

Health Effects of Chernobyl in the European Union

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- Although the radioactive fallout was mainly concentrated in the three countries close to the nuclear power plant (Ukraine, Belarus and the Russian Federation), lower concentrations came down over much of the entire Europe.

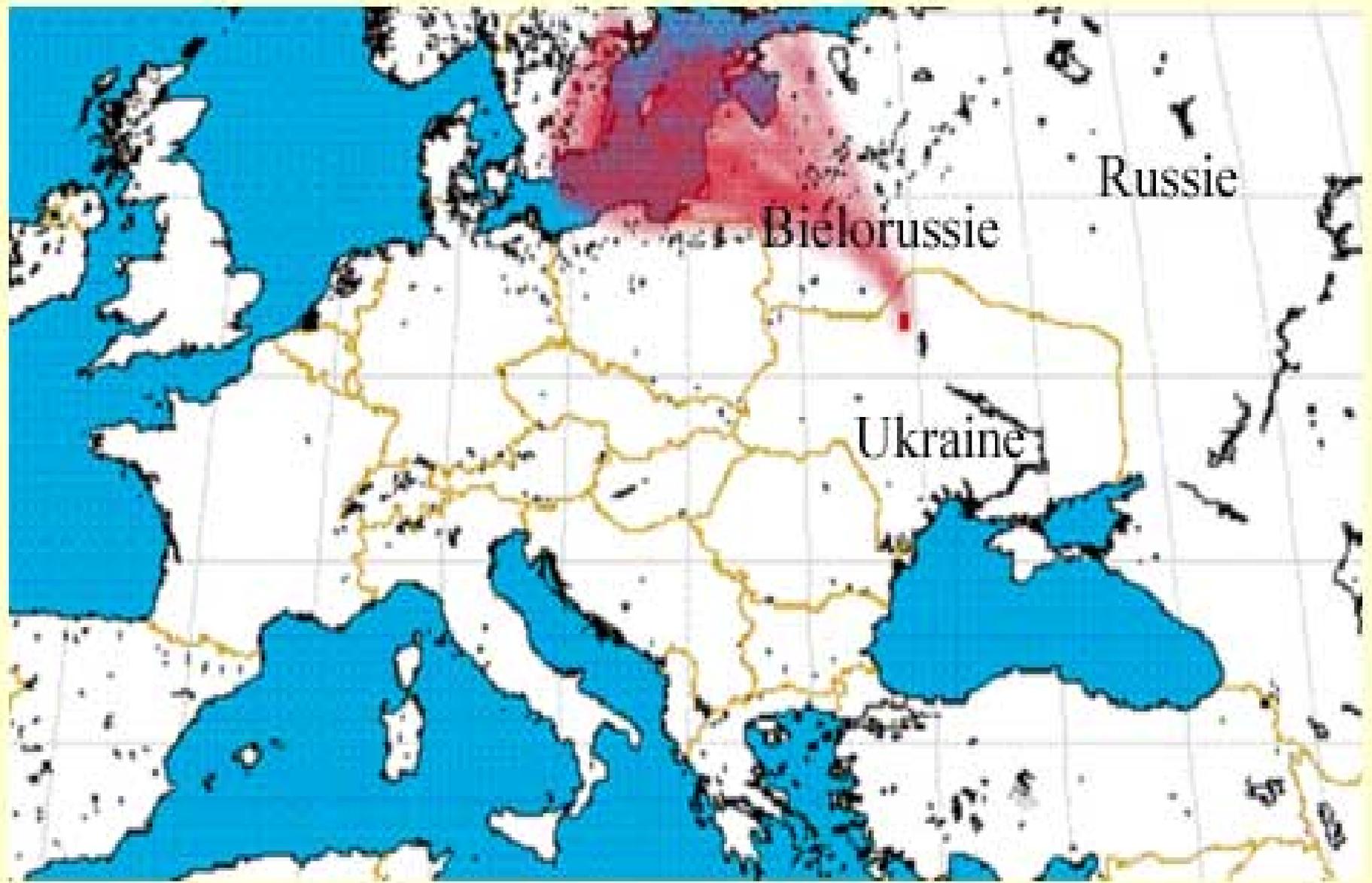
Land contamination in western Europe

- Initially the wind was blowing in a northwesterly direction and this phase was responsible for much of the deposition in the north of Europe.
- The Swedish nuclear power agency detected an increase in radioactivity and alerted other European countries in 28 April, about 60 hours after the accident had occurred.
- Later the plume shifted to the south-west and much of central Europe, as well as the northern Mediterranean and Balkans, received some deposition.

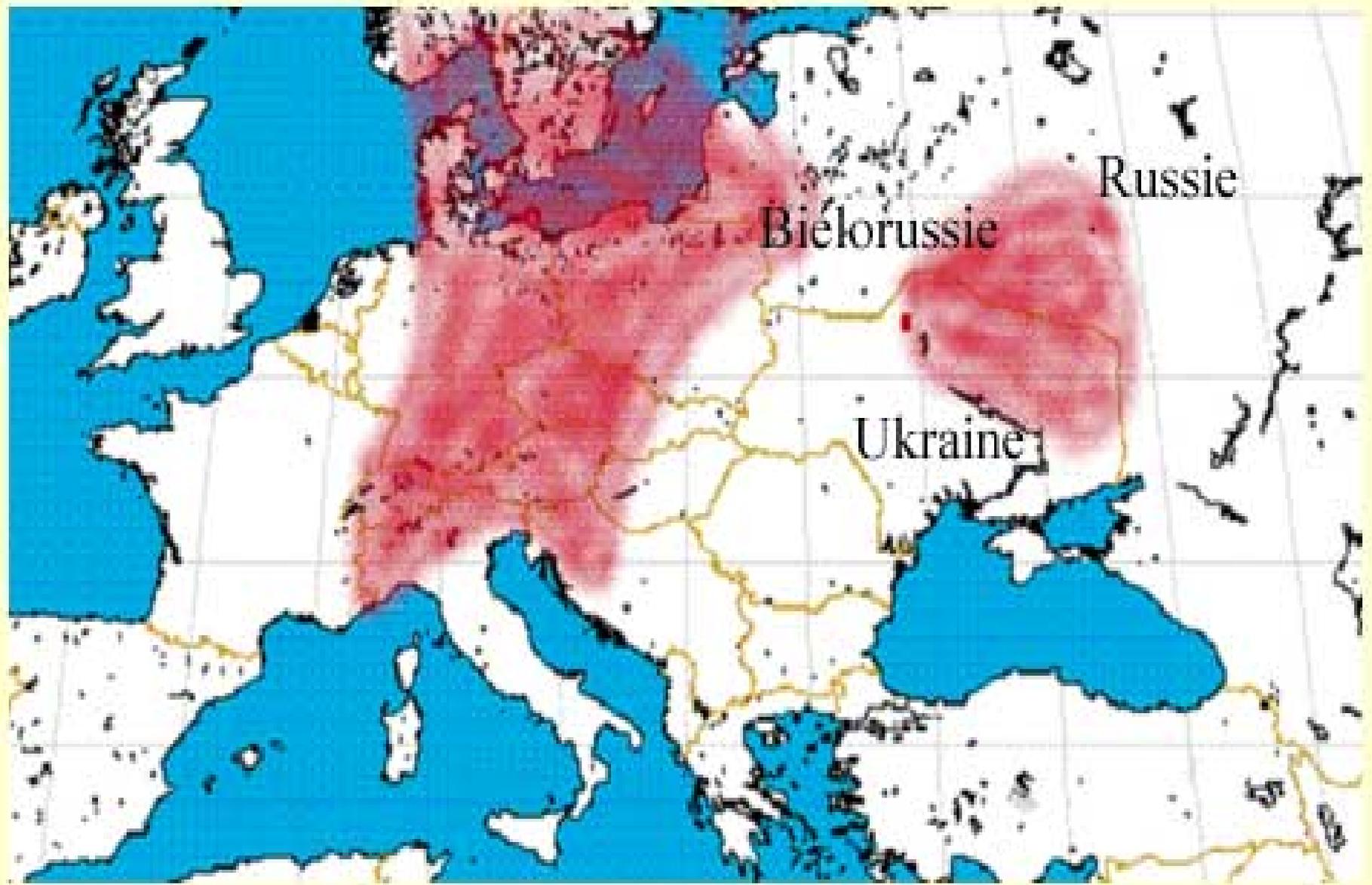
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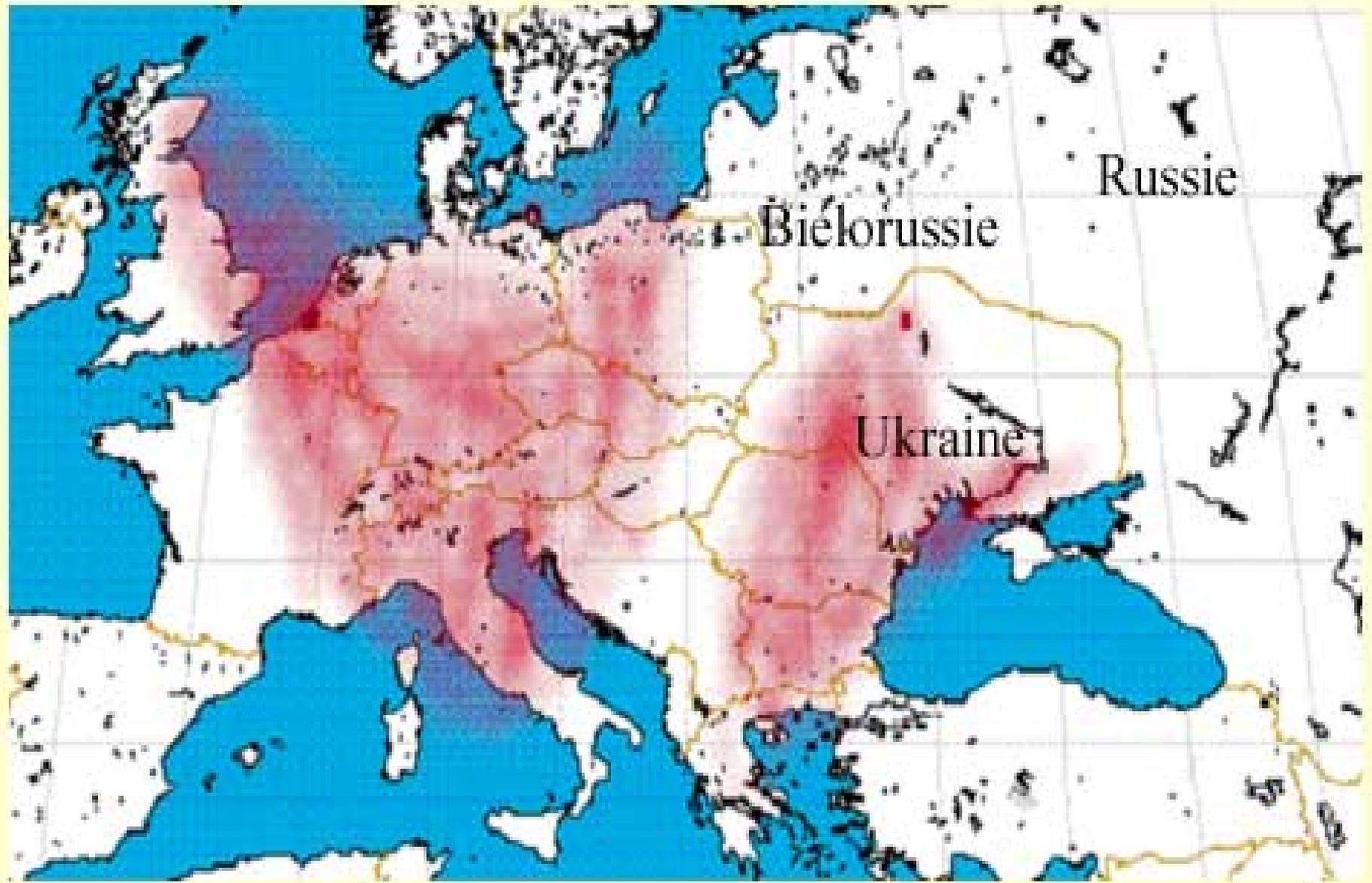
28 avril 1986



