INTERNATIONAL AGENCY FOR RESEARCH ON CANCER

WORLD HEALTH ORGANIZATION

BRIEFING DOCUMENT

The Cancer Burden from Chernobyl in Europe[1]

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Study purpose: To evaluate the human cancer burden from radioactive fallout from the Chernobyl accident in Europe as a whole.

Study conclusions

- With the exception of thyroid cancer in the most contaminated regions, trends in cancer incidence and mortality in Europe, taken together, do not at present show any increase in cancer rates that can be clearly attributed to radiation from the Chernobyl accident.
- Thus it is not possible to infer the possible cancer burden from the accident on the bases of studies of its health effects to date. The estimation of the cancer burden from Chernobyl must rely on risk prediction models developed from studies of other populations exposed to radiation in other settings.
- By 2065, these models predict that about 16,000[f] cases of thyroid cancer and 25,000 cases of other cancers may be expected due to radiation from the accident and that about 16,000 deaths from these cancers may occur. About two-thirds of the thyroid cancer cases and at least one half of the other cancers are expected to occur in Belarus, Ukraine and the most contaminated territories of the Russian Federation.
- The number of cancer cases in Europe possibly resulting from radiation exposure from the Chernobyl accident up to now, and in the lifetime of the exposed populations, is therefore expected to be large in absolute terms.
- While these figures reflect human suffering and death, they nevertheless represent only a very small fraction of the total number of cancers seen since the accident and expected in the future in Europe.
- It is unlikely therefore that the cancer burden from the largest radiological accident to date could be ever be detected by monitoring national cancer statistics.

What is new about this study?

This paper presents estimates of the cancer burden in Europe consequent to the Chernobyl accident. It is unique in that it applies state-of-the art radiation risk projection models to updated estimates of radiation dose from Chernobyl throughout Europe. The paper also includes a comprehensive examination of trends in cancer incidence and mortality data. This work was accomplished within the framework of an IARC Working Group, comprised of international experts from several relevant specialties.

[f] The figures presented here give only an order of magnitude of the possible number of radiation-related cancers. The uncertainty associated with these predictions is large. For thyroid cancers, the 95% uncertainty interval (UI) ranges from 3,400 to 72,000; for other cancers it ranges from 11,000 to 59,000. For the number of cancer deaths, the 95% UI ranges from 6,700 to 38,000 (see details below)

The Cancer Burden from Chernobyl in Europe[1]

Details about the study

Background: The Chernobyl accident, on April 26, 1986, resulted in large releases of radionuclides, which were deposited over very wide areas in the Northern Hemisphere, particularly in Europe.

The increased risk of thyroid cancer in exposed children is clearly related to radiation exposure in the most contaminated regions, but not elsewhere. The impact of the accident on the risk of other cancers in these regions and elsewhere in Europe, is less clear. The full extent of the population health impact of Chernobyl is therefore difficult to evaluate.

Ten years ago, Cardis and collaborators[2] estimated that, if the experience of other populations exposed to radiation (in particular the atomic bomb survivors in Hiroshima and Nagasaki) was applicable to the Chernobyl situation, about 9,000 deaths from cancers and leukaemia might be expected over the course of a lifetime in the most exposed populations in Belarus, the Russian Federation and Ukraine (see Table).

How the study was done: There are several approaches to estimating the cancer burden in Europe from Chernobyl. These include predicting numbers of cancer cases and number of cancer deaths using models of radiation induced risk derived from other populations exposed to radiation and studying both cancer incidence and cancer mortality rates.

We have used all of these approaches in the current paper and based our overall assessment on the comparison of the three. The study involved:

- an update of the dose distribution in Europe using new dosimetric models and radiological data;
- a comprehensive examination of trends in cancer incidence and mortality in Europe over time and by radiation dose level;
- the estimation of the number of cancer cases possibly resulting from the radiation exposure, up to now and in the 80 years following the accident (up to 2065), applying state-of-the-art risk models (from the US National Academy of Sciences BEIR VII Committee[3]) derived from studies of other irradiated populations.

The present analysis focused on 40 European countries[f]. These countries constitute the whole of what is defined geographically as Europe, excluding, however, the Caucasus, Turkey, Andorra and San Marino. In the Russian Federation, only the four most contaminated regions of (Bryansk, Kaluga, Orel and Tula, which represent only a small fraction of the territory of that country) are included. The population of the area under study was 570 million persons in 1986.

What did the study show?

Doses

Ionising radiation is a known human carcinogen[4,5]. The main contribution to the ionising radiation dose from Chernobyl is from intake of ^{131}I, ^{137}Cs and ^{134}Cs and from external exposure from a mixture of Chernobyl radionuclides present in the environment.

