Comparative analysis of the countermeasures to mitigate exposure of the public to radioiodine following the Chernobyl and Fukushima accidents. Assessment of doses to the thyroid

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Strategy before Chernobyl (1/3)

Two main documents:

- **Standards of Radiation Safety (SRS-76); (established the dose limits to the workers and the public)**

- **"Criteria for decision making on measures …." (established the radiological criteria to introduce countermeasures in the early phase)**

Strategy before Chernobyl (2/3)

Parameter	Exposure level	
	A	B
Whole-body dose from external exposure, Gy	0.25	0.75
Absorbed dose to thyroid from intake of radioiodines, Gy	0.25-0.30	2.5
Time-integrated concentration of ^{131}I in ground-level air, kBq s L^{-1}		
children	1,480	14,800
adults	2,590	25,900
Total integrated intake of ^{131}I with foodstuffs, kBq	55.5	555
Max concentration of ^{131}I in fresh milk, kBq L^{-1} or in daily diet, kBq d^{-1}	3.7	37
Ground deposition density of ^{131}I on pasture, kBq m^{-2}	25.9	259

Strategy before Chernobyl (3/3)

Countermeasures in the early phase:

- **sheltering;**
- **evacuation;**
- **intake of stable iodine to block the thyroid.**

Dosage of KI pills were recommended at that time:

- **adults and children over 2 years old**
  - **– 250 mg of KI;**
- **children up to 2 years old**
  - **– 40 mg of KI.**

Chernobyl: countermeasures (1/3)

Sheltering

Was not applied anywhere except for a part of the residents of Pripyat town, located 4 km from the damaged reactor.

Chernobyl: countermeasures (2/3)

Evacuation in 1986

Populations

About 116,000 people (24,700 Belarusians, 91,400 Ukrainians, and 186 Russians).

Dates

Pripyat town – April 27, 1986

Villages from the 10-km zone – May 2-3

Villages from the 30-km zone – May 3-7

Villages outside the 30-km zone – May-September

Chernobyl: countermeasures (3/3)

Administration of stable iodine

Pripyat town - on April 26-27, 1986.

Belarusian part of the 30-km zone – on May 1-4

Ukrainian part of the 30-km zone – on May 2-7

Outside the 30-km zone – from middle of May through August

Remark: Intake of stable iodine for the residents of Pripyat was effective. For the other populations it was too late and ineffective.

Fukushima: countermeasures (1/4)

- **March 11, 20:50 – evacuation of residents within the 2-km zone of F1;**
- **March 11, 21:23 – evacuation of residents within the 3-km zone of F1 (6,000 people);**
- **March 12, 5:44 – evacuation of residents within the 10-km zone of F1;**
- **March 12, 17:39 – evacuation of residents within the 10-km zone of F2;**
- **March 12, 18:25 – evacuation of residents within the 20-km zone of F1 (85,000 people).**

Fukushima: countermeasures (2/4)

- **March 15 – directive to the residents in the area (20-30 km radius) – to shelter (stay inside);**
- **March 15 – directive to the residents to intake of stable iodine during evacuation;**
- **March 25 – directive to the residents to deliberately evacuate in the area (20-30 km radius).**

April 21 – directive of the prime-minister:

- **around F1 – to set up de facto exclusion zone for 20 km radius**
- **around F2 – to reduce evacuation zone from 10 km to 8 km radius**

Fukushima: countermeasures (3/4)

- **April 22 – a directive to the public in the 20-30-km area – to shelter (stay inside) has been confirmed**

- **to set up a deliberate evacuation area (red line) and an evacuation-prepared area (yellow line)**

Fukushima: countermeasures (4/4)

Deliberate evacuation area:

- **a reference level of the range (20-100) mSv in case of emergency exposure according to the ICRP and IAEA has been considered;**
- **the total estimated dose during the first year will exceed 20 mSv.**

Evacuation-prepared area in case of emergency:

- **there is no control over the accidental reactors, in case of deterioration of the radiation conditions – to stay inside or to evacuate on their owns.**

Chernobyl: dose to thyroid (1/3)

Monitoring of the ^{131}I thyroidal content for the public

Territories, populations and dates:

- **Belarus** **200,000 residents. May 5 through June 1986**
- **Ukraine** **150,000 residents. May 5 through June**
- **Russia** **45,000 residents. May 15 through June**

