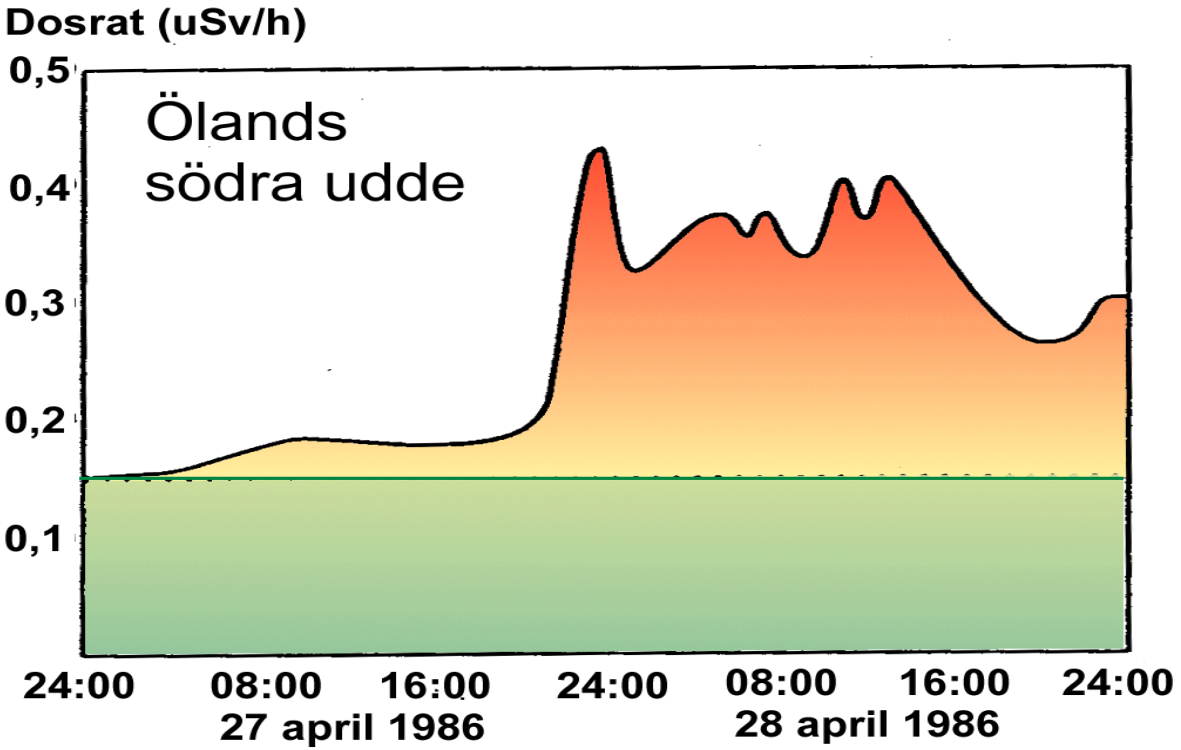
A panel discussion of questions arising after the recent Chernobyl TV-series

CHAIR: LOVISA WALDNER

CHRISTOPHER RÄÄF
ROBERT FINCK
CHRISTIAN BERNHARDSSON
SÖREN MATTSSON

Tjernobylolyckan

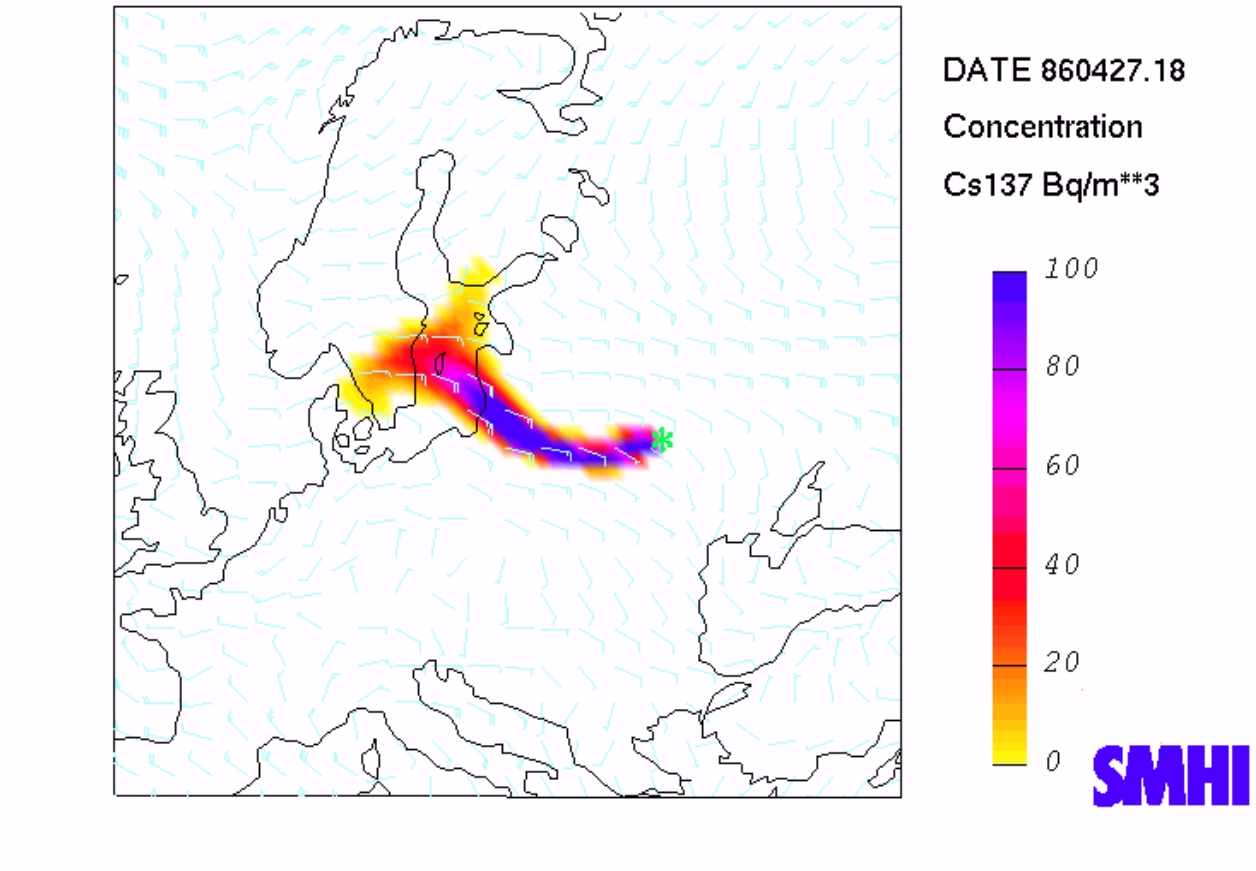
Första registrering i Sverige



Strålningsnivån vid SSI:s fasta mätstation på Ölands södra udde den 27 - 28 april 1986.