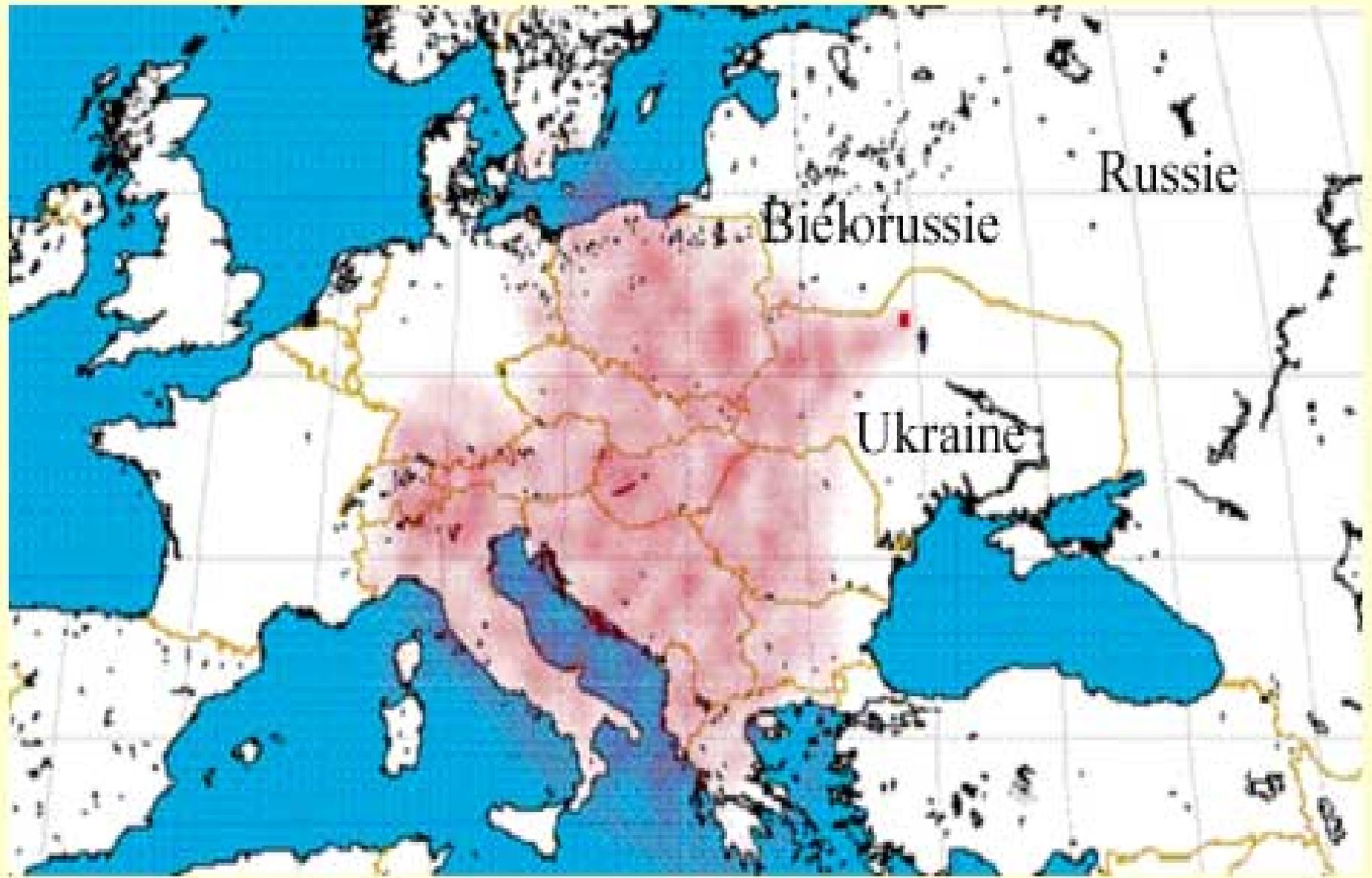
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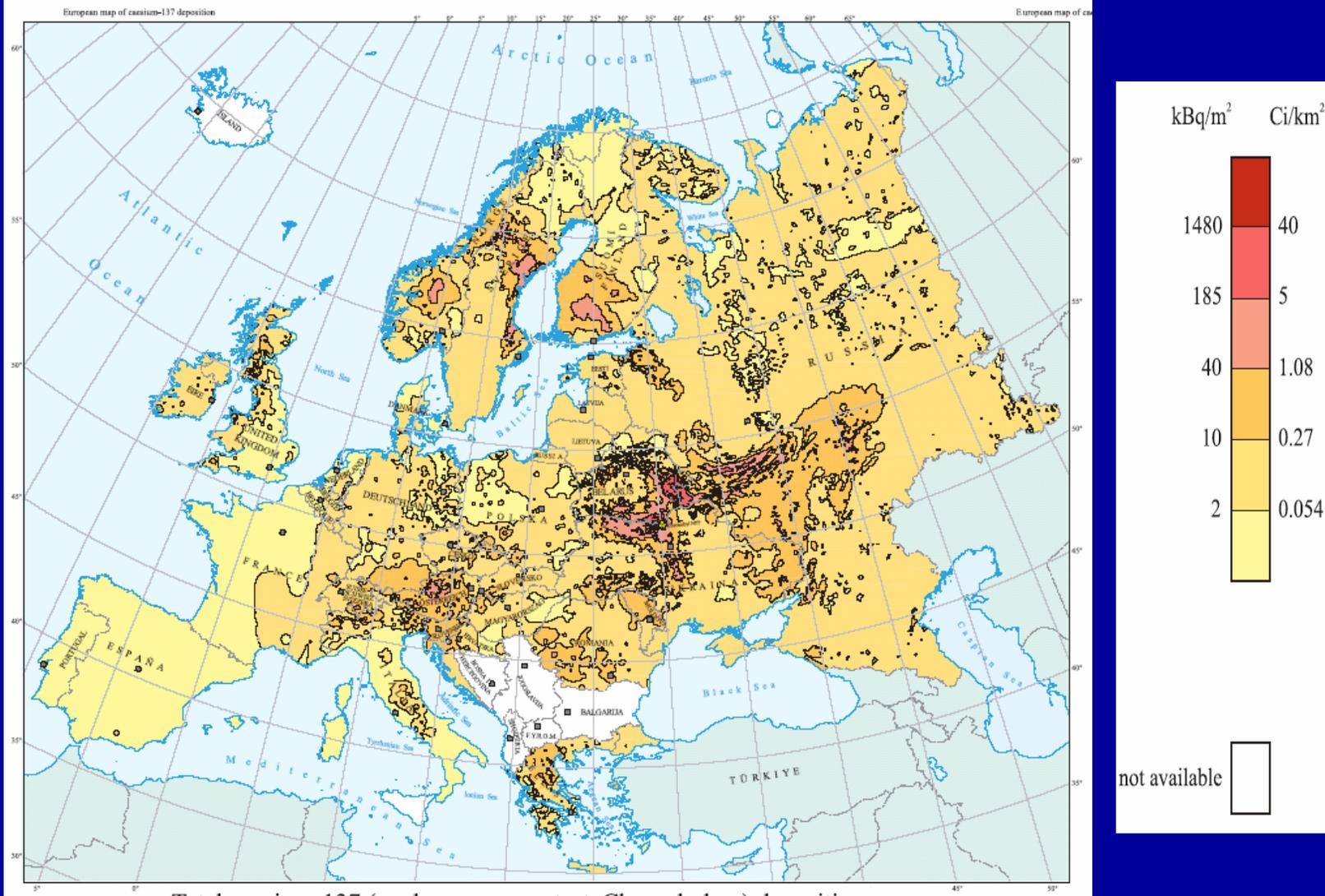
5 mai 1986



