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International Physicians  
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RESPONSIBILITY

# ippnw/psr report



**30 years living with Chernobyl  
5 years living with Fukushima**

**Health effects of the nuclear disasters in  
Chernobyl and Fukushima**



## Imprint

Report: The health effects of the nuclear disasters in Fukushima and Chernobyl  
30 years living with Chernobyl, 5 years living with Fukushima  
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# 30 years living with Chernobyl 5 years living with Fukushima

Health effects of the nuclear disasters  
in Chernobyl and Fukushima



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A Report by

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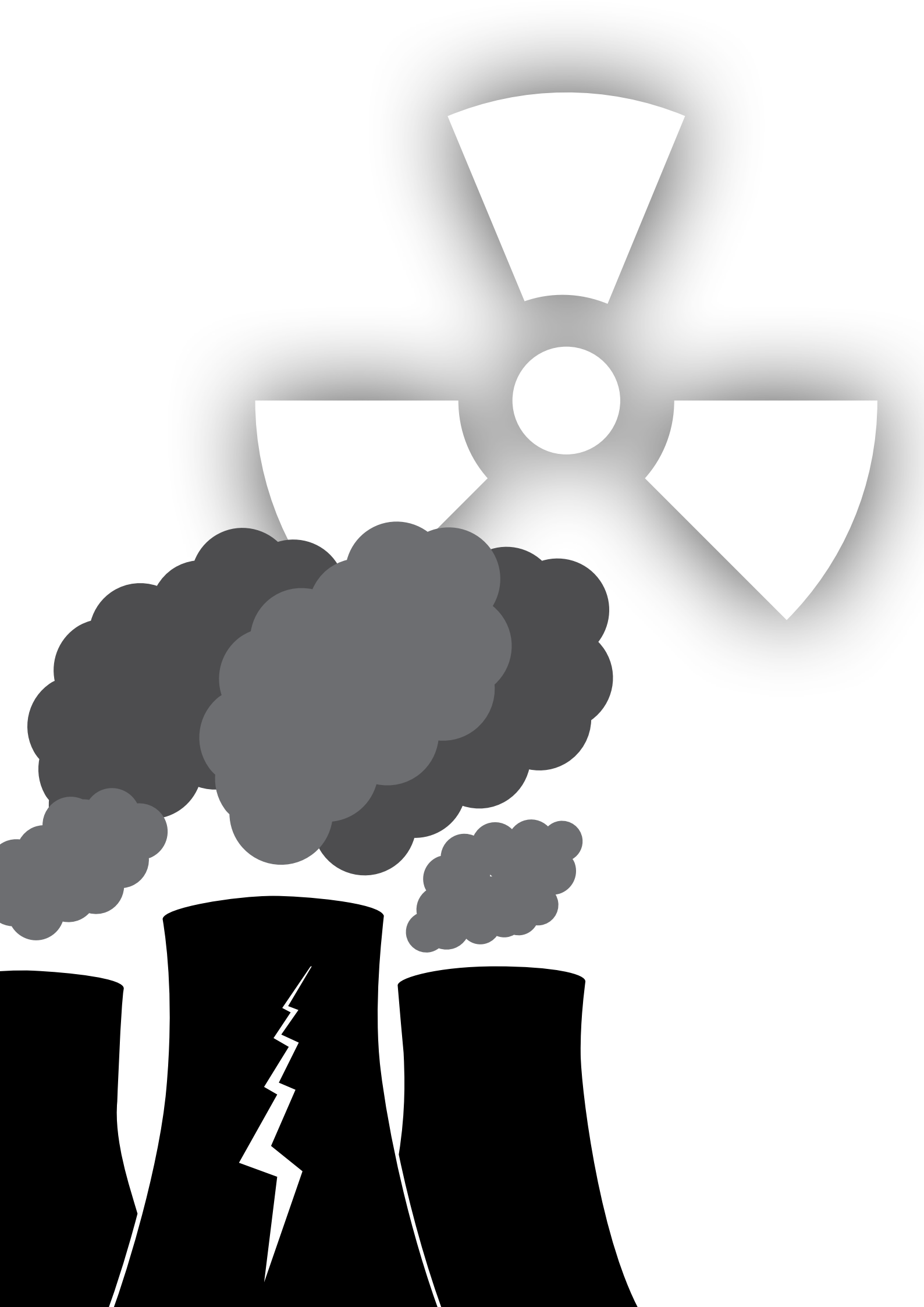




## Abbreviations

<b>BEIR</b>	Biological Effects of Ionizing Radiation report series of the American Academy of Sciences
<b>Bq – Becquerel</b>	A basic international (SI) measure of radioactivity. Defined as decay of one radioactive nucleus per second
<b>Gy – Gray</b>	An international (SI) measure for radiation dose absorbed by matter. Used in context of high doses at which all tissues and organs would be always be affected (deterministic). Defined as the amount of energy (in Joules) absorbed per mass (in kg)
<b>IAEA</b>	International Atomic Energy Agency
<b>ICRP</b>	International Commission on Radiological Protection
<b>JAEA</b>	Japanese Atomic Energy Agency
<b>PBq</b>	PetaBecquerel ( $10^{15}$ Bq)
<b>Person-Sv</b>	Collective equivalent dose of a population (number of people x average individual dose in Sv)
<b>SI</b>	International System of Units ( <i>Système international d'unités</i> )
<b>Sv – Sievert</b>	An international (SI) measure similar to Gy but adjusted for biologically equivalent radiation dose absorbed by a particular tissue type or organ. Used in context of relatively low doses where effects variable & less certain (stochastic). Defined as the amount of energy absorbed per unit of mass. In Germany, the threshold value 0.001 Sv (1 mSv) per year is officially considered safe for humans.
<b>TBq</b>	TeraBecquerel ( $10^{12}$ Bq)
<b>UNSCEAR</b>	United Nations Scientific Committee on the Effects of Atomic Radiation
<b>WHO</b>	World Health Organization







## Introduction

*“The atomic industry could take a catastrophe like Chernobyl every year.”*

HANS BLIX, 1986 IN HIS CAPACITY AS DIRECTOR OF IAEA

30 years ago, on April 26th 1986, the Chernobyl meltdown put an abrupt end to the myth of ‘safe nuclear power’. Millions of people fell victim to radioactive contamination. Vast territories became uninhabitable. The radioactive cloud spread across the entire world. An awareness of the dangers inherent in nuclear energy grew in innumerable minds. Even in Germany, people became sick and died after incorporating radioactive particles through eating and breathing.

5 years ago, on March 11th 2011, yet another total meltdown in Fukushima demonstrated just how little the human race had learned from the lessons of Chernobyl. Immense amounts of radioactivity were released accidentally (or intentionally) into the environment following numerous meltdowns, explosions, fires and leaks. On the International Nuclear and Radiological Event Scale, INES, the Daichi Fukushima nuclear power plant disaster fulfils the criteria at the highest level, the same as the Chernobyl disaster. More than 200,000 people were evacuated from their homes in Fukushima Prefecture to makeshift camps, where around one hundred thousand of them still live today. But the effects of the disaster extend far beyond the prefecture borders. Since the onset of the disaster, millions of people have been exposed to increased radiation doses – primarily in areas subjected to higher nuclear fallout, but people in less contaminated parts of the country are also having to deal with contaminated drinking water and food.

Chernobyl and Fukushima – two nuclear disasters that symbolize colossal humanitarian tragedy, health impairments for generations to come, as well as the ecological devastation caused by the nuclear chain in the last 70 years. Uranium mining, civil and military exploitation of nuclear fission, nuclear waste, fallout

and radioactive slag – clearly the atomic industry is detrimental to humanity and the environment. Not only are we acutely aware of the urgent need to abandon nuclear power, we also know this is feasible. Renewable and sustainable alternatives to fossil fuels and nuclear power have been available for some time.

First effects of the Chernobyl nuclear disaster could already be seen in 1991 with the increased incidence of thyroid cancer. Despite pressing evidence, the nuclear lobby around UNSCEAR and the IAEA refused to acknowledge the causal link of the increase to the Chernobyl meltdown. This did not change until 1996.

Even today, the medical-biological assessment of the effects of radiation is still a matter of controversy. The question is, how much radiation contamination can a society be expected to tolerate in the interests of industrial policy – similar to the appraisal of chemical and toxic damage to the environment.

The opinion of Hans Blix quoted at the beginning of this introduction is a clear example of the extremely ignorant attitude of the atomic industry and numerous UN organizations, such as UNSCEAR, the IAEA and WHO, towards the risks and the medical and biological effects of nuclear disasters.

In a report for Swedish radio shortly after the 2011 Fukushima disaster, Hans Blix – by then consultant to the Swedish nuclear power company Vattenfall – still refused to acknowledge the humanitarian and ecological magnitude of the Fukushima nuclear disaster. In his opinion, the world depends on nuclear power to cover the needs of major cities such as Shanghai and Calcutta.<sup>1</sup>

<sup>1</sup> <http://sverigesradio.se/sida/artikel.aspx?programid=2054&artikel=4410227>



Similar arguments are repeated mantra-like by the nuclear lobby. But beyond the age-old dispute between supporters and opponents of the so-called 'peaceful' use of nuclear power over the severity of the health effects of long-term radiation exposure, increasingly more studies showing that ionizing radiation is more dangerous than previously assumed are finding acceptance by both parties. The papers were written by physicians who – in the course of large-scale studies to investigate the increasing cancer risk due to medical x-ray diagnostics – found that CT examinations increased the cancer risk significantly.<sup>2</sup>

Further epidemiological studies have investigated the cancer risk for uranium miners and nuclear power plant workers, as well as for the normal population exposed to radon contamination in homes and 'background' radiation.<sup>3</sup> The results of all studies showed that even single-digit mSv radiation doses significantly increase the risk of developing cancer.<sup>4</sup> There is no threshold under which ionizing radiation would be harmless.

Russian researchers into the effects of radiation quickly became aware that the growing trend in the incidence of non-cancerous diseases, such as heart attack and stroke, resulted from the effects of radiation. Meanwhile, western scientists have now also observed a correlation between such conditions and nuclear power plant workers' exposure to radiation.<sup>5</sup>

More recent studies also found that low-dose radiation has a mutagenic effect. The gender ratio at birth (ratio of male to female newborns) appears to be a particularly sensitive marker of radiation-related genetic risk: a gender ratio shift has been found in the immediate vicinity of nuclear power stations and nuclear waste facilities in Germany, France and Switzerland, even when radiation exposure levels were in the single digit mSv range or below. Similar effects were found following atmospheric atom bomb testing and the Chernobyl nuclear disaster.<sup>6</sup>

Analyses of the Chernobyl and Fukushima study results also included the different socio-political environments in which the respective disasters occurred. It is well-known that the Japanese and Soviet governments, including the respective succe-

sors, systematically concealed the extent of the actual consequences for health and the environment.

Even today, analysis of the health effects of Chernobyl is still being hampered by the wide range of differences on many issues. Essential information concerning the sequence of events during the Chernobyl disaster and the subsequent effects on health are confidential and not publicly available. To the present day, there is no common opinion among scientists about the volumes of radioactive material released by the reactor explosion. Estimates vary and range from 3.5% to 95% of the original radioactive material.

In the first years after the disaster, the Soviet health ministry and the KGB issued a large number of prohibitions, with the result that decisive information required to assess the situation was not collected, or was kept secret, or falsified.<sup>7</sup>

The present government of Japan, which has very close links with the nuclear industry, is doing all it can to close the Fukushima file quickly. So far, the only epidemiological examinations on radiation health effects to have been conducted were mass screenings of the thyroid glands of children in Fukushima Prefecture – in keeping with the motto, "Don't look, won't find!" Moreover, so-called 'breach of secrecy' laws have been introduced to block reporting and independent research into the events in Fukushima by journalists and scientists.

This policy of trivialization and concealment is detrimental, first and foremost, to the people concerned and their health. The aim of this report, on the other hand, is to inform people about the effects of the nuclear disaster on human health and on societies that have been living with these effects for the past 30 years, in the case of Chernobyl and five years, in the case of Fukushima.

2 <https://www.ippnw.de/atomenergie/artikel/de/aerzte-zeigen-krebserkrankungen-sc.html>

3 Spycher BD et al. (2015): <http://ehp.niehs.nih.gov/wp-content/uploads/123/6/ehp.1408548.alt.pdf>

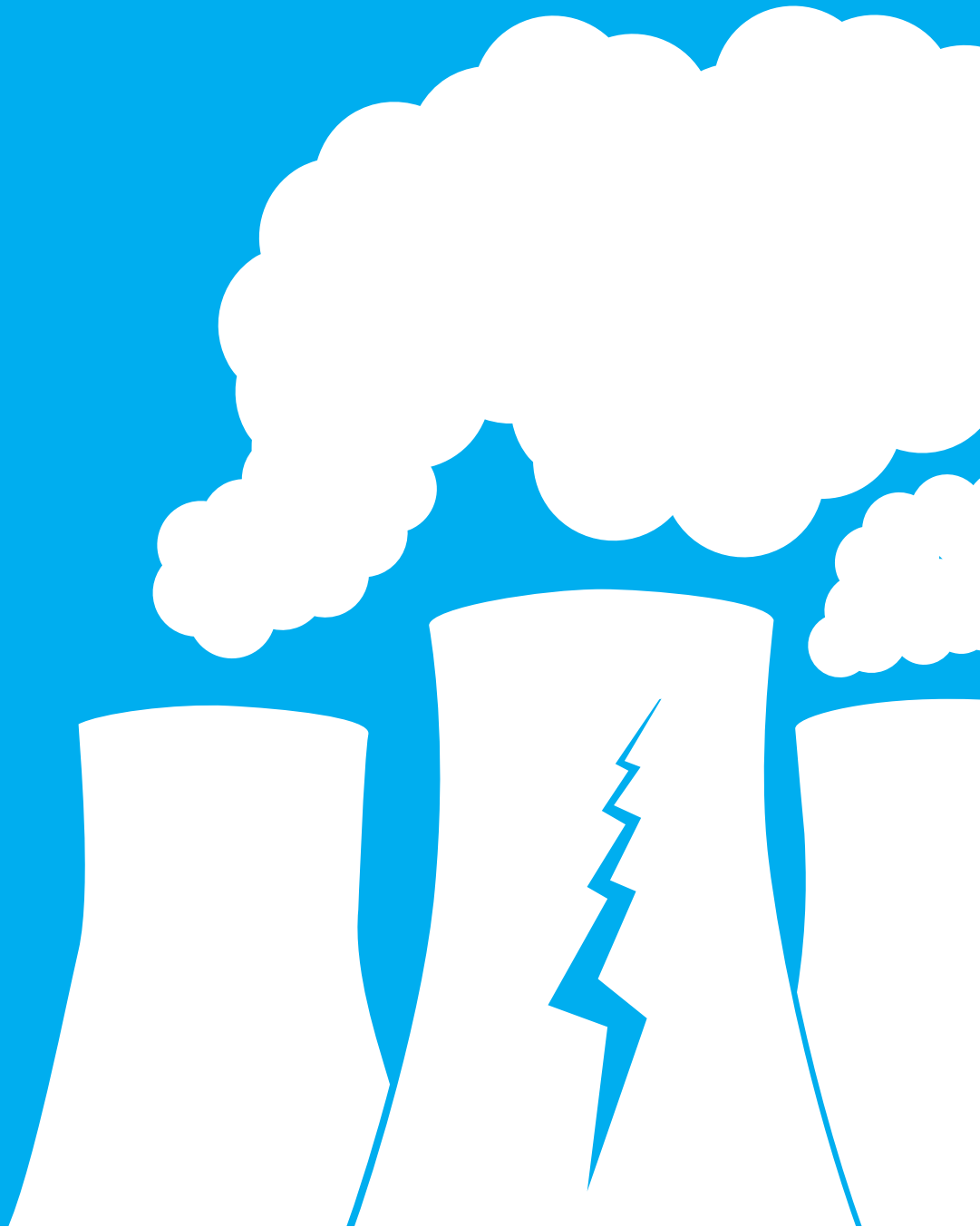
4 [http://www.ippnw-ulm.de/Dokumente/Ulmer\\_Expertentreffen\\_-\\_Gefahren\\_ionisierender\\_Strahlung.pdf](http://www.ippnw-ulm.de/Dokumente/Ulmer_Expertentreffen_-_Gefahren_ionisierender_Strahlung.pdf)

5 Little MP, Azizova TV, et al. (2012): Systematic Review and Meta-analysis of Circulatory Disease from Exposure to Low-Level Ionizing Radiation and Estimates of Potential Population Mortality Risks. Environmental Health Perspectives • volume 120 | number 11 | November 2012 pp.1503-11

6 Scherb H et al (2015): Ionizing radiation and the human gender proportion at birth – A concise review of the literature and complementary analyzes of historical and recent data. Early Human Development 91 (2015) pp. 841– 850. <http://www.ncbi.nlm.nih.gov/pubmed/26527392>

7 Yaroshinskaya A (1994): Verschlussache Tschernobyl Die geheimen Dokumente aus dem Kreml; Berlin, Basis Druck Verlag GmbH



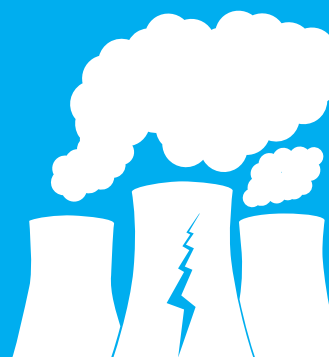


## **Part A:** 30 years living with Chernobyl

Summary of the health effects of the nuclear disaster



# 1 Summary of the effects of Chernobyl



The Chernobyl meltdown was the greatest nuclear disaster of the twentieth century. It continues to affect millions of people today,

- » an estimated 830,000 liquidators
- » more than 350,000 evacuees from the 30-km zone and other heavily contaminated areas
- » approximately 8.3 million people from the heavily radioactive-contaminated areas of Russia, Belarus and Ukraine
- » approximately 600 million people in other parts of Europe who were exposed to lower radiation doses.<sup>1 2</sup>

Around 36 % of the total radioactive fallout was over Belarus, Russia and Ukraine; about 53 % over the rest of Europe. 11 % was distributed around the rest of the globe. Figures for the collective dose range from 2.4 million person sievert (source: Soviet Union 1986, worldwide, period 70 years) to 55,000 person sievert (source: AIEA/WHO 2005, only Belarus, Russia and Ukraine, period 20 years).<sup>3</sup>

The effects on health were not as predicted by the atom lobby and its scientists:

## 1.1 Increased cancer risk

- a. **Thyroid cancer:** In the highly contaminated Gomel area in Belarus, there was a steep rise in the incidence of childhood thyroid cancer, particularly 3–4 years after the onset of the disaster. This was far quicker than had been expected. IAEA and WHO did not acknowledge the link to the meltdown for a further 10 years. In 2008 UNSCEAR put the number of thyroid cancer patients who were under 18 in 1986 at 6,848. There was a significant increase in thyroid cancer among children in Russia and Ukraine.<sup>4</sup> This not only involved children, as a rising incidence of thyroid cancer was also found among adults – particularly women – in the affected area.<sup>5</sup>
- b. **Other cancer diseases:** According to data in the national cancer register in Belarus, there was also a general increase in other types of cancer, not just thyroid cancer. Organs particularly affected were the prostate gland, skin, kidneys, intestine, bone marrow, lymphatic system and the female breast.<sup>6</sup> A significant rise in cases of breast cancer and childhood leukemia was also found in Belarus and Ukraine.<sup>7</sup> In 2002, Ivanov et al. also reported an increase in cancer diseases in the particularly heavily contaminated Russian areas of Kaluga and

1 Fairlie I, Sumner D (2006): The Other Report On Chernobyl; <http://cricket.biol.sc.edu/chernobyl/papers/TORCH.pdf>

2 Yablokov AV, Nesterenko VB, Nesterenko AV (2009): Chernobyl: Consequences of the Catastrophe for People and the Environment

3 3 USSR State Committee on the Utilization of Atomic Energy. The accident at the Chernobyl nuclear power plant and its consequences: information compiled for the IAEA Experts Meeting, 1986 August 25–9, Vienna. Part II, Annexes 2, 7, Draft, 1986 August.

4 Cardis E, et al (2011): The Chernobyl accident – an Epidemiological Perspective: CI in Oncol (R Coll Radiol). May 2011; 23(4): 251–260.

5 Mürbeth S, et al (2004): Thyroid cancer has increased in the adult populations of countries moderately affected by Chernobyl fallout; in: Med Sci Monit, 2004; 10(7): CR300–306

6 Zubets O, Okeanov A (2014): Cancer epidemiology in Belarus, [http://www.tschernobylkongress.de/fileadmin/user\\_upload/Arnoldshain\\_Doku/Zubec-Olga.pdf](http://www.tschernobylkongress.de/fileadmin/user_upload/Arnoldshain_Doku/Zubec-Olga.pdf), Okeanov AE, Sosnovskaya EY, Priatkina OP (2004): A national cancer registry to assess trends after Chernobyl accident, Swiss Medical Weekly 2004, 134: 645–649.

7 Pukkala E, Poliakov S, Ryzhov A, Kesminiene A, Drozdovich V, Kovgan L, Kyyronen P, Malakhova IV, Gulak L, Cardis E (2006): Breast cancer in Belarus and Ukraine after the Chernobyl accident. International Journal of Cancer, 2006, February 27th



Bryansk.<sup>8</sup> It was also found that the incidence of leukemia and thyroid cancer had increased in the liquidator group, in particularly.<sup>9 10</sup>

## 1.2 Non-cancer diseases

Marked increases were also found in non-cancer diseases among the highly contaminated populations of the former Soviet Union. These included benign tumors; cardiovascular, cerebrovascular, respiratory, gastrointestinal, endocrinological and mental illnesses; cataracts and inhibited intellectual development. The incidence of these diseases greatly exceeds that of cancerous conditions.<sup>11</sup> UNSCEAR needed a further 23 years before recognizing cardio- and cerebrovascular diseases and cataracts in liquidators as radiation-induced illnesses.<sup>12</sup> Both Burlakova<sup>13</sup> and Loganovsky<sup>14</sup> classed the complex interactive processes befalling liquidators who were exposed to increased radiation as premature-aging processes. Early studies with contaminated evacuees and children in Belarus, Russia and Ukraine also found an increase in blood cell mutations, with subsequent immune deficiency, as well as obstructive and non-obstructive pulmonary conditions.<sup>15 16</sup>

## 1.3 Genetic and teratogenic defects

Malformations, chromosome aberrations and an increase in perinatal morality (stillbirths) was already being registered in Belarus, Ukraine and a number of countries in Central and Eastern Europe in the first years of the nuclear disaster.<sup>17</sup>

In Belarus<sup>18</sup> and East Berlin more children were born with Down's syndrome. Different studies by A. Körblein as well as H. Scherb correlated increased perinatal mortality in Germany, Poland, Hungary and the Scandinavian countries with cesium contamination. Scherb and Sperling have estimated the number of additional stillbirths and miscarriages in Germany to be between 1,000 and 3,000.<sup>19</sup> More recent studies by Scherb and Weigelt also reveal a shift in the newborn gender ratio (male to female ratio) toward males.<sup>20</sup> According to these studies, 220,000 girls are missing in West Europe. These studies, however, are being ignored by international institutions (UNSCEAR IAEA, ICRP), as is extensive research in Belarus into malformations, stillbirths and miscarriages. Their scientists continue to believe in a threshold value for teratogenic damage. This assumption has now been refuted in numerous studies.<sup>21</sup>

8 Ivanov, V.K., Tsyb, A.F.(2002) Medical Radiological consequences of the Chernobyl accident for the population of Russia, assessment of radiation related risks. Moscow. Meditsina Publishing House, p. 389; in Burlakova & Naidich (2006): 20 years after the Chernobyl accident; Past, Present, Future, Nova Science Publishers Inc. New York

9 Kashcheev et al.(2015): Radiat Environ Biophysics 2015 Mar; 54 (1):13-23

10 Buzunov V, Omelyanetz N, Strapko N, et al. Chernobyl NPP accident consequences cleaning up participants in Ukraine—health status epidemiologic study—main results. In: Karaoglou A, Desmet G, Kelly GN, et al, eds. The radiological consequences of the Chernobyl accident. Luxembourg, Belgium: Office for Official Publications of the European Communities, 1996: 871–8.

11 Tereshenko, V.M. et al.(2003) Epidemiologic research on non-neoplastic morbidity in Chernobyl NPP accident liquidation participants in 1986–87 Hygiene of population aggregates issue 41 p. 283-287 (quoted from Greenpeace report 2006)

12 [http://www.unscear.org/docs/reports/2008/11-80076\\_Report\\_2008\\_Annex\\_D.pdf](http://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf) , p. 62

13 Burlakova E, Naidich VI (2006)

14 Loganovsky K (2012): Brain damage following the exposure to low doses of ionizing radiation as a result of the Chernobyl accident

15 Stepanova E et al (2008): Exposure from the Chernobyl accident had adverse effects on erythrocytes, leukocytes, and platelets in children in the Narodichesky region, Ukraine:A 6-year follow-up study

16 Svendsen ER et al (2010): 137 Cesium Exposure and Spirometry Measures in Ukrainian Children Affected by the Chernobyl Nuclear Incident

17 Lazjuk GI, Satow Y (2004): Some Issues on the long term investigations on genetic consequences of the Chernobyl accident; <http://www.rii.kyoto-u.ac.jp/NSRG/reports/kr21/kr21pdf/Lazjuk.pdf>; Scherb H, Weigelt E (2003): Congenital Malformation and Stillbirth in Germany and Europe Before and After the Chernobyl Nuclear Power Plant Accident; Körblein A (2006): Säuglingssterblichkeit nach Tschernobyl; <http://www.strahlentext.de/OttoHug24.htm>; Vorobtsova IE, Semenov AV (2006): Complex cytogenetic characteristic of people suffered from Chernobyl accident, <http://www.ncbi.nlm.nih.gov/pubmed/16756111>

18 Lazjuk GI et al.(1995): Frequency Changes of inherited anomalies in the Republic of Belarus after the Chernobyl accident; in: Radiation Protection Dosimetry, Vol 62 No 1 / 2, pp. 71–74

19 Scherb H, Sperling K (2011): Heutige Lehren aus dem Reaktorunfall von Tschernobyl. Naturw.Rdsch., 64. Jg., issue 5, 2011, pp. 229-239 [http://www.naturwissenschaftliche-rundschau.de/navigation/dokumente/NR\\_5\\_2011\\_HB\\_Scherb.pdf](http://www.naturwissenschaftliche-rundschau.de/navigation/dokumente/NR_5_2011_HB_Scherb.pdf)

20 Scherb H, Voigt C (2013): Strahleninduzierte genetische Effekte nach Tschernobyl und in der Nähe von Nuklearanlagen.Ulmer Expertentreffen – Gefahren von ionisierender Strahlung auch im Niedrigstrahlungsbereich – Expertise zur Grenzwertdebatte – Update 2013, October 18/19, 2013, Ulm, Germany.

21 e.g. Schmitz-Feuerhake I. (2015): Das vergessene Risiko durch ionisierende Strahlung für die Nachkommen exponierter Eltern; in: umwelt-medizin-gesellschaft | 28 | 4/2015



## 1.4 Health of liquidators

This report dedicates an extra section to the liquidators, as the group most severely affected by the Chernobyl nuclear disaster. Although data on the extent of morbidity and mortality among liquidators differs, all medical studies agree that most liquidators suffer from more than one severe condition (multimorbidity) and are incapacitated. After examining different studies, Yablokov estimates that 112,000–125,000 liquidators were already dead by 2005.<sup>22</sup> The main causes of death were stroke and heart attack, the second most common was cancer. Chernobyl researchers Burlakova<sup>23</sup> and Bebeshko<sup>24</sup> identified numerous somatic changes as radiation-induced premature aging processes.

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22 Yablokov AV (2009): Mortality after the Chernobyl Accident, in: Ann N Y Acad Sci, 2009 Nov; 1181:192-216.

23 Internationaler Kongress: 20 Jahre Tschernobyl – Erwartungen und Lehren für die Zukunft: Lecture. Prof. Elena Burlakova, Moscow: Scientific principles of the damaging effect of radiation on the state of health of the general population [http://www.strahlentelex.de/20\\_Jahre%20\\_nach\\_Tschernobyl\\_Abstracts\\_GSS\\_Berlin-Charite\\_2006.pdf](http://www.strahlentelex.de/20_Jahre%20_nach_Tschernobyl_Abstracts_GSS_Berlin-Charite_2006.pdf)

24 Bebeshko V, Bazyka D, Loganovsky V, Volovik S, Kovalenko A, Korkushko O, Manton K (2006): Does Ionizing radiation accelerate aging phenomena? (pp.13-19). In: Contributed papers to the International conference 20 years after Chernobyl Accident Future Outlook April 24 – 26, 2006, Kyiv, Ukraine, Kyiv HOLTEH



## 2 Sequence of events leading to the accident



*“Radioactivity metered 300 meters above the reactor was 18 Sv per hour. In mid-flight, the helicopter pilots felt dizzy. In order to hit the target, which was a fiery crater, they stuck their heads out of their cabins and measured it with the naked eye.”*

FROM IGOR KOSTIN: TSCHERNOBYL NAHAUFNAHME  
[ENGLISH TRANSLATION BY KEITH GESSON]

The Soviet NPP Chernobyl is about 100 kilometers north of the Ukrainian capital Kiev and close to the Belarus border. On the night of Saturday April 26, 1986, engineers were conducting an operative test on reactor 4 when it suddenly spiraled out of control: output continued to rise, the emergency shutdown failed, nuclear chain reactions were taking place at a breathtaking rate. Just 44 seconds after test began, two explosions tore the roof off the reactor and destroyed the reactor core. The cooling water began to run off, which caused the graphite rods in the reactor core to ignite, which in turn caused fuel rods to melt. The fire, which was fuelled by graphite rods and difficult to extinguish, continued to burn until May 10, 1986.