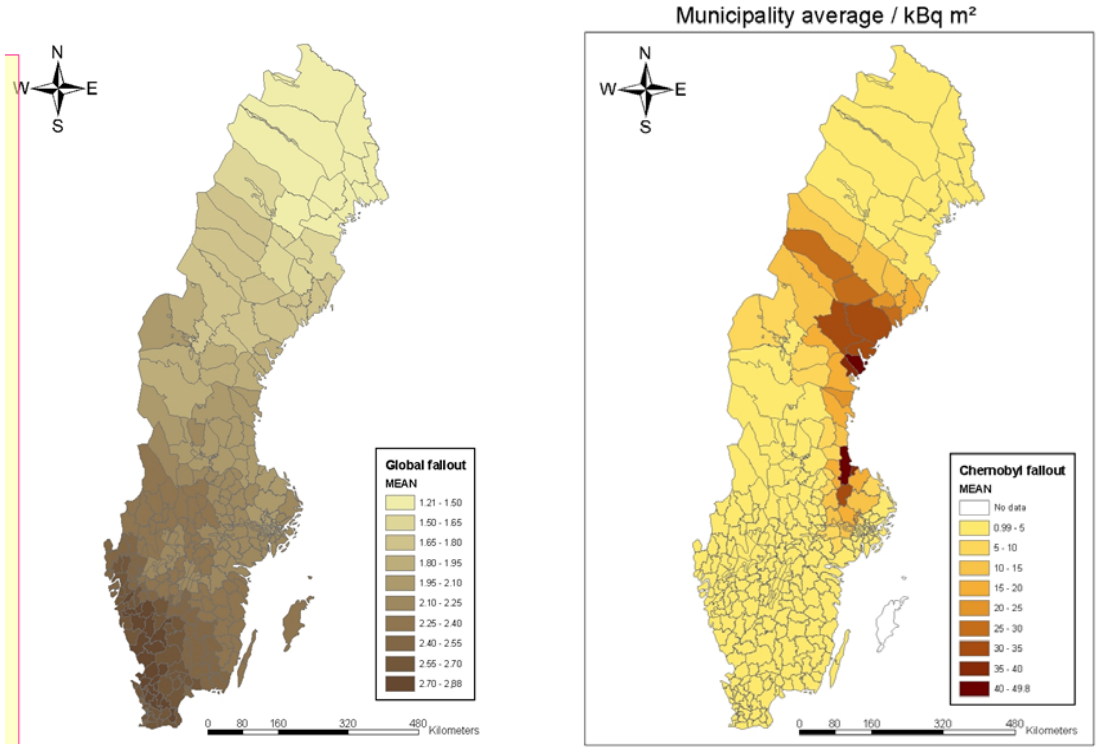
Tjernobylolyckan

Spridningen av radioaktiva ämnen den 27 april 1986 kl 18:00



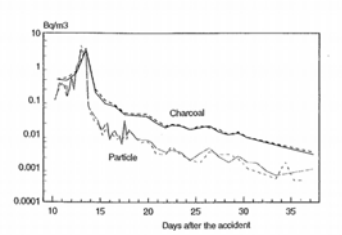
Konsekvenser till befolkning i Sverige

(inte första gången)



- Kontinuerlig deposition från NWT 1955-1985 **(1-3 kBq m^{-2})**
- Engångsdeponering 27/4-10/5 från Tjernobyl 1986 **(2-80 kBq m^{-2})**

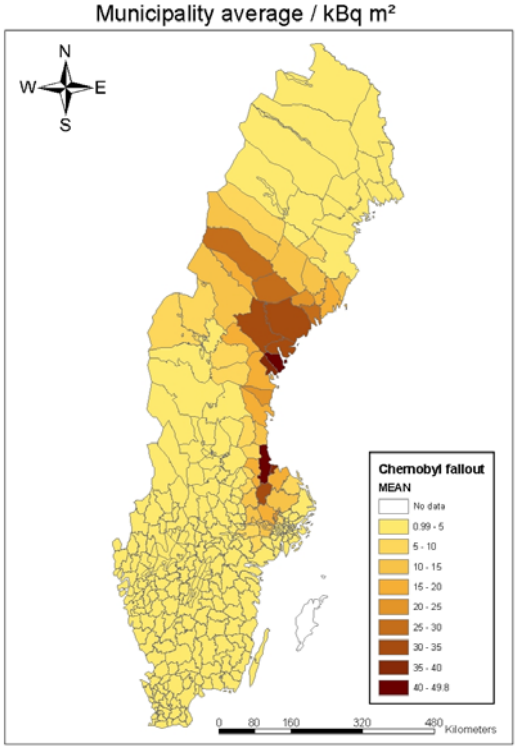
Dosbidrag från Tjernobylnedfall – vilka källor har vi?

