*Review*

# Cancer consequences of the Chernobyl accident: 20 years on

Cardis E, Howe G, Ron E, Bebshko V, Bogdanova T, Bouville A, *et al*: Cancer consequences of the Chernobyl accident: 20 years on. J. Radiol. Prot., 2006: **26**:127-140.

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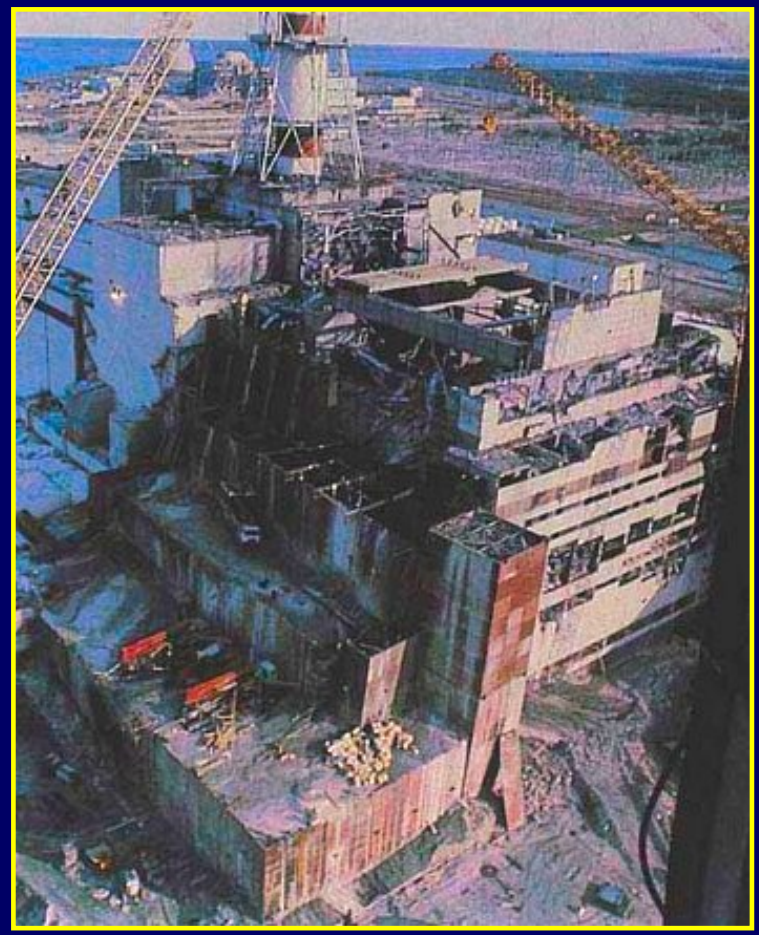
# Introduction

It has been 20 years…

- The Chernobyl disaster occurred at 0123H on 26/04/1986 at the Chernobyl Nuclear Power Plant in Pripyat, Ukraine.
- Worst accident in the history of nuclear power.
- Radioactive fallout drifted over parts of the western (former) Soviet Union, Eastern and Western Europe, Scandinavia, the British Isles, and eastern North America.
- Large areas of Ukraine, Belarus, and Russia were badly affected, approx. 5 million people exposed.