At the time, there was 190,000 kg of highly radioactive material in the reactor. The explosions and ensuing fires triggered the release of 12 trillion Becquerel (12 x 10<sup>18</sup> or 12,000,000,000,000,000 Bq or 12,000 Peta-Bq) radioactive particles into the atmosphere within just a few days – this is 200 times greater than the Nagasaki and Hiroshima atom

bombs together. It included 85 PBq cesium 137 and 1,760 PBq iodine 131.<sup>1</sup>

Frequent wind changes during the following days sent several radioactive clouds from Chernobyl scudding inland. About 36 % of the total radioactive fallout from cesium 137 was spread over the three Soviet Republics Belarus, Ukraine and Russia – mainly north of the power plant in the Belarus regions of Gomel and Mogilev. A further 53 % of the radioactive radiation was spread across Europe, mainly Scandinavia, Eastern and Central Europe and the Balkans; the remaining 11 % was distributed across the entire northern hemisphere. In Germany, contamination was particularly heavy in southeast Bavaria and Baden-Wurttemberg.<sup>2</sup>

Just 36 hours after the onset of the meltdown, increased radiation levels were already being metered in Switzerland, Czechoslovakia and Sweden. Analyzes soon showed the cause to be a nuclear power plant meltdown, but the public was still not informed. It was not until the evening of April 28 that the Soviet news agency TASS reported an accident in the Chernobyl NPP. In the GFR the incident was headlined in several newspapers the following day. In the GDR it was only a minor news item and relegated to the back pages. Both German governments initially denied that Chernobyl fallout constituted a health hazard.

In the meantime, the Chernobyl works fire service reacted to the disaster with a frantic attempt to extinguish the fire – but the graphite fire in the reactor core continued to burn for a further

1 Fairlie I, Sumner D (2006): the Other Report On Chernobyl; <http://cricket.biol.sc.edu/chernobyl/papers/TORCH.pdf>

2 Bennett B (1996): Assessment by UNSCEAR of Worldwide Doses from the Chernobyl Accident in Proceedings of an IAEA Conference One Decade after Chernobyl: Summing up the Consequences of the Accident, Vienna, 8-12 April 1996, Jan. 2016.



two weeks. The turning point was not achieved until helicopters dumped 5,000 tons of boron, lead, sand and clay onto the reactor. Over the course of the days, months and years following the meltdown, the government sent an estimated 830,000 persons in disaster response units to Chernobyl. Most of these 'liquidators' were Red Army recruits brought in from all over the Soviet Union. They cleared radioactive rubble with their bare hands, stripped polluted earth, slaughtered contaminated animals, dug up radioactive waste and constructed what has come to be known as the 'sarcophagus' in the hope of containing the extreme radiation. Manual workers, engineers, physicians, nurses and scientists were also deployed in Chernobyl and exposed to high radiation doses.

Because both the Soviet Union and the West underestimated and played down the health effects of ionizing radiation, protective measures were not introduced for the general public until it was too late, if indeed at all. Children therefore continued to play on contaminated sports and playgrounds, pedestrians walked unprotected through radioactive rain. Traditional Mayday celebrations and processions were held in Kiev and Minsk, as in all other socialist cities. Millions of people were also exposed to increased radiation through the consumption of food, drinking water and milk.

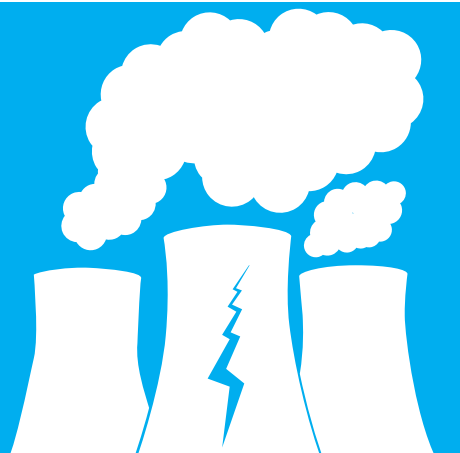
Particularly hard hit by the Chernobyl meltdown were populations in parts of the former Soviet Union. In the city of Pripyat, just three kilometers from the wrecked reactor, radiation levels rose to 250 times the normal background dose.<sup>33</sup> Residents of Pripyat complained of headaches and nausea and reported noticing a strange metallic taste just a few hours after the explosion. But the city's 50,000 inhabitants were not evacuated until 36 hours after the meltdown had begun. Milk and drinking water were not analyzed until May 1st, iodine tablets to protect the thyroid against radioactive iodine were not distributed until four weeks after the meltdown, far too late to take effect. Neither were the villages within the 30-kilometer restriction zone around the reactor nor the other contaminated areas evacuated until a week after the reactor had exploded. Many villages were leveled by bulldozers, the radioactive debris covered with a layer of soil. Around 400,000 people were forced to leave their homes, more than 8.3 million people suddenly found themselves living in a contaminated area.

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3 Repin VS (1995): Radiological-hygienic importance of radiation sources and doses for population of 30-km zone after the accident on ChNPP. Problem of reconstruction, assessment of risks. Institute of epidemiology and prophylaxis of radiation injury, National Academy of Medicine, Ukraine



### 3 Basic facts of the catastrophe



#### Populations affected by the Chernobyl disaster

Populations affected included 830,000 liquidators, 350,400 evacuees from the 30-km zone and other heavily contaminated zones, 8,300,000 people from heavily contaminated areas in Russia, Belarus and Ukraine and 600,000,000 people in less contaminated areas of Europe.<sup>1 2</sup>

Estimates of the level of soil contamination with radioactive cesium must also make allowances for pre-Chernobyl contamination with radioactive cesium from atmospheric nuclear weapon tests in the 1950s to 1970s. In 1996, De Cort et al. were commissioned by the EU to measure cesium concentrations in different European states. They estimated the cesium 137 concentration in Europe prior to the Chernobyl disaster to have been 0-3.5 kBq/m<sup>2</sup>. The map on the following page shows the level of contamination ten years after the meltdown<sup>3</sup> (see figure 3-1).

Added gamma radiation (groundshine) can be calculated from the ground concentration using complex conversion methods. On the basis of data on the behavior, exposure and concentrations of cesium 137 in the former Soviet Republics Belarus, Ukraine and Russia, an additional radiation dose of 10 mSv per kBq/m<sup>2</sup> cesium 137 can be assumed (depending on the region investigated, 7.4–13). This estimate does not include the internal radiation dose from the ingestion or inhalation of radioactive

particles, which is, of course, also indirectly contingent on concentrations in the environment.

As it is still not certain just how much radioactive material was actually released, the estimated source term, i.e. the total emissions released from the reactor, is still vague today. Fairlie/Sumner (2006) provide a summary of the exhaustive discussions on the differing estimates.<sup>4</sup>

#### Data on the numbers directly affected and the extent of contamination<sup>5</sup>:

Belarus	<b>2,500,000</b> people
Ukraine	<b>3,500,000</b> people
Russia	<b>3,000,000</b> people

<b>135,000</b>	were evacuated,
<b>400,000</b>	lost their homes and were forced to leave
<b>3,000,000</b>	persons live in areas with
	> 185,000 Bq/m <sup>2</sup> (5 Ci/km <sup>2</sup> )
<b>270,000</b>	Persons living in areas with
	> 555,000 Bq/m <sup>2</sup> (15 Ci/km <sup>2</sup> )

#### Contaminated areas:

Belarus	<b>30%; 62,400 km<sup>2</sup></b>
Ukraine	<b>7%; 42,000 km<sup>2</sup></b> and <b>40%</b> of the woodlands
Russia	<b>1.6%</b> (of the European part); <b>57,650 km<sup>2</sup></b>
<b>21,000 km<sup>2</sup></b>	were contaminated with
	185-555,000 Bq/m <sup>2</sup> (5-15 Ci/km <sup>2</sup> ) and
<b>10,000 km<sup>2</sup></b>	were contaminated with
	>555,000 Bq/m <sup>2</sup> (> 15 Ci/km <sup>2</sup> ).

Note: The above UN data differ somewhat from the data given by Fairlie and Yablokov

1 Yablokov AV, Nesterenko VB, Nesterenko AV (2009): Chernobyl: Consequences of the Catastrophe for People and the Environment

2 Fairlie I, Sumner D (2006): The Other Report On Chernobyl; <http://cricket.biol.sc.edu/chernobyl/papers/TORCH.pdf>

3 De Cort M, Dubois G, Fridman ShD, Germenchuk MG, Izrael YuG, Janssens A, Jones AR, Kelly GN, Kvasnikova EV, Matveenko II, Nazarov IM, Pokumeiko YuM, Sitak VA, Stukin ED, Tabachny LYa, Tsaturov YuS (1998): Atlas of Cesium Deposition on Europe after the Chernobyl Accident, EUR report no. 16733, Office for Official Publications of the European Communities, Luxembourg, Plate 1.

4 Fairlie I, Sumner D (2006): The other report on Chernobyl, p. 19 – 24

5 UN General Assembly A/50/418, 8.9.1995



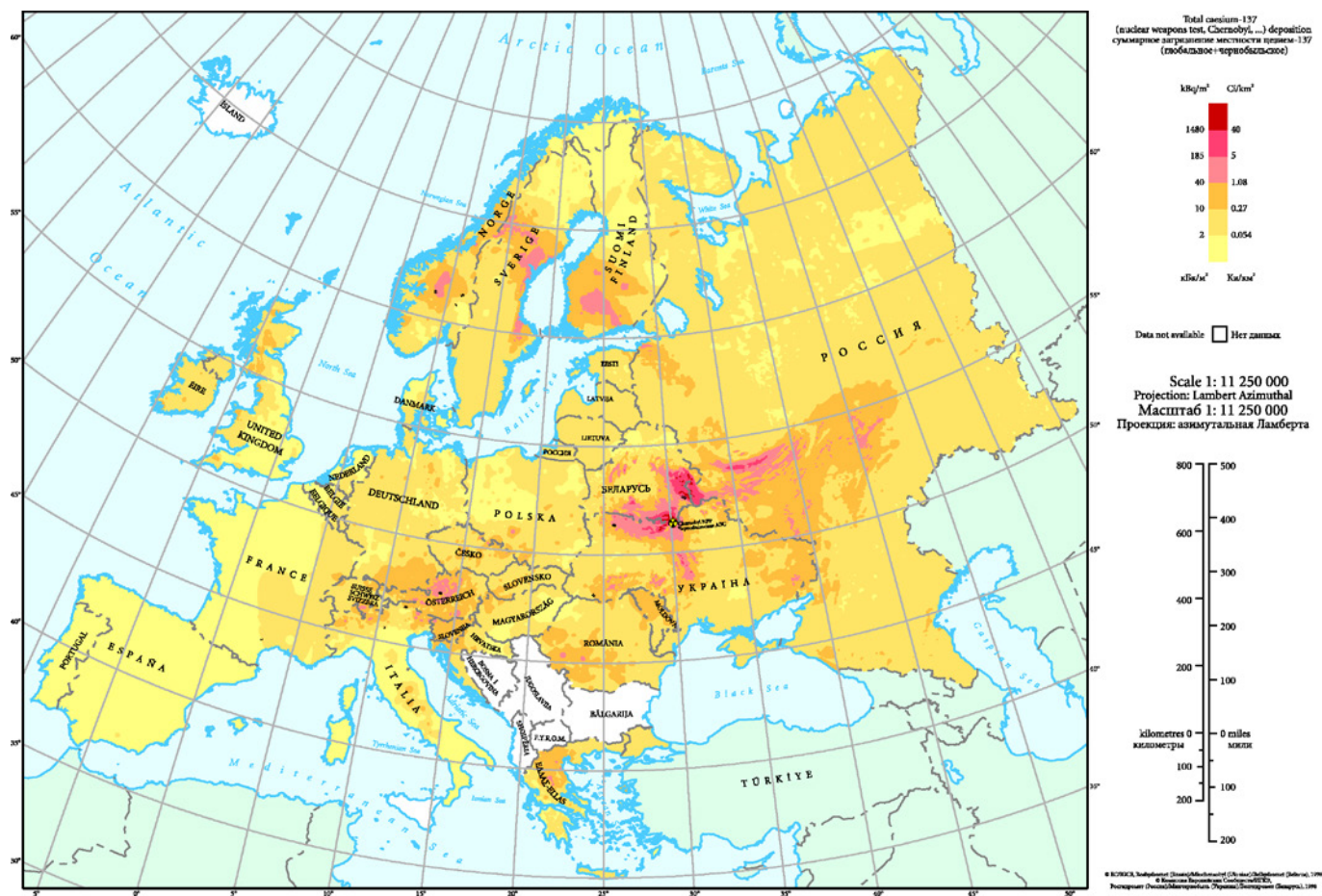


Figure 3-1

Map of Cs 137 contamination in European states according to data from EU measurements in 1996

Cs137 (kBq/qm)	Belarus	Russia	Ukraine	Total
<b>37 – 185</b>	1,543,000	1,654,000	1,189,000	4,386,000
<b>185 – 555</b>	239,000	234,000	107,000	580,000
<b>555 – 1.480</b>	98,000	95,000	300	193,300
<b>Total</b>	1,880,000	1,983,000	1,296,300	5,159,300

Table 3-1

Distribution of inhabitants in the radioactive contaminated areas of Ukraine, Belarus and Russia in 1995<sup>6</sup> (inhabitants)

6 UN Chernobyl Forum (EGE): Environmental Consequences of the Chernobyl Accident and Their Remediation: Twenty Years of Experience, Working Material, August 2005.



## Contamination in Belarus 1995 (acc. to Danielova 2014)<sup>7</sup>

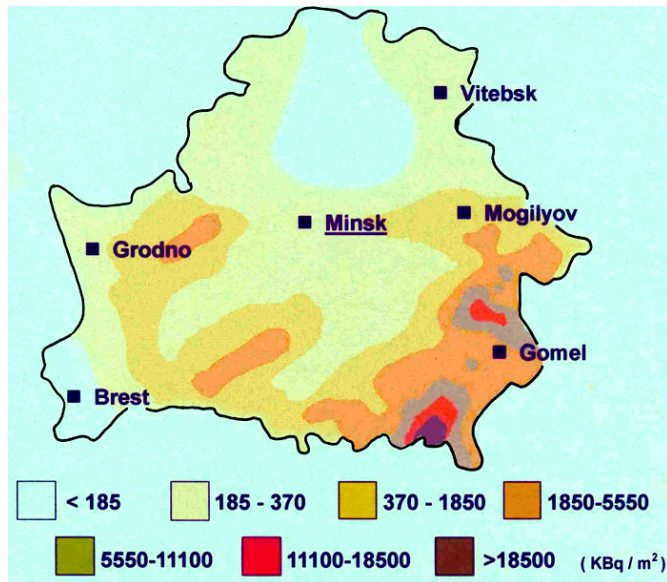


Figure 3-2

Iodine-131 contamination

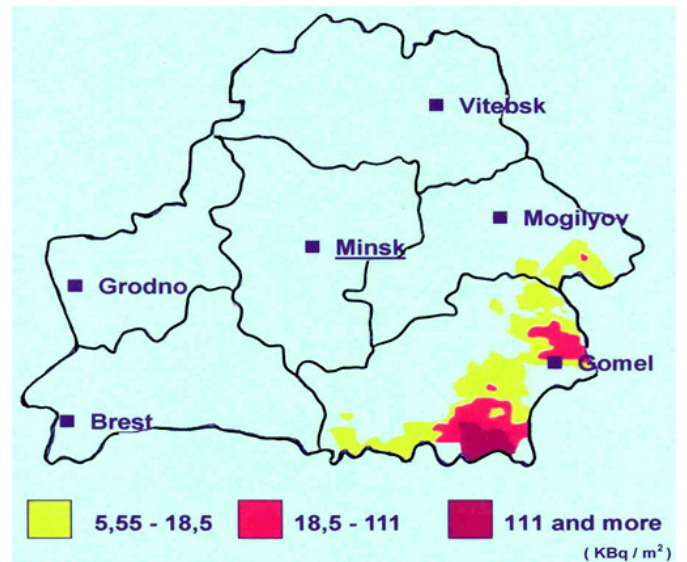


Figure 3-4

Distribution of SR 90

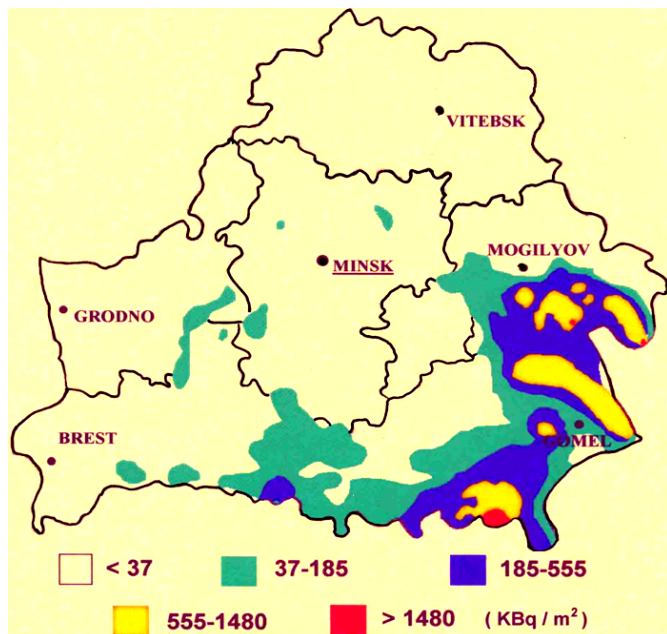


Figure 3-3

Distribution of cesium

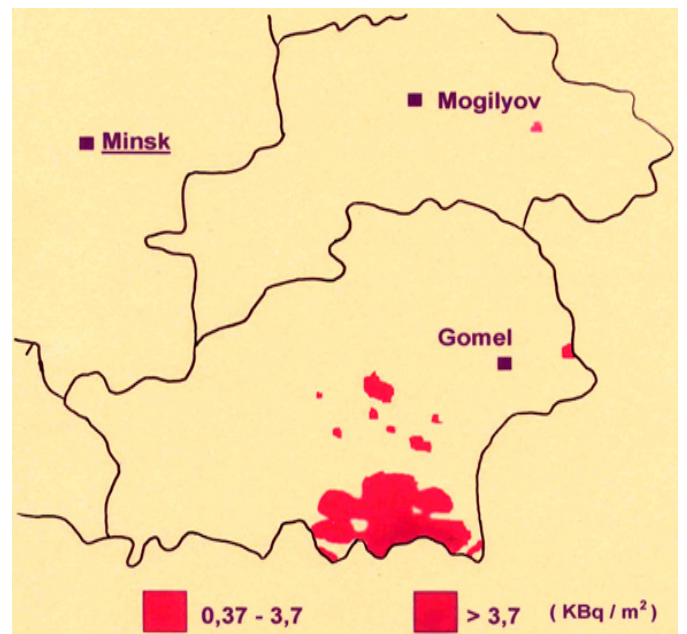


Figure 3-5

Distribution of Pu 238, 239, 240

<sup>7</sup> [http://www.tschernobylkongress.de/fileadmin/user\\_upload/Arnoldshain\\_Doku/Danilova\\_2014\\_Germany.pdf](http://www.tschernobylkongress.de/fileadmin/user_upload/Arnoldshain_Doku/Danilova_2014_Germany.pdf)



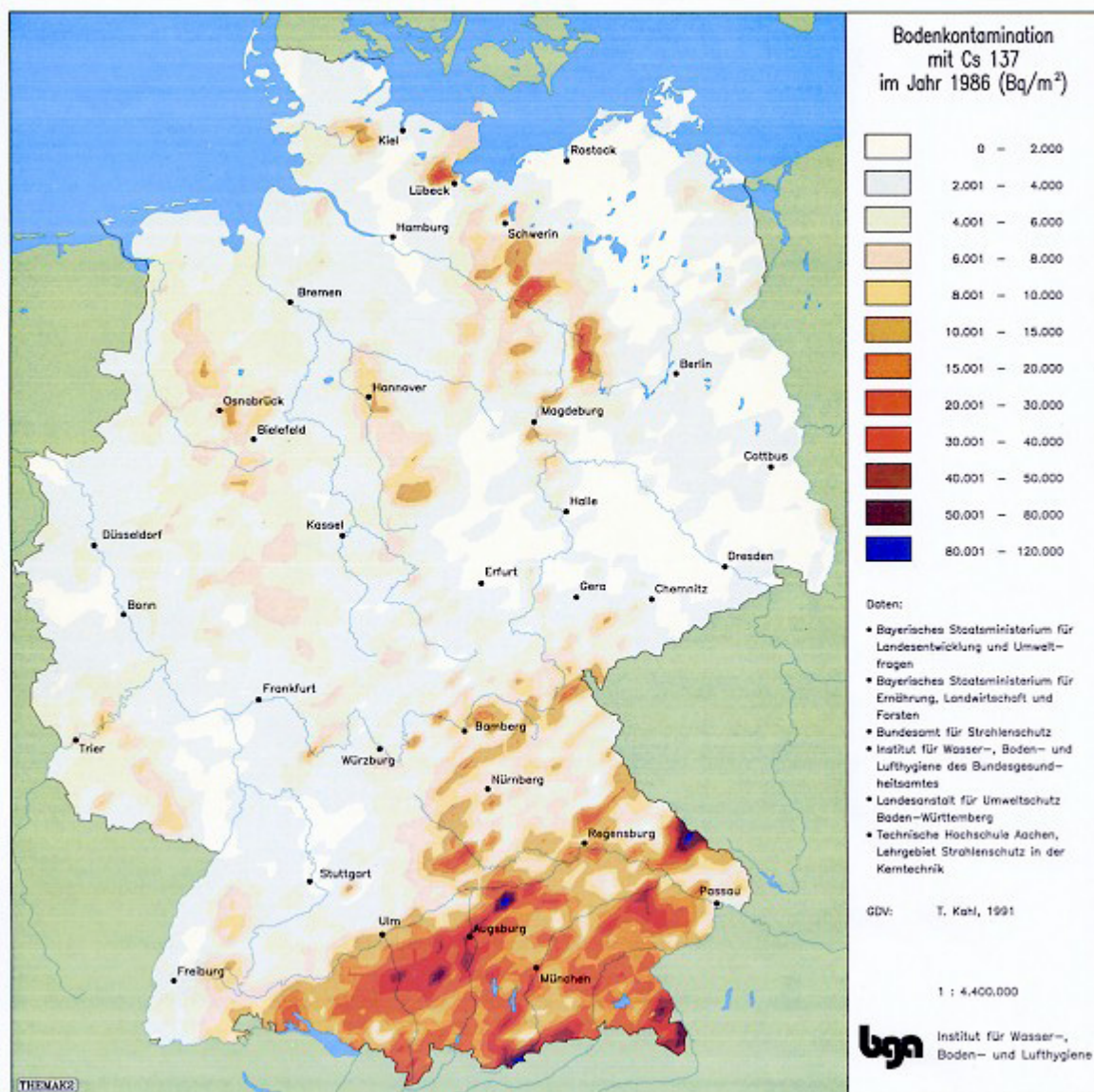


Figure 3-6

Cs 137 soil contamination in Germany

### European countries contaminated with 37–185 kBq/m<sup>2</sup> Cs137:

Sweden:	12,000 km <sup>2</sup>
Finland:	11,500 km <sup>2</sup>
Austria:	8,600 km <sup>2</sup>
Norway:	5,200 km <sup>2</sup>
Bulgaria:	4,800 km <sup>2</sup>
Switzerland:	1,300 km <sup>2</sup>
Greece:	1,200 km <sup>2</sup>
Slovenia:	300 km <sup>2</sup>
Italy:	300 km <sup>2</sup>
Moldova:	60 km <sup>2</sup>

### Cs 137 soil contamination in Germany<sup>8</sup>

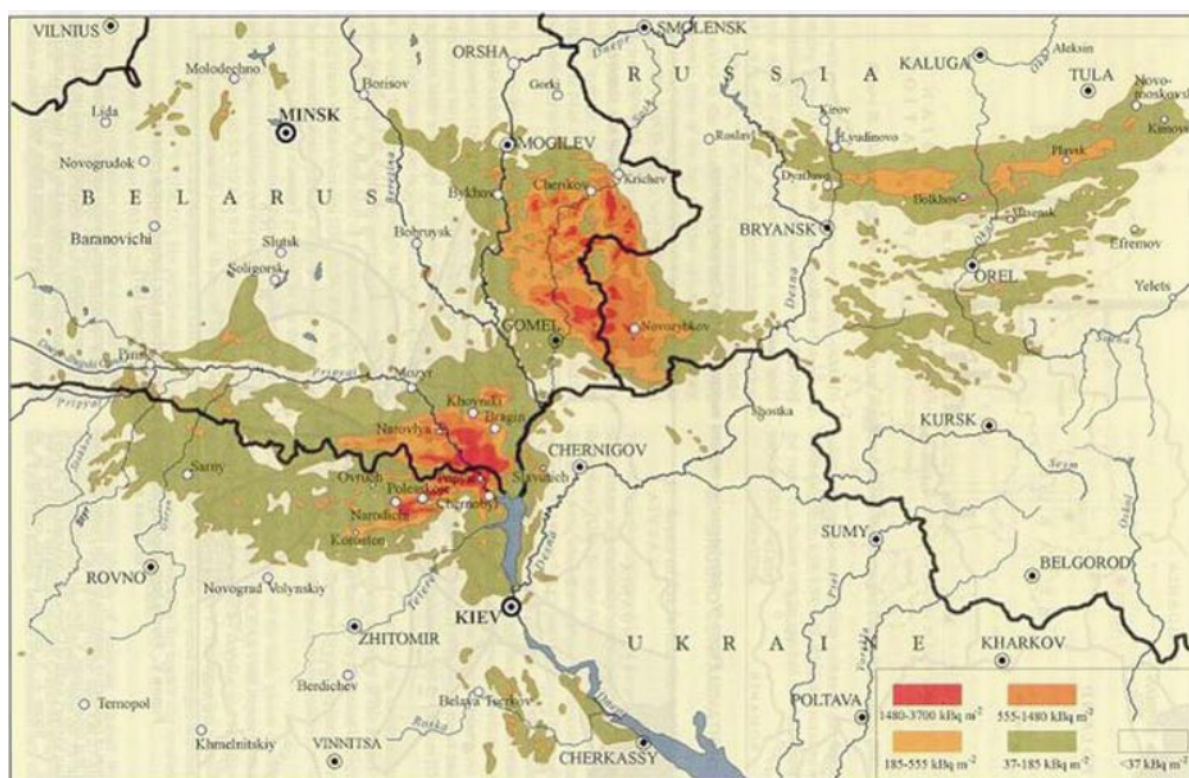
The deposition of radionuclides in the Federal Republic of Germany was through rain showers that fell between April 30 and May 5, 1986. Approximately two thirds of the deposited activity originated from the isotopes iodine-131 and tellurium 132, which have half-lives of 8 and 3 days respectively and decay relatively quickly. Of the long-lived radionuclides, cesium 137 constitutes the largest proportion with 8 %. Long-term radiation from the reactor accident is therefore due mainly to this nuclide. Following the Chernobyl disaster, radioactive contamination in Bavaria due to external gamma radiation from cesium decay products was 1 mSv/annum.<sup>9</sup>

8 BfS: Der Reaktorunfall 1986 in Tschernobyl; [https://www.bfs.de/SharedDocs/Downloads/BfS/DE/broschueren/kt/bro-tschernobyl.pdf?\\_\\_blob=publicationFile&v=6](https://www.bfs.de/SharedDocs/Downloads/BfS/DE/broschueren/kt/bro-tschernobyl.pdf?__blob=publicationFile&v=6)

9 [http://www.tschernobylkongress.de/fileadmin/user\\_upload/pdfs/ScherbVoigt\\_fehlbildungen\\_fehlende\\_geburten.pdf](http://www.tschernobylkongress.de/fileadmin/user_upload/pdfs/ScherbVoigt_fehlbildungen_fehlende_geburten.pdf)



#### 4 Assessment of the health effects of the Chernobyl meltdown



### Figure 4-1

The aim of this report is to compile an as comprehensive as possible assessment of the health effects of the Chernobyl nuclear disaster for the population. We know that the short-term effect of high-dose ionizing radiation, as well as long-term exposure to low-dose radiation, significantly increases the risk of numerous diseases, especially cancer and cardiovascular illnesses. Not only were hundreds of thousands of liquidators acutely exposed to extremely high radiation doses throughout the nuclear disaster, but also exposed were several hundred thousand evacuees from the 'death zone' and other heavily con-

taminated areas, as well as millions of people living in the heavily contaminated areas of Belarus, Russia and Ukraine.<sup>1</sup>

Radioactive fallout in other parts of the former Soviet Union, Scandinavia, Eastern and Central Europe and Asia Minor also produced areas with high concentrations of radioactive cesium,

1 A. Yaroshinskaya (2004) Verschlusssache Tschernobyl, Berlin Basisdruck-GmbH, pp. 148 – 149



iodine, strontium and other radioactive substances. Before the fire in reactor 4 was finally extinguished, contamination patterns changed according to the wind direction on any particular day.

Such a nebulous situation makes it extremely difficult to estimate the health effects for the general public. There are essentially two methods:

- » estimation of the anticipated number of cases of a given illness among the affected population based on the amount of radiation released
- » testing the affected groups and populations for significant increases in the disease incidence

Both methods have their drawbacks and entail logistical and technical problems. Furthermore, the actual amount of radioactive material released during the disaster is still not known today. Add to this the systematic secrecy policy maintained by the former USSR government which forbade doctors from linking the illnesses they were diagnosing and treating to radioactive contamination. Doctors were compelled to falsify diagnoses. In addition, research into health effects was rendered particularly difficult by the cover-up policy practiced by the respective international UN-committees (IAEA, UNSCEAR and WHO).

