Doses received from the Chernobyl Accident

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Outline

- **Doses from the Chernobyl accident:**
  - **Doses to workers**
  - **Doses to the public**
- **Comparison of the doses from Chernobyl and Fukushima.**

Dose categories

External

Uniform dose
Delivered during exposure
Due to gamma rays
Workers

Internal

Non uniform dose
Protracted in time
Due to electrons
Members of the public

Chernobyl terminology

- **Two types of dose will be presented:**
  - **Absorbed doses to the thyroid (mainly from ^{131}I)**
  - **Absorbed doses to the whole body (mainly from external irradiation and internal ^{137}Cs)**
  - **NOTE: the dose to the whole body excludes the internal dose to the thyroid.**
- **All doses will be expressed in milligrays (1 milligray = 100 mrad = 0.1 rad).**
- **All data are extracted from most recent UNSCEAR reports or from results of NCI studies conducted jointly with Belarusian and Ukrainian organizations.**

Chernobyl accident: doses to emergency workers and to clean-up workers

Emergency workers with acute radiation sickness

Severity of disease	Dose (mGy)	Number	Early deaths
Mild	800 – 2,100	41	0
Moderate	2,200 – 4,100	50	1
Severe	4,200 – 6,400	22	7
Very severe	6,500 – 16,000	21	20
Totals		134	28

Chernobyl Clean-up Workers

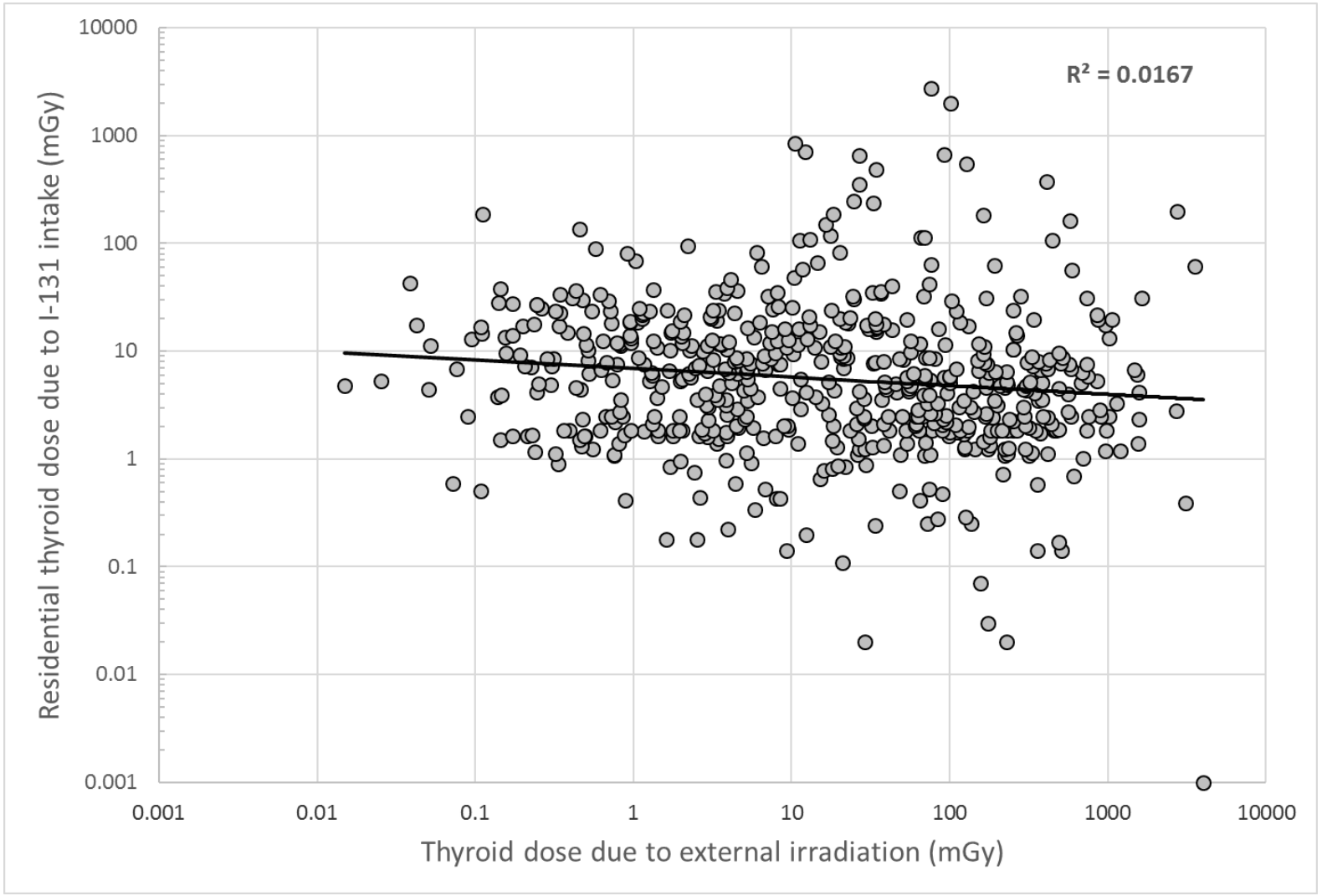
External whole-body doses to Chernobyl clean-up workers (mGy)