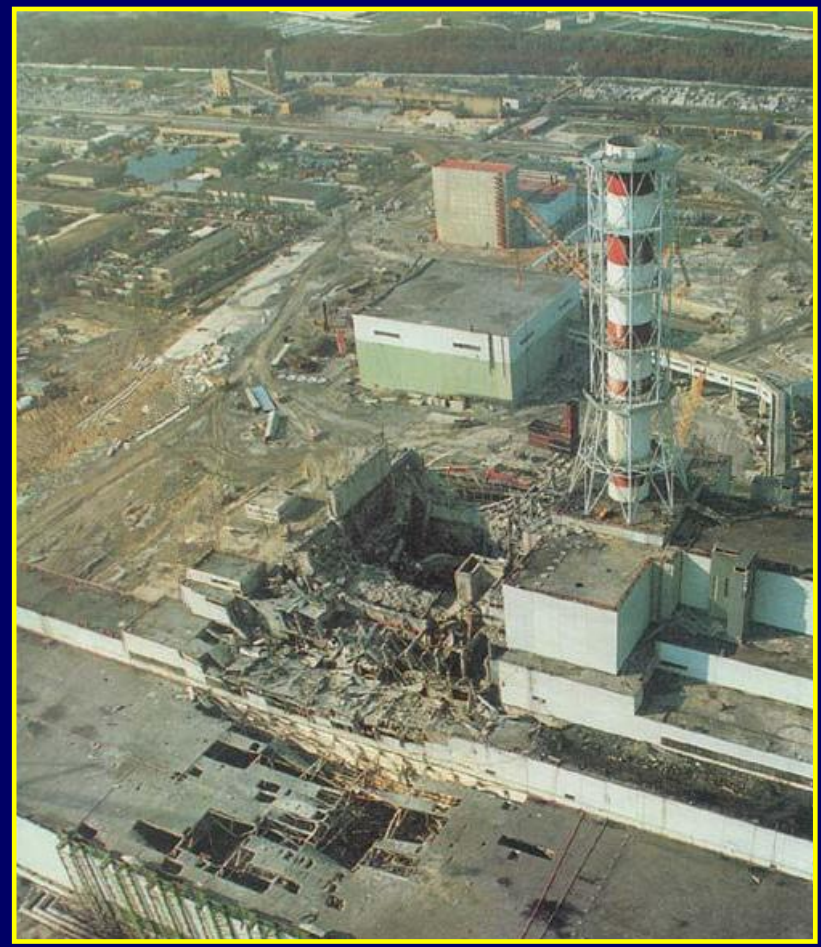
# Methods

In 2003, WHO convened Expert Group on Health (EGH) to evaluate health impact of Chernobyl.

In 2006 WHO-EGH produced technical report “Health effects of the Chernobyl accident and special health care programmes”.

Included scientifically valid studies of thyroid cancer, leukaemia and other cancers.

This report focuses on radiation dosimetry and epidemiology.