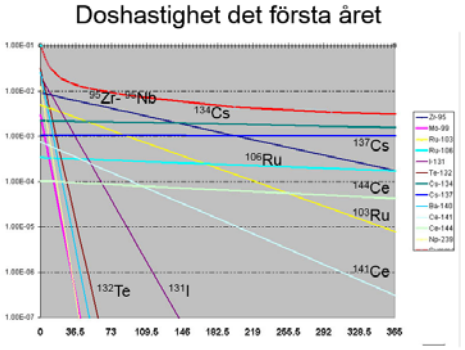


SGU-karta på 200*200 rutnät

Högupplösande gammaspektrometri på valda platser i de mest drabbade områdena

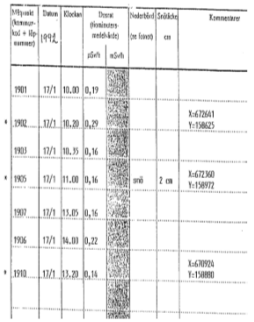
Mejeri-mjölksmätningar





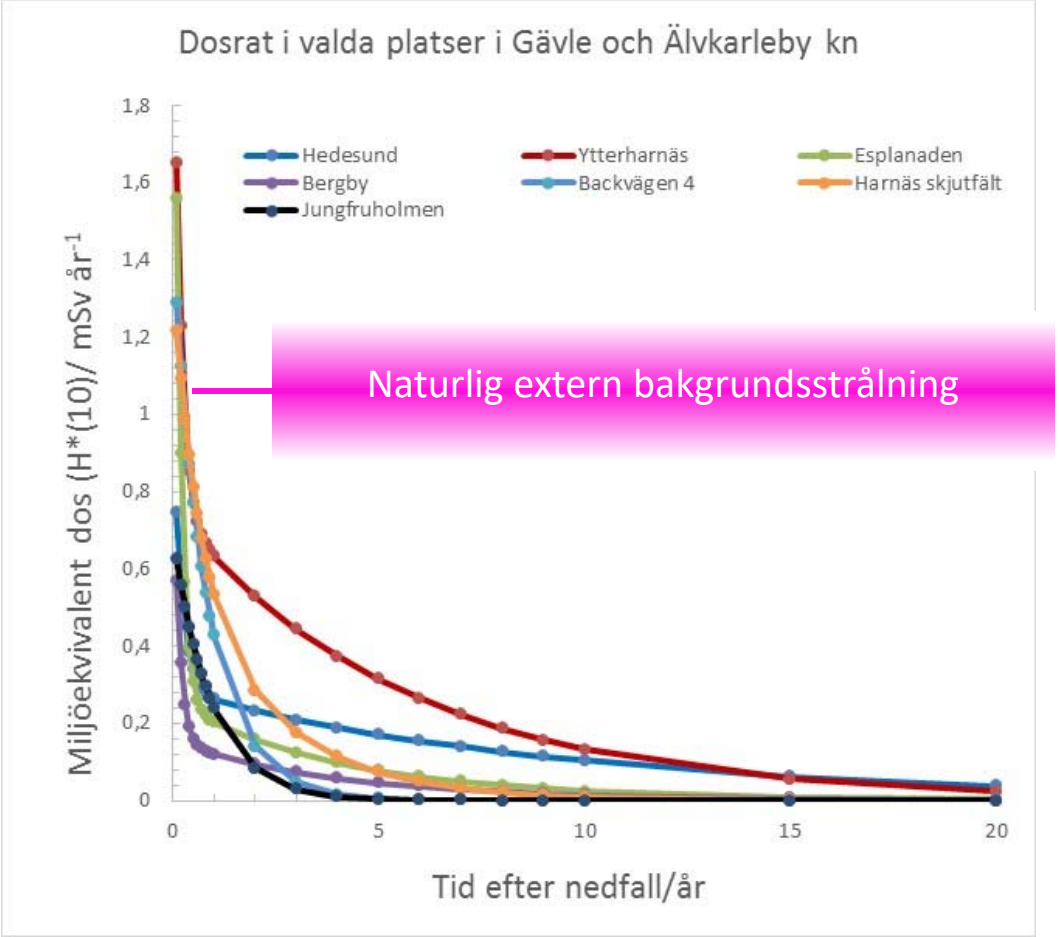
Luftprovtagare

Kommunmätningssystemet

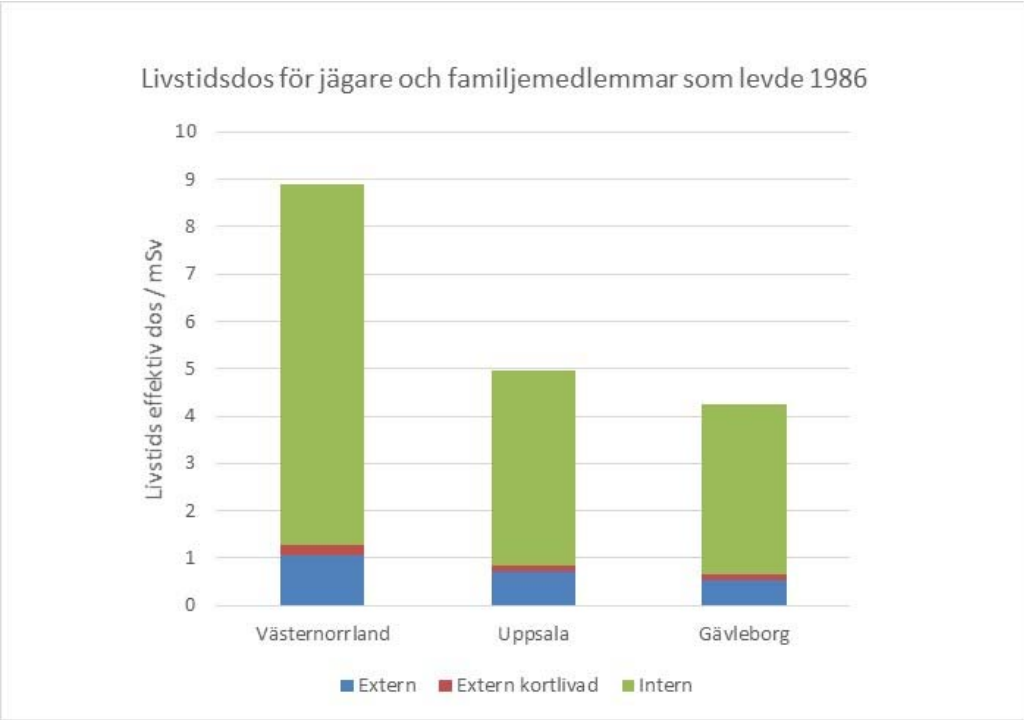


Externdosbidrag från Tjernobylnedfall

Oskärmad miljöekvivalent dosrat på valda plaster i Gävle och Älvkarleby kommun

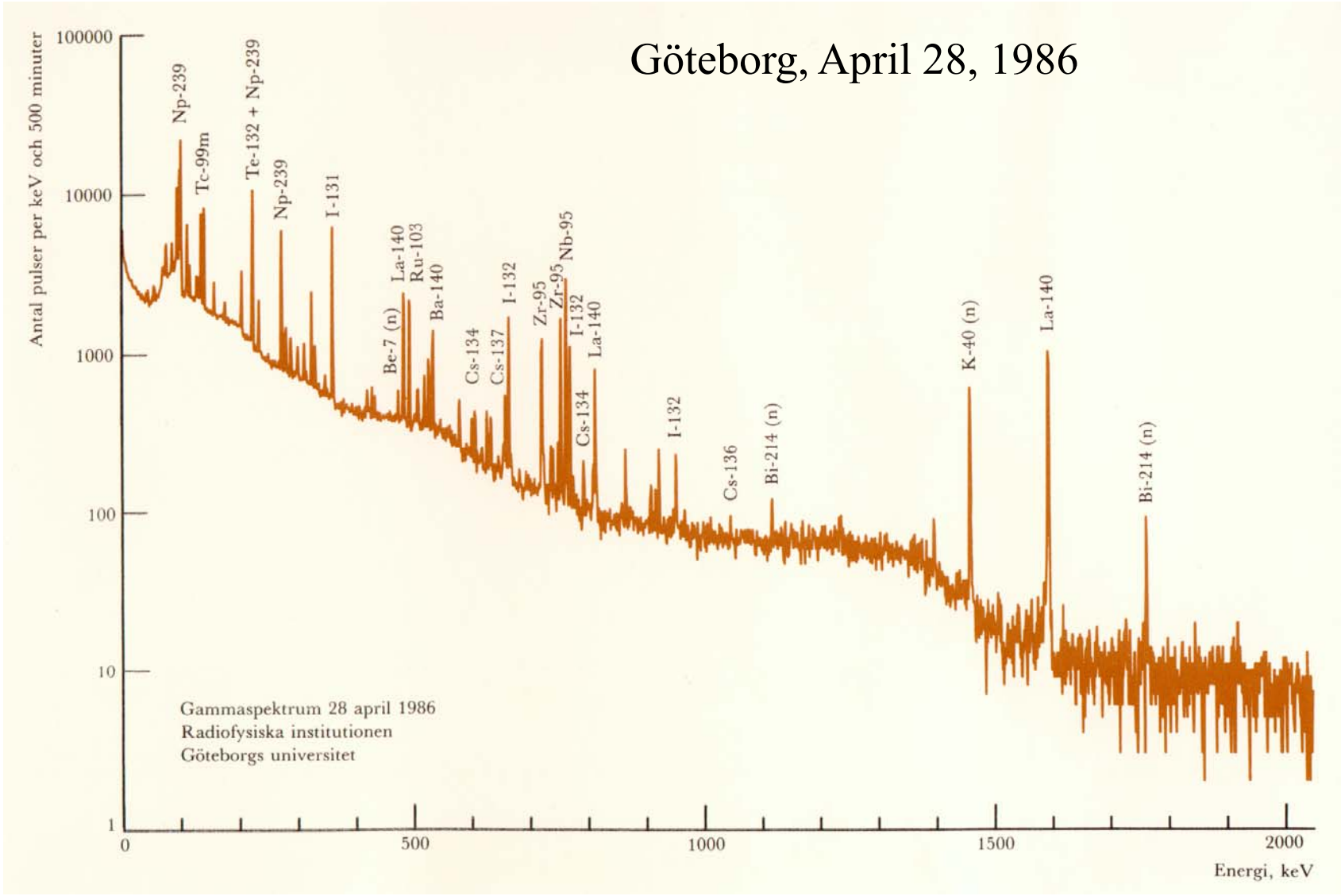


- Kollektivdos i Sverige: Ca 10,000 manSv varav ca 500 manSv till svenska jägare
- För vissa grupper (samer och jägare) dominerar interndosbidraget

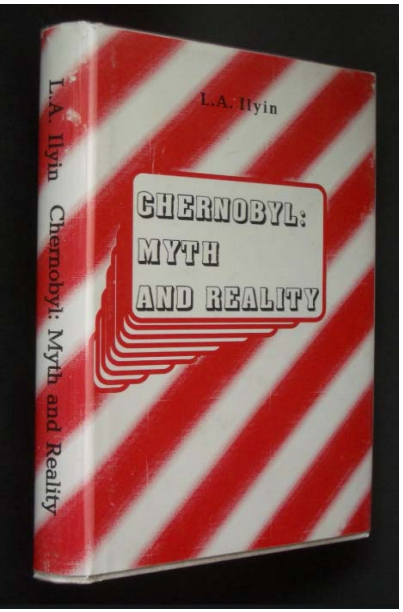


27 april
Forsmark

28 april
”Österifrån”



Mattsson och Vesanen, 1986



Moscow Megapolis, 1995
398 pages

Ilyin Leonid Andreevich

"Izrael, Burenkov and I, wearing civilian clothes, went aboard a huge military helicopter, a Mi-26, which flew off in the direction of the plant. At an altitude of 100 metres the helicopter began to circle over the reactor. I looked down and saw the destroyed building of the fourth power unit, which was as if sliced at an angle down