Year	Number of	% workers with	Mean recorded
	workers	recorded dose	dose (mGy)
1986	305,826	35	146
1987	138,173	64	96
1988	51,278	71	43
1989	24,128	69	41
1990	5,766	66	47
1986-1990	526,245	48	117

Thyroid doses to clean-up workers from external and internal irradiation

	Thyroid dose (mGy)			
	External irradiation	Intakes of ^{131}I		Total
		Inhalation	Residential	
N	608	199	585	608
Mean	160	43	30	200
Median	20	12	5.3	43
Range	0.02–4,010	~0–1,680	~0–2,730	0.1–4,860

Thyroid doses to clean-up workers: external vs internal

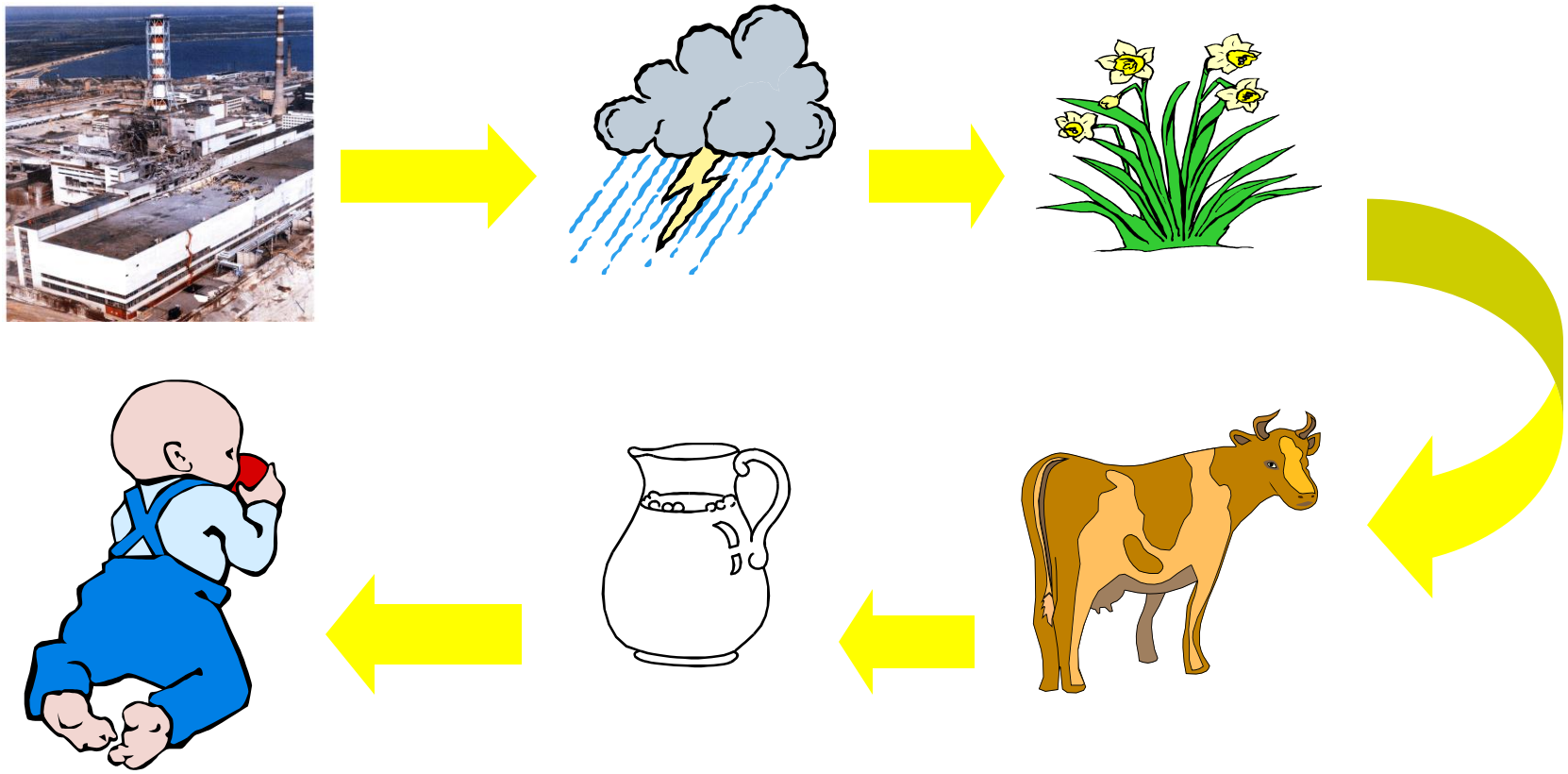


Chernobyl accident: Thyroid and whole-body doses to the public

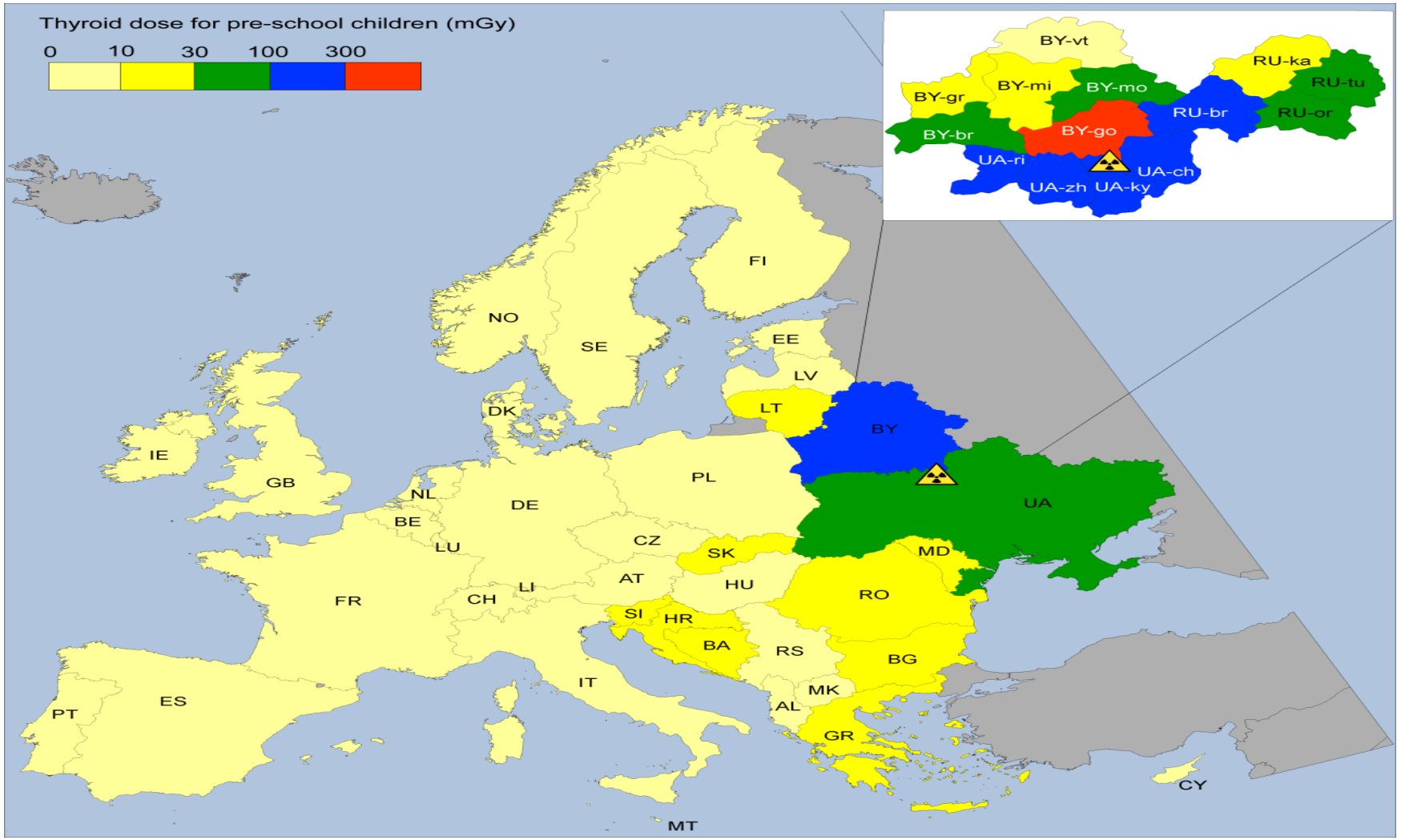
Thyroid dose: importance of ^{131}I