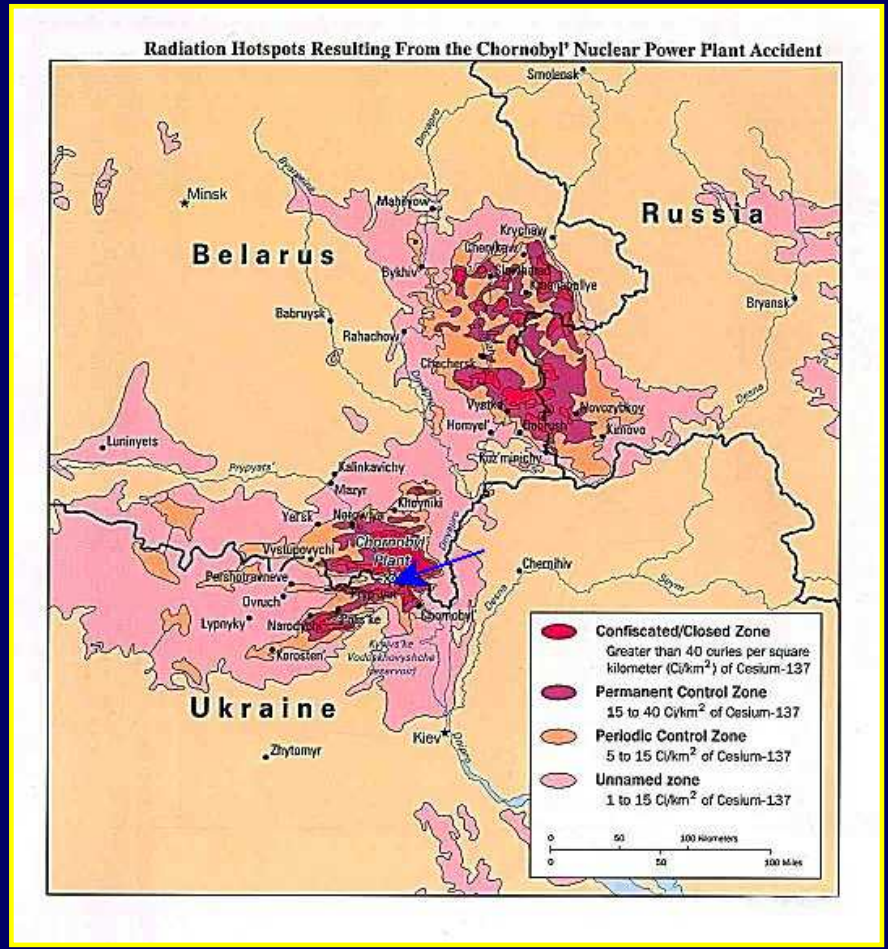
# Results – Sources and levels of dose

Greatest sources of radiation dose were:

- Intake of $^{131}I$.
- External exposure from $^{95}Zr$, $^{95}Nb$, $^{103}Ru$, $^{132}Te$, $^{132}I$, $^{140}Ba$, $^{140}La$, $^{141}Ce$ and $^{144}Ce$.
- Ingestion of $^{134}Cs$ and $^{137}Cs$.

Three major groups exposed:

- Workers (emergency and recovery operations), approx. 600K people.
- Inhabitants who were evacuated or relocated from contaminated areas, approx. 336K from Belarus, Russia and Ukraine.
- Inhabitants who were not evacuated, approx. 5 million people in Belarus, Ukraine and Russia.



# Results – Sources and levels of dose

Table 1 shows a summary of the number of persons exposed and the levels of doses received in these population groups.



**Table 1.** Estimates of mean effective doses (mSv) for population groups of interest (Cardis *et al* 1996, UNSCEAR 2000).

| Population | Approximate size of population | Mean effective dose (mSv) |
|---|---|---|
| Liquidators (1986–1987, 30 km zone) | 240 000 | 100 |
| Evacuees of 1986 | 116 000 | 33 |
| Persons living in contaminated areas: | | |
| *Deposition density of* $^{137}Cs > 37$ kBq m$^{-2}$ | 5200 000[a] | 10[b] |
| *Deposition density of* $^{137}Cs > 555$ kBq m$^{-2}$[c] | 270 000 | 50[b] |

[a] Including approximately 1 900 000 persons from Belarus, 2 000 000 from Russia and 1 300 000 from Ukraine (UNSCEAR 2000).
[b] For the period 1986–2005.
[c] Strict control zones (included in the areas with deposition density >37 kBq m$^{-2}$).

*** Average effective dose from background radiation (excl. radon) is ~1 mSv/year or 70-80 mSv over lifetime.**

# Results – Sources and levels of dose

Dose rates extremely heterogeneous in first few days, up to several Sv.

After, due to decay and practices to limit exposure, doses were generally below permissible levels (250mSv in 1986; 50-100mSv in 1987).

**Table 2.** Distribution of doses to clean-up workers as recorded in state Chernobyl registries (UN Chernobyl Forum 2006).

| Country and period | Number of clean-up workers | Percentage for whom dose is available | External dose (mSv) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | Median | 75th (%) | 95th (%) |
| Belarus | | | | | | |
| 1986–1987 | 31 000 | 28 | 39 | 20 | 67 | 111 |
| 1986–1989 | 63 000 | 14 | 43 | 24 | 67 | 119 |
| Russian Federation | | | | | | |
| 1986 | 69 000 | 51 | 169 | 194 | 220 | 250 |
| 1987 | 53 000 | 71 | 92 | 92 | 100 | 208 |
| 1988 | 20 500 | 83 | 34 | 26 | 45 | 94 |
| 1989 | 6 000 | 73 | 32 | 30 | 48 | 52 |
| 1986–1989 | 148 000 | 63 | 107 | 92 | 180 | 240 |
| Ukraine | | | | | | |
| 1986 | 98 000 | 41 | 185 | 190 | 237 | 326 |
| 1987 | 43 000 | 72 | 112 | 105 | 142 | 236 |
| 1988 | 18 000 | 79 | 47 | 33 | 50 | 134 |
| 1989 | 11 000 | 86 | 35 | 28 | 42 | 107 |
| 1986–1989 | 170 000 | 56 | 126 | 112 | 192 | 293 |