[f] Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, the Russian Federation, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom.

Both external dose and dose from intake of ^{137}Cs and ^{134}Cs are fairly uniformly distributed in the body. Most of the dose from ^{131}I (a short-lived radionuclide with half-life about 8 days), on the other hand, is absorbed in the thyroid, where it accumulates.

- Average country- and region-specific doses from external exposure and from intake of ^{137}Cs and ^{134}Cs were estimated over the period 1986-2005, i.e. 20 years after the accident, and predicted up to 2065. The dose cumulated over the period 1986-2005 represents about 85% of the dose from Chernobyl received by an average European who was alive at the time of the accident in 1986.
- Country-specific whole body doses tended to be low compared to doses from natural background radiation. In the 20 years since the accident, the average whole body doses from Chernobyl in the most contaminated regions of Belarus and of the Russian Federation were estimated to be around 10 mSv (see glossary); the average dose in Europe as a whole was about 0.5 mSv.
- For comparison, over 20 years, an average person in Europe receives a dose of the order of 20 mSv from natural background radiation (cosmic rays and dose from naturally occurring radionuclides).

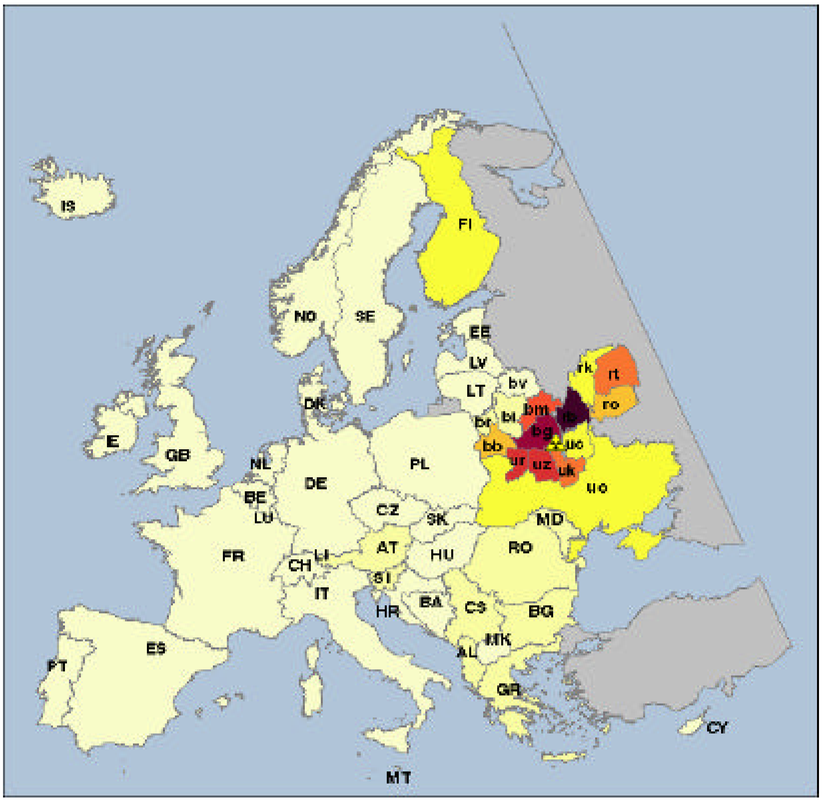

Figure 1. Spatial distribution of average country/region-specific cumulative whole body radiation doses (in mSv) from Chernobyl in Europe; doses accrued in the period 1986-2005. The location of the Chernobyl power plant is indicated by ☢

ISO country name abbreviations. For regions, the following abbreviations were used. *Belarus*: bb - Brest; bg - Gomel; br - Grodno; bi - Minsk; bm - Mogilev; bv – Vitebsk. *Russia*: rb - Bryansk; rk - Kaluga; ro - Orel; rt – Tula. *Ukraine*: rc – Chernigov; uk – Kiev; ur – Rivno; uz – Zhytomir; uo – rest of Ukraine

- Doses to the thyroid from ^{131}I are considerably higher than whole-body doses, as ^{131}I is concentrated in the thyroid.
- The highest average thyroid doses were received in the Gomel region of Belarus (630 and 150 mSv, respectively, for young children and adults), in the Bryansk region of the Russian Federation (180 and 25 mSv, respectively) and in the Zhytomir region in Ukraine (150 and 40 mSv respectively). Thyroid doses to young children were consistently higher than doses received by adults because of the much smaller mass of the thyroid in childhood.