- Iodine-131 was the most important contributor to the thyroid dose during the first 2 months after the accident
- Iodine accumulates in the thyroid gland
- As a first approximation, the thyroid dose from ^{131}I is proportional to the consumption of milk and inversely proportional to the thyroid mass
- Because the thyroid mass increases with age, from 1-2 g in infants to about 20 g in adults, the average thyroid dose decreases with increasing age

Typical pathway of exposure to ^{131}I



Thyroid dose to European populations



Average thyroid doses (mGy)

Population group	Number (thousands)	Dose to 0-6 y	Dose to Adults	All ages
Evacuees	115	1,500	350	490
Inhabitants of contaminated areas (^{137}Cs deposition greater than 37 kBq m^{-2}):				
Belarus	1,800	450	140	180
Russian Federation	2,500	110	17	27
Ukraine	2,000	370	91	120
Inhabitants of BY+RF+UA	98,000	48	12	16
Inhabitants of distant countries	500,000	-	-	1.3

Distribution of thyroid doses from ^{131}I intakes

Mean thyroid dose (mGy)	Belarusian cohort (Drozdovitch *et al* 2015)		Ukrainian cohort (Likhtarov *et al* 2014)	
	N	%	N	%
<50	1,982	16.9	2,386	18.1
50 – 199	3,005	25.6	4,344	32.9
200 – 499	2,819	24.0	2,836	21.5
500 – 4,999	3,726	31.8	3,395	25.7
5,000 – 9,999	149	1.3	170	1.3
≥10,000	51	0.4	73	0.6
Entire cohort	11,732	100	13,204	100.0
Arithmetic mean (mGy)	680		650	
Median (mGy)	270		190	