Land contamination in western Europe

- Local deposition varied largely depending on wind direction, time of arrival of the radioactive plume, terrain features, and the presence and intensity of rainfall during this period.
- The most radiologically important radionuclides detected were ^{131}I , $^{132}\text{Te}/^{132}\text{I}$, ^{137}Cs and ^{134}Cs .

Figure XI. Surface ground deposition of caesium-137 released in Europe after the Chernobyl accident [D13].

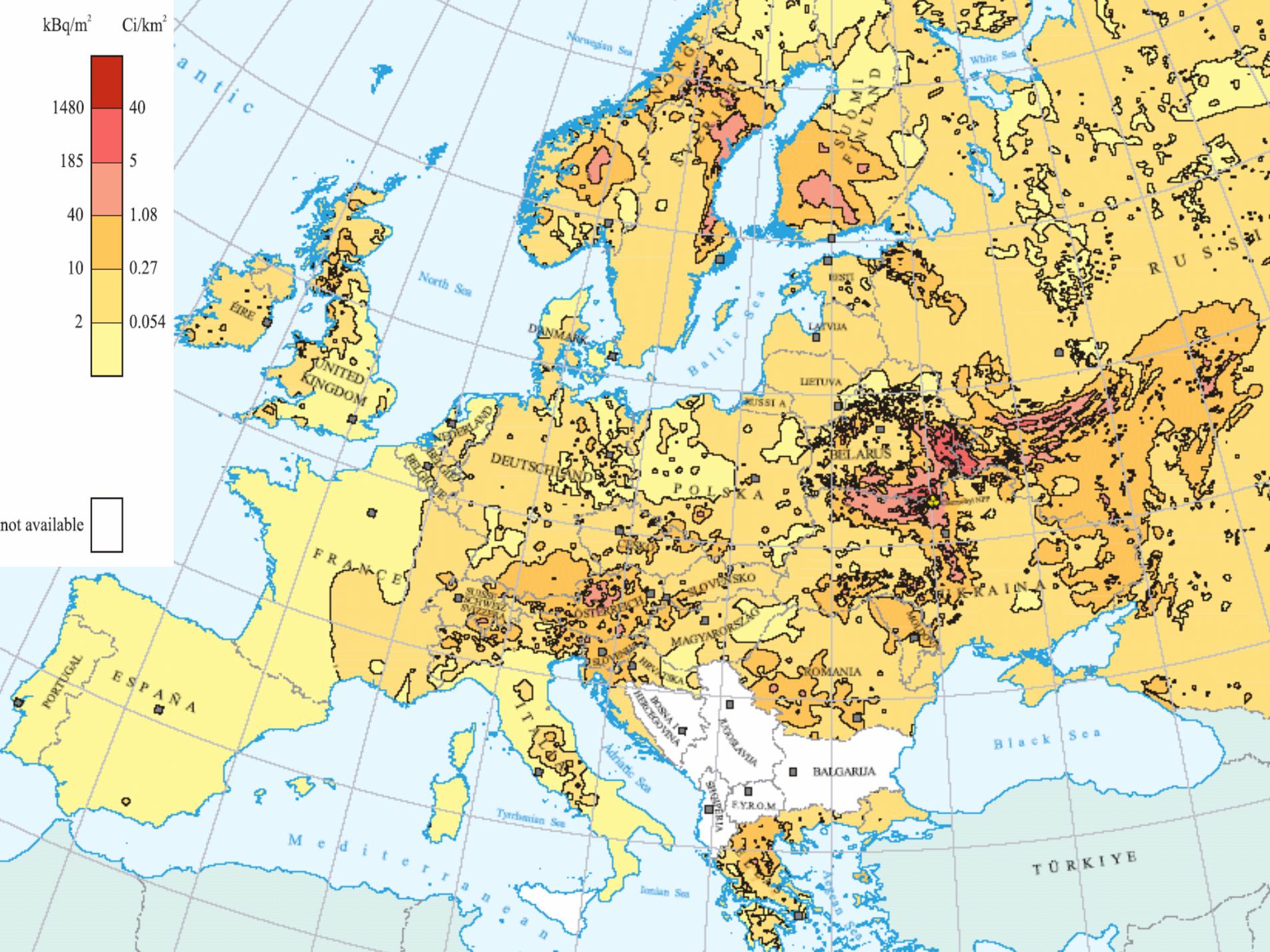


Total caesium-137 (nuclear weapons test, Chernobyl, ...) deposition

D13 De Cort, M., G. Dubois, Sh.D. Fridman et al. Atlas of caesium deposition on Europe after the Chernobyl accident. EUR 16733 (1998).

Land contamination in western Europe

- In Austria, Eastern and Southern Switzerland, parts of Southern Germany and Scandinavia, where the passage of the plume coincided with heavy rainfall, the total deposition from the Chernobyl release was high locally (up to and even exceeding 37 Bq/m²). On average, however, it remained 5 – 10 times weaker.
- Further to the west, in Spain and Portugal, the depositions amounted to practically zero (0.02 Bq/m²).
- In France, the depositions showed a gradient from east to west, in decreasing level.
- In Germany, the gradient ran from the south (“hot spots” in Southern Bavaria) to the North.
- In Greece, one of the most contaminated countries, average ¹³⁷Cs deposition was 6 kBq/m², but with variations from 0.5 to 60 kBq/m².