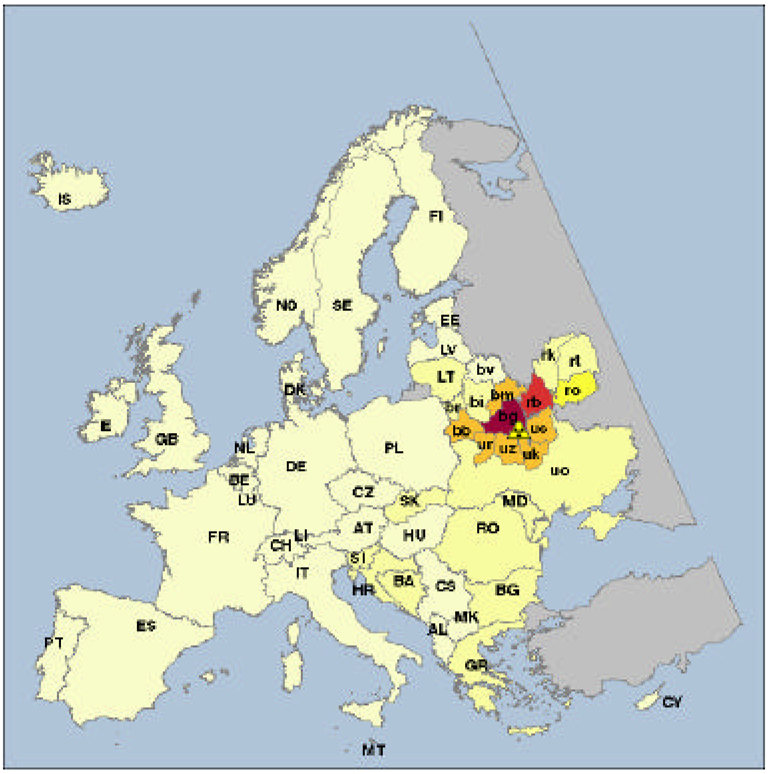

Figure 2. Spatial distribution of average country/region - specific thyroid doses (in mSv) from Chernobyl in Europe; doses to children below the age of 5 at the time of the accident; The location of the Chernobyl power plant is indicated by

ISO country name abbreviations. For regions, the following abbreviations were used. *Belarus*: bb - Brest; bg - Gomel; br - Grodno; bi - Minsk; bm - Mogilev; bv – Vitebsk. *Russia*: rb - Bryansk; rk - Kaluga; ro - Orel; rt – Tula. *Ukraine*: rc – Chernigov; uk – Kiev; ur – Rivno; uz – Zhytomir; uo – rest of Ukraine

Trends

- *Cancer incidence*
  - Thyroid cancer: Our analyses confirmed previous findings of an increased incidence of thyroid cancer due to fall-out from Chernobyl in people who were children and adolescents at the time of the accident. This increase was mainly attributable to thyroid cancer cases occurring in the most contaminated areas near the site of the accident.
  - Other cancers: For cancers other than thyroid, increasing incidence trends were seen throughout Europe. The increases, however, began before the Chernobyl accident. Although the increases seem to be stronger in the most contaminated regions, this appears to be mainly due to improvements in cancer registration and diagnosis and not to radiation from the Chernobyl accident.
- *Cancer mortality*
  - Cancer mortality rates, on the other hand, have tended to decrease throughout Europe during the period 1985 to 2000 in children and young adults, although the rate of decrease appears to be slower in Belarus and Ukraine than elsewhere. It is notable that decreases in all cancer and leukaemia mortality are seen in those 0-14 years of age at death where, based on the experience of other populations exposed to radiation, it would be expected to be largest.
  - In adults, trends in mortality rates are variable, depending on gender and whether or not cancers are related to smoking. Although increases in cancer mortality were seen in this age group in Belarus and Ukraine, they are accompanied by similar increasing trends in non-cancer mortality: they are unlikely therefore to reflect an effect of radiation from the accident.

- *Taken together*, results of analyses of time trends in cancer incidence and mortality in Europe do not, at present, indicate any increase in cancer rates – other than thyroid cancer in the most contaminated regions – that can be clearly attributed to radiation from the Chernobyl accident.