Whole-body dose: importance of ^{137}Cs

- **From a few months to several decades after the accident, ^{137}Cs is the main contributor to the whole-body dose.**
- **The relative contributions of external and internal irradiation to the dose from ^{137}Cs were on average about equal, but they depended on the type of soil, on the type of diet, and on countermeasures.**
- **Internal irradiation: ^{137}Cs is uniformly distributed in all soft tissues of the body (not in the skeleton) and is eliminated from the body within a few months.**
- **The whole-body doses from ^{137}Cs do not vary substantially according to the age of the person.**

Average whole-body doses (mGy)

Population group	Number (thousands)	External dose	Internal dose	Total dose
Evacuees	115	22	9	31
Inhabitants of contaminated areas (^{137}Cs deposition greater than 37 kBq m^{-2}):				
Belarus	1,800	8	3	11
Russian Federation	2,500	4.7	2.2	6.9
Ukraine	2,000	6.8	3.2	10
Inhabitants of BY+RF+UA	98,000	0.9	0.4	1.3
Inhabitants of distant countries	500,000	-	-	0.3

Estimates of average thyroid and whole-body doses in a Belarusian cohort (mGy)

Source	Thyroid	Whole-body
Internal (^{131}I)	590	1
Internal (^{133}I + ^{132}Te)	20	0.1
Internal (^{137}Cs)	4	4
External (mainly ^{137}Cs)	8	8
All	620	13

Comparison of Chernobyl and Fukushima

Doses to workers (mGy)

	Fukushima	Chernobyl
Number of workers	25,000	530,000
Period of work	2011-2012	1986-1990
Mean external dose	About 20 mGy	120 mGy
Number with external doses:		
100 – 200 mGy	<200	48,000
>200 mGy	0	50,000
Number with internal doses:		
2,000 – 10,000 mGy	11	About 30
>10,000 mGy	2	7

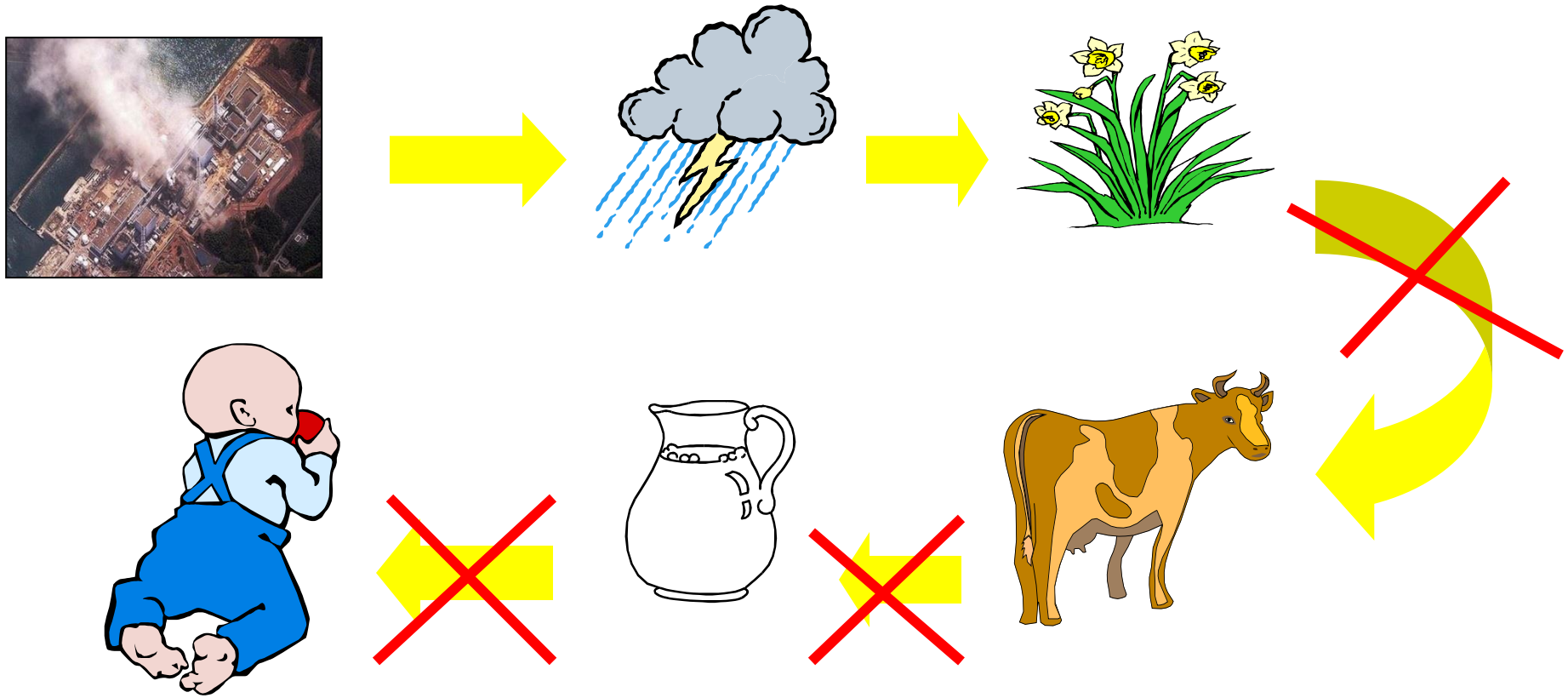
Estimated doses to highly exposed Fukushima workers