# Results – Sources and levels of dose

- Highest organ-specific dose was to Thyroid gland mainly from ingestion of contaminated milk ($^{131}$I).
- Estimation of thyroid doses based on 350K direct thyroid exposure-rate measurements from Belarus, Russia and Ukraine in first few weeks after event.
- Wide range of doses found depending on age, level of ground contamination and rate and source of milk consumption.
- Individual doses up to tens of Gy, with average in the range of few tens of mGy to several Gy, (Table 3 - next slide).
- Intake of stable iodine tablets during 6-30H post-event reduced thyroid dose of local (Pripyat) residents by factor of 6-7.

# Results – Sources and levels of dose

**Table 3.** Estimates of thyroid doses (Goulko *et al* 1996, Likhtarov *et al* 2005, Minenko 2000, UNSCEAR 2000).

| Population | Size of population | Mean thyroid dose (Gy) | | |
|---|---|---|---|---|
| | | 0–7 years | Adults | Total |
| Evacuees of 1986, including | 116 131 | 1.82 | 0.29 | 0.48 |
| villages, Belarus | 24 725 | 3.10 | 0.68 | 1.00 |
| Pripyat town | 49 360 | 0.97 | 0.07 | 0.17 |
| villages, Ukraine | 28 455 | 2.70 | 0.40 | 0.65 |
| Belarus | | | | |
| Entire country | 10 000 000 | 0.15 | 0.04 | 0.05 |
| Gomel region | 1 680 000 | 0.61 | 0.15 | 0.22 |
| Ukraine | | | | |
| Entire country | 55 000 000 | — | — | 0.01 |
| Region around Chernobyl NPP | 500 000 | — | — | 0.38 |
| Kiev city | 3 000 000 | — | — | 0.04 |
| Russian Federation | | | | |
| Entire country | 150 000 000 | — | — | 0.002 |
| Bryansk region | 1 457 500 | 0.16 | 0.026 | 0.04 |
| Kaluga, Orel, Tula regions | 4 000 000 | — | — | 0.01 |