In this report we undertake to draw on key international research results to provide the best possible assessment of the health conditions to be expected as a result of the Chernobyl nuclear disaster, before going on to analyze and summarize the relevant studies on 'the health effects of Chernobyl'.

### Survey of the health outcomes expected due to the collective radiation dose

To gain insight into the number of additional diseases to be expected as a result of the Chernobyl nuclear disaster, it is useful to first look at the estimated collective dose for the general public. The collective dose or collective life-time dose is the sum of the individual life-time doses in a population.

If, for example, an average additional individual dose of 100 mSv is calculated for a population of 1,000, the average collective dose for this group will be 100 person sievert. This estimation assumes average life expectancy and refers exclusively to the effects of radioactive fallout; it does not include natural background radiation (regional differences between 2 and 4 mSv per annum) or the radiation dose from exposure to diagnostic radiation or any other anthropogenic radiation source. One of the problems with this representation is that averages obliterate the individual risk – individual members of a population can receive significantly higher or lower doses depending on their way of life and degree of exposure. A further factor is the ability of the immune system to deal with radiation exposure. A well-known phenomenon is the increased radiation sensi-

tivity of children and people with immune deficiencies. The collective doses is nonetheless a useful instrument for calculating health consequences and the risk to larger populations. If one then multiplies the collective dose by the established radiation-medicine risk factors, one obtains an idea of the number of new cases of disease to be expected. Thus, with data from official publications on collective doses from radioactive fallout after the Chernobyl disaster, it is possible to calculate the additional cancer incidence and mortality to be expected each year. Problematic, as discussed above, is the discrepancy between the figures provided by different sources for the collective dose from Chernobyl fallout. Thus, estimations by nuclear-friendly organizations such as UNSCEAR or IAEA are significantly lower than official Soviet figures for 1986, which constitute the most comprehensive assessment of radiation doses.

### USSR 1986

The German society for reactor safety GRS, published the report on the latest insights into the accident in the nuclear power plant Chernobyl (GRS-S-40) as early as 1987.<sup>2</sup> It documents information from the Soviet Union (USSR) from August 1986 on the radiological effects of the Chernobyl accident.<sup>3</sup> The Soviet Union put the collective dose for the population evacuated from the 30-km zone (approx. 135,000 persons) at 16,000 person sievert, where this figure is based on external gamma radiation only. The size of the population affected by the Chernobyl disaster outside the 30-km zone (up to 1,000 km) was given with 75 million. The collective dose based on external gamma radiation for the first year after Chernobyl was given as 90,000 person sievert and for 50 years as 290,000 person sievert. The collective dose from Cs 134/137 ingestion over a 70 year period was put at 2,100,000 person sievert. The USSR put the total collective dose resulting from the Chernobyl accident at 2.4 million person sievert, where this figure only covers part of the population actually affected and does not include other areas affected by radioactive fallout outside the 1,000 kilometer limit, such as southern Germany.

<sup>2</sup> Gesellschaft für Reaktorsicherheit (GRS) mbH: Neuere Erkenntnisse zum Unfall im Kernkraftwerk Tschernobyl. As of: October 1986. GRS-S-40 (2nd edition, February 1987), p. 70.

<sup>3</sup> USSR State Committee on the Utilization of Atomic Energy. The Accident at the Chernobyl Nuclear Power Plant and its Consequences Working Document for the IAEA Post Accident Review Meeting. Vienna, August 1986 (Draft).



### Cardis et al. 1996

The WHO research team around Elizabeth Cardis limited their investigation to the heavily contaminated Chernobyl area (Belarus, Ukraine, Russia) and the liquidators.<sup>4</sup> The collective dose for 200,000 liquidators in the first ten years after the Chernobyl meltdowns, including 1996, is given as 20,000 person sievert. The figure for the 135,000 evacuees is 1,600 person sievert. Cardis et al. put the collective dose for 270,000 persons in severely contaminated areas (Cs 137 ground concentration >555 kBq/m<sup>2</sup>) at 10,000 – 20,000 person sievert over ten years. For 6.8 million people in areas with Cs-137 ground concentrations between 37 and 555 kBq/m<sup>2</sup> the collective dose is given as 35,000 to 100,000 person sievert by 1995. The result, when these four groups are added together, is therefore a total collective dose of between 67,000 and 142,000 person sievert for the first ten years of the nuclear disaster. According to Cardis et al., the life-time dose is calculated by increasing the respective value by 50 %.<sup>5</sup> The total life-time dose by 2056 would therefore be in the region of 100,000 to 212,000 person sievert.

### Bennett 1995/1996

In 1995/1996, the secretary of the United Nations' Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Burton Bennett, published a study on the release of radioactivity in Chernobyl<sup>6</sup> and an assessment of the worldwide radiation dose.<sup>7</sup>

Bennett puts the worldwide dose at 600,000 person sievert. Of that, 36 % is borne by the population of Belarus, Ukraine and Russia; 53 % by the rest of Europe and 11 % by the rest of the world's population. The other report on Chernobyl (TORCH)<sup>8</sup> published by Ian Fairlie and David Sumner in 2006, was constructed around Bennett's figure of 600,000 person sievert.

### US State Department of Energy (Anspaugh et al. 1988)

The US State Department of Energy put the collective dose for Ukraine, Belarus and Russia in 1988 at 326,000 person sievert.<sup>9</sup> The figure for the rest of Europe is given with 580,000 person sievert. The collective dose for the rest of the world is given as 28,000 person sievert. The total collective dose is therefore 934,000 person sievert.

### UN Chernobyl Forum 2005

The so-called 'UN Chernobyl Forum', organized by the International Atom Energy Agency (IAEA) and the World Health Organization (WHO) in 2005, produced hardly any useful information on the collective dose resulting from Chernobyl.<sup>10</sup> The IAEA and WHO named a mere 55,000 person sievert as the collective dose for Belarus, Ukraine and Russia together. The rest of Europe and the northern hemisphere were completely omitted. Their estimate for the collective dose was limited to a 20-year period (to 2006) and there was absolutely no suggestion of a life-time dose. The investigation is therefore unsuitable for assessing the full extent of the effects of Chernobyl.

### UNSCEAR-Report 2013

The 2013 report by the United Nations Scientific Committee on the Effects of Atomic Radiation provides information on the collective dose for the whole of Europe.<sup>11</sup> UNSCEAR puts the life-time dose of all those affected at 400,000 person sievert, of which 140,000 person sievert is the absorbed thyroid dose.

The choice of risk factors with which to calculate the probable cancer incidence has significant implications. We apply the internationally recognized risk factors given in the BEIR VII report, but without the dose-reduction factor DDREF (dose and dose rate effectiveness factor), which is no longer appropriate. With regard to the incidence, i.e. the emergence of new cancer cases in a population exposed to radiation, 0.2 additional cancer cases per person sievert collective dose can therefore be

4 Cardis E, Anspaugh L, Ivanov VK, Likhtarev K, Mabuchi AE, Okeanov AE, Prisyazhniuk K (1996): Estimated Long Term Health Effects of the Chernobyl Accident. In: Proceedings of an IAEA Conference One Decade after Chernobyl: Summing up the Consequences of the Accident. Vienna. April 8-12, 1996. pp. 241- 271 (Table 1).

5 cf. Fairlie I, Sumner D (2006): The other Report on Chernobyl (TORCH). Berlin, Brussels, Kiev, April 2006. p. 62.

6 Bennett B (1995): Exposures from Worldwide Releases of Radionuclides. In Proceedings of an International Atomic Energy Agency Symposium on the Environmental Impact of Radioactive Releases. Vienna, May 1995. IAEA-SM-339/185.

7 Bennett B (1996): Assessment by UNSCEAR of Worldwide Doses from the Chernobyl Accident in Proceedings of an IAEA Conference One Decade after Chernobyl: Summing up the Consequences of the Accident, Vienna, April 8-12, 1996.

8 Fairlie I, Sumner D (2006): The other Report on Chernobyl (TORCH) Berlin, Brussels, Kiev, April 2006..

9 Anspaugh LR, Catlin RJ, and Goldman M (1988): The Global Impact of the Chernobyl Reactor Accident. Science 242. pp 1513-1519.

10 IAEA/WHO (2005): Health Effects of the Chernobyl Accident and Special Health Care Programmes. Report of the UN Chernobyl Forum Expert Group 'Health' (EGH) Working draft, July 26 2005. IAEA/WHO Environmental Consequences of the Chernobyl Accident and their Remediation. Report of the UN Chernobyl Forum Expert Group 'Environment' (EGE) Working draft, August 2005

11 UNSCEAR (2014): Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly– Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami. 02.04.14, p.9 [www.unscear.org/docs/reports/2013/13-85418\\_Report\\_2013\\_Annex\\_A.pdf](http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf)



assumed (confidence interval 0.09-0.35).<sup>12</sup> At the time of the 2013 Fukushima report, the WHO assumed a risk factor of 0.2 person sievert for the cancer incidence.<sup>13</sup> The risk factor for mortality is about half as high (0.1 person sievert, confidence interval 0.05-0.19). More recent studies suggest that these figures are probably still too low.<sup>14</sup>

It is clear that the official USSR figure of 2.4 million person sievert from 1986 is far higher than any later official figures for collective doses – and, as mentioned above, only include parts of the affected populations.

Irrespective which source one is inclined to believe, one thing is certain: the figure of 4,000 deaths purported by the International Atomic Energy Agency bears no relation to the actual number of deaths, which is many times higher, and constitutes a blatant attempt by the atom lobby to play down the effects of Chernobyl. It is also clear that the number of anticipated Chernobyl-induced cancer cases could reach several tens of thousands, but could also be as many as 850,000. The number of expected cancer deaths therefore varies accordingly between several tens of thousands and half a million.

Studies on the survivors of Hiroshima and Nagasaki, as well as meta-analyses of disease data from radiation exposed populations, clearly show that the risk for radiation-induced cerebro- and cardiovascular diseases, such as heart attack or stroke, appear to be the same as for cancer illnesses.<sup>15</sup> <sup>16</sup> About equal numbers of cardiovascular diseases and cancer illnesses can therefore be expected in the exposed population. This does not yet include the neural, autoimmune, endocrinal, mental and genetic diseases also shown to result from radiation exposure but for which there are still no known reliable risk factors. It therefore becomes apparent that calculations for the anticipated cancer incidence, which are based on collective dose estimates and use conventional risk factors, can only account for a proportion of the actual morbidity and mortality burdens of the affected population. A more accurate estimate of the health effects of the Chernobyl nuclear disaster requires extensive epidemiological studies with exposed populations. A summary of the most relevant research results in this field is therefore provided below.

12 National Academy of Sciences (2006): Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation. p. 279, Table 12.5. [www.nap.edu/openbook.php?record\\_id=11340&page=8](http://www.nap.edu/openbook.php?record_id=11340&page=8)

13 WHO (2013): Global report on Fukushima nuclear accident details health risks. 28.02.13. [http://www.who.int/mediacentre/news/releases/2013/fukushima\\_report\\_20130228/en/](http://www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/)

14 IPPNW (2014): Gefahren ionisierender Strahlung. Results of the meeting of experts in Ulm on October 19, 2013. IPPNW information. January 2014. p. 3

15 Little MP, Azizova TV, Bazyka D, Bouffler SD et al (2012): Systematic Review and Meta-analysis of Circulatory Disease from Exposure to Low-Level Ionizing Radiation and Estimates of Potential Population Mortality Risks. *Environ. Health Perspect.* 2012, 120, 1503-1511

16 Shimizu Y, Kodama K, Nishi N, Kasagi F et al (2010): Radiation exposure and circulatory disease risk: Hiroshima and Nagasaki atomic bomb survivor data, 1950-2003. *BMJ* 2010, 340, b5349



Source, collective	No. of persons affected	Collective dose[person sievert ]	Expected cancer incidence and cancer mortality			
			Incidence		Mortality	
<b>Risk factors acc. to BEIR VII</b>			<b>0,09</b>	<b>0,35</b>	<b>0,05</b>	<b>0,19</b>
<b>IAEA/WHO 2005</b>						
Ukraine, Belarus, Russia		<b>55,000</b>	<b>4,950</b>	<b>19,250</b>	<b>2,750</b>	<b>10,450</b>
<b>Cardis et al. 1996 (averages and for the period 1986 – 2056)</b>						
Liquidators (1986-1987)	200,000	30,000	2,700	10,500	1,500	5,700
Evacuees	135,000	2,400	216	840	120	450
Ukraine, Belarus, Russia						
Areas with Cs 137> 555 kBq/m <sup>2</sup>	270,000	22,500	2,025	7,875	1,125	4,275
Areas with Cs 137 > 37–555 kBq/m <sup>2</sup>	6,800,000	101,250	9,113	35,438	5,063	19,238
<b>Total</b>	<b>7,405,000</b>	<b>156,150</b>	<b>14,054</b>	<b>54,6533</b>	<b>7,808</b>	<b>29,669</b>
<b>UNSCEAR 2013</b>						
Europe		<b>400,000</b>	<b>36,000»</b>	<b>140,000</b>	<b>20,000</b>	<b>76,000</b>
<b>Bennett 1995, 1996 (UNSCEAR)</b>						
Russia, Belarus, Ukraine		216,000	19,440	75,600	10,800	41,040
Rest of Europe		318,000	28,620	111,300	15,900	60,420
Rest of world		66,000	5,940	23,100	3,330	12,540
<b>Total</b>		<b>600,000</b>	<b>54,000</b>	<b>21,000</b>	<b>30,000</b>	<b>114,000</b>
<b>US Dept. of Energy (Anspaugh et al.), 1998</b>						
Russia, Belarus, Ukraine•		326,000	29,340	114,100	16,300	61,940
Rest of Europe		580,000	52,200	203,000	29,000	110,200
Rest of world		28,000	2,520	9,800	1,400	5,320
<b>Total</b>		<b>934,000</b>	<b>84,060</b>	<b>326,900</b>	<b>46,700</b>	<b>177,460</b>
<b>USSR 1986 (GRS S 40, 1987S. 70)</b>						
Evacuees (external radiation only)	135,000	16,000	1,140	5,600	800	3,040
Rest of population to a distance of ca. 1,000 km)	75,000,000					
a) through external radiation		290,000	26,100	101,500	14,500	55,100
b) ingestion (Cs 134 / 137)		2,100,000	189,000	735,000	105,000	399,00
<b>Total</b>	<b>75,135,000</b>	<b>2,406,000</b>	<b>216,540</b>	<b>842,100</b>	<b>120,300</b>	<b>457,140</b>

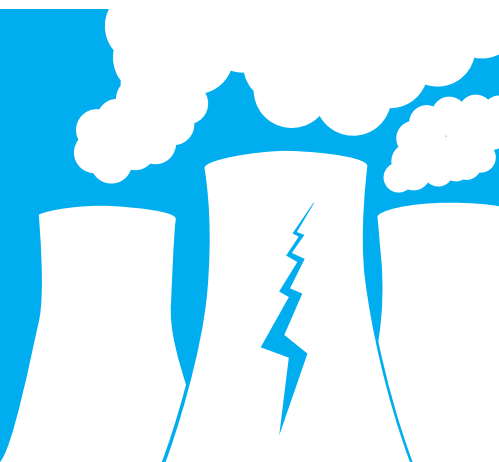
Documentation and calculations: Henrik Paulitz/IPPNW

**Table 4-1**

Chernobyl: collective dose, cancer incidence and cancer mortality



## 5 Effects on the health of liquidators



*“The most reliable robots were the soldiers. They were christened the ‘green robots’ by the color of their uniforms. Three thousand six hundred soldiers worked on the roof of the ruined reactor. [...] There was a moment when there existed the danger of a nuclear explosion, and they had to get the water out from under the reactor, so that a mixture of uranium and graphite wouldn’t get into it... So here was the task: who would dive in there and open the bolt on the safety valve?”*

SVETLANA ALEXIEVICH VOICES FROM CHERNOBYL: THE ORAL HISTORY OF A NUCLEAR DISASTER (P.133)

The 830,000 liquidators from throughout the Soviet Union – whether with or without coercion, partly informed or entirely ignorant – risked their health and their lives in an attempt to limit the consequences of the disaster. As the robots failed, human ‘bio-robots’ were sent onto the roof of the wrecked reactor to clear the radioactive rubble using just shovels and their hands. Their efforts spared others from even more serious harm. They were soldiers, fire-fighters, engineers, building workers, physicists, doctors, electro-technicians and hundreds of thousands of Red Army recruits. They worked directly at the reactor or within the 30-km death zone. Masks, protective suits and equipment were inadequate and mostly ex-army surplus. Even today, eyewitnesses still speak of fighting a “war against

radioactive radiation” and that they were duty-bound to “win through for the Soviet Union”.<sup>1</sup>

The liquidators themselves fell victim to an inadequate bureaucratic system, the blunders and lies of which continue to prevent the diagnosis of radiation-induced illnesses and their qualified treatment. These continue to block any social and financial support for the liquidators to the present day. Although treatment and research centers were set up for clean-up workers in Moscow, Obninsk, Minsk and Kiev shortly after the onset of the disaster, only about one third of those affected were actually registered, examined and monitored over the long-term. No individual radiation doses are on record for the liquidators. Most of the liquidators were young Red Army recruits from throughout the Soviet Union – from Estonia to Georgia, from Kirgizia to Siberia – and were sent back to their home countries after completing their term of service. They were therefore not included in any long-term monitoring scheme.

### 5.1 Mortality among liquidators

After analyzing various studies, A.Yablokov estimates that between 112,000 and 125,000 liquidators were already dead by 2005.<sup>2</sup> Separate studies in Russia and Ukraine name non-malignant diseases and severe multimorbidity as the main causes of death among liquidators. Malignancies only make second place as the cause of death. In 2005 Horishna examined the mortality rate among male Ukrainian liquidators and found the-

<sup>1</sup> Eyewitness reports by liquidators e.g. in Alexijewitsch S (1997) Chernobyl: The Oral History of a Nuclear Disaster (2006: Voices from Chernobyl)

<sup>2</sup> Yablokov AV (2009): Mortality after the Chernobyl Accident, in: Ann N Y AcadSci, 2009 Nov; 1181:192-216.



re had been a more than fivefold increase between 1989 and 2004. The number of deaths had risen from 300 to 1,660 per 100,000, whereas the increase in the normal male population was only from 410 to 600 per 100,000.<sup>3</sup>

## 5.2 Cancer illnesses

Numerous studies from recent years show the cancer incidence among Chernobyl liquidators has increased. In 2004 Okeanov found that the 71,840 liquidators listed in the National Belarus Cancer Registry had a significantly higher risk of developing cancer than the population in the least contaminated area of Vitebsk.<sup>4</sup> This mainly concerned cancer of the kidneys, bladder and thyroid.

In a case-control study in 2008, Kesmiene et al. found a higher risk of leukemia and non-Hodgkin's lymphoma.<sup>5</sup> A further case-control study by the same research group in 2012 with liquidators from Russia, Belarus and the Baltic countries, also found an increased risk of thyroid cancer.<sup>6</sup> A case-control study conducted in 2013 by Zablotska et al. with 110,645 Ukrainian liquidators found a significant correlation between chronic lymphatic leukemia (CLL) and radiation exposure.<sup>7</sup>

In 2002, the Ukrainian health ministry reported that the official number of sick liquidators had risen from 21.8 % in 1987 to 92.7 % in 2002.<sup>8</sup>

## 5.3 Non-cancer illnesses

The most common illnesses among liquidators included stroke and heart attack, disease of the gastrointestinal tract, hormonal disorders, disorders of the central and peripheral nervous systems, the respiratory organs and the musculoskeletal system.<sup>9</sup> This was shown in studies with a cohort comprising 68,145

male liquidators listed in the State Registry of Ukraine. The liquidators had worked in the death zone between 1986 and 1987 and been exposed to an average radiation dose of 140 mGy (50–700 mGy). The study also revealed a high rate of disability. A significant dose-effect correlation was also established for specific diseases: hypothyroidism, thyroiditis, cerebrovascular diseases and disorders of the central and peripheral nervous systems.

Yarilin compiled a summary showing how the incidence of 12 different groups of diseases affecting liquidators had changed<sup>10</sup> (see table 5.1 on the following page).

Some of the most significant non-cancer diseases are described in detail below.

### 5.3.1 Cardiovascular diseases

A WHO study as early as 1996 had already found a significant increase in cardiovascular diseases among liquidators in the Russian Federation.<sup>11</sup> In 1999, Ivanov also found that the risk of cardiovascular disease among Russian liquidators had risen by 40 %.<sup>12</sup>

In 2005, Lazyuk examined Belarus liquidators with cardiovascular diseases. His studies showed that in the review period 1992 to 1997 there had been a steep rise in the incidence of fatal cardiovascular disease among liquidators (22.1 percent) compared to the rest of the population (2.5 percent). Radiation damage to blood vessels was discussed as a possible cause.<sup>13</sup> Ivanov also determined an increased stroke risk, particularly among persons exposed to more than 150 mSv in less than six months.<sup>14</sup> Ivanov found a correlation between the mortality risk of Russian liquidators and radiation exposure. In a cohort of 47,820 persons who had been exposed to an average radiation dose of 128 mGy he found a significantly increased mortality

3 Horishna OV (2009): Chernobyl Catastrophe and Public Health Results of Scientific Investigation, in: Yablokov AV (2009): Mortality after the Chernobyl Accident, in: Ann N Y AcadSci, 2009 Nov; 1181:192-216.

4 Okeanov A (2004): A National Cancer Registry to assess after the Chernobyl accident; in: Swiss Med Weekly, 2004; 134: 645 – 649

5 Kesmiene et al (2008): Risk of hematological malignancies among Chernobyl liquidators; in: Radiat Res 2008 December; 170(6): 721–735

6 Zablotska L et al (2013): Environ. Health Perspect. 121:59–65

7 Zablotska L et al. (2013): Radiation and the risk of Chronic Lymphocytic and Other Leukemias Chornobyl Cleanup workers; in: EPH Volume 121 Number 1 January 2013

8 Nucleonics Week, May 2, 2002. Taken from Oda Becker, Helmut Hirsch 2004: 18 Jahre nach Tschernobyl, Sanierung des Sarkophags, Wettlauf mit der Zeit, published by Greenpeace e.V. Hamburg in April 2004.

9 Tereshchenko VM et al (2002): Epidemiologic researches of disability and mortality dynamics in the participants of Chornobyl NPP accident liquidation: Issue 39, p.165 -167 (in acc. with Greenpeace 2006)

10 Yarilin AA (1996): Immunological Disturbances ; in: Chernobyl Catastrophe Consequences: Human Health, Moscow, 1996, p. 68-96, Russ. Cited in: Burlakova et al: Peculiarities of Biological Action of Low Irradiation Doses and their Probable Relation to the Health Status of Participants of Chernobyl Accident Liquidation; in: Imanaka (ed.): KURRI-KR-21, 1998, pp. 223-234.

11 The Radiological Consequences of the Chernobyl Accident, European Commission and Belarus, Russian and Ukrainian Ministries on Chernobyl Affairs, Emergency Situation and Health, Report EUR 16544 EN, 1996

12 Ivanov VK et al (1999): Radiation-epidemiological analysis of the incidence of non-cancer diseases among Chernobyl liquidators, in: Radiation & Risk, 1999, Issue 11

13 Lazyuk D (2005): Cardiovascular Diseases among Liquidators and Populations; PSR/IPPNW-Swiss-congress Gesundheit der Liquidatoren in Bern, November 12, 2005

14 Ivanov VK et al (2009): Mortality of the Chernobyl Emergency Workers: Analysis of Dose Response by Cohort Studies Covering Follow-Up Period of 1992–2006; in: Radiation Health Risk Sciences, 2009, Part 4, pp. 95 -102



Diseased organ group	1986	1987	1988	1989	1990	1991	1992	1993
Infections and parasites	36	96	197	276	325	360	388	414
New tumors	20	76	180	297	393	499	564	621
Malignant new tumors	13	24	40	62	85	119	159	184
Endocrinal system	96	335	764	1,340	2,020	2,850	3,740	4,300
Blood and blood-forming organs	15	44	96	140	191	220	226	218
Psychological changes	621	9,487	1,580	2,550	3,380	3,930	4,540	4,930
Nervous system & sensory organs	232	790	1,810	2,880	4,100	5,850	8,110	9,890
Circulation	183	537	1,150	1,910	2,450	3,090	3,770	4,250
Respiratory system	645	1,770	3,730	5,630	6,390	6,950	7,010	7,110
Digestive organs	82	487	1,270	2,350	3,210	4,200	5,290	6,100
Urogenital system	34	112	253	424	646	903	1,180	1,410
Skin and subcutaneous tissue	46	160	365	556	686	747	756	726

**Table 5-1**

Incidence of 12 disease groups among liquidators  
(per 100,000 persons)

risk. The excess relative risk (ERR) of death due to a solid tumor was 0.74/Gy, for cardiovascular disease it was 1.01/Gy. He found the ERR for all causes of death to be 0.42/Gy.<sup>15</sup>

### 5.3.2 Eye diseases

Fedirko, from the research center for radiation medicine at the Ukrainian Academy of Medical Sciences, reported that 95 percent of the 5,200 liquidators he had examined suffered from eye diseases – these included cataracts, macular degeneration and chronic conjunctivitis.<sup>16</sup> Chumak et al. provide more precise assessments on dosimetry and the incidence of cataracts in a

more recent paper from 2013 describing results from 8,607 Ukrainian liquidators.<sup>17</sup>

### 5.3.3 Mental disorders

A particularly common symptom complex among liquidators is chronic fatigue syndrome (CFS). According to the Ukrainian brain specialist Loganovsky, the diagnostic criteria for CFS apply to 26 percent of those who were exposed to a radiation dose lower than 300 mSv.

Loganovsky compiled a summary of all the different types of brain damage found in the exposed groups in Ukraine: liquidators, the evacuees, the exposed children and the children of the liquidators as well as the highly exposed population. He found that doses of 250 mSv and more not only damaged brain cells directly, but also affected the cerebrovascular system, and could therefore trigger strokes. Liquidators suffer from severe

<sup>15</sup> The risk factors used for the collective dose concept describe the likelihood of further cancer cases over and above the spontaneous cancer incidence. Excess absolute risk (EAR) is normally given as a unit of 1/Sv. Thus, a mortality EAR of 0.2/Sv means that on radiation with 1 sievert, the added risk of dying of cancer is 20 % – in addition to a 25 % basic risk. This is equivalent to an excess relative risk (ERR) of 0.2/0.25, which is equal to 0.8/Sv.

<sup>16</sup> Fedirko P (2005): Eye Diseases among Liquidators: Lesions of Fundus and Macula, Vitreous and Lens; PSR/IPPNW Congress Gesundheit der Liquidatoren in Berne, 12.11.2005.

<sup>17</sup> Chumak VV et al (2013): Dosimetry for a study of low-dose radiation cataracts among Chernobyl clean-up workers. in: Radiat. Res. 2007 May; 167(5): 606-14.



attention deficits, memory dysfunction, noticeable fatigue and rapid mental exhaustion.

Malova from the Moscow Center for radiation diseases, where she is especially concerned with liquidators' health, explained "Our theory is that, in some way, the flow of blood to the brain has been, and possibly still is, reduced." These types of illnesses occur significantly more often among liquidators than the rest of the population.<sup>18</sup>

Loganovsky and Flor-Henry observed increases in the incidence of cerebrovascular diseases, schizophrenia and CFS among liquidators. They also found corresponding EEG changes in the left cerebral hemisphere, while MRI also revealed changes to the left cerebral cortices.<sup>19</sup>

To identify cognitive changes in liquidators in more detail, Loganovsky conducted a comparative study involving liquidators, PTSD veterans of the war in Afghanistan, and healthy individuals. In liquidators they found somato-sensory evoked potentials (SSEP) that correlated with the paraesthesia and general sensory organ dysfunctions common in brain damage. The same symptoms were not found in the group of Afghanistan veterans or healthy subjects.<sup>20</sup>

In a neuropsychological study, Zhavoronkova (from the neurophysiological institute of the Russian Academy of Sciences) and Kholodova (from The Institute of Radiology, Ministry of Public Health), found the higher mental and cognitive functions to be impaired: observing sluggishness of thought, increased fatigue, reduced visual and verbal memory functions, and diminished higher motor functions. As these findings are comparable to those for significantly older people, they can be regarded as premature aging processes.<sup>21</sup>

#### 5.3.4 Premature aging

Numerous studies from Russia, Belarus and Ukraine suggest that ionizing radiation can accelerate the aging process considerably. In an overview in 2006, the Ukrainian scientist Bebesheko et al. showed that the more rapid aging process brought on by ionizing radiation could provide a model for the normal aging process.

"Ionizing radiation influences both the cell structure and the cell function at molecular and genetic levels. The effects of ionizing radiation on the cells and the cellular changes are the same or similar to biological mechanisms at work during the normal aging process: reactions of free radicals, the DNA repair process, changes in the functioning of the immune system, changed mechanisms in fat metabolism, and systemic changes to the nerve system."<sup>22</sup>

Research on liquidators from Russia, Belarus and Ukraine also found that illnesses among survivors occurred 10 – 15 years earlier than would normally be expected with the normal aging process.<sup>23</sup> The following observations can be made:

- » Accelerated aging of the blood vessels – especially of the brain – and the coronary vessels<sup>24</sup>
- » Senile cataracts, arteriosclerosis of the fundus oculi blood vessels and premature myopia<sup>25</sup>
- » Loss of the higher intellectual cognitive functions due to damage to the central nervous system<sup>26</sup>

18 Malova JV (2002): Cancer patients – the participants of the liquidation of the consequences of the Chernobyl explosion: the aims and the resources of the psychological rehabilitation. Russian Scientific Center of Radiology, Psychological Rehabilitation, Moscow, 18. UICC International Cancer Congress Oslo 2002, Abstract No. O 183: in Strahlentelex 374-375/2002, p.9, Verminderte Hirnfunktionen bei Katastrophenhelfern. Die tageszeitung (taz) from July 16, 2002.