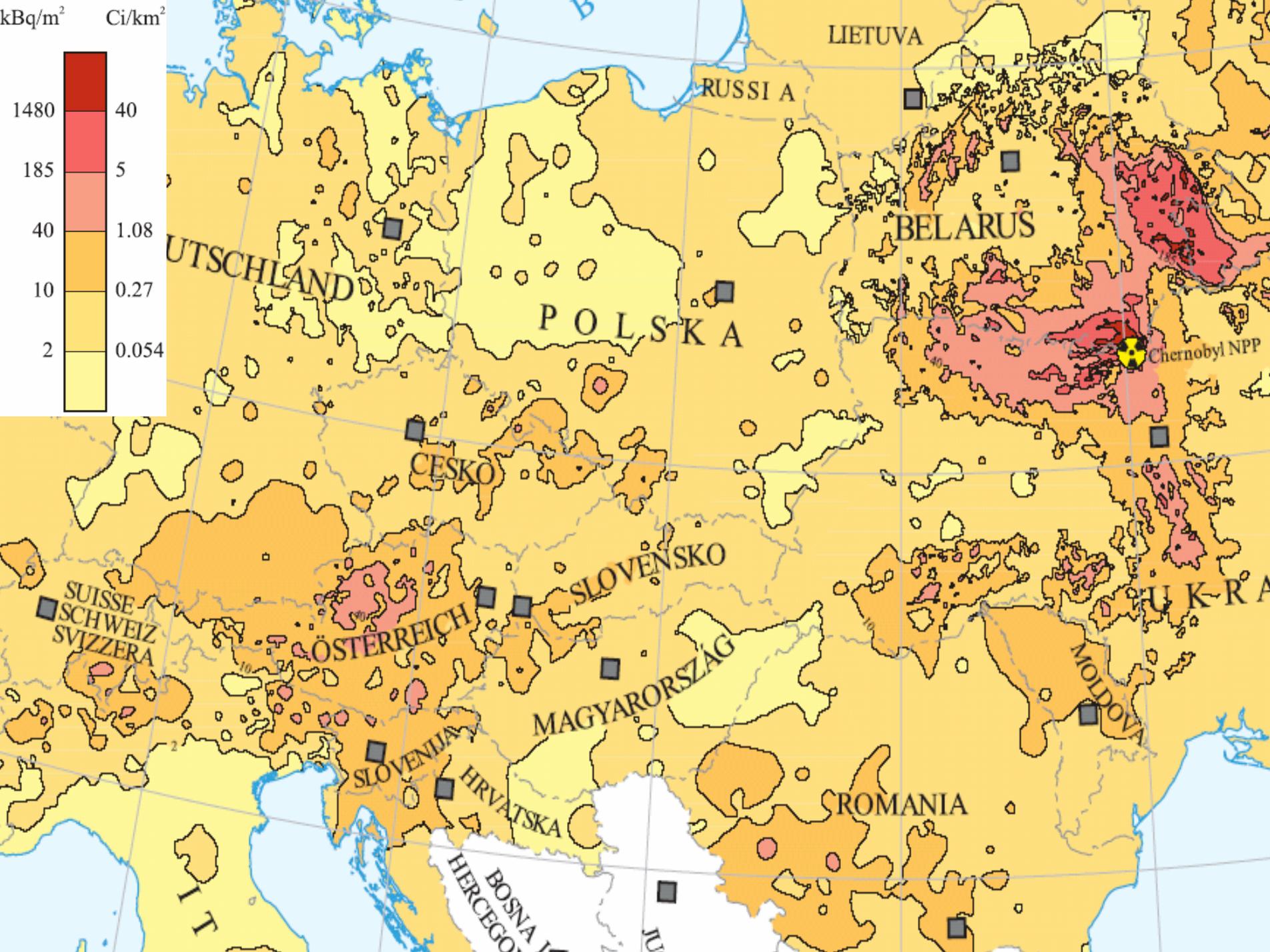
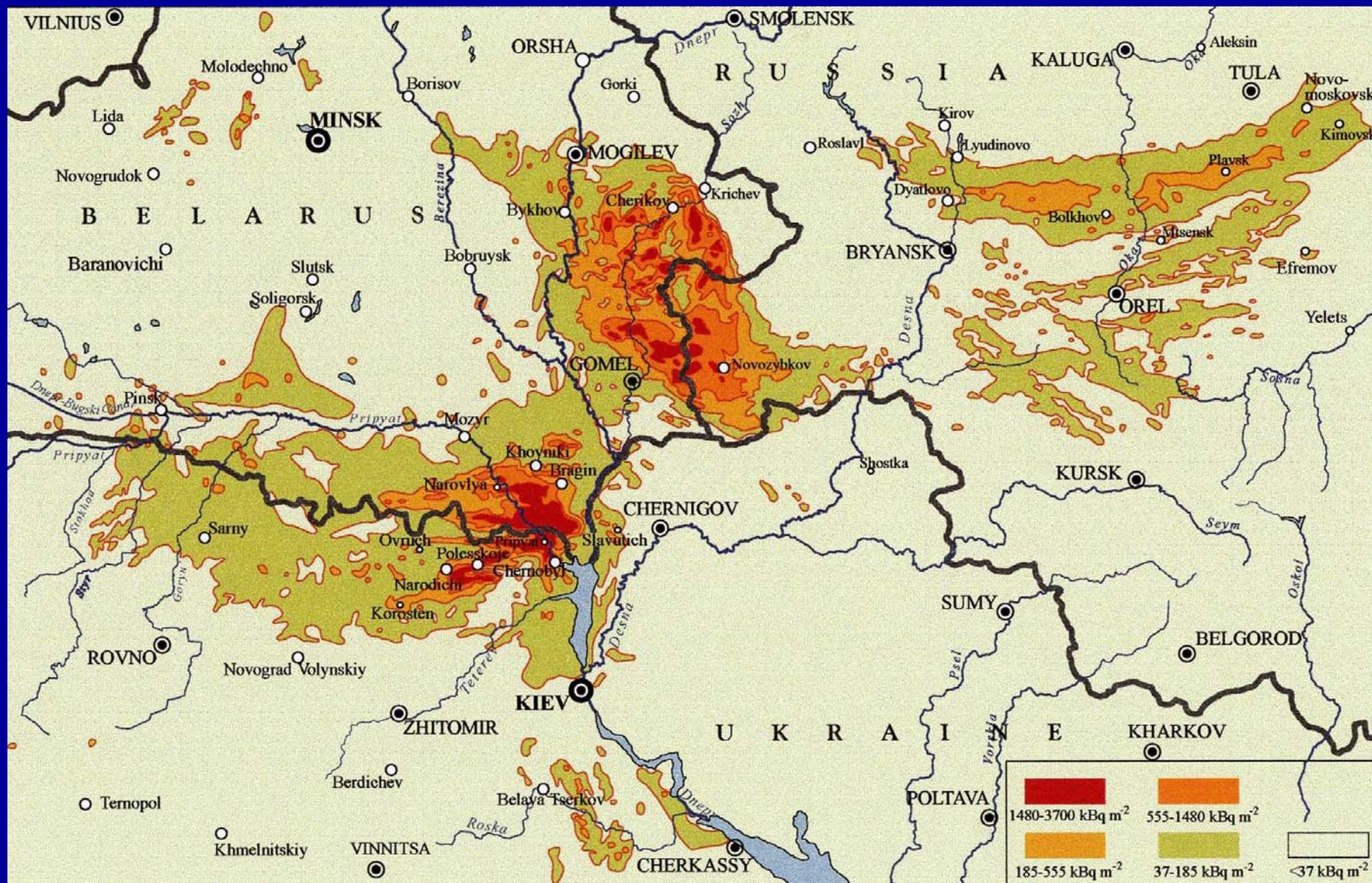


Table 5
Contaminated areas in European countries following the accident
 [124]

Country	Area in deposition density ranges (km ²) ^a			
	37-185 kBq m ⁻²	185-555 kBq m ⁻²	555-1 480 kBq m ⁻²	>1 480 kBq m ⁻²
Russian Federation	49 800	5 700	2 100	300
Belarus	29 900	10 200	4 200	2 200
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	-	-	-

^a The ¹³⁷Cs levels include a small contribution (2-4 kBq m⁻²) from fallout from the atmospheric weapons tests carried out mainly in 1961 and 1962.

Figure VI. Intensity levels of Cs-137 surface ground depositon.



One should not search for radiation-induced pathologies in Western Europe, that have not declared in heavily contaminated territories of Belarus and Ukraine.

Has there been an increase in the number of voluntary abortion ?

The news of spread of radioactivity over Europe generated much anxiety. The real impact of this anxiety among the public is difficult to assess. Some authors reported on a small increase in the number of induced abortions that temporally may have been partially due to fear and misinformation.

- *Spinelli A, Osborn JF. The effects of the Chernobyl explosion on induced abortion in Italy. Biomed Pharmacother. 1991;45:243-7.*

Radiation-induced pathologies in residents of contaminated territories of Belarus and Ukraine (excluding Emergency Workers and Liquidators).