to the foundation base. Near the ruins, lay a piled-up heap of warped metal, some of it balancing over the gaping hole and fragments of shattered concrete, and at the bottom of this shaft were flickering the remains of what had been the reactor core. Shcherbina asked the pilot to hang over the crater. The radiometer's needle went to the right and stopped at the 300 R/h mark. We felt rather nervous. We flew over the site and saw a lot of armoured trucks, cranes and bulldozers being used in clean-up operations. We saw the town from the air: it was beautiful but dead. When somebody asks me about the most powerful impression of those days, I recall this flight over Chernobyl."

Angelina K. Guskova

DISTRIBUTION OF **237** CHERNOBYL PATIENTS TREATED FOR ACUTE RADIATION SYNDROME BY THE SEVERITY OF SICKNESS AND RANGE OF WHOLE BODY EXPOSURE

Degree of ARS	Number of patients	Deaths in 3 months	Whole body dose, Gy
IV	21	20	6-16
III	22	7	4-6
II	50	1	2-4
I	41	0	1-2
I-IV	**134**	**28**	**1-16**
Not confirmed	**103**	0	<2

Ref.: Ilyin L.A.: Chernobyl - Myth and reality, Megapolis, Moscow, 1995
Wagemaker G. et al., IAEA/WHO/CEC Chernobyl Conf. Vienna, 1996