19 Flor-Henry P (2005): Radiation and the Left Hemisphere: Increased Incidence of Schizophrenia and Chronic fatigue Syndrome (CFS) in Exposed Populations in Chernobyl, Hiroshima and Nagasaki, PSR/IPPNW Congress Gesundheit der Liquidatoren in Berne, 12.11.2005

20 Human Physiology, Vol. 29, No. 1, 2003, pp. 110–117. Translated from Fiziologiya Cheloveka, Vol. 29, No. 1, 2003, pp. 122–130. Original Russian Text Copyright © 2003 by Loganovsky.

21 ISSN 0362\_1197, Human Physiology, 2010, Vol. 36, No. 4, pp. 388–398. © Pleiades Publishing, Inc., 2010. Original Russian Text © L.A. Zhavoronkova, A.P. Belostocky, M.A. Koulikov, S.V. Kuptsova, N.B. Kholodova, L.B. Oknina, 2010, published in Fiziologiya Cheloveka, 2010, Vol. 36, No. 4, pp. 22–33.

22 Bebesheko V, Bazyka D, Loganovsky K, Volovik S, Kovalenko A et al (2006): Does ionizing radiation accelerate the aging phenomena? In: International Conference. Twenty Years after Chernobyl Accident: Future Outlook. April 24 -26, 2006, Kiev, Ukraine. Contributed Papers (HOLTEH, Kiev) 1: pp.13-18 (<http://www.tesec-int.org/pdf>).

23 Yablokov A, Nesterenko V, Nesterenko A (2009): Chernobyl – Consequences of the Catastrophe for People and Environment, Annals of the New York Academy of Sciences, Vol. 1181, Boston, Mass.

24 Ivanov V, Tsyb A. et al (2005): The radiation risks of cerebrovascular diseases among liquidators, Radiatsionnabiologiya, radioecologia / Rossiiskaiakademiiianauk; VOL: 45 (3); pp. 261-70 /2005 May-Jun/

25 Fedirko P (2006): Augenerkrankungen bei Aufräumarbeitern, Schädigungen des Augenhintergrunds, der Makula, des Glaskörpers und der Linse, in: [http://www.strahlentelex.de/20\\_Jahre%20nach\\_Tschernobyl\\_Abstracts\\_GSS\\_Berlin-Charite\\_2006.pdf](http://www.strahlentelex.de/20_Jahre%20nach_Tschernobyl_Abstracts_GSS_Berlin-Charite_2006.pdf)

26 Bazyka DA, Loganovsky KM et al (2015): Gene expression, telomere and cognitive deficit analysis as a function of Chornobyl radiation dose and age: from in utero to adulthood

Kholodova N (2006): Langzeitveränderungen des Nervensystems von Liquidatoren, die 1986/1987 im Einsatz waren, in: [http://www.strahlentelex.de/20\\_Jahre%20nach\\_Tschernobyl\\_Abstracts\\_GSS\\_Berlin-Charite\\_2006.pdf](http://www.strahlentelex.de/20_Jahre%20nach_Tschernobyl_Abstracts_GSS_Berlin-Charite_2006.pdf)



- » Loss of stability of the antioxidant system (which is responsible for repairing cell chromosome damage caused by external factors).<sup>27</sup>

The Russian cancer researcher Burlakova irradiated test animals with gamma rays emitted by cesium 137 decay products with low dose rates of 0.0006 to 1.2 Gray (Gy). She then examined various biophysical and biochemical parameters of the membrane apparatus of cells. Overall, the picture was of an unusual dose dependency; dose-effect relationships were not uniform, were non-linear and of differing character. Low-dose exposure generally amplified the effects of damaging factors. The effects of irradiation were dependent on the output parameters of the bio-object. The effects of fractionated low-dose radiation within certain dose intervals was more damaging than one single acute radiation dose.

Investigations by Burlakova et al., not only found changes following irradiation in animals, but also in humans, in the structure and properties of the cell membranes, the activity of antioxidatives and regulatory enzymes, as well as in the concentration of antioxidants. Thus, she not only verified the so-called Petkau effect, but went beyond it. Irradiation decreases antioxidants such as tocopherol, vitamin A and ceruloplasmin, free radicals and their by-products increase, membranes exhibited more rigidity and the liquidity of lipid and protein components changes. According to Burlakova, general ratio changes following irradiation are the same as in the natural aging process. "Liquidators age 10 – 15 years earlier than the rest of the population. The same effect can also be seen in animals, and in their case one cannot speak of a radiation angst or radiophobia" (see figure 5-1).

## 5.4 Genetic changes in the children of liquidators

Stepanova et al. examined malformations in the children of liquidators. The highest malformation rate was in 1987–1988 when the figure was 117 per 1,000 births. This then dropped to between 83 per 1,000 births (1989–1991). In 1992 there were 67 malformations and from 1993–1997 between 24 and 60 per 1,000 births.<sup>28</sup>

There was also an increased incidence of chromosomal aberrations among children of liquidators.<sup>29</sup>

Scientists from Haifa University found that liquidators' children had seven times more genetic mutations than siblings born before Chernobyl. Although these mutations do not necessarily involve a medical illness, such accumulation is an indication of a transgenerational effect. A large number of mutations were found in children conceived immediately after the Chernobyl accident, in particular. The fathers of such children had received radiation doses of between 50 and 200 millisievert. This is about the same as the dose a power plant worker will incorporate during a 10-year period.

Tsyb found a significant increase in the incidence of all disease categories among the children of liquidators compared to children from the Russian city of Obninsk.<sup>30</sup> More frequent among liquidators' children were leukemia, congenital malformations, endocrinological and metabolic illnesses, as well as mental disorders and behavioral problems. There were also some quite significant increases in diseases of the urogenital and nervous systems, as well as of the sensory organs.

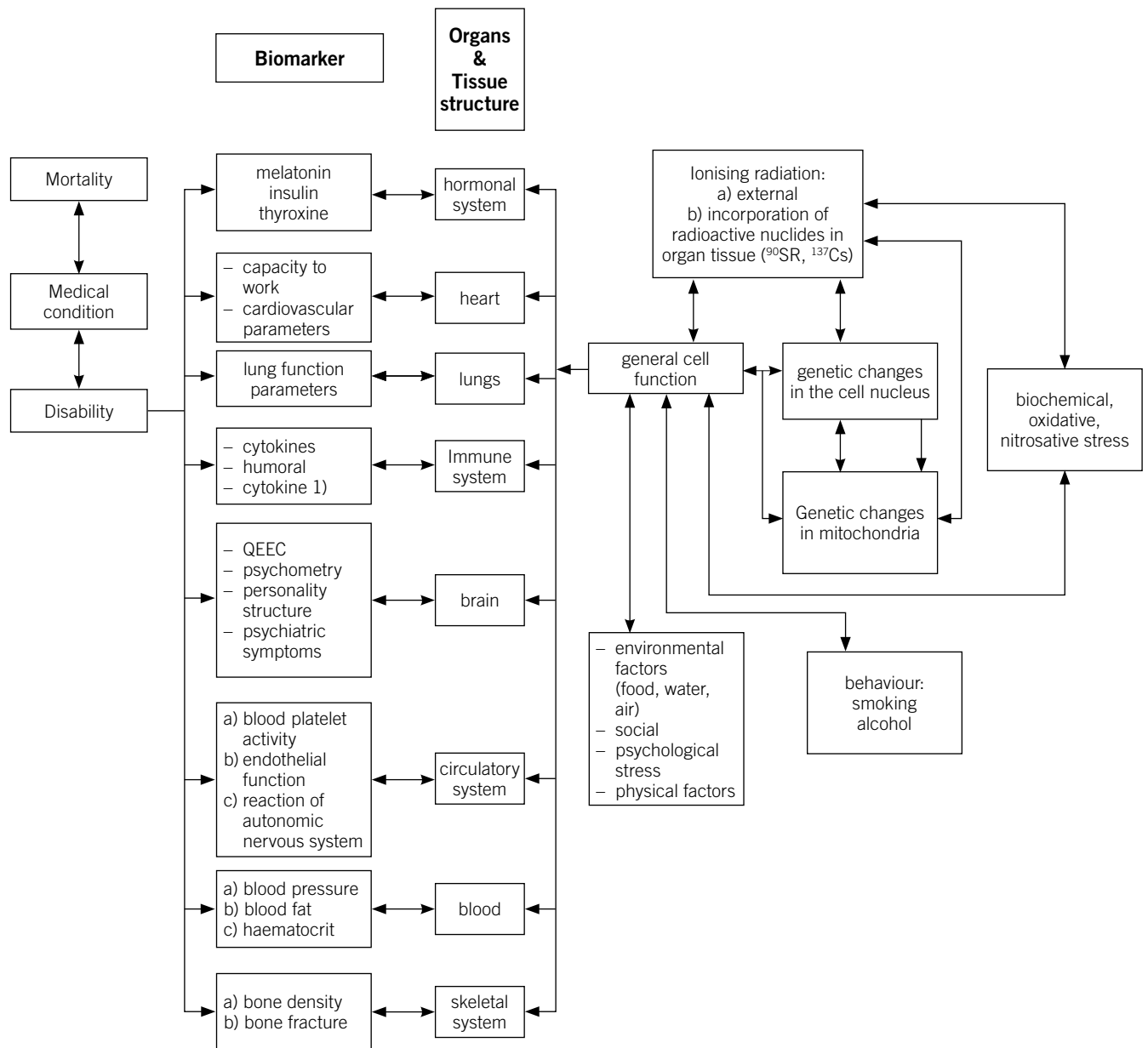
27 Burlakova E (2006): Naturwissenschaftliche Prinzipien von Schädigungen der Strahlung auf den Gesundheitszustand der Bevölkerung, in: [http://www.strahlentelex.de/20\\_Jahre%20nach\\_Tschernobyl\\_Abstracts\\_GSS\\_Berlin-Charite\\_2006.pdf](http://www.strahlentelex.de/20_Jahre%20nach_Tschernobyl_Abstracts_GSS_Berlin-Charite_2006.pdf)

28 Stepanova EI, Skvarkaya EA, Vdovenko VJ, Kondrashova VG (2004): Genetic consequences of the Chernobyl accident in children born to parents exposed to radiation. *Probl.Ecológ.Medic.Genetic.Clinic.Immunol. (Kiev)* 7(60): 312–320 (in Russian): nach Yablokov, 2009

29 Horishna OV (2005): Chernobyl Catastrophe and Public Health: Results of Scientific Investigations (Chernobyl Children's Foundation, Kiev): 59 pp. (in Ukrainian). Cited from Yablokov, 2009

30 Tsyb AF et al (2004): General characterization of health in first-generation offspring born to liquidators of the Chernobyl NPP accident consequences; *Int. J. Rad. Med.* 2004, 6 (1-4): 116-121.





**Figure 5-1**

The complex mechanisms of premature aging in acc. with Bebesko/Loganovsky<sup>31</sup>

31 Bebesko v, Bazyka D, Loganovsky K et al: (2006): Does Ionizing Radiation accelerate Aging phenomena? International Conference 20 years after Chernobyl Accident; cited from: Yablokov (2009) Chernobyl-Consequences of the Catastrophe



## 6 Effects on the health of the contaminated population



After liquidators, the evacuees and the residents of heavily contaminated areas were exposed to the next highest radiation doses following the Chernobyl nuclear disaster. They are therefore expected to suffer the most severe health effects. As with liquidators, radiation-induced cancers, particularly thyroid cancer, must be viewed on the one side and radiation-induced non-cancer illnesses on the other. This will be done below on the basis of the results of selected studies:

### 6.1 Increased cancer incidence

#### 6.1.1 Thyroid cancer in the Chernobyl area

Before Chernobyl, thyroid cancer was relatively rare in Belarus, Russia and Ukraine. Surprisingly fast, just four years after the disaster, there was a massive rise in the incidence in the contaminated areas. The first sign was a rapid increase in the incidence of childhood thyroid cancer just 3–4 years after the meltdown. Physicians also observed the particularly aggressive growth potential of thyroid tumors and the rapid development of metastases in other organs, especially the lungs. Histological examinations revealed that almost all diagnosed cases were papillary thyroid carcinomas.

Data from the cancer registries of Belarus, Russia and Ukraine show that the highest morbidity was among those still in early childhood at the time of the reactor disaster.<sup>1</sup> The fact that

children were strongly affected is taken as a robust indication of the sensitivity of the thyroid glands of infants and small children to the carcinogenic effect of radioactive iodine. By the end of 1990, the annual incidence among children between 0 and 18 year of age in Belarus was thirty times that of the 1986 average for the normal population. The annual incidence of new cases of thyroid cancer per 100,000 population in Gomel between 1986 and 1998 was 407, compared to just seven cases per 100,000 per annum between 1973 and 1985. In 1995 the incidence of thyroid cancer in children (0–14) peaked in Belarus. Instead, the cancer incidence increase shifted towards the adolescent and adult groups.<sup>2</sup>

Lengfelder et al. pointed out that with increasing temporal distance from the accident, more and more of the children contaminated with iodine in 1986 would become adolescents and then reach adulthood. They will continue to carry their life-time risk of developing thyroid cancer into their higher age group. According to the Otto Hug Radiation Institute, which conducted extensive studies in the region over many years, 3,000 adults in Belarus will have developed radiation-induced thyroid cancer by the year 2000. In 1980, the average annual incidence of new thyroid cancer cases for adults over the age of 30 in Belarus was 1.24 per 100,000 population. In 1990, the rate was already 1.96 and by the year 2000 it had risen to 5.76. This is equivalent to a fourfold increase.<sup>3</sup>

The thyroid cancer rate in the 50 – 64 age group was five times higher after the nuclear disaster (1986–1998) than before

1 Fuzik MM, Prysyazhnyuk AY, Gristchenko VG, Zakordonets VA, Slipenyuk YeM, Fedorenko ZP, Gulak LO, Okeanov Aye (2004): Thyroid cancer, Peculiarities of process in a cohort being in International Journal of Radiation Medicine 2004, 6(1-4): 24-29.

2 Frenzel C, Lengfelder E (2011): 25 Jahre nach der Tschernobylkatastrophe [http://www.umg-verlag.de/umwelt-medizin-gesellschaft/111\\_fl.pdf](http://www.umg-verlag.de/umwelt-medizin-gesellschaft/111_fl.pdf)

3 Okeanov AE, Sosnovskaya EY, Priatkina OP (2004): A national cancer registry to assess trends after Chernobyl accident, Swiss Wkly 2004, 134: 645-649.





**Figure 6-1**

Estimated iodine contamination on May 10, 1986 in Belarus (from Olga Zubetsk, Presentation at the Arnoldshain conference in 2014, [http://www.tschernobylkongress.de/fileadmin/user\\_upload/Arnoldshain\\_Doku/Zubec-Olga.pdf](http://www.tschernobylkongress.de/fileadmin/user_upload/Arnoldshain_Doku/Zubec-Olga.pdf))

(1973–1985), while in the 64+ age group it was 2.6 times higher.<sup>4 5</sup> Although the databases of the Chernobyl Research Centers of the three former Soviet Republics (Bryansk for Russia, Gomel and Minsk for Belarus, Kiev for Ukraine) provide a great deal of additional information on the rise in thyroid cancer cases in adults, this has gone almost unnoticed by western research groups. Thus, most of the scientific literature available to the international public concerns the increased number of cases of childhood thyroid cancer. Mahoney et al., however, point out that an increase in the rate of thyroid cancer in Belarus can be seen all age groups, not just in children.<sup>6</sup>

As the effects of radioactive contamination extended throughout the entire Soviet Republic of Belarus, the cancer rate also increased across the entire republic accordingly. The highest peak

was in the heavily contaminated Gomel area.<sup>7</sup> The following map shows the extent of contamination with radioactive iodine in the state (see figure 6-1).

Following the Chernobyl meltdown a higher rate of thyroid cancer was also recorded outside the heavily contaminated areas of Belarus – especially in Russia and Ukraine. Fuzik et al. looked at the development of the thyroid cancer incidence in the radioactively contaminated areas of Ukraine between 1989 and 2008. They found a statistically significant rise in the incidence of thyroid cancer among men and women (women in heavily contaminated areas increased 3.3 fold and in areas with low contamination 2.3 fold; men in heavily contaminated areas increased 2.6-fold and in areas of low contamination 1.4 fold).<sup>8</sup> The thyroid cancer incidence in Russia was also found to have

4 Lengfelder E, Frenzel C (2002): 16 Jahre nach Tschernobyl. Weiterhin dramatisches Ansteigen der Schilddrüsenkarzinome in Belarus. Der Heilungserfolg ist bei zahllosen Patienten weiter von intensiver westlicher Hilfe abhängig. Otto Hug Strahleninstitut MHM. Sept. 2002.

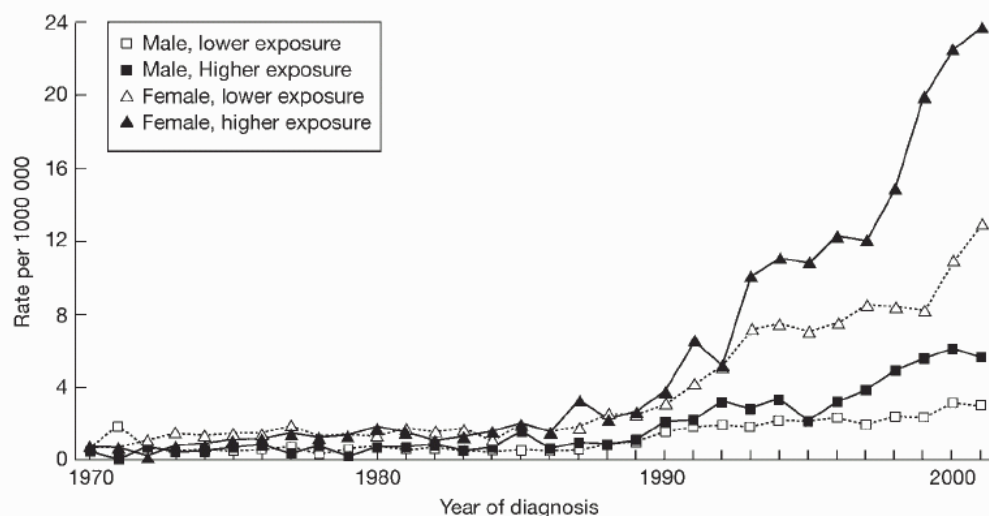
5 Lengfelder E, Rabes H, Scherb H, Frenzel C (2003): Factors influencing the assessment of Chernobyl health consequences and the contribution of international non-governmental organizations to research and treatment of thyroid pathologies in Belarus. 4th International Conference, June 2-6, 2003, Kiev, Ukraine, Chernobyl Children – Health effects and psychosocial rehabilitation, Proceedings, International Journal of Radiation Medicine 2003, Addendum.

6 Mahoney MC, et al (2004): Thyroid cancer incidence in Belarus: examining the Impact of Chernobyl. IntJ Epid33, 1025-1033

7 Mahoney MC, et al. (2004): Thyroid cancer incidence in Belarus: examining the Impact of Chernobyl. IntJ Epid33, 1025-1033

8 Fuzik M, Pryslyazhnik A, et al. (2011): Thyroid cancer incidence in Ukraine: Trends with reference to the Chernobyl accident; in: Radiat Environ Biophys (2011) 50:47–55





**Figure 3** Annual age-adjusted thyroid cancer incidence rate, by calendar year, gender, and area of exposure,<sup>a</sup> Belarus, 1970–2001

**Figure 6-2**

Figure taken from: Mahoney, MC et al. (2004): Thyroid cancer incidence in Belarus: examining the Impact of Chernobyl *IntJ Epid*33, 1025-1033

risen after the Chernobyl meltdown. Between 1991 and 2008, the research group around Ivanov diagnosed 978 cases of thyroid cancer in a cohort of 309,130 in the especially contaminated regions of Bryansk, Kaluga, Oryol and Tula.<sup>9 10</sup>

Just how many of the total number of thyroid cancer cases can be causally linked to the Chernobyl nuclear disaster is still a matter of debate among scientists.

Whereas UNSCEAR and other researchers from international cancer research centers only consider childhood thyroid cancer to be radiation-induced, others (Demidchik, Prysyazhnuk, Mahoney, Scherb, Lengfelder) infer from the retrieved data that the incidence of thyroid cancer among adults has also increased. Thus, in 2008 UNSCEAR put the number of persons from Belarus, Russia and Ukraine who were treated for thyroid cancer at 6,848 (only children and young people up to age 18).<sup>11</sup> Demidchik, on the other hand, recorded 12,236 thyroid cancer cases in the period 1986–2004 in Belarus alone (children, young

adults and adults).<sup>12</sup> In a recent paper Demidchik put the number of radiation-induced cases of childhood thyroid cancer in Belarus at 1,044.<sup>13</sup> The Ukrainian National Report puts the number of cases of thyroid cancer among children and young adults in 1986–2004 at 3,385, of which 572 were Chernobyl-related.<sup>14</sup>

Cardis<sup>15</sup> estimates that by 2065 the total number of existing and expected cases of thyroid cancer will reach 15,700, while Malko believes the number will be 85,778.<sup>16</sup>

In July 1998, the European Commission, the US Energy Ministry and the National Cancer Institute of the US Health Ministry hosted an international symposium on radiation and the thyroid gland in Cambridge (MA). At the symposium representatives of the World Health Organization (WHO) developed a prognosis based on the temporal development of childhood thyroid cancer

9 Ivanov VK, et al (2012): Radiation epidemiological studies of thyroid cancer incidence after the Chernobyl incidence; in: *Radiat Prot Dosimetry* 2012 Sep; 151(3): 489-99

10 Ivanov VK, Kenigsberg Y, Tronko ND, et al (2006): Communication to UNSCEAR Secretariat

11 [http://www.unscear.org/docs/reports/2008/11-80076\\_Report\\_2008\\_Annex\\_D.pdf](http://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf)

12 Yablokov (2009): p. 167

13 Demidchik YuE, et al (2015): Major factors Affecting Incidence of Childhood thyroid Cancer in Belarus after the Chernobyl Accident: Does Nitrate in Drinking Water Play a role? *PLoS ONE* 10(9): e0137226.

14 Yablokov (2009): p. 169

15 Cardis E, Krewski D, Boniol M et al (2006): Estimates of the cancer burden in Europe from radioactive fallout from the Chernobyl accident. *IntJ Cancer* 2006; 119: 1224-35.

16 <http://www.greenpeace.org/romania/Global/romania/binaries/2009/8/raportul-malko.pdf>



cases that had occurred up to that time. Of all 0 to 4 year-old children in the Gomel area at the time of the reactor catastrophe, one third will develop thyroid cancer during their lifetime.<sup>17</sup>

According to the WHO prognosis, this means that in the Gomel area of Belarus alone, more than 50,000 people who were 0-4 years of age at the time of the catastrophe will develop thyroid cancer. This figure must be extended to include all the other age groups, i.e. juvenile and adult residents of the heavily contaminated Gomel area at the time of the meltdown. As a result of radioactivity, they also have a higher risk of developing thyroid cancer. The Otto Hug Radiation Institute estimates well above 100,000 thyroid cancer cases in the Gomel area alone as a result of the Chernobyl nuclear disaster.<sup>18</sup> In 2006, 20 years after the onset of the nuclear disaster, the institute had already registered 10,000 cases.<sup>19 20</sup>

To the present day, a reliable estimate of the total number of thyroid cancer cases in the former Soviet Union which can be causally linked to the Chernobyl nuclear disaster is still not available, and probably never will be. However it can be assumed that, as a result of radioactive fallout from the Chernobyl meltdown, several hundred thousand human beings throughout the Chernobyl area and Europe will develop thyroid cancer (children, young adults, adults).

### 6.1.2 Other types of cancer in the Chernobyl area

Since 1973, Belarus has maintained a state-wide registry of all information concerning malignant tumors. A study by Okeanov et al. compared cancer cases from the period 1976 – 1985 with those from 1999 – 2000.<sup>21</sup> This revealed a 39.8-percent significant increase in the cancer incidence. Prior to Chernobyl, annual morbidity was 155.9 cases per 100,000 inhabitants, in the aftermath of Chernobyl it was 217.9 cases per 100,000. The increased cancer rate mainly involved cancer of the intestine, bladder and thyroid.

The increase was significant throughout all areas of Belarus. In the most contaminated Gomel area, however, the 55.9-percent cancer rate increase was significantly higher than in areas with less contamination. The increase was particularly high for the inhabitants of areas of Gomel with exceptionally high cesium-137 contamination, i.e. above 555,000 Becquerel per square meter. Several studies deal with the cancer prevalence of individual locations. The most relevant research results are examined in more detail below. A lot of the studies examine only single areas of Ukraine or Belarus. One should therefore bear in mind that similar developments are also to be expected in other irradiated areas and are not limited merely to the areas examined. The results of 100 years of radiation research also apply in this case; every radiation dose, no matter how small, measurably increases a population's statistical risk of cancer and therefore morbidity in a population and there is a linear dose-morbidity correlation with no threshold under which ionizing radiation would be harmless. This means that, although one finds particularly pronounced health effects of ionizing radiation in heavily contaminated areas, these effects are also present to a lesser extent in less heavily contaminated areas, where they are usually drowned out by 'statistical background noise'.

### Tumors of the digestive and respiratory organs

From 1993 to 2002 morbidity for tumors of the digestive and respiratory organs increased in significantly highly contaminated areas compared to areas with the lowest radioactive burden (cancer incidence in digestive organs): 141.5 per 100,000 in the most heavily contaminated areas compared to 104.7 per 100,000 in the least contaminated areas.

17 Cardis E et al (1999): Observed and predicted thyroid cancer following the Chernobyl accident: Evidence for factors influencing susceptibility to radiation induced thyroid cancer. In: G. Thomas et al.: Radiation and Thyroid Cancer. EUR 18552 EN, World Scientific, Singapore 1999, pp.395-405.

18 Lengfelder E, Frenzel C (2006): 20 Jahre nach Tschernobyl. Erfahrungen und Lehren aus der Reaktorkatastrophe. Otto Hug Strahleninstitut MHM. Informationen, February 2006.

19 Lengfelder E, Frenzel C (2002): 16 Jahre nach Tschernobyl. Weiterhin dramatisches Ansteigen der Schilddrüsenkarzinome in Belarus. Der Heilungserfolg ist bei zahllosen Patienten weiter von intensiver westlicher Hilfe abhängig. Otto Hug Strahleninstitut MHM. Sept. 2002.

20 Lengfelder E, Rabes H, Scherb H, Frenzel C (2003): Factors influencing the assessment of Chernobyl health consequences and the contribution of international non-governmental organizations to research and treatment of thyroid pathologies in Belarus. 4th International Conference, June 2-6, 2003, Kiev, Ukraine, Chernobyl Children – Health effects and psychosocial rehabilitation, Proceedings, International Journal of Radiation Medicine 2003, Addendum.

21 Okeanov AE, Sosnovskaya EY, Priatkina OP (2004): A national cancer registry to assess trends after Chernobyl accident, Swiss Wkly 2004, 134: 645-649.



Year	Remaining life expectancy (in months) following diagnosis for	
	Stomach cancer	Lung cancer
1984	62	38
1985	57	42
–	–	–
1992	15,5	8,0
1993	11,0	5,6
1994	7,5	7,6
1995	7,2	5,2
1996	2,3	2,0

**Table 6-1**

Remaining life expectancy after diagnosis for stomach and lung tumors before and after the Chernobyl accident (Lugyny district, Schitomir area, Ukraine)

Cancer rate for respiratory organs: 83.7 compared to 53.1 per 100.000).<sup>22</sup> A study in the Ukrainian district of Lugyny in the aftermath of Chernobyl also found life expectancy to be significantly reduced following the diagnosis for cancer of the stomach and lungs. Whereas in 1985 life expectancy following the initial diagnosis of stomach or lung cancer was 57 and 42 months respectively, 10 years after the Chernobyl nuclear disaster this had dropped to a mere 2.3 and 2 months respectively.<sup>23</sup> This effect is due, among other things, to cellular repair mechanisms.

## Breast cancer

There were also abnormalities in respect of breast cancer morbidity among women. In areas with very high cesium contamination (Gomel and Mogilev in Belarus), breast cancer is typically diagnosed in women between the ages of 45 and 49, which is 15 years earlier than in women who live in the Belarus area of Vitebsk, which was least affected by Chernobyl. The shift in the onset of the illness to younger age groups is particularly marked in the more severely hit rural population in the contaminated areas.

In 2006 Pukkala et al. also found a significant increase in the incidence of breast cancer in the Gomel and Mogilev areas (Belarus), as well as in Chernigov, Kiev and Schitomir (Ukraine). In the period 1997–2001, it was also found that the risk in heavily contaminated areas was about double that of the least contaminated part of the investigated area. Pre-menopausal women were particularly hard hit by the increased breast cancer incidence. The authors consider it highly unlikely that such increase is due to more intense diagnostic activity in these areas.<sup>24</sup>

## Brain tumors

Over a 25-year period Orlov et al. examined data on tumors in the central nervous systems (CNS) of children under the age of 15 in Ukraine, excluding the districts of Dnepropetrovsk, Donetsk, Zaporozhye and Charkov. In the 10 years before Chernobyl (1976-1985) a total of 756 children were diagnosed with brain tumors; in the 10 years after Chernobyl the figure was 1,315. This is 76.9 % more than in the previous period—despite a population deficit of 3 million children at that time.<sup>25</sup>

The situation in respect of small children is even more unsettling. Orlov and Shaversky reported a series of 188 brain tumors in children under the age of three. Nine of these cases were diagnosed between 1981 and 1985; 179 between 1986 and 2002. The number of patients rose in comparison to the 5-year period before the meltdown (9 cases 1981–1985) by factor 5 (46 cases 1986–1990). In subsequent years the number of new cases increased further by more than seven-fold (69 cases 1991–1995), and to more than five times the initial incidence (48 cases 1996–2000). The increase in the incidence of CNS tumors among breast-fed children was even steeper. Whereas between 1981 and 1985 there was not a single diagnosed case in this age group, there were 4 cases from 1986 to 1990, 16 from 1991 to 1995 and 11 from 1996 to 2000.<sup>26</sup>

All in all, the incidence rate among the under three year-olds increased by more than 5 fold, and for children under 12 months it was even higher at 10 fold. This figure is even more striking if the simultaneous drop in the birth-rate is taken into account. This increase was not only reflected in the incidence of malignant tumors, but also in the incidence of benign tu-

22 Okeanov AE, Sosnovskaya EY, Priatkina OP (2004): A national cancer registry to assess trends after Chernobyl accident, Swiss Wkly 2004, 134: 645-649.