# Results – Epidemiology (Thyroid cancer)

**Main health effect seen was dramatic increase in thyroid cancer in persons exposed as young people.**

**Increase first observed in early 1990s in Belarus and continues to date in Ukraine and Russia.**

**(Fig. 1).**

**By 1995, incidence of childhood thyroid cancer increased to 4 per 100K compared with pre-event rate of 0.04 per 100K**

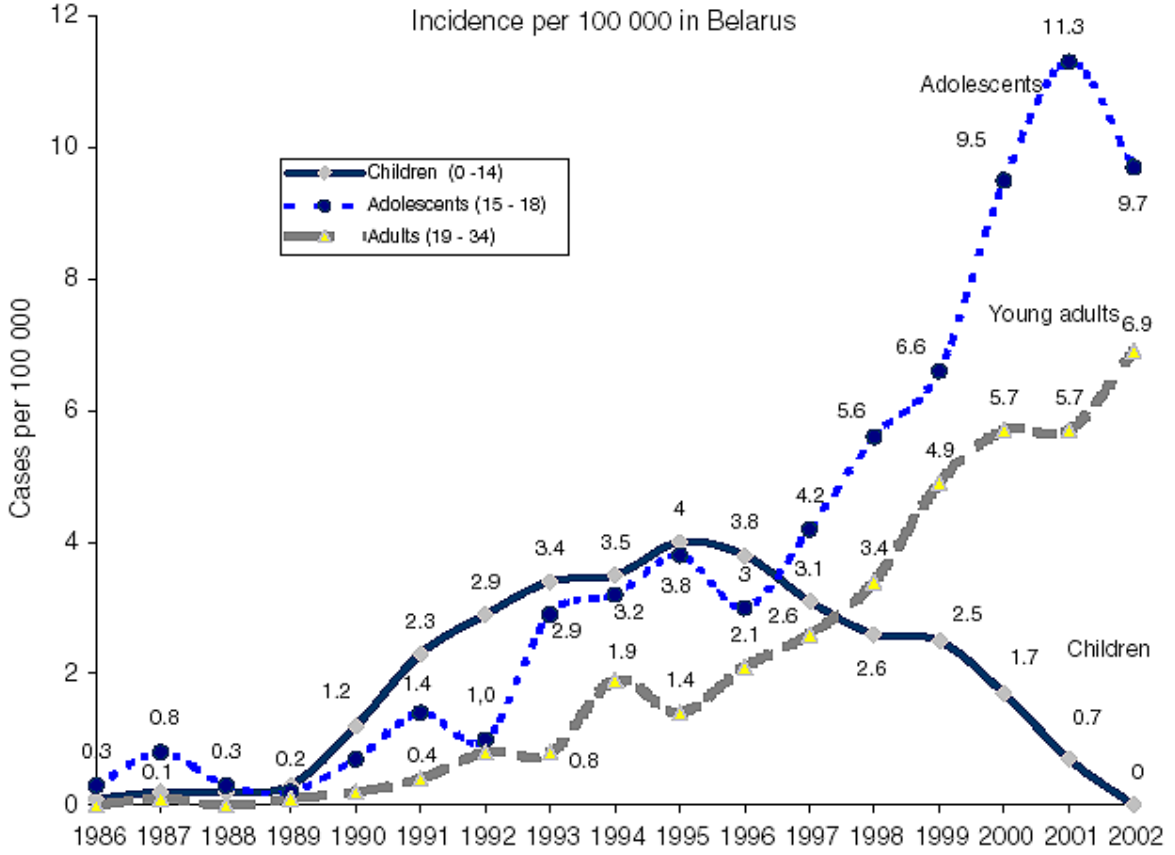



**Figure 1.** Annual incidence of childhood, adolescent and adult thyroid cancer in Belarus (courtesy of Yu E Demidchik).

# Results – Epidemiology (Thyroid cancer)

- As those who were children at time of event have aged, thyroid cancer rates have declined to near zero.
- There has been a parallel increase in incidence in adolescents and slightly later in young adults.

Actual numbers of thyroid cancer cases shown in Table 4.

**Table 4.** Number of cases of thyroid cancer diagnosed between 1986 and 2002, by country and age at exposure.

| | Number of cases | | | |
|---|---|---|---|---|
| Age at exposure (years) | Belarus[a] | Russian Federation (4 most contaminated regions)[b] | Ukraine[c] | Total |
| <15 | 1711 | 349 | 1 762 | 3822 |
| 15–17 | 299 | 134 | 582 | 1015 |
| Total | 2010 | 483 | 2 344 | 4837 |
| Population aged less than 15 years in 1986 | 2 300 000 | 1 100 000 | 11 000 000 | 14 400 000 |

[a] Cancer Registry of Belarus, 2006.
[b] Cancer subregistry of the Russian National Medical and Dosimetric Registry, 2006.
[c] Cancer Registry of Ukraine, 2006.

* Total cases ~ 5000, of which 15 fatal.

# Results – Epidemiology (Thyroid cancer)

- At time of event, it was widely held that radioactive iodines were much less carcinogenic than external photon exposure as little or no effects of the isotopes of iodine on the child's thyroid were available.

- An excess relative risk (ERR) (iodine vs. external photons) was derived from several studies and showed that the risk of cancer from iodine isotopes was only slightly lower than from photons.

- There was some indication that iodine deficiency at time of exposure may increase risk of developing thyroid cancer among persons exposed as children.

# Results – Epidemiology (Leukaemia)

Leukaemia incidence and mortality are considered 'markers' of radiation risks in exposed populations.

- The European Childhood Leukaemia Lymphoma Study (ECLIS) found no evidence of a radiation-related increase in the incidence of leukaemia in first 5 years post-event.
- Two case-control studies found a significant association between leukaemia risk and radiation dose to bone marrow in Ukraine.
- However, results difficult to interpret due to problems with selection and compatibility controls in Ukraine. No significant increase found in Russia or Belarus.