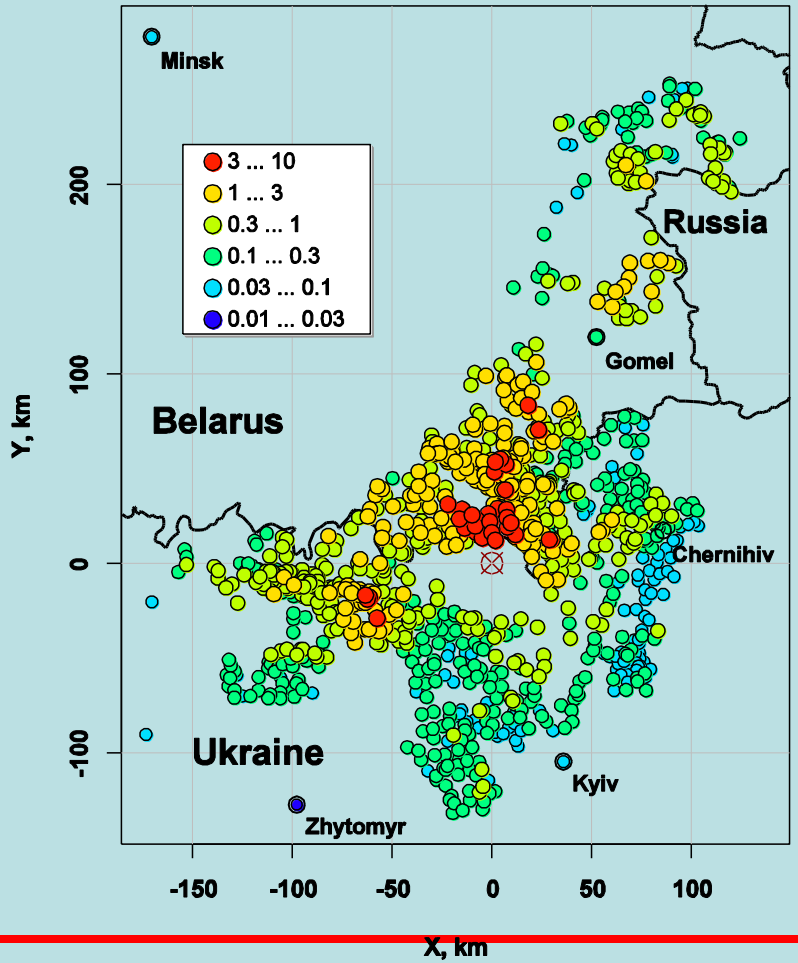
Chernobyl: dose to thyroid (2/3)

Individual doses derived from direct thyroid measurements for the Belarusian residents (Savkin and Shinkarev, 2007)

Area	Age-group	Thyroid dose, Gy		
		<0.3	0.3-2.5	>2.5
Evacuated villages from three southern raions of Gomel Oblast	0-3y	5.6%	39.8%	54.6%
	Adults	32.5%	60.0%	7.5%
Non-evacuated villages of three southern raions of Gomel Oblast	0-3y	14.5%	55.8%	29.8%
	Adults	65.3%	33.7%	0.9%
Contaminated territories of Mogilev Oblast	0-3y	61.1%	37.1%	1.9%
	Adults	94.0%	6.0%	0.02%

Chernobyl: dose to thyroid (3/3)

Average thyroid dose (Gy) for the children (0-17y) in the Belarusian and Ukrainian settlements based on thyroid measurements (Jacob et al, 2006)



Fukushima: dose to thyroid (1/2)

Thyroid measurements

- **Fukushima prefecture on March 26-30, 2011.**
- **1080 children aged up to 15y.**
- **From three settlements: Iitate village, Kawamata town, Iwaki city.**

- **Hirosaki city on April 12-16.**
- **62 evacuated people of various ages.**
- **From Tsushima district of Namie Town and coastal area of Minami Soma City.**

Fukushima: dose to thyroid (2/2)

According to the WHO report on
"Preliminary dose estimation …" (2012)

- **1 settlement (Namie town) – (100-200) mGy;**
- **Fukushima prefecture (excepting Namie town) – (10-100) mGy;**
- **In prefectures neighboring Fukushima – (1-10) mGy;**
- **All other Japanese prefectures – (1-10) mGy;**
- **The main contributors to thyroid dose – inhalation and ingestion intakes and external exposure from fallout**

Chernobyl vs Fukushima: dose to thyroid (1/2)

❖ **A large-scale monitoring of the thyroidal radioiodine content of the public following the Chernobyl accident – the basis for reliable estimate of individual thyroid doses for measured people and for developing realistic radioecological models to assess thyroid doses to unmeasured people.**

❖ **A small number of direct thyroid measurements following the Fukushima accident – allows for using them only to validate the radioecological models of thyroid dose reconstruction.**

Chernobyl vs Fukushima: dose to thyroid (2/2)

- **Measurements of the ^{131}I thyroidal content:**
  - **Chernobyl – more than 400,000 residents**
  - **Fukushima – less than 2,000 residents**
- **Dominant pathway of ^{131}I:**
  - **Chernobyl – ingestion intake with fresh cows' milk**
  - **Fukushima – inhalation intake**
- **Range of dose to the thyroid:**
  - **Chernobyl – up to 50,000 mGy**
  - **Fukushima – up to a few hundred mGy**

Lessons (1/6)

The strategy on the introduction, implementation, and withdrawal of countermeasures is driven by relevant national radiological criteria.

Lessons (2/6)

Early notification of the people and immediate introduction of emergency plans are extremely important.

Lessons (3/6)

Large-scale monitoring of thyroidal iodine content among the public is a solid basis for reliable estimates of thyroid doses. Early start of those measurements allows their use for adjusting the time and scale of countermeasures.

Lessons (4/6)

Timely implementation of urgent countermeasures in the early phase of a radiological emergency is the most effective means to avert radiation doses to the population.

Effectiveness of the countermeasures (in terms of cost per unit of averted dose) following the Chernobyl accident

Countermeasures	USD per 1 man-Sv	Area, time
External exposure		
Sheltering	0.02-1	Pripyat, April 26-27, 1986
Relocation	130,000-500,000	Contaminated areas, 1990
Internal exposure		
Iodine prophylaxis	0.02-0.1	April-May, 1986
Restriction of consumption of food	13,800-120,000	Bryansk Oblast, Russia, 1989

Lessons (5/6)

Preventing of ingestion intake of radioiodines by the public (Fukushima accident) is a strong measure for mitigation of the exposure to the thyroid that might have been several orders of higher if an ingestion intake had not been precluded (Chernobyl accident).

Lessons (6/6)

In the intermediate and late phases of the accident the decision on the selection of specific countermeasures should be based on cost-benefit analysis while taking into account the public perception and acceptance of those strategies.

Thank you
for your attention!