23 Godlevsky I, Nasvit O: Dynamics of Health Status of Residents in the Lugyny District after the Accident at the ChNPP; in: T. Imanaka (ed.): Research Activities about the Radiological Consequences of the Chernobyl NPS Accident and Social Activities to Assist the Sufferers by the Accident, KURRI-KR-21, pp.149-159.

24 Pukkala E, Poliakov S, Ryzhov A, Kesminiene A, Drozdovich V, Kovgan L, Kyyronen P, Malakhova IV, Gulak L, Cardis E (2006): Breast cancer in Belarus and Ukraine after the Chernobyl accident. International Journal of Cancer, February 27th.

25 Orlov YA et al (2002): Tumors of the central nervous system in children (morbidity rates in Ukraine for 25 Years); Int. J. Rad. Med. 2002, 4(1-4):233-240.

26 Orlov YA, Shaversky AV (2004): Indices of neurooncologic morbidity dynamics among younger children in Ukraine; Int. J. Rad. Med. 2004 6(1-4): 72-77.



mors.<sup>27</sup> Although benign tumors do not form metastases or spread to other tissue, they can cause severe life-threatening conditions due to displacement of healthy brain tissue.

## Childhood leukemia

More than 4 million people in Ukraine alone were affected by radioactive fallout from the Chernobyl disaster. To examine the effects of radiation on pregnancy and the link to leukemia, Noshchenko et al. examined the incidence of different types of leukemia among children born in 1986. The children's development was monitored over a 10-year period. The cumulative morbidity among children from contaminated and non-contaminated areas was compared. The relative risk for all type of leukemia was significantly higher in contaminated areas. Among boys there was a dramatic increase in the risk rate for acute lymphatic leukemia (ALL), while among girls it was not quite so severe. For both sexes combined, the relative risk for acute lymphatic leukemia in contaminated districts was more than three times that of non-contaminated districts (relative risk  $RR = 3.4$ ). A causal relationship to radioactive fallout is therefore highly probable.<sup>28</sup>

Just one year later, Noshchenko et al. published the results of a case-controlled study that examined the risk of acute leukemia for those aged 0-20 years at the time of the catastrophe. They found a statistically significant increase in the leukemia risk for men whose estimated radiation exposition had been greater than 10 mSv. A significant correlation was found between acute leukemia and radiation exposure in the period 1993-1997, in particular for acute lymphatic leukemia. An analogous correlation was also found for acute myeloid leukemia for the period 1987-1992.<sup>29</sup>

In his most recent research into leukemia risk in 2010, Noshenko found that leukemia risk was significantly higher for children in contaminated areas of Ukraine who had received a dose greater than 10 mSv.<sup>30</sup> It is still being debated whether there was also an increase in the incidence of childhood leukemia in Belarus. According to official sources there was no morbidity increase. However, in a statistical trend analysis of Belarus source

data on the leukemia incidence, Körblein showed there was a significant increase of 33 % in leukemia morbidity among children under the age of 14 in 1987, the year after the Chernobyl nuclear disaster. In 1987 the increase among children who were under 12 months at the time of the reactor disaster was even more dramatic at 152 %.<sup>31</sup>

### 6.1.3. Cancer morbidity in other European countries.

As explained above, the health effects of the Chernobyl nuclear disaster did not stop at the borders of the former Soviet Union but extended to the rest of Europe, albeit to a lesser extent. Wherever there was radioactive fallout, people were exposed to increased radiation – and will continue to be, considering the long physical half-life of cesium 137, for example. Below is a brief summary of the most relevant studies underlining the health effects of the meltdown for the rest of Europe. As there are no relevant pan-European studies on the total number of cancer cases caused by the nuclear disaster, this can only be estimated on the basis of the calculations in chapter 4.

## Thyroid cancer

In the period investigated period 2003–2008, Radespiel-Tröger et al. also found an increased incidence of papillary thyroid cancer in Germany. Possible causes include increased diagnostic activity, above-ground nuclear testing and the Chernobyl nuclear disaster. The authors advocate further epidemiological studies to research causality and analyze regional differences in Germany.<sup>32</sup>

The Czech Republic was affected by the Chernobyl fallout to much the same extent as East Germany and Bavaria. But, as opposed to Germany, the Czech Republic keeps a cancer registry for adults, which makes epidemiological studies on morbidity increases possible in the first place. On the basis of data from the Czech cancer registry, Mürbeth and Scherb were able to show that thyroid cancer morbidity has been on the increase ever since the Chernobyl meltdown. They estimated that 400 additional thyroid cancer cases in the country were attributable to Chernobyl contamination (95%-CI: 187 – 688). The increase in the incidence of thyroid cancer was found in both men and women. From 1990 on, the number of thyroid cancer cases rose for both sexes from 2.0 percent per annum to 4.6 percent (95%-CI: 1.2-4.1,  $p=0.0003$ ). The incidence rate was significantly higher among women than men. The risk increase for women began as early as 1989 ( $p=0.0005$ ). The shortest latency period among women was in the Czech Republic, where from the nuclear disaster to the onset of illness was four years.

27 Orlov YA et al (2002): Tumors of the central nervous system in children (morbidity rates in Ukraine for 25 Years); *Int. J. Rad. Med.* 2002, 4(1-4):233-240.

28 Noshchenko AG, Moysich KB, Bondar A, Zamostyan PV, Drosdova VD, Michalek AM (2004): Patterns of acute leukemia occurrence among children in the Chernobyl region, *Int. J. Epidemiol.* 2001; 30:125-129.

Strahlentelex, 408-409/2004, p.2 et seq., Epidemiolo-gie: Vermehrt akute Leukämien bei Kindern um Tschernobyl.

29 Noshchenko AG, Zamostyan PV, Bondar OY, Drosdova VD (2002): Radiation-induced Leukemia risk among those aged 0-20 at the time of the Chernobyl accident: a case-control study: *Int. J. Cancer* 99 609-618(2002).

30 Noshchenko AG, Bondar OY, Drozdova VD (2010): Radiation induced Leukemia among children aged 0-5 years at the time of the Chernobyl accident: Int. J. Cancer 2010 Jul 15: 127(2):412-26.

31 [http://www.strahlentelex.de/Stx\\_13\\_626-627\\_S01-04.pdf](http://www.strahlentelex.de/Stx_13_626-627_S01-04.pdf)

32 <http://www.springermedizin.de/inzidenzzunahme-des-papillaerenschilddruesenkarzinoms-in-deutschland/4894698.html>



This latency period is comparable to that of the Chernobyl area.<sup>33</sup> Data from the Czech Republic is particularly revealing, as an extremely large population was monitored over a very long period – the study is based on 270 million person years. Further studies showing an increasing thyroid cancer incidence among young adults and adults were conducted in a number of other countries, including Poland and the North of England.<sup>34 35</sup>

## Neuroblastoma

A study published in 1993 by the Mainz childhood cancer registry showed a statically significant clustering of neuroblastoma in children born in the more heavily contaminated areas of Germany in 1988. Two years after the meltdown the incidence of neuroblastoma increased in ratio to soil contamination with cesium. Such dose-effect relationship is taken as evidence of a causal link to the nuclear disaster. According to the authors of the study the discovery of the neuroblastoma cluster constitutes “one of the most conspicuous fluctuations in the history of the childhood cancer registry”.

Damage to the parental germ cells prior to conception were discussed as a possible cause.<sup>36 37</sup>

## Leukemia

Michaelis et al. studied the leukemia morbidity rate for infants born in West Germany between July 1, 1986 and December 31, 1987. From a cohort of around 930,000 children, 35 developed leukemia within their first year of life, which is an increase of 1.5 fold over the rate of previous years.<sup>38</sup>

Petridou et al. analyzed all cases of childhood leukemia in Greece since Chernobyl. They found that leukemia morbidity among children born shortly after the reactor disaster (between July 1, 1986 and December 31, 1987) was 2.5 times greater than among children born either before, or long after the disaster (between January 1, 1980 and December 31, 1985; and between January 1, 1988 and December 31, 1990). The authors suspect this increase is the result of in-utero radiation exposure in the aftermath of the Chernobyl accident.<sup>39</sup>

In Scotland in 1987, there was a 37-% increase in leukemia morbidity among children under four. In the same year, looking at the 0-18 age group, the study found a total of 48 cases of childhood leukemia. This amounts to 13 more than were to be expected. Of the 48 diagnosed cases, alone 33 were children under four years of age.<sup>40</sup>

Reports from Romania also studied leukemia in children in the aftermath of the Chernobyl disaster. Davidescu et al. also conducted a case-controlled study in five East Romanian districts between 1986 and 2000. The group exposed to contaminated food comprised 137,072 children (37 cases of leukemia), while the group with no contact to contaminated food comprised 774,789 children (204 cases of leukemia).

Although the leukemia incidence rate for the age group 0–10 was not significantly higher in the contaminated areas than in the comparison area (270 to 263,  $p>0.05$ ), the leukemia incidence rate among children born between July 1986 and March 1987, however, was significantly higher than among those born between April 1987 and December 1987 (386 to 173,  $p=0.03$ ). The effect is most evident in the 0-1 age group. The incidence rate correlates with the equivalent dose for the bone marrow.<sup>41</sup>

## General increase in the cancer incidence

According to calculations by Tondel et al., by 1996 the Chernobyl reactor disaster resulted in 849 excess cancer cases in the fallout areas in northern Sweden. The authors conducted a cohort study encompassing all inhabitants of northern Sweden who were 60 and under at the time of the disaster (1986–1987 = 1,143,182 persons). Soil pollution with cesium-137 was correlated with the number of cancer cases (22,409 from 1988 to

33 Mürbeth S et al. (2004): Thyroid cancer has increased in the adult populations of countries moderately affected by Chernobyl fallout. *Med Sci Monit.* 2004 Jul; 10(7):CR300-6.

34 Szybinski Z, Olko P, Przybylik-Mazurek E, Burzynski M (2001): Ionizing radiation as a risk factor for thyroid cancer in Krakow and Nowy Sacz regions. *Wiad Lek.* 2001, 54 (Suppl. 1): 151-156 (Polish).

35 Cotterill SJ, Pearce MS, Parker L (2001): 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(8): 1020-1026.

36 Michaelis J et al (1993): Fall-Kontrollstudie zum Anstieg der Neuroblastom-Inzidenz für im Jahr 1988 geborene Kinder; *Medizinische Informatik, Biometrie und Epidemiologie* 76/1993. *Strahlentelex*, 166-167/1993, p. 4, Dr. Hayo Dieckmann, Tschernobylfolgen auch in Deutschland messbar.

37 Henze G (1991): Vermehrt Neuroblastome bei Säuglingen in Süd-deutschland. 30.10.91, FU Berlin. Cited in *Strahlentelex*, 122-123/1992, p. 8.

38 Michaelis J, Kaletsch U, Burkart W, Grosche B (1997): Infant leukemia after the Chernobyl accident, *Nature*, Vol. 387, 15 May 1997, p. 246. J. Michaelis, Mainz, Press release on 11.06.1997. *Strahlentelex*, 252-253, p. 1 et seq., Kinderleukämien, Nach dem Tschernobyl-Unfall erkrankten mehr Säuglinge in Deutschland an Blutkrebs.

39 *Nature*, 24.7.1996, cited in *Strahlentelex*, 230-231/1996, p. 12, Leukämie in Griechenland. *Strahlentelex*, 252-253, p. 1 f., Kinderleukämien, Nach dem Tschernobyl-Unfall erkrankten mehr Säuglinge in Deutschland an Blutkrebs.

40 *The Lancet* Sept. 1988; *Strahlentelex*, 42/1988, Mehr Leukämien in Schottland.

41 Davidescu D et al (2004): Infant leukemia in eastern Romania in relation to exposure in Utero due to the Chernobyl accident; *Int. J. Rad. Med.* 2004, 6(1-4):38-43.



Ailment/organ	Registered incidence per 100,000 inhabitants Adults and young persons					
	1987	1988	1989	1990	1991	1992
III Endocrinal system	631	825	886	1,008	4,550	16,304
V Psychological disturbances	249	438	576	1,157	5,769	13,145
VI Neural system	2,641	2,423	3,559	5,634	15,518	15,101
VII Circulatory system	2,236	3,417	4,986	5,684	29,503	98,363
IX Digestive organs	1,041	1,589	2,249	3,399	14,486	62,920
XII Skin & subcutaneous tissue	1,194	947	1,262	1,366	4,268	60,271
XIII Muscular-skeletal system	768	1,694	2,100	2,879	9,746	73,440

**Table 6-2**

Dynamic somatic diseases among inhabitants of northern Ukraine that were affected by the accident at the nuclear power plant in Chernobyl (1987–1992)<sup>44</sup>

1996). The cancer risk for all forms of cancer taken together. Lung cancer risk in particular increased in proportion to fallout-exposure. The risk increase was put at 11 percent per 100,000 Bq/m<sup>2</sup> (95% CI = 0.03-0.20).<sup>42 43</sup>

## 6.2 Non-cancerous diseases

Just a few years after the Chernobyl nuclear disaster, not only the liquidators, but also the populations of heavily contaminated areas exhibited diseased organ systems: the hematopoietic, lymphatic, cardiac, pulmonary, gastrointestinal and endocrinological systems were all affected, but most of all, the thyroid gland. The resulting conditions are non-malignant, long-term somatic diseases upon which the injurious agent ionizing radiation exerts its effect. They are dose-related and can become noticeable early on (e.g. damage to blood cells) or not until years later (cataract, sterility).

The above table (6.2) shows the increased frequency of various diseases among the inhabitants of heavily contaminated areas. The data is taken from a study by Nyagu et al. in which a spe-

cific population in the Chernobyl area was subjected to repeated examinations over several years. Distinct to unexpected high morbidity increases are apparent for all groups of diseases. All figures are per 100,000 inhabitants. Many inhabitants suffer from more than one illness (multimorbidity).

Table (6.3) is taken from the same study and shows how the number of healthy individuals in each of four populations decreases over time. In 1987, for example, 78.2 % of liquidators were healthy, by 1996 the proportion of healthy liquidators had dropped to 15 %.

Group IV – Children of affected parents – is the most disturbing group. Their state of health also deteriorates to an alarming degree over time. This raises the question of whether genetic changes have already taken place.

The following figures show a growing trend in the incidence of non-cancerous diseases among children and young people.

Compared to healthy control groups, children exposed to ionizing radiation in the aftermath of the Chernobyl nuclear disaster exhibited morbidity increases in the following groups of diseases:<sup>46</sup>

42 Tondel M et al (2004): Increase of regional total cancer incidence in north Sweden due to the Chernobyl accident? J.Epidemiol.Community Health 58 (2004) 1011-1016., Strahlentext, 430-431/2004, Vermehrt Krebserkrankungen in Nordschweden nach der Katastrophe von Tschernobyl.

43 Tondel M, Lindgren P, Hjalmarsson P, Hardll L, Persson B (2006): Increased Incidence of Malignancies in Sweden After the Chernobyl Accident – A Promoting Effect?, American Journal of Industrial Medicine 49:159-168.

44 Nyagu AI (1994): Medizinische Folgen der Tschernobyl-Havarie in der Ukraine, Chernobyl Ministry of Ukraine, Scientific Center for Radiation Medicine, Academy of Medical Sciences of Ukraine, Pripyat scientific-industrial association, Scientific-Technical Center, Kiev – Chernobyl 1994 (Russian).

45 46 Prysyazhnuk A et al (2002): Review of Epidemiological finding in Study of Medical Consequences of the Chernobyl Accident population; in: Recent Research Activities about the Chernobyl NPP Accident in Belarus, Ukraine and Russia KURRI-KR-79 (Kyoto University, Kyoto), pp. 188–287.



Categories of victims	Healthy proportion of population in %									
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
I Liquidators	78.2	74.4	66.4	53.3	35.8	28.8	23	19.8	17.6	15
II Evacuees	58.7	51.6	35.2	26.2	29.7	27.5	24.3	21.1	19.5	17.9
III Inhabitants of affected areas	51.7	35.4	35.2	26	31.7	38.2	27.9	24.5	23.1	20.5
IV Children of affected parents	80.9	66.8	74.2	62.9	40.6	n/s	36.9	32.4	32.1	29.9

**Table 6-3**

Health decline in the affected Ukrainian population<sup>46</sup>

- » Thyroid diseases 32.6 %  
(15.4 % in the control group,  $p < 0.05$ )
- » Pulmonary and bronchial diseases 26.0 %  
(control group 13.7 %,  $p < 0.05$ )
- » Cardiovascular diseases 57.8 %  
(control group 31.8 %,  $p < 0.05$ )
- » Gastrointestinal diseases 18.9 %  
(control group 8.9 %,  $p < 0.05$ )
- » Immune deficiencies 43.5 %  
(control group 28.0 %,  $p < 0.05$ )
- » Endocrine infertility in girls 32.0 %  
(control group 10.5 %,  $p < 0.05$ )

As the effects of ionizing radiation can be most impressively demonstrated in children, the different non-cancerous diseases in this population will be looked at in more detail below.

#### 6.2.1 Diseases of blood-forming organs and the lymphatic system

The Ukrainian Chernobyl researcher Stepanova has published a number of papers on the altered state of health in children from highly contaminated areas.

She analyzed the blood samples of 1,251 children from the Narodicheski area of Schitomir Oblast in Ukraine that had been given regular medical checks between 1993 and 1998. She correlated this data with the level of radioactive cesium soil contamination and found a direct correlation between the reductions in all three cell lines (erythrocytes, leucocytes and thrombocytes) and the concentration of radioactive cesium in soil. The Ukrainian scientist Grodzynsky was also able to show that the incidence of anemia and leucopenia, as well as the reduction in the number of red and white blood cells, was higher among children and young people from contaminated areas. Symptom frequency rose from 12.7 per 100,000 in 1987 to 30.5 per 100,000 in 1995; the average for the population was 12.6 per 100,000.<sup>47</sup> Ten years after the onset of the nuclear disaster, Lukyanova and Lenskaya also found lower white blood-cell counts in children from the contaminated areas of Bryansk,

46 Nyagu AI (1994): Medizinische Folgen der Tschernobyl-Havarie in der Ukraine, Chernobyl Ministry of Ukraine, Scientific Center for Radiation Medicine, Academy of Medical Sciences of Ukraine, Pripjat scientific-industrial association, Scientific-Technical Center, Kiev – Chernobyl 1994, Kryshanovskaja: data for 1993-1996, personal statement.

47 Grodzynsky DM (1999): General situation of the radiological consequences of the Chernobyl accident in Ukraine. In: Imanaka, T. (Ed.), Recent Research Activities on the Chernobyl NPP Accident in Belarus, Ukraine and Russia, KURRI-KR-7 (Kyoto University, Kyoto): pp. 18–28.



Russia.<sup>48</sup> Horishna specifically examined the children of liquidators in the contaminated areas and found they suffered 2–3 more often from conditions of the blood-forming organs than children from non-contaminated areas.<sup>49</sup>

### 6.2.2 Cardiovascular diseases

In Belarus, Russian scientists Tsybul'skaya and Bandashevsky found that more than 70 % of examined children under 12 months of age had cardiac arrhythmia and that this correlated with soil contamination levels (185,000 kBq/m<sup>2</sup> – 740,000 kBq/m<sup>2</sup>).<sup>50</sup> Burlak et al. observed early symptoms of arteriosclerosis in 55.2 % of children from areas in which radioactive contamination was 5–15 kBq/m<sup>2</sup>.<sup>52</sup> Meanwhile, the Belarus National Report on the consequences of Chernobyl recorded a significant increase in circulatory diseases among the children of contaminated parents.<sup>53</sup> Prysyzhnyuk et al. were able to show that the risk of cardiovascular disease among children exposed to in-utero radiation was greater than for non-irradiated children (57.8% vs. 31.8%,  $p < 0.05$ ).<sup>54</sup> In 2006 Komorgortseva found cardiovascular disease to be three to five times more common in three heavily contaminated regions in the Russian Bryansk province.<sup>55</sup>

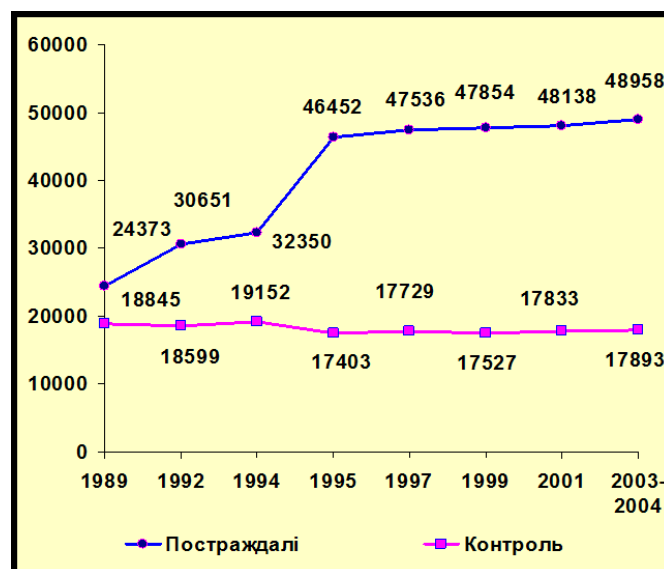


Figure 6-2

Increase in incidence of non-cancerous diseases per 10,000 children and young people aged 0-14 according to Nyagu et al.; Ukraine National Report<sup>56</sup>

**pink:** control group from uncontaminated areas in Ukraine  
**blue:** children from heavily contaminated areas

Recent animal tests<sup>57</sup> confirmed observations by scientists in the Chernobyl area whereby relatively low doses of ionizing radiation can suffice to damage the cardiovascular system.

### 6.2.3 Benign thyroid diseases

Prysyzhnyuk et al. examined Ukrainian children who had received doses of 2 Gy or been exposed to radioactivity in-utero. By 2002 the proportion of healthy subjects in this cohort had dropped to 5 %. At first, between 1986 and 1987, these children were diagnosed with functional disorders of the thyroid, then from 1990 with autoimmune thyroiditis and then from 1992 with persistent benign thyroid disease.<sup>58</sup> Leonova and Astakhova found that 10 years after the onset of the nuclear disaster there was a threefold increase in cases of autoimmune thyroiditis.<sup>59</sup>

48 Lukyanova AG, Lenskaya RV (1996): Cytological and chemical characteristics of peripheral blood lymphocytes in Chernobyl children, 1987–1995. *Hematol. Transfusiol.* 41 (6): 27–30 (Russian). Cited from Yablokov (2009)

49 Horishna OV (2005): Chernobyl Catastrophe and Public Health: Results of Scientific Investigations (Chernobyl Children's Foundation, Kiev): 59 pp. (in Ukrainian).

50 Tsybul'skaya IS, Sukhanova LP, Starostin VM, Mytyurova LB (1992): Functional condition of the cardiovascular system in young children under the chronic impact of low dose irradiation. *Matern. Child-hood* 37(12): 12–20 (Russian).

51 Bandazhevsky Yul (1997): Pathology and Physiology of the Incorporated Ionizing Radiation (Gomel Medical Institute, Gomel): 104 pp. (Russian).

52 Burlak G, Naboka M, Shestopalov V (2006): Noncancer endpoints in children–residents after Chernobyl accident. International Conference. Twenty Years After Chernobyl Accident: Future Outlook. April 24–26, 2006, Kiev, Ukraine. Contributed Papers, Vol. 1 („HOLT-EH," Kiev): pp. 37–40

53 National Belarussian Report (2006). Twenty Years After the Chernobyl Catastrophe: Consequences for Belarus Republic and Its Surrounding Area (Shevchuk, V. F. & Gurachevsky, V. L., Eds.) (Belarus, Minsk): 112 pp. (Russian).

54 Prysyzhnyuk Aye, et al (2002): Review of epidemiological finding in the study of medical consequences of the Chernobyl accident in Ukrainian population. In: Imanaka T. (Ed.), Recent Research Activities on the Chernobyl NPP Accident in Belarus, Ukraine and Russia, KURRI-KR-79 (Kyoto University, Kyoto), pp. 188–287.

55 Komogortseva LK (2006): Ecological consequences of Chernobyl catastrophe in Bryansk province: Twenty years after. International Scientific and Practical Conference. Twenty Years After the Chernobyl Catastrophe: Ecological and Social Lessons. June 5, 2006, Moscow (Materials, Moscow): pp. 81–86 (Russian).

56 Nyagu A (2006) Presentation at the BFS Workshop: Gesundheits-folgen von Tschernobyl, München 9-10.11.2006

57 European commission: Radioprotection No 170: Recent scientific findings and publications on the health effects of Chernobyl (2011), p. 17; <https://ec.europa.eu/energy/sites/ener/files/documents/170.pdf>

58 Prysyzhnyuk Aye, et al (2002): Review of epidemiological finding in the study of medical consequences of the Chernobyl accident in Ukrainian population. In: Imanaka T (Ed.), Recent Research Activities on the Chernobyl NPP Accident in Belarus, Ukraine and Russia, KURRI-KR-79 (Kyoto University, Kyoto), pp. 188–287.

59 Leonova TA, Astakhova LN (1998): Autoimmune thyroiditis in pubertal girls. *Public Health* 5: 30–33 (Russian).



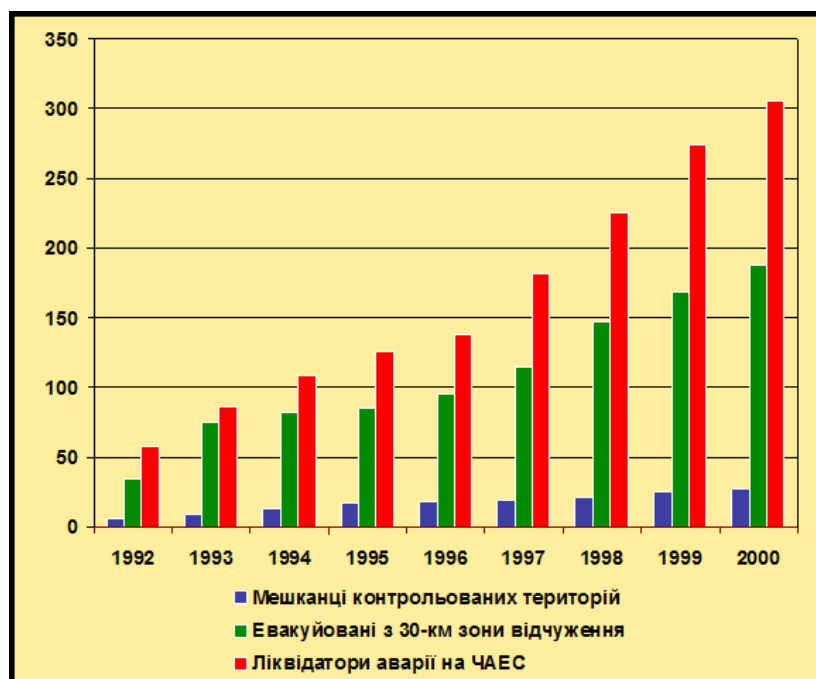


Figure 6-3

Non-cancer thyroid diseases (Autoimmune thyroiditis, hypothyroidism)  
 red bar = liquidators,  
 green = evacuees from 30-km zone,  
 blue = control group (Ukraine without contaminated population)

The radiation-exposed non-pediatric population also developed thyroid diseases. Nyagu discovered there was a 30–40 percent increase in benign thyroid diseases, particularly among liquidators and evacuees.<sup>60</sup> These include autoimmune thyroiditis and the associated complications, and hypothyroidism.

#### 6.2.4 Diabetes

Endocrinologists from the Heinrich Heine University in Düsseldorf and the Belarusian endocrine advice center in Minsk cooperated on an investigation into the development of diabetes amongst children and young adults in Belarus. Over a lengthy period, 1980 to 2002, the annual incidence of type 1 diabetes mellitus was monitored in two areas of Belarus with very different levels of contamination. The two part analysis involved comparing data from 1980–1986 with that of 1987–2002; and data from the highly contaminated Gomel area with that of the Minsk area where contamination was relatively low.

The study involved a total of 643 patients from the Gomel area and 302 patients from the Minsk area. In 1980–1986 (before Chernobyl) there was no significant difference between the in-

cidence rates in Gomel and Minsk. In the aftermath of Chernobyl (1987-2002), however, a highly significant difference ( $p < 0.001$ ) was found between incidence rates. The authors also discovered that, whereas in the Minsk area there was no significant difference in the incidence rates before and after Chernobyl, in the highly contaminated Gomel area ( $p < 0.05$ ) about twice as many children and young adults developed type 1 diabetes mellitus after Chernobyl compared to before. The highest average incidence rate was registered in the Gomel area in 1998.<sup>61</sup>

#### 6.2.5 Pulmonary diseases

In a study with children from the highly contaminated Nardichesky area, Svendsen, Kopalkov and Stepanova were able to show that protracted, low-dose radiation exposure caused a significant increase in obstructive pulmonary diseases.<sup>62</sup> The

60 Nyagu A (2006) Presentation at the BFS Workshop: Gesundheits-folgen von Tschernobyl, München 9-10.11.2006

61 Zalutskaya A, Mokhort T, Garmaev D, Bornstein SR (2004): Did the Chernobyl incident cause an increase in Typ 1 diabetes mellitus incidence in children and adolescents? Diabetologia 2004 Jan; 47(1): 147-8. Strahlen-tele, 416/2004, Zuckerkrank nach Tschernobyl.