Worker	Internal thyroid (mGy)	External whole-body (mGy)
I1	11,800	88
I2	10,800	103
E1	780	199
E2	700	192

Doses to the public (mGy)

	Fukushima			Chernobyl		
Population group	**Number (thousands)**	**Thyroid dose (mGy)**	**Whole-body dose (mGy)**	**Number (thousands)**	**Thyroid dose (mGy)**	**Whole-body dose (mGy)**
Evacuees	**110**	**About 20**	**About 3**	**115**	**490**	**31**
Inhabitants of contaminated areas	**2,000**	**10**	**1**	**6,400**	**102**	**9**
Inhabitants of distant countries	**500,000**	**<0.1**	**0.01**	**500,000**	**1.3**	**0.3**

Fukushima: reduction of doses from ^{131}I



Summary (Chernobyl accident)

- **Chernobyl accident:**
  - **Whole-body doses to 134 emergency workers with acute radiation syndrome were in the range from 800 to 16,000 mGy.**
  - **Whole-body doses to over 500,000 cleanup workers were highest in 1986 (140 mGy) and decreased from year to year until 1990.**
  - **The average thyroid doses to 115,000 evacuees from BY, UA and RF in 1986 were 490 mGy and were much higher than the whole body doses (mainly from external irradiation and internal ^{137}Cs), which averaged 31 mGy.**
  - **The average doses to the 6,400,000 inhabitants of the contaminated areas (with a ^{137}Cs deposition greater than 37 kBq m^{-2} were about 100 mGy to the thyroid and 9 mGy to the whole-body.**
  - **The estimated doses to 500,000,000 inhabitants of distant countries are 1.3 mGy to the thyroid and 0.3 mGy to the whole body.**

Summary (Fukushima versus Chernobyl)

- **The doses resulting from the Fukushima accident were smaller (by a factor of about 10) than the doses from the Chernobyl accident because:**
  - **The accident was less “destructive”, thus reducing the occurrence of very high doses and the number of workers.**
  - **The releases of radioactive material and the size of the contaminated areas were smaller.**
  - **Quick implementation of countermeasures (evacuation, sheltering, food restrictions, monitoring).**
  - **The accident occurred during the winter, when leafy vegetables were not growing and cows were not on pasture.**

Thank you for your attention