Cause of death from radiation damage

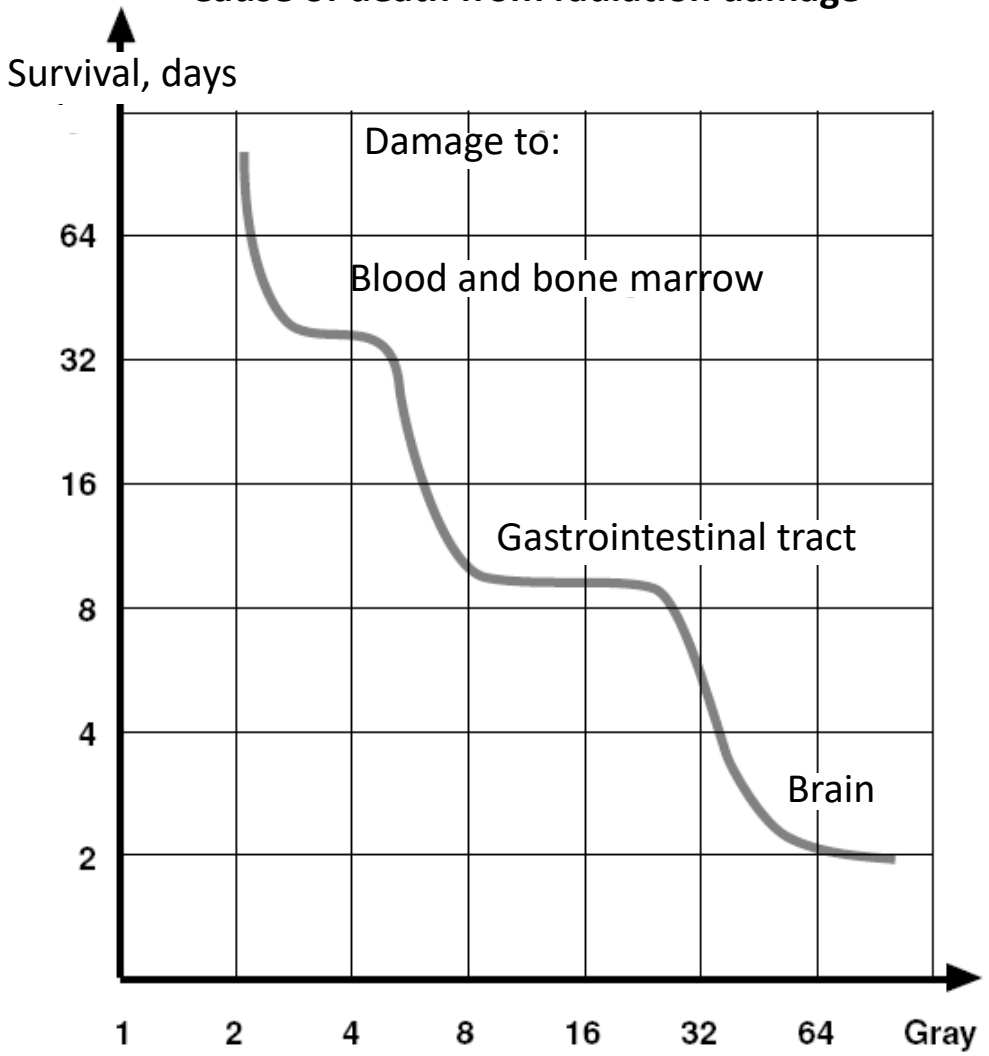


Table VIII Prodromal phase of acute radiation syndrome

Symptoms and medical response	ARS degree and the approximate dose of acute WBE (Gy)				
	Mild (1-2 Gy)	Moderate (2-4 Gy)	Severe (4-6 Gy)	Very severe (6-8 Gy)	Lethal[a] (>8 Gy)
Vomiting					
Onset	2 h after exposure of later	1-2 h after exposure	Earlier than 1 h after exposure	Earlier than 30 min after exposure	Earlier than 10 min after exposure
% of incidence	10-50	70-90	100	100	100
Diarrhoea	None	None	Mild	Heavy	Heavy
Onset	-	-	3-8 h	1-3 h	Within minutes of 1 h
% of incidence	-	-	< 10	> 10	Almost 100
Headache	Slight	Mild	Moderate	Severe	Severe
Onset	-	-	4-24 h	3-4 h	1-2 h
% of incidence	-	-	50	80	80-90
Consciousness	Unaffected	Unaffected	Unaffected	May be altered	Unconsciousness (may last seconds/minutes)
Onset	-	-	-	-	Seconds/minutes
% of incidence	-	-	-	-	100 (at > 50 Gy)
Body temperature	Normal	Increased	Fever	High fever	High fever
Onset	-	1-3 h	1-2 h	< 1 h	< 1 h
% of incidence	-	10-80	80-100	100	100
Medical response	Outpatient observation	Observation in general hospital, treatment in specialized hospital if needed	Treatment in specialized hospital	Treatment in specialized hospital	Palliative treatment (symptomatic only)

[a]With appropriate supportive therapy individuals may survive whole body doses as high as 12 Gy [36].

Villages visited in Bryansk oblast:

- Demenka
- Kuznets
- St Bobovichi
- St Vishkov
- Veprin
- Yalovka

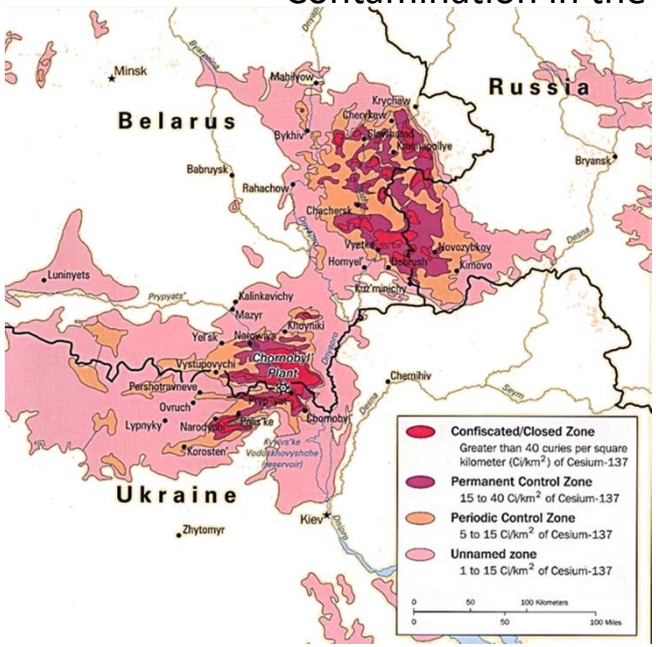
70 kopek/day
(20 öre/dag!)

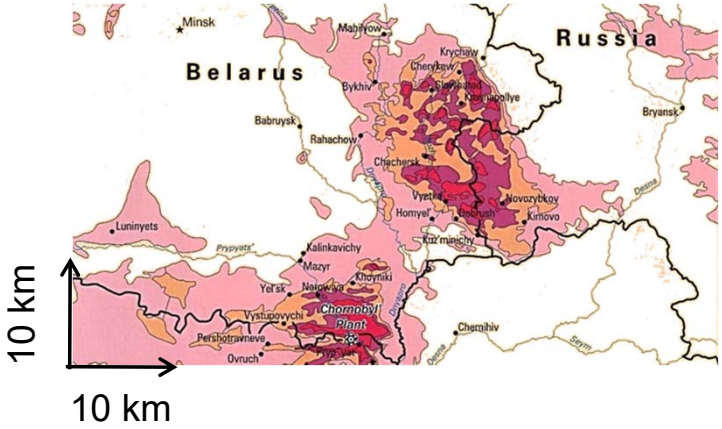
^{137}Cs: 500 - 3 000 kBq/m^2

Compare Sweden
A $_{^{137}Cs}$ < 120 kBq/m^2

^{137}Cs contamination in Belarus

Contamination in the “Gomel-Bryansk” area





- **+36 h:** Evacuation of Pripyat initiated, one month later the entire 30-km zone
  - Up to September 116 000 were relocated (incl. parts of Gomel-Bryansk)
- **1986-1988:** Implementation of various RP measures, e.g. restrictions, clean-up, resettlement.

A farmer from Uvel'e wrote on the gate of his home before leaving for the Kaluga region: "Forgive us, Paternal Home, for leaing you!"