62 Svendsen ER, Kolpakov IE, Stepanova YI et al (2010): 137 Cesium exposure and spirometry measures in Ukrainian children Affected by the Chernobyl Nuclear Accident; in: Environ Health Perspect. 2010 May; 118(5):720-5.



cohort comprised 415 children who had regular spirometry tests by a pulmonologist between 1993 and 1998. Cesium 137 soil concentrations fluctuated between 29 and 879 kBq/m<sup>2</sup>. Russian scientists also found a correlation between increases in obstructive lung disease and the level of radioactive soil contamination in Bryansk.<sup>63</sup>

### 6.2.6 Brain damage / mental illnesses

Ukrainian neurologist Nyagu conducted a highly detailed assessment of the effects of radioactive contamination on the mental abilities and mental health of children. Numerous further Russian and Ukrainian studies are only available in Russian, with English summaries by Yablokov (2009). The research group around Nyagu examined the effects of in-utero irradiation on children and young people from the contaminated areas and compared the results to those of a non-irradiated control group. The comparison found a significant increase in cognitive development disorders, minor intellectual impairments and behavioral disorders among children exposed to prenatal radiation. The whole-body doses for irradiated fetuses was between 10.7 and 92.5 mSv, the organ dose for the thyroid between 0.2 and 2 Gy.<sup>64</sup>

A major study on brain damage and in-utero irradiated fetuses was also carried out in Sweden. The study involved 562,637 persons born between 1983 and 1988. The most severe damage was found in those exposed to radioactive fallout between the 8th and 25th week of pregnancy.

A dose-effect relationship in respect of areas with low and high levels of contamination could also be verified.<sup>65</sup>

These studies clearly show that, contrary to the opinion of the ICRP, in-utero irradiation – even in relatively small amounts – causes brain damage.

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63 Yablokov A, Nesterenko V, Nesterenko A (2009): Chernobyl – Consequences of the Catastrophe for People and Environment, Annals of the New York Academy of Sciences, vol. 1181, Boston, Mass, pp. 95 – 96

64 Nyagu AI, et al: Intelligence and Brain Damage in Children Acutely Irradiated in Utero As a Result of the Chernobyl Accident. Department of Neurology, Institute for Clinical Radiology, Research Center for Radiation Medicine of Academy of Medical Sciences of Ukraine. <http://www.rri.kyoto-u.ac.jp/NSRG/reports/kr79/kr79pdf/Nyagu.pdf>

65 Almond D, Edlund L, Palme M (2007): Chernobyl's sub-clinical legacy: Prenatal exposure to radioactive fallout and school outcomes



## 7 Genetic and teratogenic effects

In this chapter we will present studies showing the damaging effect of ionizing radiation on fertility, as well as the teratogenic (fetal development) and mutagenic (e.g. Down syndrome and chromosome aberrations) effects. Increases in infant mortality and the stillbirth rate are also among the teratogenic effects of ionizing radiation. There was also a shift in the gender ratio, i.e. ratio of boys to girls in a birth cohort, as a result of the Chernobyl nuclear disaster. Whether this is a teratogenic effect or an epigenetic process is still not adequately explained.

According to the previous scientific doctrine on the biological effects of radiation, there should be no teratogenic effect below a threshold of 100 mSv. This is challenged by the results of Chernobyl research studies.

The following papers on the different types of genetic damage, the fetus and the course of pregnancy are taken from summaries prepared by Schmitz-Feuerhake.<sup>1 2 3</sup>

### 7.1 Congenital malformations in the Chernobyl area

Belarus has maintained a central register of malformations and other congenital defects since 1979.<sup>4</sup> Its existence before Chernobyl allows a comparison of the malformation rates before and after Chernobyl. Table 7-1 by Schmitz-Feuerhake specifies the incidence of different types of malformations.<sup>5</sup>

There was also an increased incidence of developmental disorders involving evident gene mutation and appearing as a de novo mutation, i.e. not present in parents.<sup>6</sup> Later work by Lazjuk and Zatsepin shows that in areas where radioactive soil contamination with cesium 137 was above 555 kBq/m<sup>2</sup>, there was a marked increase in the number of children born with malformations, particularly in the two years after the onset of the disaster (1987–1989).<sup>7</sup>

1 Schmitz-Feuerhake I, et al (2016): Genetic Radiation Risks –A neglected Topic in the Low-Dose Debate; Korean Journal Environmental Toxicology 2016;0:e2016001

2 Busby C, Lengfelder E, Pflugbeil S, Schmitz-Feuerhake I (2009): The evidence of radiation effects in embryos and fetuses exposed to Chernobyl fallout and the question of dose response. In: Med. Conflict Survival 2009 Jan-Mar;25(1):20-40.

3 Schmitz-Feuerhake I (2014): Genetische Folgen ionisierender Strahlung im Niederdosisbereich: [http://www.tschernobylkongress.de/fileadmin/user\\_upload/Arnoldshain\\_Doku/Schmitz-Fgenetisches\\_Risiko2014.pdf](http://www.tschernobylkongress.de/fileadmin/user_upload/Arnoldshain_Doku/Schmitz-Fgenetisches_Risiko2014.pdf)

4 Lazjuk G, Verger P, Gagniere B, et al (2003): The congenital anomalies registry in Belarus: a tool for assessing the public health impact of the Chernobyl accident. Reprod. Toxicol. 17: 659-666.

5 Schmitz-Feuerhake I (2015): Das vergessene Risiko durch ionisierende Strahlung für die Nachkommen exponierter Eltern [http://www.umg-verlag.de/umwelt-medizin-gesellschaft/415\\_sf\\_z.pdf](http://www.umg-verlag.de/umwelt-medizin-gesellschaft/415_sf_z.pdf)

6 Lazjuk G, Satow Y, Nikolaev D, Novikova I (1999): Genetic consequences of the Chernobyl accident for Belarus Republic. In: IMANAKA, T. (Ed): Recent Research Activities on the Chernobyl NPP Accident in Belarus, Ukraine and Russia, KURRI-KR-7, Kyoto University, Kyoto: 174-177.

7 [https://inis.iaea.org/search/search.aspx?orig\\_q=RN:37057675](https://inis.iaea.org/search/search.aspx?orig_q=RN:37057675)



Type of malformation	Increase by
Anencephaly	39 %
Spina bifida	29 %
Cleft lip/palate	60 %
Polidactyly	910 %*
Limb distortions	240 %*
Esophageal atresia	13 %
Rectal atresia	80 %*
Multiple malformations	128 %*

\*significant  $p > 0.05$

**Table 7-1**

Increase in the rate of congenital malformations in the 17 most heavily contaminated areas of Belarus 1987–1994 in percent (Original source: Lazjuk et al. 1997)<sup>8</sup>

Wertelecki was able to show that the rate of malformations had also risen in Ukraine.<sup>9 10</sup> His study found a significant increase in neural tube defects, microcephaly and microphthalmia in the area of Polissia-Rivne Ukraine approx. 200 kilometers from Chernobyl. The study data was compared to the EUROCAT data on malformations. The study area is still highly contaminated, possibly due to a soil type with low porosity. The local population lives on local agricultural products and uses firewood from forests still heavily contaminated to this day. In Polissia there are 25.96 neural tube defects per 10,000 live births, which is the highest rate in Europe (cf. table 7.2, following page).<sup>11</sup>

## 7.2 Congenital malformations across Europe

In the aftermath of the meltdown, the rate of malformations not only soared in the former USSR, but also in other parts of Europe. In the GDR, in contrast to the GFR, an autopsy was required by law for all miscarriages and deaths of children under the age of 16. The registry of congenital malformations in Jena

showed a fourfold increase in isolated malformation in 1986–1987 compared to 1985, which then subsided in subsequent years. The increase mainly affected the central nervous system and the abdominal wall.<sup>12</sup> An analysis of the GDR central registry of congenital malformations showed an increase in cases of cleft lip and palette of about 9.4% in 1987 (compared to the 1980–1986 average). This was more pronounced in the northern areas, where there had been most fallout.<sup>13</sup> According to the 1987 annual health report for Berlin, the incidence of malformations in stillborn infants in West Berlin doubled. Most frequently affected were the hands and feet, then the heart and urethra, in addition to an increase in the incidence of facial clefts.<sup>14</sup> Bavaria is the only German state to have recorded data on congenital malformations before and after Chernobyl. Data for 1984 to 1991 was collected in retrospect by order of the Bavarian Ministry of State for Development and the Environment. In southern Bavaria, where contamination by radioactive fallout was relatively high, the rate of congenital malformations at the end of 1987 – seven months after the Chernobyl nuclear disaster – was almost twice as high as in northern Bavaria. In November and December 1987 the rate of congenital malformations in Bavarian districts showed a highly significant correlation to the level of cesium soil contamination. Küchenhoff et al. found a temporal correlation between the rate of congenital malformations in southern and northern Bavaria and cesium exposure during pregnancy. In November and December 1987 the rate of congenital malformations in the 10 most heavily contaminated Bavarian districts was almost three times that of the 10 least contaminated districts ( $p < 0.001$ ).<sup>15</sup> Scherb et al. found a correlation between the rise in the rate of congenital malformations following Chernobyl and cesium concentrations in the soil of the Bavarian administrative districts.<sup>16</sup>

12 Lotz B, et al (1996): Veränderungen im fetalen und kindlichen Sektionsgut im Raum Jena nach dem Reaktorunfall von Tschernobyl, Bonn, Speech: Society for Medical Documentation, Statistics and Epidemiology, 1996. zit. in Hoffmann W (2001): Fallout from the Chernobyl nuclear disaster and congenital malformations in Europe. Archives of Environmental Health 56 (2001) 478-484.

13 Ziegłowski V, Hemprich A: Facial cleft birth rate in former East Germany before and after the reactor accident in Chernobyl. Mund Kiefer Gesichtschirurgie 1999; 3:195-199; zit. In Hoffmann W (2001): Fallout from the Chernobyl nuclear disaster and congenital malformations in Europe. Archives of Environmental Health 56 (2001) 478-484. Strahlentelex, 374–375/2002, p.9f. Schmitz-Feuerhake I, Fehlbildungen in Europa und der Türkei.

14 Hoffmann W (2001): Fallout from the Chernobyl nuclear disaster and congenital malformations in Europe. Archives of Environmental Health 56 (2001) 478-484. Strahlentelex, 374–375/2002, p.9f. Schmitz-Feuerhake I, Fehlbildungen in Europa und der Türkei.

15 Körblein A (2001): Folgen von Tschernobyl: Fehlbildungen bei Neugeborenen in Bayern. Umweltnachrichten 94/2001, Umweltinstitut München e.V. Dezember 2001, p. 11-16 Strahlentelex, 360-361/2002, p.5f., Fehlbildungen bei Neugeborenen in Bayern.

16 Scherb H, Weigelt E (2004): Spaltgeburtenrate in Bayern vor und nach dem Reaktorunfall in Tschernobyl, Mund Kiefer Gesichtschir 2004, 8: 106-110.

8 Lazjuk G, et al.: Changes in the Registered Anomalies in the Republic of Belarus Radiation Injury and the Chernobyl Catastrophe. STEM CELLIS9 97;15(suppl2):255-260

9 Wertelecki W (2010): Malformations in a Chornobyl-Impacted Region. Pediatrics 2010;125; e836-e843, <http://www.pediatrics.org/cgi/content/full/125/4/e836>

10 Wertelecki W, et al (2014): Blastopathies and microcephaly in a Chernobyl-impacted region of Ukraine, Congenital Anomalies 2014; 54, 125–149

11 <https://vimeo.com/66984287>



Region	Effects	Reference
<b>Weißrussland</b>		
National Register on congenital malformations and genetic diseases	Anencephaly, spina bifida, cleft lip/palette, polydactyly, atrophy of the limbs, Down syndrome	Lazjuk et al. 1997
Highly contaminated Gomel area	Congenital malformations	Bogdanovich 1997; Savchenko 1995
District Chechersky in Gomel Region	Congenital malformations	Kulakov et al. 1993
Mogilev Region	Congenital malformations	Petrova et al. 1997
Brest Region	Congenital malformations	Shidlovskii 1992
<b>Ukraine</b>		
Polesky Kiev Region	Congenital malformations	Kulakov et al. 1993
Lygyny Region		Godlevsky, Nasvit 1998
<b>Turkey</b>	Anencephaly, spina bifida	Akar et al.1988/89; Caglayan et al. 1990; Güvenc et al. 1993; Mocan et al. 1990
<b>Bulgaria</b>		
Pleven Region	Malformations of the heart and CNS diverse congenital malformations	Moumdjiev et al. 1992
<b>Croatia</b>	Malformation found on autopsy of stillbirths and neonatal deaths	Kruslin et al. 1998
<b>Germany</b>		
GDR	cleft lip and/or palette	Zieglowski, Hemprich 1999 Scherb, Weigelt 2004
Central register Bavaria	Cleft lip and/or palette Congenital malformations	Körblein 2003, 2004; Scherb, Weigelt 2003
Annual Health Report West Berlin 1987	Congenital malformations and stillbirths	Strahlentelex 1989
Register of congenital malformations Jena	Isolated congenital malformations	Lotz et al. 1996

**Table 7-2**

Summary of congenital malformations after the Chernobyl disaster  
acc. to Schmitz-Feuerhake<sup>17</sup>

17 Busby C, Lengfelder E, Pflugbeil S, Schmitz-Feuerhake I (2009): The evidence of radiation effects in embryos and fetuses exposed to Chernobyl fallout and the question of dose response; in: [http://acsir.org/12-Busby\\_et\\_alMCS\\_2009.pdf](http://acsir.org/12-Busby_et_alMCS_2009.pdf)



On the basis of the Bavarian data, Scherb and Weigelt conclude that between October 1986 and December 1991, there must have been 1,000 to 3,000 additional congenital malformations in Bavaria alone.<sup>18</sup>

At the beginning of 1987, reports of an accumulation of anencephaly and neural defects in newborns arrived from western Turkey and the eastern Black Sea coast, which had been particularly hard hit by radioactive fallout.<sup>19 20 21 22</sup>

### 7.3 Down syndrome, congenital malformation and CNS defects in Germany and Europe

Sperling also observed a sharp rise in cases of trisomy 21 (Down syndrome) in Berlin nine months after Chernobyl. In January 1987, 12 children in West Berlin were born with Down syndrome, whereas normally only two or three cases would be expected. This figure is highly significant and virtually rules out coincidental fluctuation.<sup>23</sup> In eight cases the probable date of conception coincides with the highest measured increase in radioactivity in Berlin.<sup>24</sup> In an extensive data analysis published in the British Medical Journal, Sperling et al. confirmed the 1987-increase observed in the incidence of Down syndrome. The former 'island-status' of the city and the jurisdiction of Sperling's institute over all Down syndrome children in West Berlin meant that he could base his analysis on very precise figures taken from complete data sets, unheard of in other federal states. Sperling could find no other possible cause of the chromosomal disorder other than the radioactive fallout during the previous spring. He assumed there could be a possible causal link between this increase and radioactive fallout in cen-

tral Europe in spring 1986, particularly iodine-131 found in the air and food which has a half-life of 8 days.<sup>25</sup>

In an extended study, Sperling, Neitzel and Scherb examined pan-European data on the occurrence of Down syndrome in the aftermath of the Chernobyl disaster. They examined maternal, age-standardized data on Down syndrome and the number of corresponding live births in seven European countries: Bavaria and West Berlin in Germany, Belarus, Hungary, the Lothian region of Scotland, Northwest England and Sweden for the period 1981–1992. They found increases in the number of Down syndrome cases nine months after the Chernobyl cloud had passed over each respective area, as well as a surge in the overall trend. Thus, there was a continuing increase in the rate of Down syndrome cases that may be linked to long-term soil contamination with cesium 137.<sup>26</sup> An increased incidence of abnormalities (including disorders of the central nervous system and limb deformities) was also registered in areas of Finland with higher contamination levels. Further cases of CNS defects were also observed in Denmark, Hungary and Austria.<sup>27</sup> Saxén et al. found that between August and December 1986 there was a significant increase in premature births to mothers who had lived in areas of Finland more heavily contaminated by Chernobyl fallout during the first three months of pregnancy.<sup>28</sup> Malformations of the heart and CNS, as well as multiple anomalies could be observed in the Pleven region of Bulgaria. In Croatia autopsies were performed at the University Clinic of Zagreb on all premature stillbirths and newborns that died within the first 28 days of life between 1980 and 1993.

Here too, the rate of CNS-anomalies was found to have risen in the aftermath of the Chernobyl meltdown.<sup>29</sup>

18 Otto-Hug-Bericht Nr. 24. Strahlentelex, 388-389/2003, S. 6 ff., Auch in Deutschland und anderen Ländern Europas starben nach Tschernobyl deutlich mehr Säuglinge, gab es mehr Fehlbildungen und Totgeburten.

19 Güvenc H, Uslu MA, Güvenc M, Ozkici U, Kocabay K, Bektas S (1993): Changing trend of neural tube defects in Eastern Turkey; J. Epidemiol. Community Health, 1993, 47:40-41.

20 Caglayan S, Kayhan B, Montesoglu S, Aksit S (1990): Changing incidence of neural tube defects in Aegean Turkey; Pediatric and Perinatal Epidemiology, 1990, 4:264-268.

21 Akar N, Cavadar AO, Arcasoy A (1988): High incidence of Neural Tube defects in Bursa, Turkey; Pediatric and Perinatal Epidemiology 1988, 2:89-92.

22 Mocan H, Bozkaya H, Mocan ZM, Furtun EM (1990): Changing incidence of anencephaly in the eastern Black Sea region of Turkey and Chernobyl; Pediatric and Perinatal Epidemiology 1990, 4:264-268.

23 Strahlentelex, 5/1987, 19. März 1987, S. 1f., 'Mongolismus' 9 Monate nach Tschernobyl.

24 Strahlentelex, 166-167/1993, S. 4, Tschernobylfolgen auch in Deutschland messbar.

25 Sperling K, Pelz J, Wegner R-D, Dörries A, Grüters A, Mikkelsen M (1994): Significant increase in trisomy 21 in Berlin nine months after the Chernobyl reactor accident, temporal correlation or causal relation?, British Medical Journal 1994, 309: 158-62, 16 July 1994. Sperling K, Pelz J, Wegner R-D, Schulzke I, Struck E (1991): Frequency of trisomy 21 in Germany before and after the Chernobyl accident, Biomed & Pharmacother, 1991, 45, 255-262. Strahlentelex, 184-185/1994, S. 1 f., Behinderte Kinder in Berlin durch Tschernobyl.

26 Sperling K, Neitzel H, Scherb H (2012): Evidence for an increase in trisomy 21 (Down syndrome) in Europe after the Chernobyl reactor accident; in: Genetic Epidemiology Volume 36, Issue 1, pages 48–55, January 2012

27 Hoffmann W (2001): Fallout from the Chernobyl nuclear disaster and congenital malformations in Europe. Archives of Environmental Health 56 (2001) 478-484. Inge Schmitz-Feuerhake, Fehlbildungen in Europa und der Türkei, Strahlentelex, 374-375/2002, p.9f.

28 Saxén L, Rytömaa T (1989): British Medical Journal, 298: 995-997. Strahlentelex, 60-61/1989, S. 8, Vermehrt Frühgeburten behinderter Kinder in Finnland.

29 Hoffmann W (2001): Fallout from the Chernobyl nuclear disaster and congenital malformations in Europe. Archives of Environmental Health 56 (2001) 478-484. Inge Schmitz-Feuerhake, Fehlbildungen in Europa und der Türkei, Strahlentelex, 374-375/2002, S. 9 f.



## 7.4 Stillbirths and the rise in perinatal mortality in the former USSR

In 1987, the year after the reactor accident, there was an increase in the number of stillbirths and premature deaths among infants in the Ukrainian and Belarusian territories around Chernobyl. This suggests a causal relation to radioactive fallout, particularly cesium on account of its ability to cross the placenta. A second wave of perinatal mortality occurred in Belarus and Ukraine after 1989. This renewed increase could be attributed to the exposure of pregnant women to radioactive strontium.<sup>30</sup> In the three Ukrainian regions of Schitomir, rural Kiev and urban Kiev, the difference between the statistically predictable and the actual rate of perinatal mortality was 151 child deaths in 1987 and 712 child deaths between 1988 and 1991. Thus, a total of 863 children in just these three regions died before, during or shortly after birth as a result of radioactive fallout from Chernobyl.<sup>31</sup>

In Belarus, perinatal mortality in the heavily contaminated Gomel region in 1987 was higher than in the other areas of Belarus, albeit not significantly due to the low number of cases.<sup>32</sup> Körblein, however, points out that, in the first half of the 1990s, perinatal mortality in the Gomel area was about 30 % higher than in other rural areas of Belarus. This is possibly attributable to the delayed effect of radioactive isotopes absorbed during puberty. The analysis showed that between 1987 and 1998, 431 more children died in the Gomel area than would have been expected according to data for comparable areas.<sup>33</sup> This is consistent with data on changes in perinatal mortality in Germany following above-ground nuclear testing in the 1950s and 60s.

Kulakov et al. found that perinatal mortality in the Ukrainian district Polesky–Kiev increased from 15.1 to 17.8 percent between 1987 and 1989. The greatest increase of 37.4 % was in the first year. Stillbirths accounted for most of the deaths.

## 7.5 Stillbirths and the rise in perinatal mortality across Europe

In 1987 there was an increase in the stillbirth rates in a number of European countries (Austria, Denmark, Germany, Italy, Norway, Switzerland, Poland, Hungary and Greece). In the period 1986 to 1992 this resulted in around 3,200 additional stillbirths in these countries.<sup>34</sup>

Separate analyzes for Germany and Poland found the increase to be around 5 % more than for previous years.<sup>35 36</sup>

Of the Scandinavian countries, Finland was the hardest hit by Chernobyl.<sup>37</sup> A Finnish study showed there had been a drastic increase in the premature birth of children conceived during the first four months after Chernobyl, in areas where the dose rate and soil contamination with cesium 137 were highest.<sup>38</sup> Scherb and Weigelt also analyzed the stillbirth incidence in Finland. For the period 1977 to 1994, they found there was a highly significant watershed in 1987.

30 Körblein A (2003): Strontium fallout from Chernobyl and perinatal mortality in Ukraine and Belarus. *Radiats Biol. Radioecol.* 2003 Mar-Apr; 43(2):197–202. *Strahlentelex*, 398–399/2003, p. 5.

31 Körblein A (2005): Studies of pregnancy outcome following the Chernobyl accident. Unpublished.

32 Körblein A (2003): Säuglingssterblichkeit nach Tschernobyl. Report No. 24/2003 of the Otto Hug Strahleninstituts, pp. 6–34.

33 Körblein A (2005): Studies of pregnancy outcome following the Chernobyl accident. Unpublished.

34 Scherb H, Weigelt E (2003): *Environ Sci & Pollut Res • Special Issue 1* (2003): 117 – 125

35 Scherb H, Weigelt E (2003): Zunahme der Perinatalsterblichkeit, Totgeburten und Fehlbildungen in Deutschland, Europa und in hoch belasteten Gebieten deutschen und europäischen Regionen nach dem Reaktorunfall von Tschernobyl im April 1986. Report No. 24/2003 of the Otto Hug Strahleninstituts, pp. 35–75.

36 <http://www.alfred-koerblein.de/chernobyl/deutsch/index.htm>

37 Körblein A (2008): Säuglingssterblichkeit nach Tschernobyl in skandinavischen Ländern, *Strahlentelex* 510–511, 2008

38 Harjulehto T, Aro T, Rita H, Rytömaa T, Saxén L (1989): The accident at Chernobyl and outcome of pregnancy in Finland. *Br Med J.* 1989; 298: 995–997. *Strahlentelex* 178–189/1994, p.7, Neugeborenensterblichkeit nach Tschernobyl.



## 7.6 Gender ratio shift

The gender ratio, i.e. the rate of male to female births, in a given region is normally constant. In the Caucasian region it is about 106 boys to 100 girls. Every shift is an indicator of a possible stress factor for the mother or the unborn child during pregnancy. As ionizing radiation causes genome and cell mutation, it can also trigger early miscarriages and therefore influence the gender ratio at birth.

An analysis by Scherb of the gender ratio in Europe showed there was a significant correlation between the level of Chernobyl radioactive fallout and the reduction in the number of female newborns. He calculated that in Europe in the wake of the Chernobyl disaster, approximately 800,000 fewer girls were born and had probably already been killed by the effects of radiation at the embryonic or fetal stage, causing the pregnancy to terminate by early miscarriage (sometimes almost certainly unnoticed).<sup>39</sup>

Since then, Seit and Voigt have investigated numerous other nuclear locations (nuclear power plants, nuclear waste disposal sites) and found the same trend: fewer female newborns contingent on the respective level of radiation exposure, even if this was below 1 mSv.<sup>40 41</sup>

## 7.7 Chromosome aberrations

Although chromosomal aberrations seldom occur spontaneously, they become more frequent with ionizing radiation. Dicentric chromosomes, which are typical radiation-induced aberrations, have been found in survivors of the atomic bombings of Hiroshima and Nagasaki, in the aftermath of nuclear accidents and following vocational radiation exposure.

Chromosome defects in lymphocytes can be used as quantitative biological indicators to estimate body dose. This is done by the microscopic examination of lymphocytes in a blood smear for dicentric or ring chromosomes. Fluorescent microscopy is also applied in the same way to look for translocations. Translocation is the reciprocal rearrangement of chromosome segments – genetic material is transferred from the original chromosome to a ‘false’ chromosome. Whereas permanent chromosome aberrations are not necessarily synonymous with illness, they are, however, an indication of the scale of cell damage. Damage to the ovum or sperm increases the risk of developing cancer or a genetic defect.

Proof of an increase in chromosome aberrations is provided by data on contaminated populations in the registration and research centers of the three former Soviet republics affected by the Chernobyl nuclear disaster. They show that not only the highly contaminated groups such as liquidators are affected, but also travelers who stayed only briefly in a contaminated area in the days after the accident. Yablokov provides a summary of the findings on chromosomal damage.<sup>42</sup> A few examples of the numerous studies are given below.

At the international Physicians for Chernobyl conference, Schmitz-Feuerhake and Pflugbeil presented calculations from studies on the chromosome aberrations found in evacuees from the 30-km zone and the heavily contaminated Gomel area<sup>43</sup> (cf. Table 7-3 on the following page).

39 Scherb H, Voigt K (2007): Trends in the Human Sex Odds at Birth in Europe and the Chernobyl Nuclear Power Plant accident; in: *Reprod. Toxicol* 2007 Jun;23(4):593-9. Epub 2007 Apr 5, [http://www.strahlentelex.de/Stx\\_10\\_558\\_S01-04.pdf](http://www.strahlentelex.de/Stx_10_558_S01-04.pdf)

40 Scherb H, Voigt K (2011): The human sex odds at birth after the atmospheric atomic bomb tests, after Chernobyl, and in the vicinity of nuclear facilities. *Environ Sci Pollut Res Int* 18(5) 697- 707.

41 Scherb H, Voigt K, Kusmierz R (2015): Ionizing radiation and the human gender proportion at birth-A concise review of the literature and complementary analyzes of historical and recent data. *Early Hum Dev* 91(12) 841-850.

42 Yablokov AV, Nesterenko VB, Nesterenko AV (2009): Chernobyl - Consequences of the Catastrophe for people and environment; *Annals of the New York Academy of Sciences*, Vol 1181; 2009, pp. 65-71

43 Schmitz-Feuerhake I, Pflugbeil S (2006): How reliable are the dose estimates of UNSCEAR for populations contaminated by Chernobyl fallout? A comparison of results by physical reconstruction and biological dosimetry



Region	Examinees	Date of examination	Methods	Result Average increase + Particularities	Author	Comments
Evacuees from Pripjat and vicinity	43 adults	1986	Dic	18-fold, no over-dispersion	Maznik et al. 1997	Author's findings 430 mSv
Evacuated zone	60 children	1986	Dic+cr	15-fold, no over-dispersion	Mikhalevich et al. 2000	Author's findings 400 mSv
Evacuees from Pripjat and vicinity	102 adults, 10 children	1987–2001	Dic+cr	Maximum 18-fold in 1987, then decline but still increased	Maznik 2004	Author's findings 360 mSv
Evacuated zone	244 children	1991	Dic+cr	circa 100-fold *)	Sevan'kaev et al. 1993	Dosis calculation acc. to IAEA (1991) 1-8 mSv
Evacuees from Pripjat	24 children	1991–1992	Dic	circa 3-fold *)	DeVita et al. 2000	
Evacuees from 30-km zone	12 adults	1995	Dic+cr	7–10 fold *)	Pilinskaya et al. 1999	
Residents of the evacuation zone	33 non- evacuees, adults	1998-1999	Dic+cr	5.5-fold	Bezdrobnaia et al. 2002	

**Table 7-3**

Bio-dosimetry in evacuees from the 30-km zone  
**Dic** dicentric chromosomes, **cr** ring chromosomes  
 \*) Author's estimate



Examinees	Date of examination	Methods	Result Average increase & particularities	Author	Comments
43 pregnant women 18 infants	1986–1987	Dic+cr	5-fold 40-fold	Feshenko et al. 2002	
8 persons	1988–1990	Dic+cr	circa 40-fold *)	Serezhenkov et al. 1992	Compare with ESR
330 healthy adults	1988–1990	Dic+cr, Tralo, FISH	15-fold 6.5-fold	Domracheva et al. 2000	
46 patients with hematological cancerous condi- tions	1988–1990	Dic+cr, Tralo, FISH	(6-18)-fold (6.5-16)-fold	Domracheva et al. 2000	
35 adults	1990	Dic	circa 30-fold *) over-dispersion; 2 multi-aberrant cells	Vershaeve et al. 1993	
36 children	1994	Dic	(3.2-8)-fold	Barale et al. 1998	
20 children	1996	Tralo, FISH	3-fold significant	Scarpato et al. 1997	Controls from Pisa
70 children	1996	Dic+cr	18-fold	Gemignani et al. 1999	10 years after the accident

Table 7-4

Bio-dosimetry inhabitants of Gomel and Gomel area

**Dic** dicentric chromosomes, **cr** ring chromosomes,  
**Tralo** translocations

\*) Authors' estimate

The radiation dose to which each subject must have been exposed can be calculated on the basis of the number of chromosome aberrations. In calculating dosage, Schmitz-Feuerhake and Pflugbeil not only drew on cytogenic studies, but also on the results of work by Imanaka and Koide, who put the average external dose alone at between 20 and 320 mSv (cf. Table 7-4).