Thyroid cancer

Chernobyl Forum

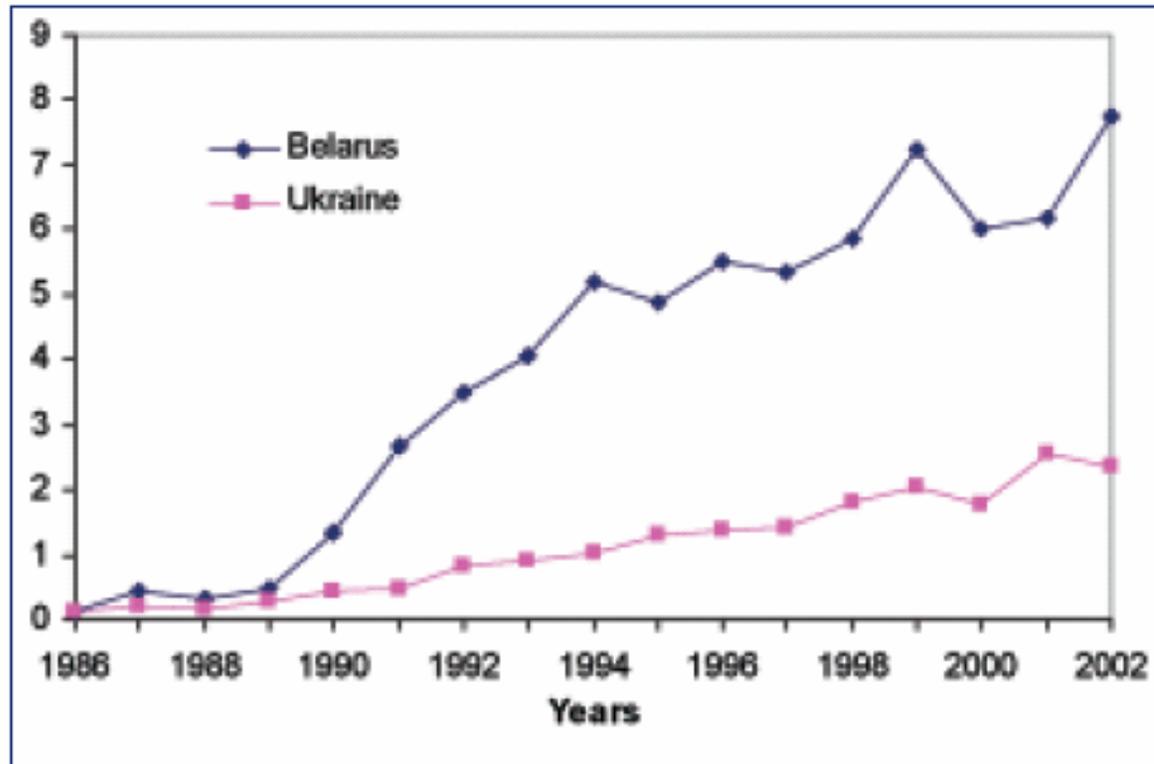


FIG. 3. Incidence rate of thyroid cancer in children and adolescents exposed to ^{131}I as a result of the Chernobyl accident (Jacob et al., 2005).

Leukemia

Chernobyl Forum

There have been many post-Chernobyl studies of leukaemia morbidity in the populations of areas contaminated with radionuclides in the three countries. There is no convincing evidence that the incidence of leukaemia has increased in children or adult residents of the exposed populations in Russia and Ukraine.

Other solid cancers

Chernobyl Forum

Because of the generally low doses received, however, there remains a lack of evidence of any measurable effect of Chernobyl radiation exposures on solid cancers in the general population except for childhood thyroid cancer, since higher doses to the thyroid gland were received by children in contaminated areas.

Congenital malformations

Chernobyl Forum

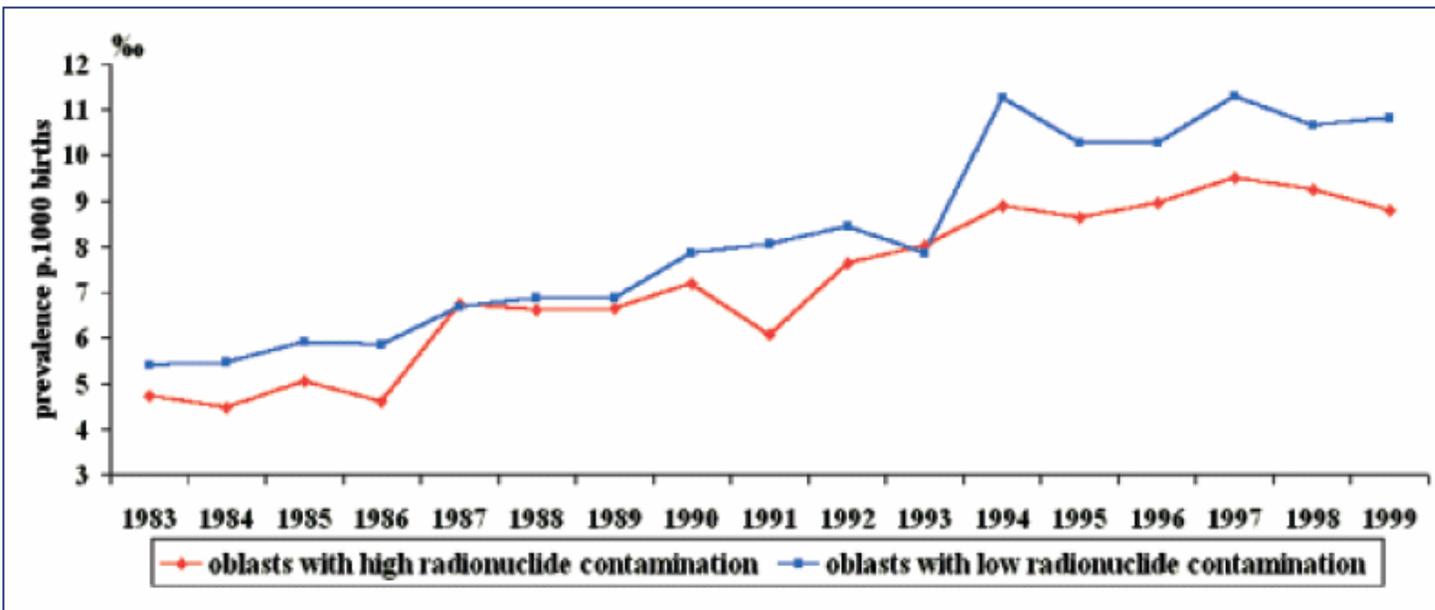


FIG. 4. Prevalence at birth of congenital malformations in 4 oblasts of Belarus with high and low levels of radionuclide contamination (Lazjuk et al., 1999).

**We will focus on childhood thyroid cancer,
examining respectively data from heavily
contaminated regions and those from
Western Europe.**

Thyroid cancer and ionizing radiation: data before Chernobyl.

- The follow-up of survivors of atomic bombs has established that thyroid exposure during childhood increases the risk of thyroid cancer. No increase is clearly apparent below a radiation dose of 0.1 Gy.

Thompson DE, et al. Cancer incidence in atomic bomb survivors. Part II: solid tumors, 1958-1987. Radiat Res 1994;137:S17-S67.

Intervention levels for administration of stable iodine

- Before the Chernobyl accident, most countries would consider administration of stable iodine if internal thyroid radiation is expected to exceed 100 mGy (avertable dose).

Excess risk for thyroid cancer in atomic bomb survivors

Age at exposure (years)	Excess Relative Risk (per Sv)	Excess Absolute Risk (per 10 000 PY Sv)
< 10	~ 9.5	~ 4.4
10-19	~ 3	~ 2.7
> 20	~ 0.1*	~ 0.2

Data adapted from Thompson et al.

Cancer incidence in atomic bomb survivors. Part II: solid tumors, 1958-1987.
Radiat Res 1994;137:S17-S67.

Thyroid cancer in those exposed as children

A sharp increase in childhood thyroid cancer started four years after the accident.

In the years 1993-1997, the incidence of childhood thyroid cancer in areas of Gomel, south Belarus, were about one hundred times higher than usual incidence for this disease in children.

Why the thyroid gland ?

- The huge release of iodine radioisotopes, and the ability of the thyroid to avidly concentrate iodine as part of its normal metabolism, make the thyroid the critical organ.
- Doses received by the thyroid gland are about one to two orders of magnitude higher than those received by other organs.

Why children ?