Projections

- *For Europe up to now*
    - The risk projection models we used suggest that radiation from the Chernobyl accident may have caused about 1,000 (95% Uncertainty interval (UI) 200 – 4,400) cases of thyroid cancer and 4,000 (95% UI 1,700 – 10,000) cases of other cancers in Europe by now, representing about 0.01% of all cancers in the period since the accident.
    - Two-thirds of the predicted thyroid cancer cases and half of the other cases are estimated to have occurred in Belarus, the Russian Federation and Ukraine.
- *For Europe up to 2065 (i.e. at end of the average life expectancy of Europeans born at the time of the accident in 1986)*
    - By 2065, models predict that about 16,000 (95% UI 3,400 – 72,000) cases of thyroid cancer and 25,000 (95% UI 11,000 – 59,000) cases of other cancers may be expected due to radiation from the accident and that about 16,000 deaths (95% UI 6,700 – 38,000) from these cancers may occur (Table).
    - Again, two-thirds of the thyroid cancer cases and at least one half of the other cancers are predicted to occur in Belarus, Ukraine and the most contaminated territories of the Russian Federation.
- *Put in Perspective*
    - The predicted numbers are small relative to the several hundred million cancer cases that are expected in Europe up to 2065 due to other causes.
    - Although these estimates are subject to considerable uncertainty, they provide an indication of the order of magnitude of the possible impact of the accident.
    - The estimates are consistent with those derived by Cardis et al in 1996[2] for the most exposed populations of Belarus, Russia and Ukraine (Table).
    - It is unlikely that the cancer burden from the largest radiological accident to date could be detected by monitoring national cancer statistics.

TABLE – Summary of populations, average doses and predicted number of cancer deaths: comparison of results of current study with those of published previously

Population	Approximate size of population	Mean cumulative whole body dose (mSv)	Predicted numbers of cancer deaths	Predicted % of cancer deaths due to radiation in the population	Reference
Chernobyl liquidators, evacuees and residents of strict control zones	600,000	66	4,000	3.5%	*Cardis et al, 1996[2]; cited in UN Chernobyl Forum, 2006[6,7]*
Chernobyl liquidators, evacuees and residents of strict control zones and persons living in "contaminated areas"*	~6,000,000	14	9,000	0.9%	*Cardis et al, 1996[2]; cited in UN Chernobyl Forum, 2006[6,7]*
Europe**	~570,000,000	0.5	16,000	0.01%	*Cardis et al 2006 – this paper[1]*

**Deposition density of ^{137}Cs >37 kBq/m²*

Note about low doses effects

There is controversy concerning the effects of low and very low doses of radiation such as those received by most of the European population from the Chernobyl accident.

The predictions made in this study are based on models developed by the BEIR VII Committee[5] which, following a comprehensive and critical review of available epidemiological, biological and biophysical data, concluded that the risk would continue in a linear fashion at lower doses without a threshold, and that even the smallest dose has the potential to cause a small increase in risk to humans.

Glossary

Radiation dose is radiation energy deposited in the human body per unit mass of tissue. Note that the interaction of ionising radiation with living matter may damage human cells, causing death to some and modifying others. Exposure to ionising radiation is measured in terms of absorbed energy per unit mass, i.e. *absorbed dose*. The unit of absorbed dose is the gray (Gy), which is a joule per kilogram (J/kg).

Radionuclides: A radionuclide is an element with an unstable nucleus that decays spontaneously by emitting radiation. Radionuclides may be subdivided into naturally occurring - radionuclides that are normally present in the earth - and artificially produced.

Sievert: The sievert (Sv) is a unit of *dose equivalent* which takes into account the fact that, for the same *absorbed* dose, there is a difference in the efficiency of different types of radiation (such as neutrons, beta, gamma, x-rays) to cause damage (DNA breaks, cancer, etc.). The *dose equivalent* in sievert is equal to the *absorbed dose* in gray multiplied by a radiation weighting factor that takes into account this different effectiveness (1 Sv =1000 mSv=100 rem).

UI (Uncertainty Interval): The uncertainty intervals shown in this paper represent the range of the possible numbers of cases/deaths that might occur due to radiation from the Chernobyl accident, taking into account uncertainties in the predictions. Larger intervals indicate greater uncertainty. The uncertainty intervals presented here include statistical uncertainties in radiation risk models, uncertainties in dose distribution, uncertainties related to the choice of models for transport of risk between populations with different background cancer rates and for extrapolation of risks following primarily external high dose and high dose-rate exposure to low dose and low dose-rate exposures involving a mixture of external and internal radiation. Further uncertainty arise, however, from the varying quality of cancer incidence and mortality rates throughout Europe, the assumption of constant population demographics and incidence and mortality rates over time and, in particular, from the unknown shape of the dose-response relationship at the very low radiation doses received in many countries from Chernobyl.

Whole body dose is the dose resulting from irradiation of whole body in a more or less uniform manner. Whole body dose is expressed in Sv in this study.

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