EMERCOM 1996

Dates of intervention decisions and types of criteria used

	Date	Criteria	Population or territories affected
1.	06 May 86	I(131) in foodstuff	~150 ths people
2.	12 May 86	100 mSv/year	~100 ths people
3.	15 May 86	Dose rate (1,3,5,20 mP/hour)	<100 ths people
4.	16 May 86	Total activity in foodstuff	<100 ths people
5.	30 May 86	Total activity in foodstuff	2 m. people
6.	30 May 86	Dose rate and concentration in foodstuff	<700 ths sg.km
7.	12 Jun 86	Dose rate	<50 ths people
8.	22 Aug 86a	Cs(137) in the soil	0.2 ths people
9.	22 Aug 86a	Cs(137) in the soil (15 Ci/km2)	78.7 ths people
10.	24 Oct 86	Dose rate and surface contamination	<50 ths people
11.	23 Apr 87	30 mSv/year	78.7 ths people
12.	29 Jul 87	Dose rate and surface contamination	<50 ths people
13.	12 Aug 87	Cs(137) in the soil and social factors(15 Ci/km2)	+17.9 ths people
14.	15 Dec 87	Cs(134) Cs(137) in foodstuffs	1.5 m. people
15.	23 May 88	Cs(134) e Cs(137) in the soil andfoodstuffs	10 ths sg.km
16.	18 Jul 88	25 mSv/year	96 ths people
17.	19 Jul 88	Dose rate and surface contamination	<50 ths people
18.	13 Sep 88	Cs(137) in the soil and social factors(15 Ci/km2)	+6.0 ths people
19.	06 Oct 88	Cs(134) Cs(137) in foodstuffs	2 m. people
20.	22 Nov 88	350 mSv	
21.	24 May 89 e 05 Oct 89	350 mSv	4.7 ths people
22.	20 Oct 89	AD	100 ths people
23.	30 Dec 89	Cs in the soil(15 Ci/km2) and social factors	+0.7 ths people
24.	26 Jan 90	Cs in the milk	200 ths people
25.	16 Mar 90	350 mSv	+2.3 ths people
26.	11 May 90	part/min cm2	>10 ths people
27.	28 Sep 90	Cs in the soil 1,5,10,15,30 Ci/km2	259.6 ths people
28.	22 Jan 91	Cs(137) in foodstuffs	3 m. people
29.	11 Mar 91	Cs in the milk	+75 ths people
30.	19 Feb 91	Cs(134) and Cs(137) in the soil and foodstuffs	35 ths sg.km
31.	08 Apr 91	1 and 5 mSv/year	
32.	15 May 91	Cs in the soil 1,5,10,15,40 Ci/km2 LAD	
33.	28 Dec 91	Cs in the soil and social factors(	2.3 m. people
34.	25 Feb 92	Cs in the soil and social factors(	+0.2 m. people
35.	18 Jun 92	Cs in the soil, LAD	
36.	01 Oct 92	AD see 33 and 34 (State program)	3 m. people
37.	25 Dec 92	AD see 33 and 34 (Territory)	8 ths sg.km
38.	05 Apr 92	Cs in the soil and social factors(	+0.1 m. people
39.	21 Jul 93	Cs(137) in foodstuffs	3 m. people
40.	23 Apr 95	Cs in the soil and social factors(	+70 ths people
41.	17 Jul 95	1,5,20 mSv/year	~50-100 ths people

- **1988-1990:** 350 mSv dose limit
- **1989-:** Another 220 000 were relocated to other areas
- **1991:** Concept of zoning and isoline of 37 kBq m^{-2} →

Territories in RF 1990

Inhabitants x1000	**2249**	**347**	**91**	**"-"**
Dose (mSv/y)	**1-5**	**5-15**	**15-40**	**>40**

	Area with ^{137}Cs deposition density range (km^2)			
	37–185 kBq/m^2	185–555 kBq/m^2	555–1480 kBq/m^2	>1480 kBq/m^2
Russian Federation	49 800	5 700	2100	300
Belarus	29 900	10 200	4200	2200
Ukraine	37 200	3 200	900	600
Sweden	12 000	–	–	–
Finland	11 500	–	–	–
Austria	8 600	–	–	–
Norway	5 200	–	–	–
Bulgaria	4 800	–	–	–
Switzerland	1 300	–	–	–
Greece	1 200	–	–	–
Slovenia	300	–	–	–
Italy	300	–	–	–
Republic of Moldova	60	–	–	–

- **Main measures in 1986-1995**
  - Resettlement, decontamination, protective measures in agriculture/forestry, restrictions on foodstuffs, ”renovation of the infrastructure”

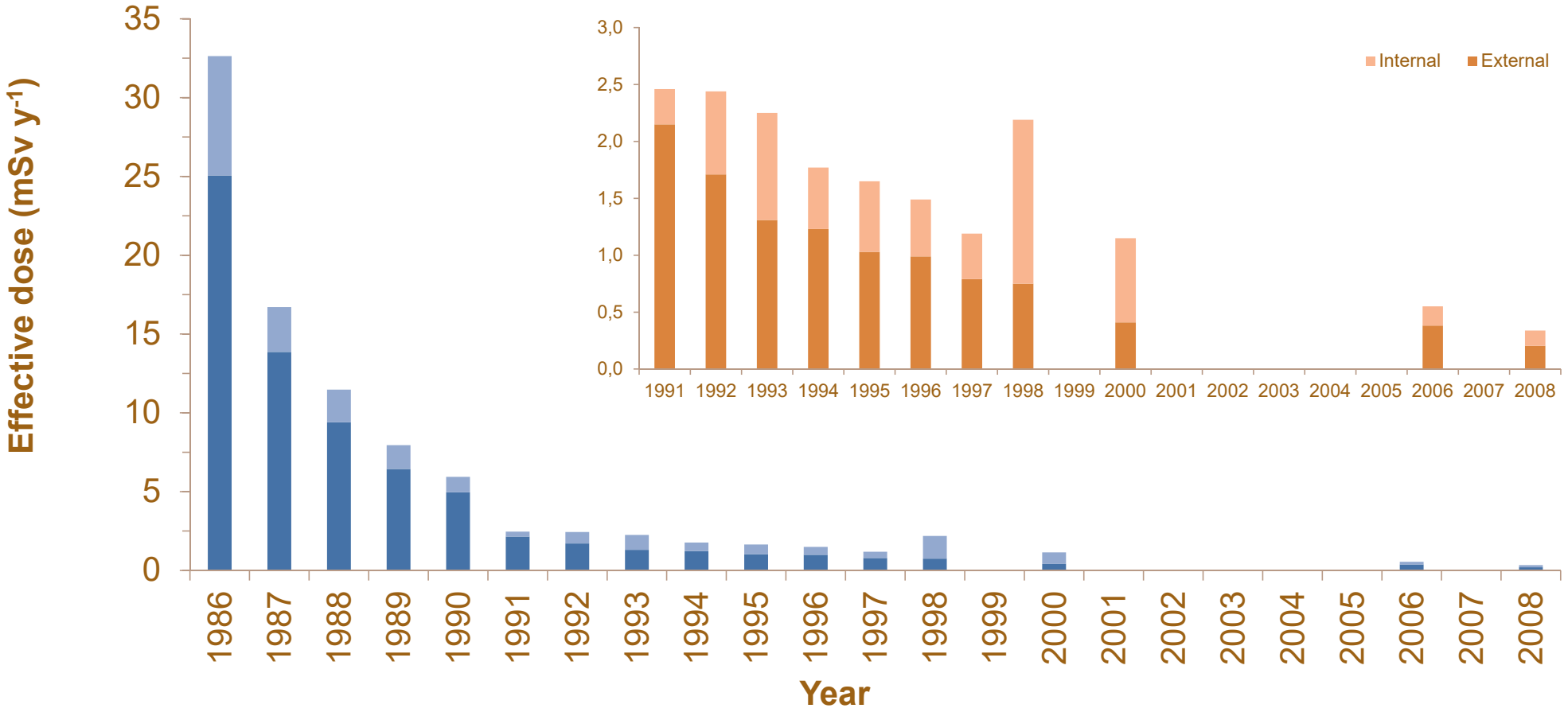
- **1991:** Body of state control – EMERCOM of Russia is formed
  - *Not only protective measures:*
    - Mitigation planning for 1992-1995-2000 incl. ”Children of Chernobyl” and ”Dwelling for liquidators”
    - Development of health services, special medical aid, environmental monitoring, activities for reducing radiation commitments, sanitary restrictions, social/psychological/economical rehabilitation of the population in the areas
    - Initially, more than 50% of the budget was spent on compensations