The phenomena of over-dispersion and the occurrence of multi-aberrant cells are an indication of exposure to alpha radiation, e.g. by plutonium (cf. Table 7-5).



Region	<sup>137</sup> Cs kBq/m <sup>2</sup>	Examinees	Date of examination	Methods	Findings average increase & particularities	Author	Remarks
Ukraine / Lugyny Malahovka region		130 children	1988–1990	Dic+cr	Increase up to 6.6 times in 1990	Eliseeva et al. 1994	Effect cannot be accounted for due to <sup>137</sup> Cs
Russia/Kaluga Region Mladenik Ogor	140 43	17 adults 16 adults	1989	Dic+cr	ca. 5 times *) ca. 2 times *)	Bochkov et al. 1991	
Russia/Province Bryansk Clynka Yordevka Klincy Russia/Kaluga Region Uljanovo Chicdra	633 444 230 140 100	61 adults 432 adults 170 adults 666 adults 548 adults	1989–1998	Dic+cr	7 times 1.5 times 2 times 4 times 2.5 times	Sevan'kaev 2000	2 multi-aberrant Zellen  27 multi-aberrant cells
Kaluga-Bryansk Region Province Uljanova Province Chicdra	200 100	333 children & juveniles 407 children & juveniles	1989–1998 1990–2003	Dic+cr	3 times 3.7 times no increase	Sevan'kaev et al. 2005	Physical esti- mates (to 2001) 11.4 mSv and 6.7 mSv
Ukraine Region	> 550	6 adults	1991	Dic	ca. 5 times*)	Ganina et al. 1994	
Bryansk and Provinz Bryansk	> 550	1300	1992	unstable; stable	5 % > 400 mSv 1 % 1000 mSv	Vorob'ev et al. 1994	Physical esti- mates 17-35 mSv, multi-aberrant cells
Provinz Bryansk Mirnye	> 1100	100 adults	1993	cr	4 times, 6 multiaberrant cells	Salomaa et al. 1997	Controls by Krasnye Rog < 37 kBq/m <sup>2</sup> (Dics 0.43%, multi-aberrant cells 2)

**Tabelle 7–5:**

Biological dosimetry in highly contaminated regions > 37 kBq/m<sup>2</sup>

**Dic** dicentric Chromosomen, **cr** Ringchromosomen

\*) Abschätzung durch die Autoren



Some of these studies are briefly examined in more detail below. In a study with 87 children Stepanova et al. found a significant increase in chromosome aberrations, not only among children of survivors of acute radiation syndrome, but also among children evacuated from the Pripjat region, compared to a control group. (Group 1: children from survivors of acute radiation syndrome born 1987–1988; Group 2: children evacuated from the Pripjat region born 1983–1985; Control group: children from non-contaminated areas).<sup>44</sup>

Over a period of 14 years Pilinskaya et al. examined various severely contaminated groups of Chernobyl victims (survivors of acute radiation syndrome, liquidators and persons from contaminated areas) and found substantial increases in chromosome aberrations in all groups. They also established that even relatively small radiation doses could trigger chromosome aberrations.<sup>45</sup>

Baleva et al. described genetic instability as the result of lasting radiation exposure and the role of DNS repair mechanisms in respect of different diseases, such as cancer or malformations in children.<sup>46</sup> From a total population of 104,555 Russian children, 608 were selected from contaminated areas of Bryansk Province. They had either been evacuated or resettled or were the children of liquidators. Cesium soil contamination in the region was above 1,665 kBq/m<sup>2</sup>. The control group was a cohort of children from areas of Bryansk Province where there was no soil contamination. Group 1 comprised children born prior to Chernobyl, Group 2: children contaminated in-utero and after (born 1987–1988); Group 3: children born 1988–1993; Group 4: children born 1995–2000. Compared to the control group, children from irradiated zones exhibited a significant increase in chromosome aberrations – dicentric and ring chromosomes, as well as translocations. A comparison of irradiated groups showed the rate of repair mechanisms in children born before 1986 to be higher. All children exposed to radiation in-utero or born after Chernobyl had considerably fewer repair mechanisms. The ability of their cells to adapt to radiation by means of repair mechanisms was rapidly exhausted. The accumulation of malformations, perinatal mortality and the increased cancer risk in the irradiated populations of all three former Soviet republics affected by Chernobyl are undoubtedly linked to the effects of chronic radiation exposure.

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44 Stepanova EI, Misharina JA (1997): Cytogenic effects in children born to participants in the cleanup of the Chernobyl accident consequences – acute radiation syndrome survivors and children evacuated from Pripjat (IAEA CN 67/19) [https://inis.iaea.org/search/search.aspx?orig\\_q=RN:29017301](https://inis.iaea.org/search/search.aspx?orig_q=RN:29017301)

45 Pilinskaia MA, Shemetun AM, Dybski SS, Dybskaia EB, Pedan LR, Shemetun EV (2001): The results of 14 year cytogenetic monitoring of priority follow-up groups of Chernobyl accident victims in: Vest Ross Akad Med Nauk. 2001;(10):80-4.

46 Sipyagina AE, Baleva LS, Karakhan NM, Sukhorukov VS (2015): Role of Postradiation Genome Instability in Evaluating the Development of Radiation-Determined Pathology in Children After the Chernobyl; In AASCIT Journal of Medicine 2015; 1(2): 18-22 Accident and Investigation









## **Part B:** 5 years living with Fukushima

Summary of the health's effects of the nuclear disaster



## Introduction



On March 11, 2016, Japan and the world will commemorate the beginning of the Fukushima nuclear catastrophe five years ago. Enormous amounts of radioactive substances entered the environment due to the meltdown of 3 nuclear reactors at the Fukushima Daiichi nuclear power plant, several explosions breaching the containment vessels, fires, leaks and the controlled release of radioactive discharge. More than 200,000 people were evacuated from Fukushima Prefecture to makeshift camps, where about one hundred thousand still live as refugees today. But the effects of the nuclear catastrophe extend far beyond the borders of the prefecture. Since the onset of the disaster, millions of people have been exposed to elevated doses of radiation – mostly in areas with higher nuclear fallout, and people in less contaminated parts of the country have to deal with radioactively contaminated drinking water and food.

International Physicians for the Prevention of Nuclear War (IPPNW), is well aware of the close links between the civilian and military nuclear industries and of the risks inherent in both. We are committed to a scientific assessment of the health effects of the entire nuclear chain – from uranium mining to nu-

clear waste. In this respect, civilian nuclear disasters such as Three Mile Island, Chernobyl or Fukushima provide particularly striking examples of the nuclear industry's harmful impact on public health. As physicians and scientists we must ask the following questions to fully examine the Fukushima nuclear disaster:

- How could this disaster occur?
- How much radioactivity was released?
- How will it affect the environment?
- What health consequences are to be expected in the affected population?

These are the issues we aim to address with this publication.



of 200,000 people were ordered to leave their homes.<sup>1</sup> Naoto Kan, Japan's Prime Minister at the time, later stated that the 30 million people of the Tokyo Metropolitan area had been spared radioactive contamination "by a hair's breadth".

The tsunami generated by the earthquake caused loss of the emergency diesel electric generators. This failure of backup electric power to keep cooling water circulating to the reactors and spent fuel pools, resulted in core meltdowns in reactor units 1, 2 and 3. The power plant operator, Tokyo Electric Power Company (TEPCO), began to vent steam from the reactor buildings to reduce the increasing pressure in the reactors to prevent larger explosions. But the steam also transported large amounts of radioactive particles into the atmosphere – a risk believed at the time to be the lesser evil. Despite this, there were numerous explosions in the three reactors.

Although Japan's disaster management contingency plans for earthquakes and tsunamis are among the best in the world, the Japanese authorities were hopelessly overwhelmed by three nuclear meltdowns and the release of radioactive clouds. The first evacuation order was given for a 3 km zone on the evening of March 11. On the evening of March 12, this was extended to a 12 km zone around the stricken reactors. By this time, the first hydrogen explosion had already destroyed reactor 1. A total

3 Wagner W. „Ex-Premier Kan über Fukushima-Katastrophe: ‚Die Frage war, ob Japan untergeht‘“. Spiegel Online, 09.10.15. <http://www.spiegel.de/politik/ausland/ex-premier-ueber-fukushima-die-frage-war-ob-japan-untergeht-a-1056836.html>



the fuel rods in reactor 1 melted, 70-100% of the fuel rods melted in reactor 2 and 63% of the fuel rods melted in reactor 3.<sup>4,5</sup> Cooling water was contaminated with radiation in the reactor before flowing back into the sea in large quantities via groundwater aquifers.

On March 25, people living within a 30 km radius of the nuclear power plant were asked to leave their homes and the contaminated area voluntarily. On April 12, the nuclear meltdown in Fukushima was upgraded to severity level 7 on the International Nuclear Event Scale INES, the highest possible rating, previously only assigned to the Chernobyl disaster. On April 22, the Japanese government finally extended their evacuation recommendation to cover the municipalities of Katsurao, Namie, Iitate and parts of Kawamata and Minamisoma, within a 50 km area around the wrecked reactor buildings.

At the time of the accident, the authorities decided not to distribute iodine tablets that would have prevented uptake of damaging radioactive iodine-131 into the thyroid, leaving the population unprotected. The World Health Organization (WHO) criticized this omission in their Fukushima Report, stating that the anticipated incidence of thyroid cancer among the general public had increased because this vital preventive measure had been neglected.<sup>6</sup> In their official report of June 2012, the National Diet of Japan Nuclear Accident Independent Investigation Committee (NAIIC) found that the Fukushima nuclear accident was not simply the result of a natural disaster, but was profoundly man-made.



*“The commission concludes that the situation continued to deteriorate because the crisis management system of the Kantei, [Prime Minister’s office] the regulators and the other responsible agencies did not function correctly. Residents’ confusion over the evacuation stemmed from regulators’ negligence and failure over the years to implement adequate measures against a nuclear accident, as well as a lack of action by previous governments and regulatory authorities focused on crisis management. The crisis management system that existed for the Kantei and the regulators should protect the health and safety of the public, but it failed in this function.”<sup>7</sup>*

4 Japanese Atomic Information Forum (JAIF). “TEPCO: Melted fuel ate into containment vessel”. Earthquake Report No. 278, 01.12.11. [www.jaif.or.jp/english/news\\_images/pdf/ENGNEWS01\\_1322709070P.pdf](http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1322709070P.pdf).

5 Kumai H. „Researchers: More than 70% of No. 2 reactor’s fuel may have melted“. Asahi Shimbun, 27.09.15. <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201509270023>

6 World Health Organisation (WHO). “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami”. 23.05.1212, p.49. [http://whqlibdoc.who.int/publications/2012/9789241503662\\_eng.pdf](http://whqlibdoc.who.int/publications/2012/9789241503662_eng.pdf)

7 The National Diet of Japan. „The official report of The Fukushima Nuclear Accident Independent Investigation Commission of the National Diet of Japan“. 05.07.12, p 18–19. [http://www.nirs.org/fukushima/naaic\\_report.pdf](http://www.nirs.org/fukushima/naaic_report.pdf)



Finally, there are frequent leaks at the power plant itself – particularly from the cracked underground vaults of the reactor

6 Makinen, Julie, "After 4 years, Fukushima cleanup remains daunting, vast." March 3, 2015. <http://www.latimes.com/world/asia/la-fg-fukushima-nuclear-cleanup-20150311-story.html>



buildings and from containers holding radioactive contaminated water, which were hastily welded together and already exhibit numerous defects. According to TEPCO, 300 tons of radioactive wastewater still flow unchecked into the ocean every day – more than 500,000 tons since the beginning of the nuclear disaster.<sup>7</sup> The amount and composition of radioactive isotopes fluctuate widely so that it is not possible to ascertain the actual effect this radioactive discharge will have on marine life. What is clear, however, is that increasing amounts of strontium-90 are being flushed into the sea. Strontium-90 is a radioactive isotope that is incorporated into living organisms in a similar way to calcium – in bones and teeth. As it travels up the marine food chain, it undergoes significant bioaccumulation and, because of its long biological and physical half-lives, will continue to contaminate the environment for the next hundreds of years.<sup>8</sup>

An estimated 23% of nuclear fallout from the Fukushima disaster occurred over mainland Japan.<sup>9</sup> The most severely affected regions are located in the eastern half and center of Japan's main island Honshu. The island's west coast, however, remained largely unaffected by nuclear fallout due to the island's mountainous topography that, which forms a meteorological divide. Increased dose rates were also found in the far south and north of Japan, however.<sup>10</sup> People throughout the country came into contact with radioactive isotopes – via radioactive air, water and contaminated food. For this reason it is crucial to consider not only the radioactive exposure of the population in Fukushima and the neighboring prefectures Chiba, Gunma, Ibaraki, Iwate, Miyagi and Tochigi, but also that of the more distant prefectures affected by nuclear fallout. On March 15 and 21, for example, high amounts of fallout not only landed in Tokyo, but also in the prefectures of Kanagawa, Saitama, and Shizuoka.<sup>11</sup> Tea plantations in Shizuoka Prefecture, 400 km south of Fukushima, and 140 km from Tokyo, were so heavily contaminated that the 2011 tea harvest had to be withdrawn from the market.<sup>12</sup> The following map created by a researcher

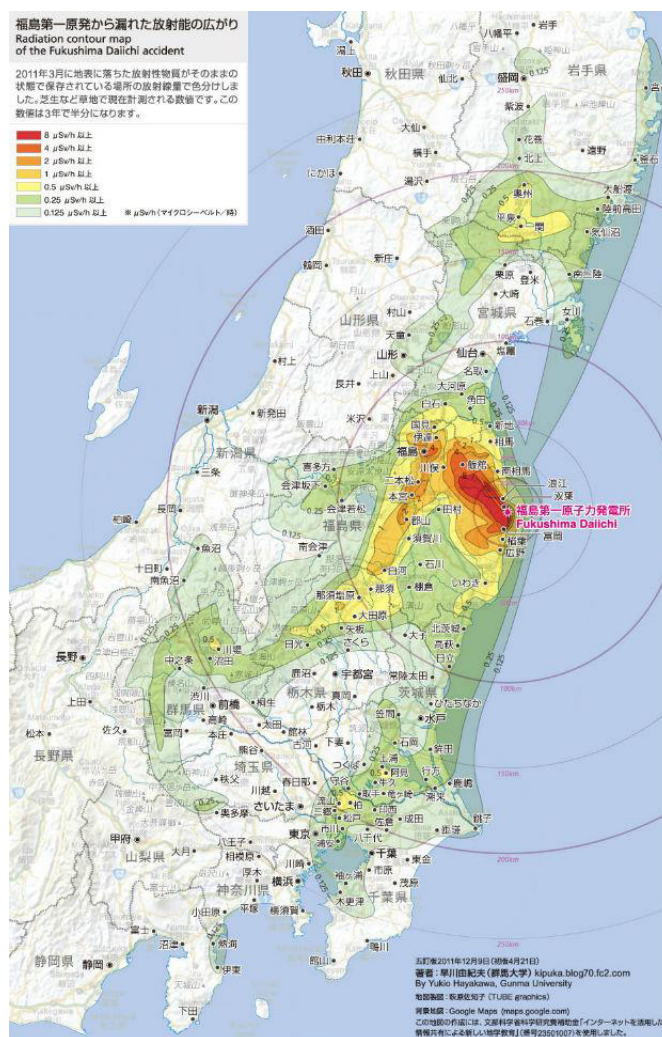


Figure 2-1

Map of radioactive contamination in northern Japan

at Gunma University shows the radioactive contamination of Honshu Island at the end of 2012.

There are principally five pathways by which humans come into contact with radioactivity during and after a nuclear disaster:

- » External radiation exposure to 'cloudshine': direct irradiation from the radioactive cloud. This can involve all types of radioisotopes, such as xenon-133, iodine-131 or cesium-137.
- » External radiation exposure to 'groundshine': is direct irradiation from terrestrial radioactive particles, particularly gamma emitters like barium-137m, a decay product of cesium-137.
- » External radiation via superficial contamination of skin, hair and clothing, particularly by beta emitters like cesium-137, strontium-90 or iodine-131. Beta radiation is

7 Tsukimori O, Hamada K. "Japan government: Fukushima plant leaks 300 tpd of contaminated water into sea | Reuters". Reuters, 07. 08.13. <http://www.reuters.com/article/2013/08/07/us-japan-fukushima-water-idUSBRE9760AU20130807>.

8 Kiger PJ. "Fukushima's Radioactive Water Leak: What You Should Know". National Geographic, 09.08.13. <http://news.nationalgeographic.com/news/energy/2013/08/130807-fukushima-radioactive-water-leak/>

9 Evangelio N et al. "Global deposition and transport efficiencies of radioactive species with respect to modelling credibility after Fukushima (Japan, 2011)". J Environ Radioact. 2015 Nov;149:164-75. <http://www.ncbi.nlm.nih.gov/pubmed/26254209>

10 Hirose K. "Fukushima Dai-ichi nuclear power plant accident: summary of regional radioactive deposition monitoring results". J. Environ. Radioact. 111, 13-17. <http://dx.doi.org/10.1016/j.jenvrad.2011.09.003>

11 Priest ND. "Radiation doses received by adult Japanese populations living outside Fukushima Prefecture during March 2011, following the Fukushima 1 nuclear power plant failures". J Environ Radioact 2012 Dec; 114:162-170. [www.ncbi.nlm.nih.gov/pubmed/22770771](http://www.ncbi.nlm.nih.gov/pubmed/22770771).

12 Shizuoka Prefectural Government. "Test Results for Radioactivity on Tea Produced in Shizuoka Prefecture". 20.05.11. [www.pref.shizuoka.jp/sangyou/sa-340/20110520\\_test\\_results\\_radio\\_activity.html](http://www.pref.shizuoka.jp/sangyou/sa-340/20110520_test_results_radio_activity.html).



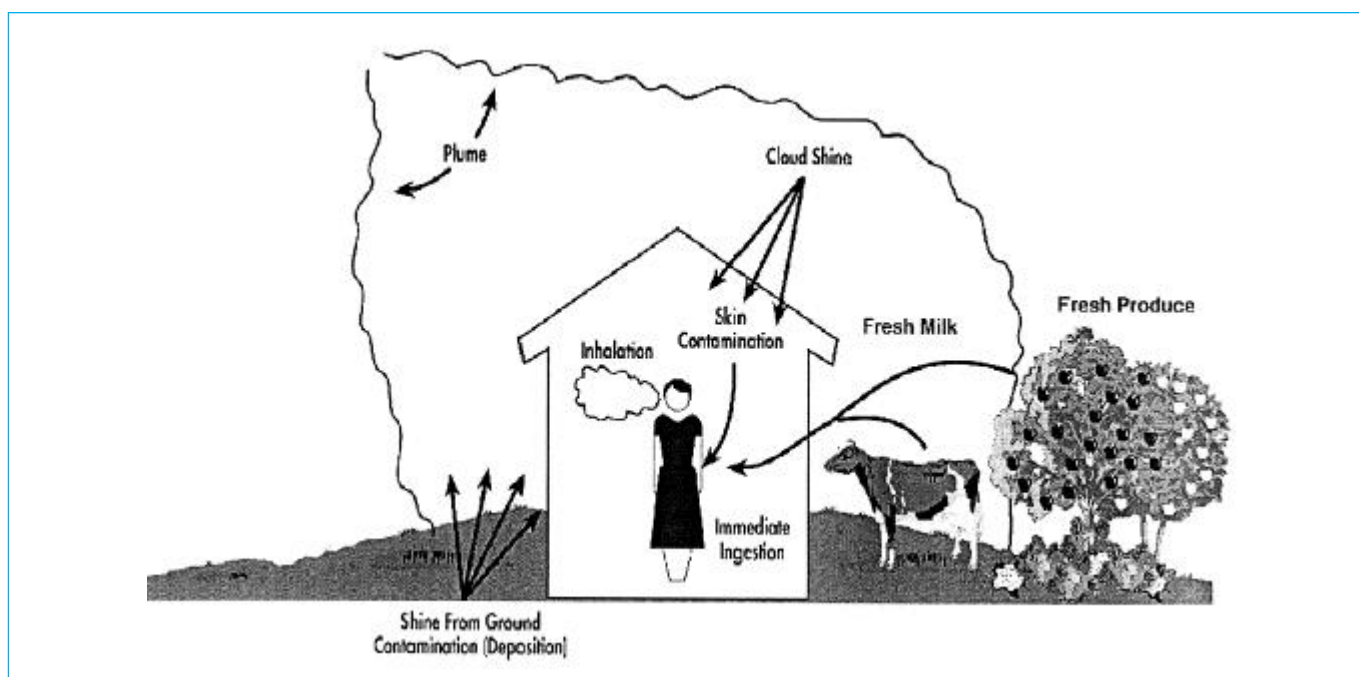


Figure 2-2

Illustration showing the different radiation exposure pathways

blocked by clothing but with direct contact can penetrate the skin.

- » Internal radiation exposure can be due to inhaled radioactive particles, particularly alpha emitters like plutonium, or beta emitters like cesium-137, strontium-90 and iodine-131.
- » Internal radiation can be due to exposure to radioactive particles ingested with food or drinking water, particularly alpha emitters like plutonium, or beta emitters like cesium-137, strontium-90 and iodine-131

In order to calculate individual and collective radiation doses it is therefore important to know not only the total amount of radioactive emissions, but also the radiation concentrations in air, water and food. The following chapters will take a look at the available data regarding emissions and contamination.

## 2.1 Atmospheric emissions

Radioactive isotopes were repeatedly released into the atmosphere with the smoke and fumes from explosions and the fire in the spent fuel pool of reactor 4, through the evaporation of cooling-water, as well as through the deliberate venting of the reactors. Even today, the magnitude of the total emissions, also referred to as 'source term' in scientific literature, is just as contentious as in the Chernobyl disaster. While calculations by scientists from independent institutions indicate higher levels, the World Health Organization (WHO) and the United Nations Sci-

entific Committee on the Effects of Atomic Radiation (UNSCEAR) cite the much lower numbers propagated by the Japanese Atomic Energy Agency JAEA.<sup>13</sup>

Stohl et al. at the Norwegian Institute for Air Research (Norsk Institutt for Luftforskning – NILU) calculated that in the period between March 12 and March 19, the Fukushima power plant released 35.8 PBq of cesium-137 (confidence interval CI 23.3 – 50.1).<sup>14</sup> Japanese Atomic Energy Agency (JAEA), however, published significantly lower cesium-137 emissions of only 13 PBq.<sup>15</sup>

It appears reasonable to look for a reliable meta-analysis of all available source term calculations. The most extensive summary of all emission estimates is the study by Aliyu et al, which compares the data from 14 different scientific papers and sub-

13 Terada H et al. "Atmospheric discharge and dispersion of radionuclides during the Fukushima Dai-ichi Nuclear Power Plant accident. Part II: verification of the source term and analysis of regional-scale atmospheric dispersion". J Environ Radioact 2012 Oct; 112: 141–154. [www.sciencedirect.com/science/article/pii/S0265931X12001373](http://www.sciencedirect.com/science/article/pii/S0265931X12001373).

14 Stohl A et al. "Xenon-133 and cesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition". Atmos. Chem. Phys. Discuss. 11, Nr. 10 (20.10.11): 28319–28394.

15 Terada H et al. "Atmospheric discharge and dispersion of radionuclides during the Fukushima Dai-ichi Nuclear Power Plant accident. Part II: verification of the source term and analysis of regional-scale atmospheric dispersion". J Environ Radioact 2012 Oct; 112: 141–154. [www.sciencedirect.com/science/article/pii/S0265931X12001373](http://www.sciencedirect.com/science/article/pii/S0265931X12001373).



jects them to critical analysis.<sup>16</sup> The authors estimate the emissions of the major radioisotopes as follows:

Radioisotope	Amount released	Sources
Iodine-131	150-160 PBq	Masson 2011
Cesium-137	12-55 PBq	IRSN 2012, Masson 2011, Kantei 2011 , Stohl 2012
Strontium-90	0.01-0.14 PBq	Povinec 2012

**Table 2.1**

Estimated atmospheric emissions following the Fukushima disaster

The way emissions are calculated is highly relevant for estimating radiation doses and therefore for predicting health effects in the affected population. It should go without saying that, in the interests of public health, the most trustworthy and reliable data should be used if the objective is effective protection from the impact of radiation. It is therefore incomprehensible that, instead of also drawing on data from independent and neutral institutions, the WHO and UNSCEAR apply the lowest estimates possible. This exclusive reliance on JAEA data is astonishing, given that the Japanese parliament accused precisely this agency of contributing to the catastrophe through corruption, collusion and negligent conduct. Citing the JAEA as a neutral source in this matter should therefore be out of the question.

Furthermore, all release amount estimates only cover the first three days after the onset of the nuclear disaster, despite the release of further radioactivity from the reactors every day since – mainly through evaporation of radioactive contaminated cooling water. At this point it must also be mentioned that, in addition to the well-known radioactive substances iodine-131, cesium-137 and strontium-90, short-lived radioisotopes like iodine-133, cesium-134 and strontium-89 were also released – in the case of radioactive cesium for example, the ratio of cesium-134 to cesium-137 is 1:1. This means, release amounts given for cesium-137 only constitute half of the actually released relevant substances. Furthermore, a large number of radioactive particles, whose effects on human health are not sufficiently known, were also emitted. According to Japanese government sources, relevant amounts of the following substances

were released during the nuclear disaster: plutonium-239 and -240, barium-140, tellurium-127m, tellurium-129m, tellurium-131m, tellurium-132, Ruthenium-103, ruthenium-106, zirconium-95, cerium-141, cerium-144, neptunium-239, yttrium-91, praseodymium-143, neodymium-147, curium-242, iodine-132, iodine-135, antimony-129, molybdenum-99 and xenon-133.<sup>17</sup> Although they were found in groundwater, sediment and soil samples, these substances are not included in JAEA's emission estimates.<sup>18</sup> By restricting emission estimates to JAEA data, both WHO and UNSCEAR may be systematically underestimating the health effects.

Finally, not only the total amounts of individual isotopes are relevant, but also their spatial distribution. Greek and French researchers found that most (approx. 76%) of the radioactive fallout occurred over the Pacific Ocean and about 23% over mainland Japan. As a result of radioactive fallout over the main island Honshu, the local dose rate rose from an average of 0.05  $\mu$ Sv/h before the onset of the nuclear disaster to levels 10 to 760 times higher, with values between 0.5 and 38  $\mu$ Sv/h.<sup>19</sup> The remaining 2% of radioactive emissions were distributed over Canada (40 TBq), the US (95 TBq), Greenland (5 TBq), the North Pole (69 TBq), Europe (14 TBq), especially Russia, Sweden and Norway, as well as other parts of Asia (47 TBq), particularly Russia, the Philippines and South Korea.<sup>20</sup> Although the fact that most fallout occurred over the ocean can be viewed as a blessing for the population of the surrounding prefectures, this by no means implies that their health is not endangered, as will be shown in the following chapters.

## 2.2 Discharge into the Pacific Ocean

Possibly the most serious ecological damage caused by the nuclear disaster was the radioactive contamination of the Pacific Ocean off the Japanese coast. In addition to radioactive fallout over the sea, a further factor in the radioactive pollution of the Pacific was the continuous discharge of contaminated water from the wrecked nuclear reactors. In the last three years, enormous volumes of water have been continuously pumped into the reactor buildings in an attempt to cool them. Large amounts

17 Nuclear Emergency Response Headquarters. "Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety – The Accident at TEPCO's Fukushima Nuclear Power Plant", 07.06.11. [www.iaea.org/newscenter/focus/fukushima/japan-report/](http://www.iaea.org/newscenter/focus/fukushima/japan-report/).

18 Zheng J et al. "Isotopic evidence of plutonium release into the environment from the Fukushima DNPP accident". *Sci. Rep.* 2 (08.03.12). doi:<http://www.nature.com/srep/2012/120308/srep00304/full/srep00304.html>.