Therefore, current information is scant and conclusions cannot be drawn about increases in childhood leukaemia due to Chernobyl.

# Results – Epidemiology (Leukaemia)

Results of leukaemia studies among adults are equally inconclusive.

- Studies of leukaemia risk among adult populations are ecological in nature (outcomes available at population level) and generally indicate an increase in leukaemia incidence over time, that does not appear to be related to level of contamination.
- An approx. 2x increase is reported in a very large cohort of workers in Russia with registered doses between 150 and 300 mSv, but does estimates are unreliable in these studies.
- On-going case-control studies of workers with individual dose estimates are expected to provide additional information on the magnitude of a possible increased risk of leukaemia.

# Results – Epidemiology (Solid cancers)

- Data from Chernobyl on solid cancers other than thyroid is sparse.
- No significant increase in the incidence of solid cancers was seen in a cohort of over 55K Russian workers or among residents of the contaminated region of Kaluga in Russia.
- Analyses of breast cancer rates indicate a significantly increased incidence compared to general population of Ukraine.
- A large increase in breast cancer incidence was found in all areas of Belarus and Ukraine reflecting improvements in cancer diagnosis and registration.
- Increases in rates of bladder and kidney cancers have also been reported.

# Discussion

- Study of consequences of Chernobyl has provided important information concerning the magnitude of the risk following exposure to radioactive iodines in childhood and adolescence
- Lack of evidence of any clearly demonstrated effect of Chernobyl radiation exposures on the risk of leukaemia or solid cancers other than thyroid cancer.
- Reports of elevated incidence of all solid cancers combined but may be due to improvements in diagnosis, reporting and registration.
- Because studies of external radiation indicate that radiation-related risks of solid cancers remain elevated throughout life, it is too early to evaluate the full radiological impact of the Chernobyl accident.

# Discussion

- The fact that no significant increased cancer risk (apart from thyroid) has been conclusively demonstrated, does NOT imply no increase in risk has occurred.

- Given the large number of individuals exposed, the absolute number of cancer cases caused by even a small increase in the relative risk could be substantial in future.

In 1996, Cardis *et al* predicted the health effects of Chernobyl radiation, based on other populations (Japan).

- The predicted lifetime excess of cancer was 4K for workers, evacuees and contaminated residents. A further 5K deaths were predicted for residents of other affected areas, giving a total of 9K for Ukraine, Russia and Belarus.

Although the absolute number is large, it represents only ~1% of the total number of cancers expected from other causes.

# Conclusions

- After 20 years, the large increase in thyroid cancer among those exposed in childhood continues. Fortunately, few of these have been fatal.

- The absence of a demonstrated increase in total cancer risk is not proof that no increase has occurred. Based on data from Japan, a small increase in the relative risk is expected, even at low to moderate doses.

- Given very large number of people exposed, a small increase in relative risk would result in a substantial number of radiation-related cancer cases in future.

# What to believe?

- Scientific assessments show that, except for the still closed, highly contaminated 30 km area surrounding the reactor, radiation levels have mostly returned to acceptable levels.
- 30 workers died within 4 months post-event due to high absorbed dose.
- "Chernobyl death toll 90,000", says Greenpeace, (The Greenpeace report looks at the entire population of the potential area affected, more than 100 million, while UN statistics were limited only to 600,000 people in the immediate vicinity).
- "Research into the aftermath of the meltdown at the Soviet nuclear reactor has suggested that low levels of radioactivity are not as harmful as believed – and may even be beneficial" – The Times, 10/07/2006.

# Further information

- Nuclear Energy Agency (NEA)

www.nea.fr/html/rp/chernobyl/chernobyl.html

- International Atomic Energy Agency (IAEA)

www.iaea.org/NewsCenter/Focus/Chernobyl

- World Health Organisation (WHO)

www.who.int/mediacentre/news/releases/2005/pr38/en/index

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