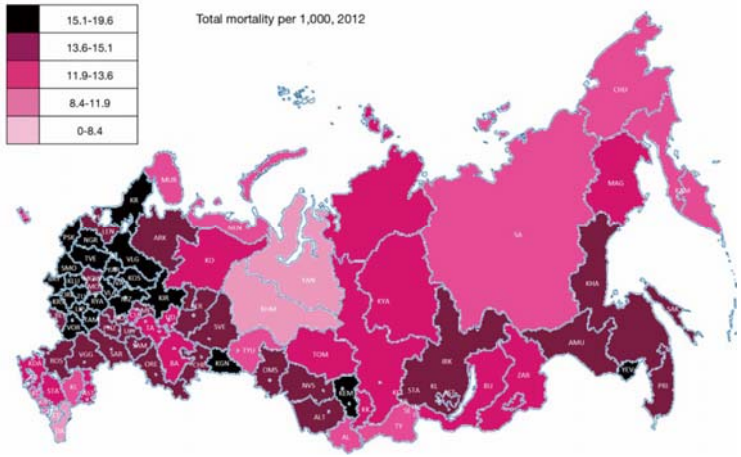


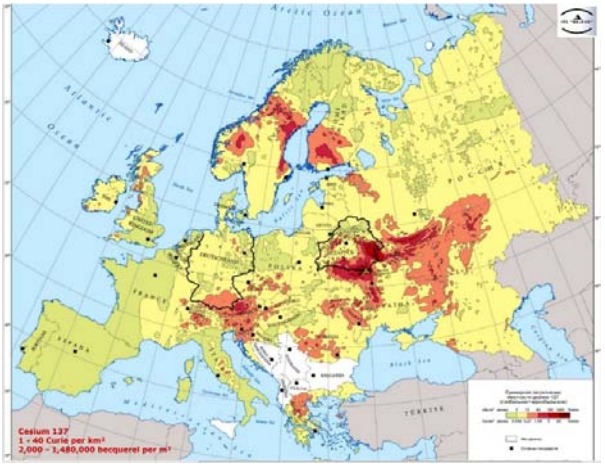
- **1992:** The individual member states take responsibility of the continued effort of the mitigation process
- **Today** the aim is to repopulate the majority of the areas

Average annual external- and internal effective “Chernobyl-dose” to inhabitants in selected villages in the Gomel-Bryansk spot



Late non-radiation induced effects to be considered





N.B: The health effects induced by inadequately performed remedial actions causing adverse and impaired quality of life compared to:

1. *Non-exposed*
2. *To exposed individuals not undergoing remedial actions (!?)*

Due to general increase in mortality and morbidity in all former USSR-countries between 1985 to 2000, these hypothesis will likely be very difficult, if not impossible, to resolve

Late radiation induced effects – non-cancerous effects to be considered

Cardiovascular: Evidence from radiation therapy – NASA:s limiting factor for space travelers

Organ	30 d Limit [mGy-Eq]	1 Year Limit [mGy-Eq]	Career Limit [mGy-Eq]
Lens	1000	2000	4000
Skin	1500	3000	6000
BFO	250	500	Not applicable
Heart	250	500	1000
CNS	500	1000	1500

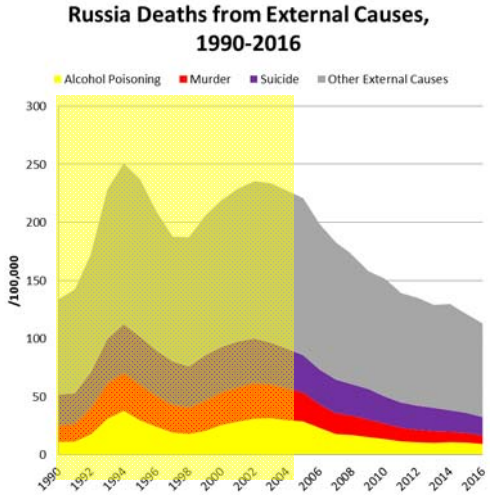
N.B that the limit is 10 times higher than the current limit for Swedish rescue personnel!

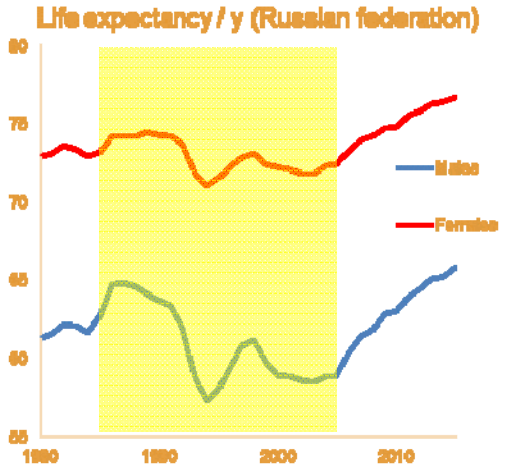
Was radiation induced CV-disease detected after Chernobyl?