- The thyroid of children is much more vulnerable to radiation. Vulnerability is highest in the younger age groups.
- Moreover, radiation doses to the thyroid (energy deposit per unit organ mass) were several times higher in children than in adults, and were highest in the younger age groups. (High iodine intake combined with small organ mass).
- Thus, in any region, the cohort of children aged less than 5 years at the time of the accident is the one most at risk.

*Hindie E, Leenhardt L, Vitaux F, Colas-Linhart N, Grosclaude P, Galle P, Aurengo A, Bok B.
Non-medical exposure to radioiodines and thyroid cancer.
Eur J Nucl Med Mol Imaging. 2002;29 Suppl 2:S497-512. Review.*

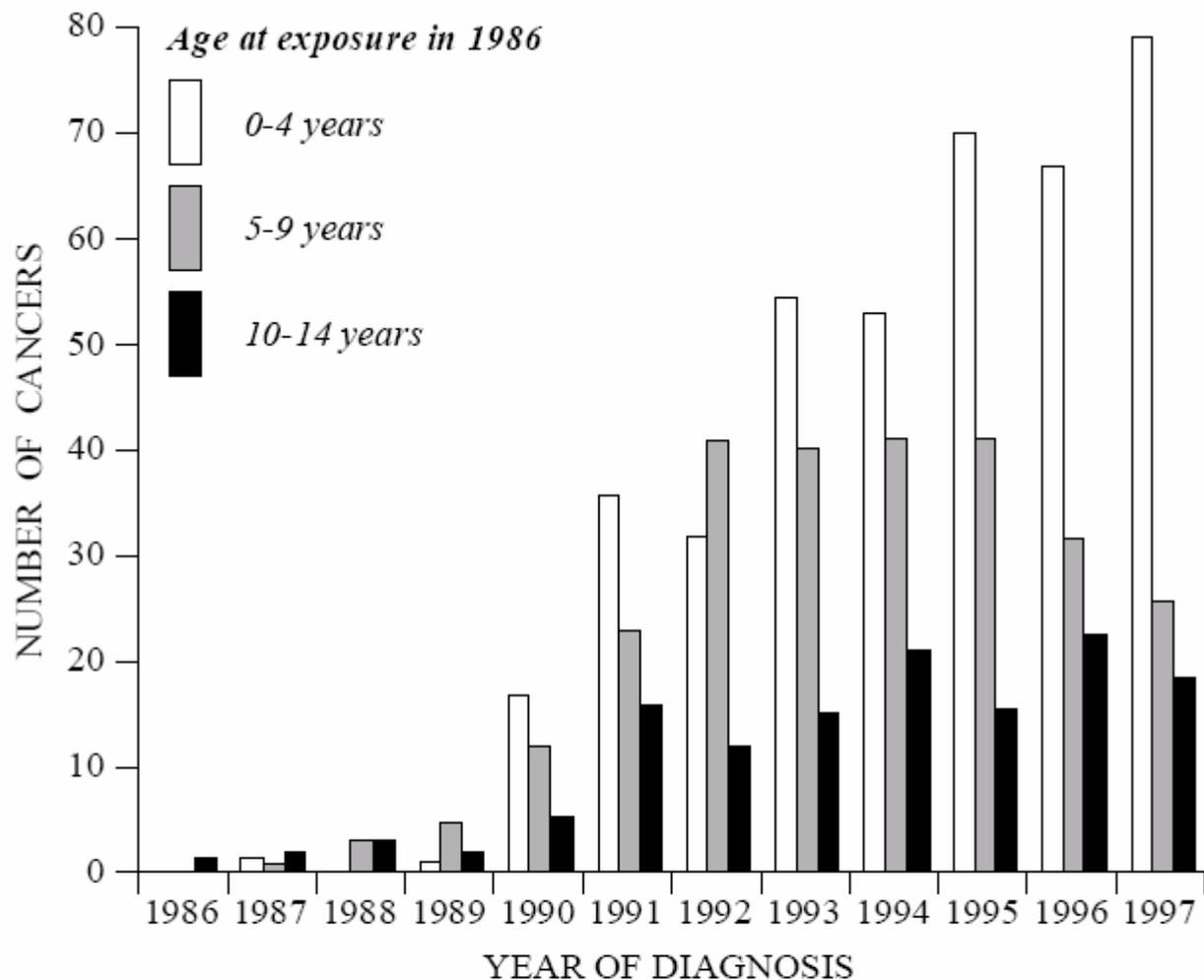


Figure XXVI. Number of diagnosed thyroid cancer cases in Belarus as a result of the Chernobyl accident [K41].

Comparison of thyroid doses in heavily contaminated areas of Belarus and Ukraine and those in Western Europe.

Thyroid doses in heavily contaminated areas.

- Thyroid contamination occurred through several routes. During the first days, inhalation, and ingestion of contaminated water and raw vegetables, were the major sources. Later, ingestion of contaminated milk became predominant.
- Many uncertainties limit the accuracy of thyroid dose estimates. The respective importance of short-lived isotopes (^{133}I ; $^{132}\text{Te}/^{132}\text{I}$) and ^{131}I is also difficult to assess.
- The contribution of short-lived isotopes should have been maximal in evacuees, in whom it may have exceeded that of ^{131}I . In contrast, when contamination resulted from ingestion of cow milk, the contribution of short-lived isotopes would have been small.

Thyroid doses in Belarus and Ukraine.

- Thyroid doses were not uniform. In Belarus, more than half the collective thyroid dose resulted from exposure in the Gomel region. In Ukraine, a large part of the collective thyroid dose resulted from exposure in eight districts located around the Chernobyl reactor.
- Based on 27 000 measurements sampled from the contaminated districts of the Gomel region of Belarus, 30% of those aged less than 4 had received a thyroid dose higher than 2 Gy (2000 mGy).
- Similarly, in Ukraine, the average thyroid dose for children aged less than 4 from the evacuated 30-km zone (Pripyat city, and other settlements) exceeds 2 Gy.

Estimates of collective thyroid doses to populations of Belarus

<i>Country/region</i>	<i>Population</i>	<i>Collective thyroid dose (man Gy)</i>
Belarus [D1, G7]		
Brest	1 400 000	101 000
Gomel	1 700 000	301 000
Grodno	1 200 000	49 000
Minsk	3 200 000	68 000
Mogilev	1 300 000	32 000
Vitebsk	1 400 000	2 000
Entire country	10 000 000	553 000

Table 22
Estimates of thyroid doses from intake of ^{131}I received by the evacuees of Belarusian villages
 [G15]

<i>Age at time of accident^a (years)</i>	<i>Number of measured persons</i>	<i>Arithmetic mean thyroid dose (Gy)</i>	<i>Median thyroid dose (Gy)</i>	<i>Estimated number of residents^b</i>	<i>Collective thyroid dose (man Gy)</i>
<1	145	4.3	2.3	586	2 519
1-3	290	3.7	1.7	966	3 573
4-7	432	2.1	1.2	1 199	2 517
8-11	460	1.4	0.86	1 105	1 548
12-15	595	1.1	0.61	1 392	1 531
16-17	221	1.0	0.59	704	704
>17	7 332	0.68	0.38	18 773	12 766
Total	9 475			24 725	25 158

a Derived from information on year of birth; e.g. age <1 includes children born in 1986 and 1985.

b Based on the age distribution available for 17,513 evacuees.

Table 21
Estimates of thyroid doses from intake of ¹³¹I received by the Ukrainian evacuees of towns and villages within the 30-km zone
 [G8, R12]

<i>Age at time of accident (years)</i>	<i>Pripyat town [G8]</i>			<i>Chernobyl town ^a</i>			<i>Evacuated villages ^a</i>			<i>Total collective dose (man Gy)</i>
	<i>Number of persons</i>	<i>Arithmetic mean dose (Gy)</i>	<i>Collective dose (man Gy)</i>	<i>Number of persons</i>	<i>Arithmetic mean dose (Gy)</i>	<i>Collective dose (man Gy)</i>	<i>Number of persons</i>	<i>Arithmetic mean dose (Gy)</i>	<i>Collective dose (man Gy)</i>	
<1	340	2.18	741	219	1.5	329	369	3.9	1 439	2 509
1-3	2 030	1.28	2 698	653	1	653	1 115	3.6	4 014	7 265
4-7	2 710	0.54	1 463	894	0.48	429	1 428	1.7	2 428	4 320
8-11	2 710	0.23	623	841	0.15	126	1 360	0.62	843	1 592
12-15	2 710	0.12	325	846	0.11	93	1 448	0.46	666	1 084
16-18	2 120	0.066	140	650	0.09	59	941	0.39	367	566
>18	36 740	0.066	2 425	9 488	0.16	1 518	21 794	0.40	8 718	12 661
Total	49 360		8 315	13 591		3 206	28 455		18 475	29 996

^a Assumes same age distribution of population as Pripyat.

