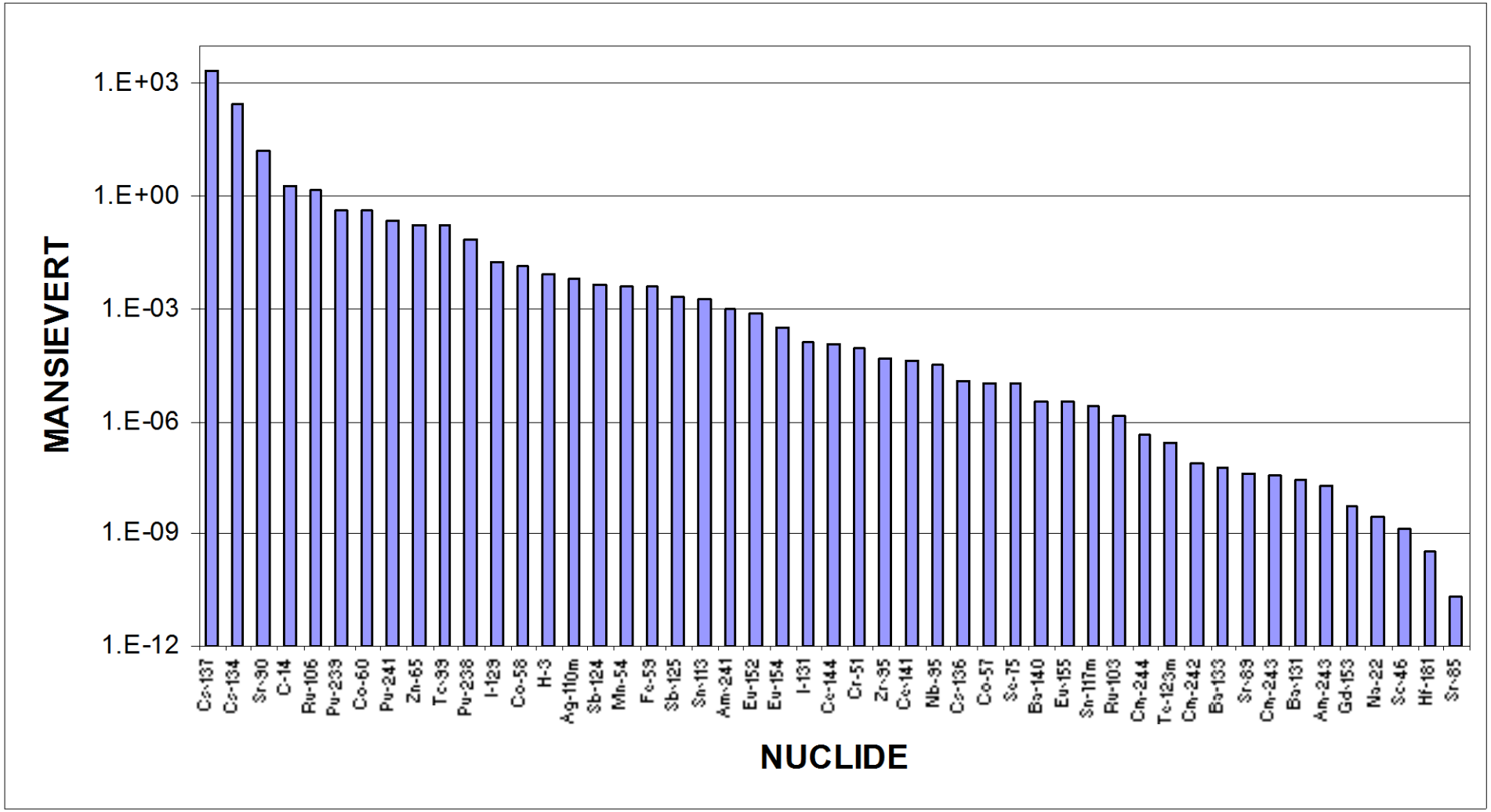
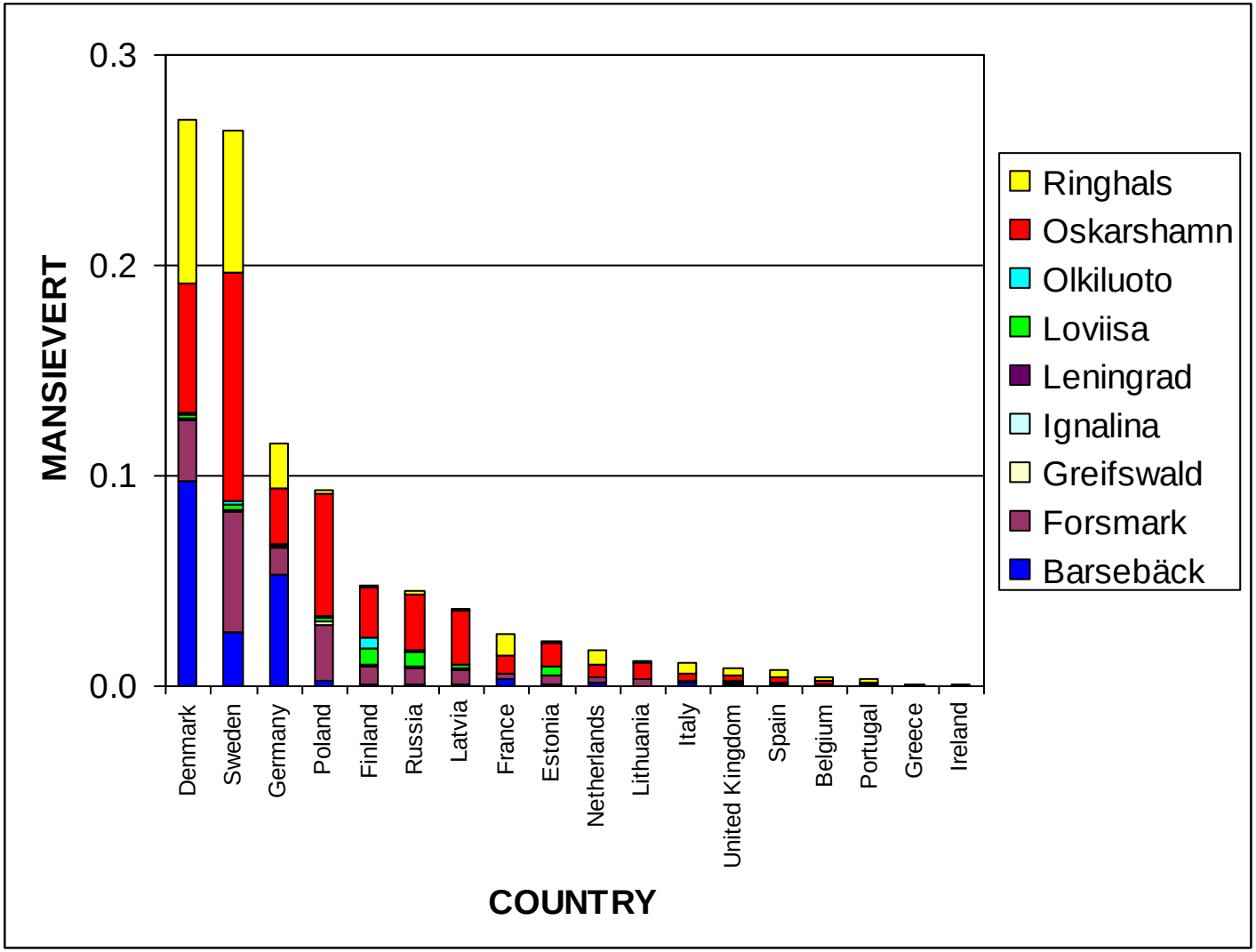


Collective Dose



Collective Dose



Collective Dose from NPP