Late non-radiation induced effects to be considered

Effects brought on by stress:

- *Cardiovascular diseases?*
- *Substance and alcohol abuse?*
- *Suicides?*





The effects of radiation

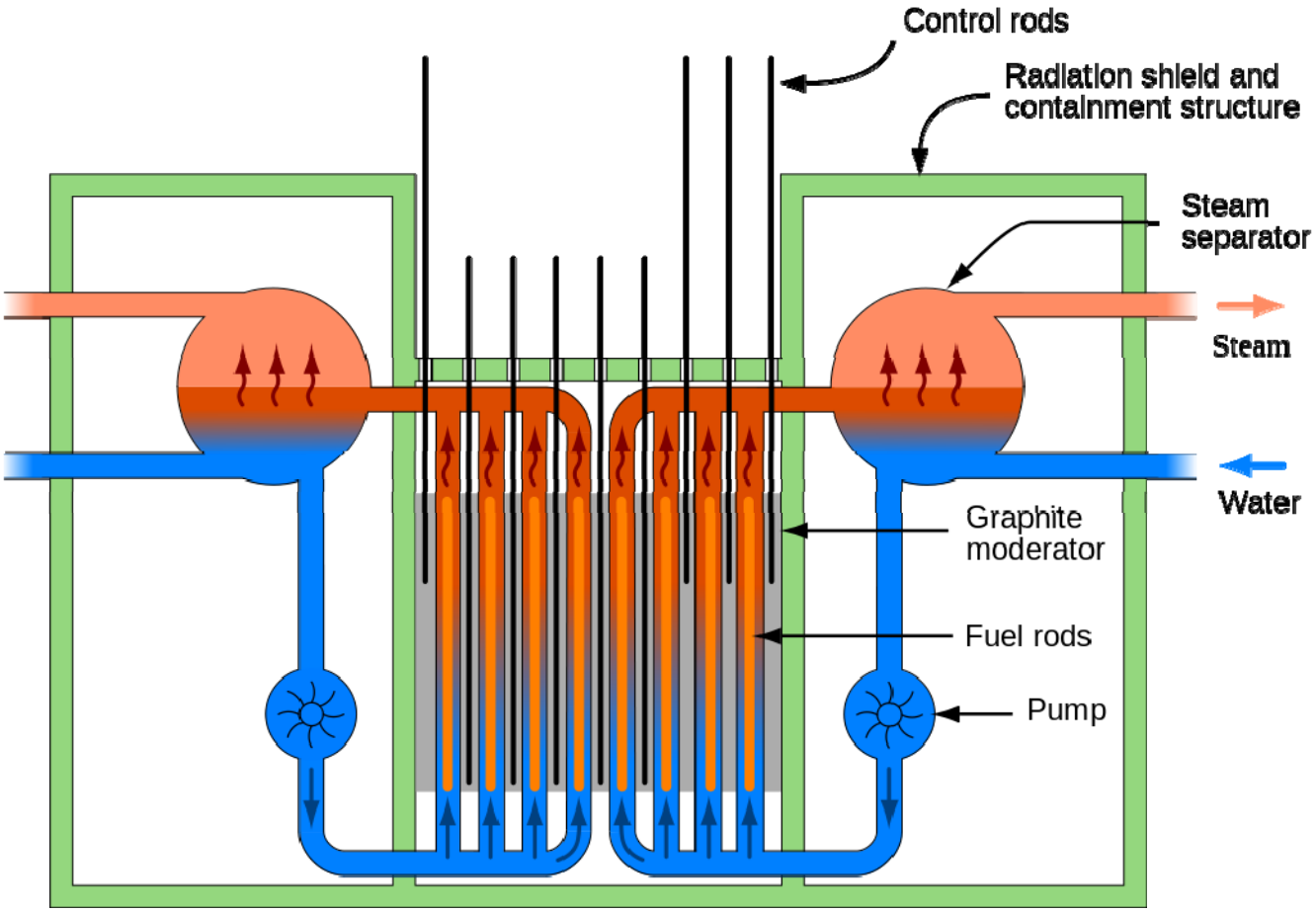
- Why were the firemen dangerous to people close to them after the accident?
  - External dose rate at 1 m?
- It is said that the baby ”absorbs” all radiation and protects the mother, is this true?
- In the series, a fireman is burnt by a block of graphite on the grounds. What is the timeline for radiation burns?

Possible consequences of the meltdown

- What would have happened if the melted core had reached the pools of water?
  - Explosion?
  - Contaminated ground water?

Questions?

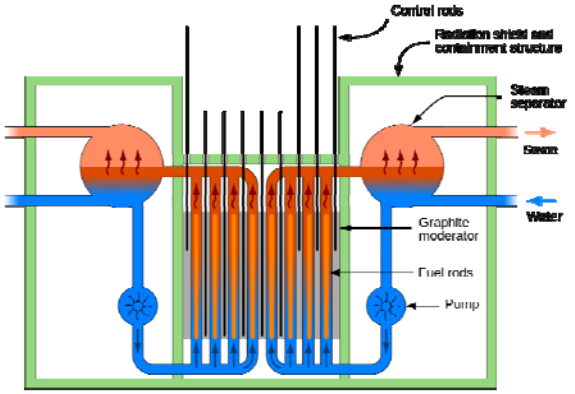
RBMK (*Reaktor Bolsjoj Mosjnosti Kanalny)*: high power duct reactor



RBMK-reactor

RBMK (översatt): högtrycksreaktor av kanaltyp

- The neutrons are moderated by both the graphite and the coolant (water)
- If the vapor content of the water channels increases, moderation of neutrons decreases and the effect increases
- Difficult to control when power increase from zero or from low effects
- Only the control rods can control the effect



What happens in a RBMK-type reactor?

- Can be run with low enriched uranium (<2% 235U)
  - Note: high production of weapons plutonium through this reaction:

$$^{238}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{239}_{92}\mathrm{U} \xrightarrow[23.5\ \mathrm{min}]{\beta^-} {}^{239}_{93}\mathrm{Np} \xrightarrow[2.3565\ \mathrm{d}]{\beta^-} {}^{239}_{94}\mathrm{Pu}$$

- Graphite as a moderator (slows down the neutrons formed at the nuclear fission so that they can split new uranium nuclei) gives different velocity distribution of the neutrons in the core than when water is used as a moderator

- The graphite must constantly be cooled with water

- The design means that if the power increases from low power then the vapor content increases, which leads to further power increase, etc. This makes the reactor unstable except at maximum power output, it has a so-called positive void coefficient. The power increase must then be controlled by inserting control rods to affect neutron flow and thus power.

- Western reactors always have a negative void coefficient because they are moderated by water. A higher vapor content impairs the moderation of neutrons and the nuclear fission stops.

Control rod: contains substances that can absorb neutrons, e.g. alloys of silver, indium and cadmium, boron carbide, hafnium or hafnium dicarbide.

But: the end of the control rods in the RMBK reactors are made of graphite to give the reactor a little extra push when pulled out to start the reactor. **This is the Achilles heel of the construction** as the reactor gets the same extra thrust right at the beginning when pushed in to stop the chain reaction.