Thyroid doses in Western Europe.

- In Western Europe, contamination with iodine-131 occurred mainly through ingestion of contaminated milk, and raw vegetables. The contribution of short-lived isotopes is negligible.
- Some products considered to have a radioactive burden higher than a "safety threshold" were not approved for sale by local authorities.
- Thyroid doses are not always correlated with the level of radioactive deposit. They also depended on whether cows were on pasture, on dietary habits, and on the avidity of the thyroid for iodine, being higher in countries with low iodine in diet.

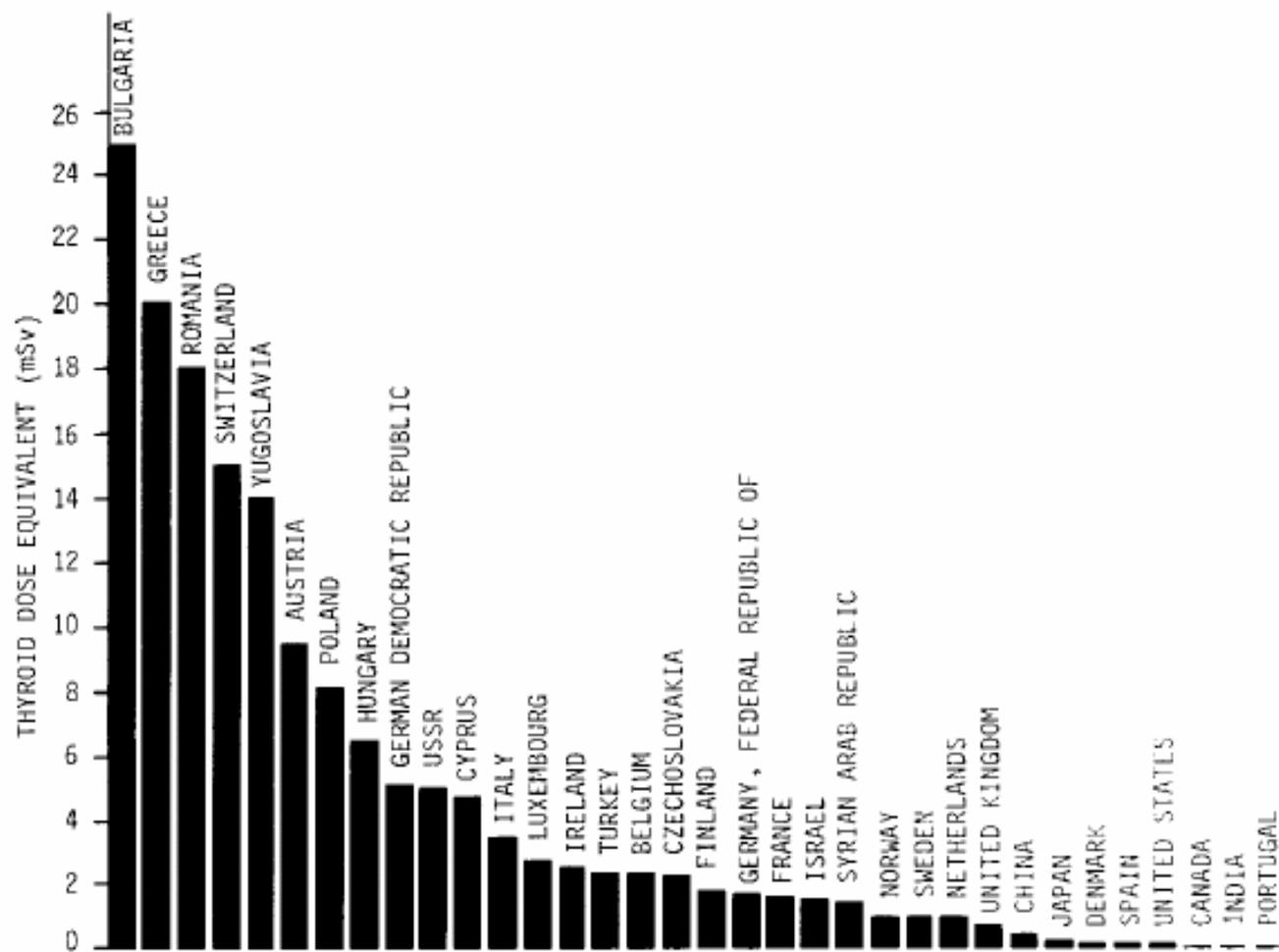


Figure XV. Country-wide average infant thyroid dose equivalents from the Chernobyl accident.

Thyroid doses in Western Europe.

- Estimates of thyroid absorbed doses to infants vary from one country to another and in different regions, from less than 0.1 mGy in Portugal and Spain to about 6 mGy in the south of Germany, and up to 30 mGy in the north of Greece.
- Even in the most affected regions, infant thyroid doses in Western Europe are one hundred times lower than those received by inhabitants of south Belarus and northern Ukraine.
- Adult thyroid doses were lower than infant doses by a factor of 5.

Childhood thyroid cancer in the heavily contaminated territories.

- Usual incidence rates of childhood thyroid cancer in Europe range between 0.4 and 1.5 cases per million.
- During the period 1993-1997, incidence rates of childhood thyroid cancer (under 15 years at diagnosis) in Belarus averaged 53 cases per million per year.
- As expected, the increase was not uniform. Incidence rates were as high as 150 in the Gomel region, while in the region of Vitebsk, they were close to natural incidence.

Table 57
Thyroid cancer incidence rates in children under 15 years old at diagnosis

Region	Number of cases per 100 000 children												
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Belarus [P9]													
Brest	-	-	0.4	-	3.3	2.9	3.7	11.6	8.1	8.8	7.3	8.2	8.0
Vitebsk	-	-	-	-	0.5	1.4	1.4	-	1.0	-	-	1.2	-
Gomel	0.4	0.7	0.7	0.7	5.6	15.0	11.2	13.9	15.9	17.9	16.9	16.0	7.1
Grodno	1.1	0.6	0.5	1.1	0.6	2.2	3.2	2.7	2.2	2.8	2.4	3.1	3.3
Minsk city	-	-	0.4	-	1.5	1.9	2.7	3.5	1.2	3.9	0.5	2.0	3.7
Minsk	-	0.4	0.4	0.4	-	1.7	3.2	2.0	3.0	0.9	2.8	3.9	1.6
Mogilev	-	-	-	-	1.0	0.5	0.5	3.2	2.2	2.9	1.8	2.6	2.0
Total	0.2	0.3	0.4	0.3	1.9	3.9	3.9	5.5	5.1	5.6	4.8	5.6	3.9

Thyroid cancer in those exposed as children in the heavily contaminated territories.

- Increased incidence of thyroid cancer continues to be observed as the population exposed as children aged into adolescence and now adulthood.
- Between 1992-2000 in Belarus, Russia, and Ukraine about 4000 cases of thyroid cancer were diagnosed among those who were children and adolescents (0-18 years) at the time of the accident (Chernobyl Forum).
- **Not all these cases are due to radiation.**
- With the aging of the cohort, carefully controlled epidemiological studies will be required to estimate the excess cancer risk, as the natural incidence increases with age and as screening can strongly influence the results.

Jacob P, et al. Thyroid cancer among Ukrainians and Belarusians who were children or adolescents at the time of the Chernobyl accident.

J Radiol Prot. 2006 ;26:51-67. Epub 2006 Mar 7.

Thyroid cancer in Western Europe before and after Chernobyl.

- Even if the thyroid radiation was quite low, millions of young children in Western European countries have been exposed to these low levels of contamination. Patients with a new diagnosis of thyroid cancer may ask about a possible link with the accident.
- In order to detect a specific increase in thyroid cancer one should focus on age groups who are most at risk (i.e. children, and especially so those exposed below 5 years).
- When an increase in thyroid cancer occurs during childhood or adolescence it would be easy to differentiate (low natural incidence).
- Studies focusing on adults in Western Europe are not justified. Thyroid doses received by adults were very low, the adult thyroid is much less sensitive to radiation, and the extreme effects of screening on the incidence of thyroid cancer in adults renders any search for a small increase elusive.

Thyroid cancer in Western Europe before and after Chernobyl.

- Studies were initiated in several countries of eastern and southern Europe, outside the former USSR.
- An International Union against Cancer (UICC) review collated results from studies in Greece, Croatia, Turkey, and Poland and was reported by Sali et al, in 1996.

Sali D, Cardis E, Sztanyik L, Auvinen A, Bairakova A, Dontas N; Grosche B, Kerekes A, Kusic Z, Kusoglu C, Lechpammer S, Lyra M, Michaelis J, Petridou E, Szybinkisz ?, Tominaga S, Tulbure R, Turnbull A, Valerianova Z.

Cancer consequences of the Chernobyl accident in Europe outside the former USSR: a review. Int J Cancer 1996;67:343-352.

- The authors conclude to no increase in incidence attributable to radiation from Chernobyl.
- However, the duration of follow-up in most studies was less than 7 years, and most of them did not focus on the childhood population.

Table 52
Populations in Europe examined in epidemiological studies
[S12]

<i>Country</i>	<i>Study region</i>	<i>Age group</i>	<i>Average absorbed dose (mGy) ^a</i>
Thyroid studies			
Croatia	Whole country	All ages	15 ^b
Greece	Whole country	20-60 years	5
Hungary	Whole country	All ages	3 ^b
Poland	Krakow, Nowy Sacz	All ages	4 ^b
Turkey	Five most affected areas on Black Sea coast and Edirne province	All ages	1.5 ^b

Several more reports were recently published

- One study from England
- One study from France
- One study from Italy
- One study from Austria

The study from England

- **Cotterill et al, reported on an increase in childhood thyroid cancer in the North of England.**

Cotterill SJ, Pearce MS, Parker L.

*Thyroid cancer in children and young adults in the North of England. Is increasing incidence related to the Chernobyl accident?
Eur J Cancer. 2001;37:1020-6.*

- **The authors noted that 4 cases have been diagnosed in the period 1987-1997, while only 3 cases were registered in the period 1968-1986.**
- **The comparison stands on very small numbers.**
- **Moreover, two of the four cases occurred in the period 1987-1990, where no increase is expected.**
- **The incidence was actually lower in 1991-1997 (2cases) than in 1987-1990 (2 cases).**

The study from France

- **In France, cases of childhood thyroid cancer (under 15 years) are registered in pediatric, or specialized cancer registers.**
- **The incidence studied by age and by period show no significant change with time that could be related to the Chernobyl accident.**
- **Incidence rates were lower in the years 1993-1997 (0.79 per million) than in the years 1987-1992 (1.06 per million).**

Leenhardt L, Grosclaude P, Cheri-Challine L et al. Mise en place d'un dispositif de surveillance épidémiologique nationale des cancers thyroïdiens, rapport intermédiaire. InVS, 9745 Paris November 20001.

Hindie E, Leenhardt L, Vitaux F, Colas-Linhart N, Grosclaude P, Galle P, Aurengo A, Bok B.

Non-medical exposure to radioiodines and thyroid cancer.

Eur J Nucl Med Mol Imaging. 2002;29 Suppl 2:S497-512. Review.

Evolution of the incidence of childhood thyroid cancer in France by period

Incidence per million (number of cases)

Age at discovery (years)	Years 87-92	Years 93-97
0-4	0.0 (0)	0.15 (1)
5-9	0.96 (8)	0.55 (4)
10-14	2.23 (18)	1.62 (12)
Total	1.06 (26)	0.79 (17)

Hindie E, Leenhardt L, Vitaux F, Colas-Linhart N, Grosclaude P, Galle P, Aurengo A, Bok B. Non-medical exposure to radioiodines and thyroid cancer. Eur J Nucl Med Mol Imaging. 2002 Aug;29 Suppl 2:S497-512.

- *With the permission of B Lacour « Registre des Tumeurs Solides de l'Enfant ».*

The study from Italy

- Chiesa and colleagues examined in 1996-1997, 3949 children born in 1985 or 1986, and attending school in Milan.
- In total, 1% had palpable thyroid nodules. Based on ultrasound findings, ten of the palpable nodules were submitted to further investigation.
- All proved benign.
- The authors conclude that the high costs of their study, in relation to the finding of no increase in thyroid disease indicate that further population studies in areas that received only low radiation after Chernobyl are not justified.

Chiesa F, Tradati N, Calabrese L, Gibelli B, Giugliano G, Paganelli G, De Cicco C, Grana C, Tosi G, DeFiori E, Cammarano G, Cusati A, Zurrada S.

Thyroid disease in northern Italian children born around the time of the Chernobyl nuclear accident.

Ann Oncol. 2004;15:1842-6.

The study from Austria

- **Gomez Segovia et al, reported data from Carinthia, a region of Austria where thyroid doses may have been higher than average Europe, based on somewhat higher contamination, and also because relative iodine deficiency was prevailing at the time of the accident.**
- **The authors do not comment specifically on childhood thyroid cancer.**
- **However, from the figures presented, the incidence of thyroid cancer in children and adolescents (0-20 years) during the period 1990-2001 appears to be normal.**
- **The incidence was less than 1 case per million per year for boys, and less than 2 cases per million per year for girls. Thus, as of 2001, the specific cohort most at risk, (age <5 at the time of the accident), has shown no increase.**

Gomez Segovia I, Gallowitsch HJ, Kresnik E, Kumnig G, Igerc I, Matschnig S, Stronegger WJ, Lind P.

Descriptive epidemiology of thyroid carcinoma in Carinthia, Austria: 1984-2001. Histopathologic features and tumor classification of 734 cases under elevated general iodination of table salt since 1990: population-based age-stratified analysis on thyroid carcinoma incidence.

Thyroid. 2004;14:277-86.

Thyroid cancer in Western Europe after Chernobyl “preliminary conclusions”.

- Infant thyroid doses in Western Europe generally ranged from 1 to 30 mGy.
- From follow-up of atomic-bomb survivors, there is no evidence that irradiation at levels below 100 mGy leads to an increase in thyroid cancer.
- *So far published data do not point to a specific increase in childhood thyroid cancer in Western Europe, that could be linked to the Chernobyl accident.*
- It is unlikely that follow-up beyond this age provides useful information, due to extreme effects of screening on the incidence of thyroid cancer in adults.
- It is my opinion that predictions through formulae of an excess number of thyroid cancer cases, and number of thyroid cancer deaths in Western Europe related to Chernobyl are not justified.

Lessons from the accident

Age at exposure

- The thyroid gland is known to be increasingly sensitive to external radiation with decreasing age.
- In the case of a power-plant accident, the importance of age is amplified, as the level of thyroid irradiation itself increases with decreasing age.
- Protecting children should be the priority.

Nutritional iodine deficiency

- Ukraine and Belarus are areas of iodine deficiency. Efforts at salt iodination slackened in the decade that preceded the accident.
- The relation between dietary iodine status and thyroid uptake of radioactive iodine is well known.
- The risk induced by iodine deficiency is probably not only due to the resulting higher thyroid uptake. Higher TSH levels, resulting from iodine deficiency, may act as an epigenetic factor, accelerating the onset of cancer.
- Many European countries have borderline or low iodine intake, and are thus at an increased risk in case of a nuclear accident. One mean of protection should be eradication of iodine deficiency.

Contribution of short-lived radioisotopes of iodine

- The role of short-lived radioisotopes deserves further investigation. Indeed, the respective responsibilities of ^{131}I and short-lived iodines have not yet been fully clarified.

Hindie E, Leenhardt L, Vitaux F, Colas-Linhart N, Grosclaude P, Galle P, Aurengo A, Bok B.

Non-medical exposure to radioiodines and thyroid cancer.

Eur J Nucl Med Mol Imaging. 2002;29 Suppl 2:S497-512. Review.

Improving communication

- The diversity of local situations, dissenting opinions among experts, as well as political and psychological factors, made that the reactions of national authorities in various EU-Member countries have been extremely varied and uncoordinated, thereby leading to confusion among the public. This is clearly an area where European harmonization is needed.
- Many efforts has been made :
 - The European Commission established the “European Community Urgent Radiological Information System” (ECURIE) through which the EU Member states are required to promptly notify the Commission on radiological emergencies and provide all information relevant to minimizing the foreseen radiological consequences.
 - The AIEA developed the “International Nuclear Event Scale” (INES) to facilitate communication on the severity of nuclear accidents,
 - etc.

Establishing uniform intervention levels for administration of stable iodine

- The Chernobyl accident pointed to a necessity of a uniform legislation for food monitoring and established “safety thresholds” processing.
- Uniform European legislation should also be adopted considering the administration of stable iodine:
 - The level of contamination (the threshold) that should trigger the administration of stable iodine.
 - The proper timing and duration of such protection.
 - The amount to be given for each age group, including new-borns and pregnant women.
 - The daily amount to be given in case of repeated administration.

Thank you