19 Aliyu AS et al. « An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident". *Environ. Internat.* 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-El-2015.pdf>

20 Evangeliou N et al. "Global deposition and transport efficiencies of radioactive species with respect to modelling credibility after Fukushima (Japan, 2011)". *J Environ Radioact.* 2015 Nov; 149:164-75. <http://www.ncbi.nlm.nih.gov/pubmed/26254209>

16 Aliyu AS et al. "An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident". *Environ. Internat.* 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-El-2015.pdf>



of radioactive wastewater are generated every day as a result and are discharged into the sea and groundwater depots, or evaporate into the atmosphere. Regarding the question of the total extent of radioactive contamination of the Pacific Ocean, Kawamura et al. from JAEA calculated a total of 124 PBq of iodine-131 and 11 PBq of cesium-137. The JAEA study, however, only analyses the extremely short period between March 21 and April 6, 2011. With regard to the radioactivity released between March 11 and 21, i.e. the first ten days after the first explosion in the nuclear power plant, the authors write, “no direct release into the ocean was assumed before March 21 because the monitoring data were not available during this period.” A similar approach is applied to radioactive fallout after April 6, 2011 when the authors state “There is no information on the amounts released into the atmosphere after April 6. It was assumed, therefore, that the radioactive materials were not released into the atmosphere after April 6.”<sup>21</sup>

The continuing radioactive contamination of the ocean is therefore entirely ignored, despite the disclosure by the operator TEPCO that 300 tons of contaminated wastewater were discharged into the sea every day. Researchers from the French atomic agency IRSN estimated that between March and July of 2011 the amount of cesium-137 released into the Pacific amounted to 12-41 PBq.<sup>22</sup> The majority of studies also fail to include strontium-90 emissions, which were also released into the ocean in significant quantities and now pose an additional hazard to the marine food chain. An exception is the research group around Povinec from the University of Bratislava, which calculated total emissions of strontium-90 into the Pacific to be 0.1-2.2 PBq.<sup>23</sup>

Radioisotope	Amount released	Sources
Iodine-131	124 PBq	Kawamura 2011
Cesium-137	12-41 PBq	Bailly du Bois 2012
Strontium-90	0.1-2.2 PBq	Povinec 2012

**Table 2.2**

Estimated amounts discharged into the Pacific as a result of the Fukushima disaster

21 Kawamura H et al. “Preliminary Numerical Experiments on Oceanic Dispersion of 131-I and 137-Cs Discharged into the Ocean because of the Fukushima Daiichi Nuclear Power Plant Disaster”. *Journal of Nuclear Science and Technology*, 01.11.11. [www.tandfonline.com/doi/pdf/10.1080/18811248.2011.9711826](http://www.tandfonline.com/doi/pdf/10.1080/18811248.2011.9711826).

22 Bailly du Bois P et al. “Estimation of marine source-term following Fukushima Dai-ichi accident.” *J Environ Radioact.* 2012 Dec;114:2-9. <http://www.ncbi.nlm.nih.gov/pubmed/22172688>

23 Povinec PP et al. “Radiostrontium in the western North Pacific: characteristics, behavior, and the Fukushima impact”. *Environ Sci Technol.* 2012 Sep 18;46(18):10356-63. <http://www.ncbi.nlm.nih.gov/pubmed/22873743>

Despite such grave shortcomings in the calculation of total emissions into the Pacific Ocean and the ongoing discussion among scientists about realistic estimates, there is broad agreement that the Fukushima nuclear disaster already constitutes the most serious radioactive contamination of the world’s oceans in human history – comparable with the effects of atmospheric nuclear weapons tests and surpassing the radioactive fallout from Chernobyl or discharge from nuclear reprocessing plants like Sellafield and La Hague.<sup>24,25,26</sup>

IAEA analyzed seawater in the vicinity of the Fukushima nuclear power plant and published concentrations of 130,000 Bq/l for radioactive iodine and up to 63,000 Bq/l for radioactive cesium.<sup>27,28, 29</sup>

The nuclear industry tries to argue that dilution decreases the effect of radioactive waste on the marine environment and food chain. Radioactive particles do not disappear but are merely distributed over a larger area. This is dangerous for two reasons: first, as there is no safe threshold of ionizing radiation, the spread of radioactive contamination in the Pacific Ocean leads to a greater number of people being affected.<sup>30</sup> Even the smallest amount of radiation has the potential to cause disease if ingested with water or food. Second, the repeated distribution of long-lived radioisotope sediments, such as cesium-137 and strontium-90, which can also be stirred up by seaquakes or storms, leads to bioaccumulation of radioactivity in marine animals through the trophic cascade: numerous plankton samples taken from the coast of Fukushima Prefecture in 2012 already

24 Institut de Radioprotection et de Sûreté Nucléaire (IRSN). «Synthèse actualisée des connaissances relatives à l’impact sur le milieu marin des rejets radioactifs du site nucléaire accidenté de Fukushima Dai-ichi.» 26.10.11. [www.irsn.fr/fr/actualites\\_presse/actualites/documents/irsnn-impact\\_accident\\_fukushima\\_sur\\_milieu\\_marin\\_26102011.pdf](http://www.irsn.fr/fr/actualites_presse/actualites/documents/irsnn-impact_accident_fukushima_sur_milieu_marin_26102011.pdf).

25 Woods Hole Oceanographic Institution (WHOI). “Researchers Assess Radioactivity Released to the Ocean from the Fukushima Daiichi Nuclear Power Facility”. 06.12.11. [www.whoi.edu/page.do?pid=7545&tid=282&cid=123049&ct=162](http://www.whoi.edu/page.do?pid=7545&tid=282&cid=123049&ct=162).

26 IAEA. “Worldwide marine radioactivity studies (WOMARS) - Radionuclide levels in oceans and seas”. Januar 2005. [www-pub.iaea.org/MTCD/publications/PDF/TE\\_1429\\_web.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/TE_1429_web.pdf).

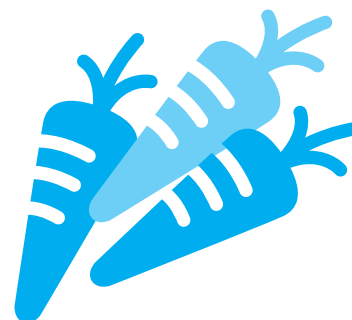
27 IAEA. “Fukushima Nuclear Accident Update”. 31.03.11. [www.iaea.org/newscenter/news/2011/fukushima310311.html](http://www.iaea.org/newscenter/news/2011/fukushima310311.html).

28 Weiss D. “Contamination of water, sediments and biota of the Northern Pacific coastal area the vicinity of the Fukushima NPP”. *Gesellschaft für Anlagen- und Reaktorsicherheit*, 31.10.11. [www.eurosafe-forum.org/userfiles/2\\_2\\_%20paper\\_marine%20environment\\_Fukushima\\_20111031.pdf](http://www.eurosafe-forum.org/userfiles/2_2_%20paper_marine%20environment_Fukushima_20111031.pdf).

29 Buesseler K et al. “Impacts of the Fukushima nuclear power plants on marine radioactivity”. *Environ Sci Technol.* 2011 Dec 1;45(23):9931-5. 01.12.11. [www.ncbi.nlm.nih.gov/pubmed/22013920](http://www.ncbi.nlm.nih.gov/pubmed/22013920).

30 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). “BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation”. 2006. [www.nap.edu/openbook.php?record\\_id=11340&page=8](http://www.nap.edu/openbook.php?record_id=11340&page=8).





exhibited increased concentrations of cesium-137.<sup>31</sup> Cesium-137 in plankton is ingested by smaller fish, which are eaten in turn by larger fish, which are then caught and sold on the fish markets in the Pacific region.<sup>32</sup> Thus, bone-seeking radioactive strontium with its long biological half-life as well as the radioactive isotopes of cesium endanger the population of coastal regions, as well as potential consumers of algae, seafood and fish from the affected zone. Especially in a country like Japan where these food products constitute a substantial part of the regular diet, the long-term radioactive contamination of seafood and algae is a significant health risk, as will be shown in the following chapter.

## 2.3 Radioactive contamination of food products

In addition to the source term, the radioactive contamination of food and drinking water is also important for calculating the total radioactive dose that a person is exposed to after a nuclear accident. As noted above, there simply is no 'safe threshold' of radioactivity in food and drinking water. Even the tiniest amounts of radioactivity have the potential to cause tissue damage, genetic mutations and cancer.<sup>33</sup> According to the German Society for Radiation Protection (GRS), it is estimated that a person is normally exposed to about 0.3 mSv per year by ingesting radionuclides in food and drink. This can be considered the 'permissible level' of radioactivity ingested with food and drink to avoid excessive health risks. In order not to exceed this level, the amount of radioactive cesium-137 should not exceed 8 Bq/kg in milk and baby formula and 16 Bq/kg in all other foods. Because of its short half-life, radioactive iodine should not be permitted in food at all. In Japan however, the permissible level of radioactive cesium-137 in milk and baby formula is 50 Bq/kg and 100 Bq/kg for all other foods. For radioactive iodine-131 the permissible level is 300 Bq/kg for milk and other liquids and 2,000 Bq/kg for solid foods.<sup>34</sup> Japanese threshold values are therefore stricter than those in the European Union (see table), but still not low enough to effectively prevent excessive health risks.

	Baby formula and milk products	Other foods
Japan	50 Bq/kg	100 Bq/kg
EU	370 Bq/kg	600 Bq/kg
IPPNW recommended	8 Bq/kg	16 Bq/kg

**Table 2.3**

Safe exposure levels for radioactive cesium (Cs-134/Cs-137)<sup>35</sup>

	Baby formula	Milk and other liquids	Solid foods
Japan	100 Bq/kg	300 Bq/kg	2,000 Bq/kg
EU	150 Bq/kg	500 Bq/kg	2,000 Bq/kg
IPPNW recommended	0 Bq/kg	0 Bq/kg	0 Bq/kg

**Table 2.4**

Safe exposure levels for radioactive iodine (especially iodine-131)<sup>36</sup>

The Fukushima nuclear meltdown caused major contamination of food and drinking water, particularly during the first months. According to the IAEA, nearly all vegetable and milk samples taken in Ibaraki and Fukushima Prefectures one week after the earthquake revealed levels of iodine-131 and cesium-137 above the radioactivity thresholds specified for food and drink in Japan.<sup>37</sup> Over the course of the following months, food was often found to be contaminated:

31 Aliyu AS et al. "An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident". Environ. Internat. 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-EI-2015.pdf>

32 Buesseler KO et al. "Fukushima-derived radionuclides in the ocean and biota off Japan." Proc. Natl. Acad. Sci. USA 109, 5984-5988. [www.pnas.org/content/109/16/5984.full.pdf](http://www.pnas.org/content/109/16/5984.full.pdf)

33 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). "BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation". 2006. [www.nap.edu/openbook.php?record\\_id=11340&page=8](http://www.nap.edu/openbook.php?record_id=11340&page=8)

34 Foodwatch. Kalkulierter Strahlentod". 20.09.11. [www.foodwatch.org/uploads/tx\\_abdownloads/files/foodwatch\\_report\\_kalkulierterStrahlentod\\_20110920.pdf](http://www.foodwatch.org/uploads/tx_abdownloads/files/foodwatch_report_kalkulierterStrahlentod_20110920.pdf)

35 Foodwatch. "Strahlen-Grenzwerte für Lebensmittel". 23.10.2012. <https://www.foodwatch.org/de/informieren/strahlenbelastung/mehr-zum-thema/eu-grenzwerte>

36 Foodwatch. "Strahlen-Grenzwerte für Lebensmittel". 23.10.2012. <https://www.foodwatch.org/de/informieren/strahlenbelastung/mehr-zum-thema/eu-grenzwerte>

37 IAEA. "Fukushima Nuclear Accident Update", 24.03.11. [www.iaea.org/newscenter/news/2011/fukushima240311.html](http://www.iaea.org/newscenter/news/2011/fukushima240311.html)



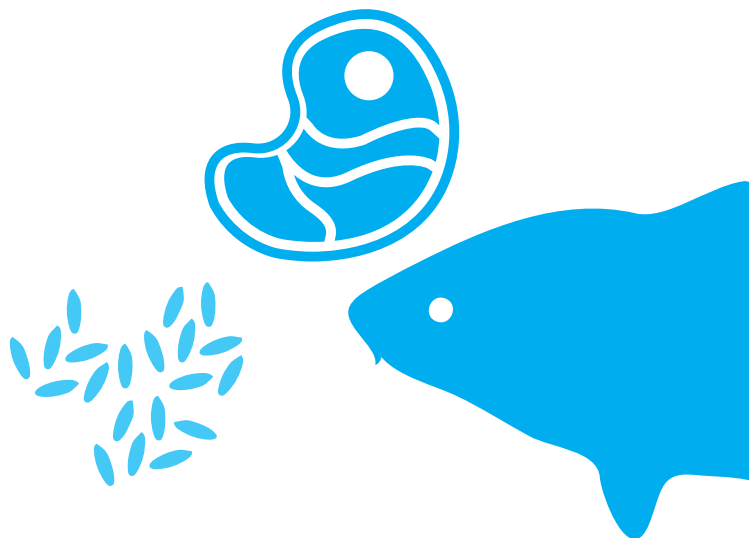
» **Fruit and vegetables:** A survey by the Japanese Science Ministry (MEXT), which was conducted outside the Fukushima Prefecture evacuation zone one week after the earthquake, found contaminated vegetables in the municipalities of Iitate, Kawamata, Tamura, Ono, Minamisoma, Iwaki, Date, Nihonmatsu, Shirakawa, Sukagawa, Ootama, Izumizaki and Saigou, some with iodine-131 concentrations as high as 2,540,000 Bq/kg and cesium-137 concentrations up to 2,650,000 Bq/kg. One month after the meltdowns, iodine-131 concentrations in some regions were still above 100,000 Bq/kg and cesium-137 above 900,000 Bq/kg.<sup>38</sup> In Ibaraki Prefecture, about 100 km south of the Fukushima plant, the prefectural government discovered spinach with radioactive iodine levels of up to 54,100 Bq/kg and radioactive cesium up to 1,931 Bq/kg. In addition to spinach, most other vegetable samples also contained radioisotopes, most notably mustard plants 1,200 Bq/kg iodine-131, parsley 12,000 Bq/kg iodine-131 and 2,110 Bq/kg cesium-137 and Shiitake mushrooms 8,000 Bq/kg cesium-137. Lesser amounts of radiation were found on lettuce, onions, tomatoes, strawberries, wheat and barley.<sup>39</sup>

» **Milk:** In the first weeks of the nuclear catastrophe, even the IAEA issued a warning not to drink milk from Fukushima Prefecture as it contained dangerous levels of iodine-131 and cesium-137.<sup>40</sup>

» **Beef:** The sale of beef was temporarily regulated when radioactivity levels in beef from Fukushima, Tochigi, Miyagi and Iwate Prefectures exceeded the permitted tolerance limits.<sup>41</sup>

» **Rice:** According to the Fukushima prefectural government, contaminated rice with up to 1,050 Bq/kg cesium was found in Onami District, as well as in the city of Date.<sup>42</sup> To this day, rice samples from Fukushima still regularly exceed official limits.<sup>43</sup>

» **Drinking water:** In spring of 2011, the IAEA warned that permissible levels of iodine-131 were exceeded in drinking water samples taken in the prefectures of Fukushima, Ibaraki, Tochigi, Gunma, Chiba and Saitama between March 17th and 23rd.<sup>44</sup> Even in the northern districts of Tokyo, tap water was found to contain 210 Bq/L iodine-131 and residents were warned not to drink it.<sup>45</sup>



» **Fish and seafood:** Even today, fish and seafood caught in the vicinity of the Fukushima Daiichi plant still contain high levels of cesium, more than 10,000 Bq/kg – in extreme cases even up to 740,000 Bq/kg.<sup>46,47,48,49</sup>

» **Tea:** According to the Shizuoka prefectural government, tea leaves harvested 400 km south of Fukushima contained 679 Bq/kg cesium-137. In June of 2011, radioactive green tea from Japan was discovered in France.<sup>50</sup>

38 Ministry of Education, Culture, Sports, Science and Technology (MEXT). "Important Information from Japanese Government, Readings of Dust Sampling". 18.04.11. [http://eq.wide.ad.jp/files\\_en/110418dust\\_1000\\_en.pdf](http://eq.wide.ad.jp/files_en/110418dust_1000_en.pdf)

39 Ibaraki Prefectural Government. "Ibaraki Prefecture Agricultural Products Test Results". 08.08.11. [www.pref.ibaraki.jp/bukyoku/seikan/koku-ko/en/links/agriculture\\_radiation.html](http://www.pref.ibaraki.jp/bukyoku/seikan/koku-ko/en/links/agriculture_radiation.html)

40 IAEA. "Fukushima Nuclear Accident Update". 20.03.11. [www.iaea.org/newscenter/news/2011/fukushima200311.html](http://www.iaea.org/newscenter/news/2011/fukushima200311.html)

41 TEPCO. "Current Status of Fukushima Daiichi Nuclear Power Station". 27.01.12. [www.tepco.co.jp/en/nu/fukushima-np/f1/images/f12np-gaiyou\\_e\\_3.pdf](http://www.tepco.co.jp/en/nu/fukushima-np/f1/images/f12np-gaiyou_e_3.pdf)

42 Japanese Atomic Information Forum (JAIF). "Cesium detected from more Fukushima rice". Earthquake Report No. 276, 29.11.11. [www.jaif.or.jp/english/news\\_images/pdf/ENGNEWS01\\_1322541949P.pdf](http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1322541949P.pdf)

43 Ministry of Health, Labour and Welfare. "Emergency monitoring test results". Juli 2015. <http://www.mhlw.go.jp/file/04-Houdouhappyou-11135000-Shokuhinzenbu-Kanshianzenka/0000091483.pdf>

44 IAEA. "Fukushima Nuclear Accident Update", 20.03.11. [www.iaea.org/newscenter/news/2011/fukushima200311.html](http://www.iaea.org/newscenter/news/2011/fukushima200311.html)

45 "Regarding the Limitation of Tap Water for Infants to Intake - Disaster Information 65th - Translation Edition". Multilingual Support Center for the Tohoku Earthquake out at Pacific Ocean, 23.03.11. <http://eqinfo.jp.net/?p=2999>

46 Weiss D. "Contamination of water, sediments and biota of the Northern Pacific coastal area the vicinity of the Fukushima NPP". Gesellschaft für Anlagen- und Reaktorsicherheit, 31.10.11. [www.eurosafe-forum.org/userfiles/2\\_2\\_%20paper\\_marine%20environment\\_Fukushima\\_20111031.pdf](http://www.eurosafe-forum.org/userfiles/2_2_%20paper_marine%20environment_Fukushima_20111031.pdf)

47 TEPCO. "Nuclide Analysis results of seafood, 20 km from Fukushima Daiichi nuclear power plant". 15.03.13. [http://www.tepco.co.jp/nu/fukushima-np/f1/smp/2013/images/fish\\_130315-j.pdf](http://www.tepco.co.jp/nu/fukushima-np/f1/smp/2013/images/fish_130315-j.pdf)

48 World Health Organization (WHO). "Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami". 23.03.12. [http://www.who.int/ionizing\\_radiation/pub\\_meet/fukushima\\_dose\\_assessment/en](http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/en)

49 TEPCO. "Analyzed result of nuclide in fish - Port in Fukushima Daiichi NPS". 18.08.15. [http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/fish01\\_150818-e.pdf](http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/fish01_150818-e.pdf)

50 Shizuoka Prefectural Government, "Test Results for Radioactivity on Tea Produced in Shizuoka Prefecture".



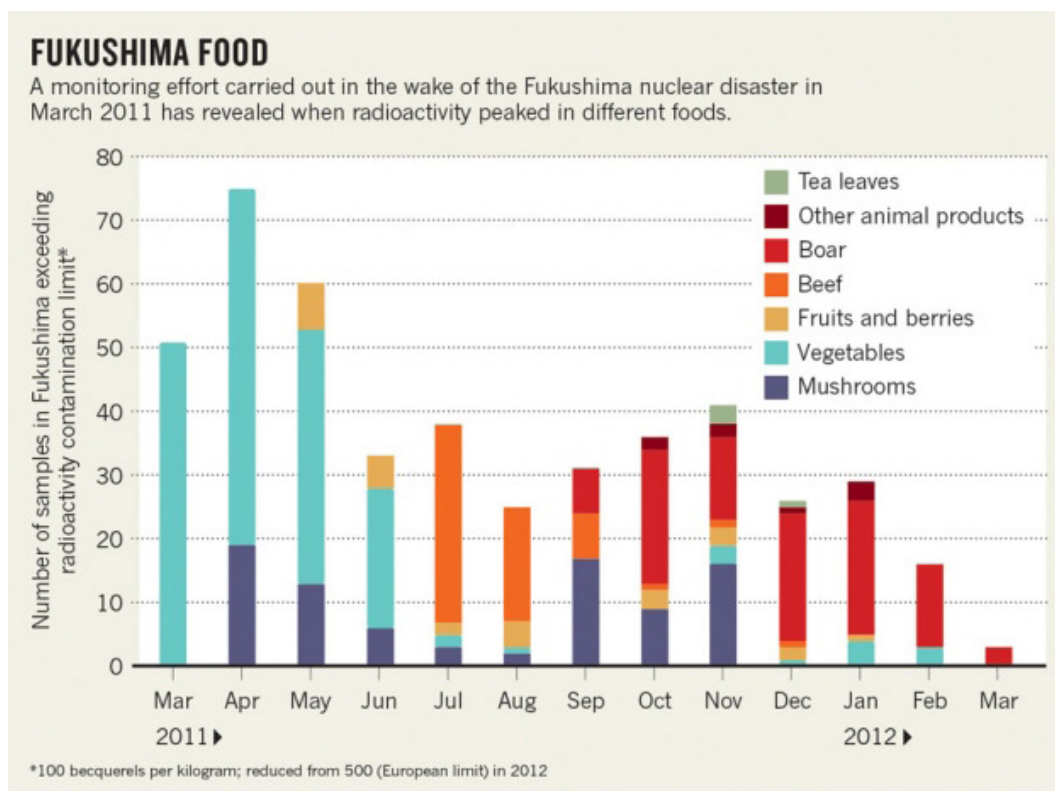


Figure 2.1

Evaluation of food radioactivity 2011/2012

Figure 2.1 from Nature magazine<sup>51</sup> shows the number of food samples exceeding permitted values and illustrates the course of radioactive contamination in selected foods in the year following the nuclear meltdowns.

Natural decay of radioactivity, trade restrictions and preventive measures allowed the gradual reduction of radioactivity in most foods in Japan, except fish, seafood, game, forest fruits and homegrown crops from contaminated areas. But there was still relevant absorption of radioactivity through food and drinking water, particularly in the first year of the nuclear disaster. A scientific estimate of the individual and collective radiation doses ingested with contaminated food would be required to assess the overall health risk to the affected population.

But the reports of the responsible international institutions, WHO and UNSCEAR, only draw on the food database of the IAEA – an organization set up to “promote the safe, secure and peaceful use of nuclear technologies” and “to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world.”<sup>52</sup> IAEA officials are nominated by national nuclear energy organizations, which means that when it comes to assessing the effects of nuclear disasters, the IAEA has a profound conflict of interest. The IAEA database

contains 125,826 food samples that were collected in the first year of the nuclear disaster, two thirds (66.9%) of which, however, are beef samples.<sup>53</sup> Although the remaining 40,000 samples are roughly classified according to the month and location of collection, they can hardly be considered representative of the huge quantities of food consumed in the contaminated areas.

If, in a country like Japan with a population of more than 120 million, between 6 and 81 eggs are tested each month, this does not allow any meaningful conclusions to be drawn about the overall contamination of eggs in the country. The same applies to the ridiculously small sample size for freshwater fish (eleven) or fruit juice (sixty-three) that were analyzed by the IAEA during the course of the first year. From a total of 135 radioactive isotopes, samples were only taken for iodine-131 and cesium-137. Strontium-90 – a particular cause of concern for human health – was ignored altogether. Nor is it entirely clear if these samples were collected in areas of low, middle or high contamination. The level of radioactivity in the food samples collected by the Japanese authorities exceeded those of the IAEA database samples many times over. The following table gives maximum values for vegetable samples in the IAEA data-

51 Gibney E. “Fukushima Data show rise and fall in food radioactivity.” Nature, 27.02.15. <http://www.nature.com/news/fukushima-data-show-rise-and-fall-in-food-radioactivity-1.17016>

52 IAEA. “Atoms for Peace”. 1957. [www.iaea.org/About](http://www.iaea.org/About)

53 UNSCEAR. “2013 Report, Annex A - Levels and effects of radiation exposure due to the nuclear accident after the 2011 great East-Japan earthquake and tsunami - Attachment C-8: FAO/IAEA food database”. July 2014. [http://www.unscear.org/docs/reports/2013/UNSCEAR\\_2013A\\_C-8\\_FAO\\_IAEA\\_food\\_database\\_2014-07.pdf](http://www.unscear.org/docs/reports/2013/UNSCEAR_2013A_C-8_FAO_IAEA_food_database_2014-07.pdf)



base (taken from the 2012 WHO Fukushima Report)<sup>54</sup> and comparable samples collected by MEXT, Japan's ministry of science and technology.<sup>55</sup> Neither IAEA nor the WHO has explained why these samples were not included in the IAEA database.

Radioisotope	WHO/IAEA	MEXT
Iodine-131	54,100 Bq/kg	2,540,000 Bq/kg
Cesium-131	41,000 Bq/kg	2,650,000 Bq/kg

**Table 2.5**

Differing values for vegetable samples

The estimation of health effects can only be as accurate as the data it is based upon. The method of choosing food samples and the sample size influence the results of the data and therefore the calculations of possible health effects. To this day, a scientifically sound estimate of individual and collective radiation doses ingested through contaminated food in Japan is neither possible nor politically desired.

54 WHO. "Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami". 23.03.12, S.106, Tabelle A8.2. [http://whqlibdoc.who.int/publications/2012/9789241503662\\_eng.pdf](http://whqlibdoc.who.int/publications/2012/9789241503662_eng.pdf)

55 MEXT. "Important Information from Japanese Government, Readings of Dust Sampling". 18.04.11. [http://eq.wide.ad.jp/files\\_en/110418dust\\_1000\\_en.pdf](http://eq.wide.ad.jp/files_en/110418dust_1000_en.pdf)



### 3 Consequences of the nuclear disaster for human health



The carcinogenic nature of ionizing radiation has been known for a long time.<sup>1</sup> People exposed to radiation at the workplace become ill significantly more often than non-exposed people. A meta-analysis of data from 15 countries in 2007 was able to show a significant correlation between the radiation dose and the incidence of cancer, with no lower threshold dose in persons exposed to radiation.<sup>2</sup> The US National Academy of Sciences' Advisory Committee on the Biological Effects of Ionizing Radiation states in its BEIR VII report that there is no lower threshold dose and that even small amounts of radiation have the potential to cause tissue damage and genetic mutations. Exposing a large population to low-dose radiation can therefore have a similar effect as the exposure of a small population to a high radiation dose. The dose-risk model of the BEIR-VII report states that exposure of a population of 100,000 to an average 1 mSv would result in an average of 20 (confidence interval CI 9 to 35) persons developing cancer. The same number of cancer cases would be expected if 1,000 people were exposed to 100 mSv radiation. In both cases, the risk factor 0.2 per Person-Sievert is assumed for the cancer incidence (CI 0.09-0.35).<sup>3</sup> The WHO also uses a cancer risk factor of 0.2/PSv in their 2013 Fukushima Report.<sup>4</sup> The risk factor for cancer mortality is about half as high (0.1/PSv, CI 0.05-0.19).

If this model is applied to the situation in Japan in the aftermath of the Fukushima nuclear disaster, the following picture emerges: clean-up workers at the plant were probably exposed to the highest doses. This was, however, a comparatively small group. Radioactive fallout and the continuous contamination of the ocean, drinking water and food means that an even greater proportion of the Japanese population is being exposed to low-dose radiation, especially in the most heavily contaminated areas. But people living in the greater Tokyo area are also affected, as are the consumers of products with increased radiation throughout the entire country. This radioactive contamination will continue to have an effect on the population for a long time to come – strontium-90 and cesium-137 have physical half-lives of 28 and 30 years respectively; it will be 300 years before decay brings radiation down to an acceptable level.

The greatest challenge for public health policy in the coming decades will be the chronic exposure of large parts of the population to low-dose radiation. As cancer carries no seal of origin, the cause of a specific cancer case cannot be causally linked to a specific event. Moreover, Japan already has a relatively high 'natural' cancer incidence – approximately every second person in Japan will develop cancer in the course of a lifetime. Despite this, appropriate epidemiological studies could differentiate excess radiation-induced cancer cases from the 'background noise' of the natural cancer incidence. This was clearly demonstrated in the study of childhood leukemia and cancers near German nuclear reactors, which found a significant increase of childhood cancers in areas around NPPs.<sup>5</sup> But such studies do not serve the interests of the Japanese authorities and the powerful nuclear lobby. Their organizations there-

1 WHO. "Cancer prevention". [www.who.int/cancer/prevention/en](http://www.who.int/cancer/prevention/en)

2 Cardis E et al. «The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: estimates of radiation-related cancer risks". *Radiat Res.* 2007 Apr;167(4):396-416, April 2007. [www.ncbi.nlm.nih.gov/pubmed/17388693](http://www.ncbi.nlm.nih.gov/pubmed/17388693)

3 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). "BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation". 2006, S. 279, Tabelle 12.5. [www.nap.edu/openbook.php?record\\_id=11340&page=8](http://www.nap.edu/openbook.php?record_id=11340&page=8)

4 WHO. "Global report on Fukushima nuclear accident details health risks". 28.02.13. [www.who.int/mediacentre/news/releases/2013/fukushima\\_report\\_20130228/en/index.html](http://www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/index.html)

5 Kaatsch P et al. "Leukaemia in young children living in the vicinity of German nuclear power plants". *Int J Cancer.* 1220:721-726, 2008. [www.rachel.org/lib/leukemias\\_near\\_german\\_nukes.080215.pdf](http://www.rachel.org/lib/leukemias_near_german_nukes.080215.pdf)



fore contend that “a discernible increase in cancer incidence in this population that could be attributed to radiation exposure from the accident is not expected.”<sup>6</sup> In the following two chapters this claim will be examined on the basis of the two mainly affected populations: the clean-up workers and the general public. This paper will then go into the results of the ongoing thyroid cancer study by the Fukushima Medical University as this is the only study so far, which looks into a possible link between increased cancer incidence and the Fukushima nuclear disaster.

### 3.1 Health effects in occupationally exposed people

The people most acutely affected by high radiation doses in Fukushima were, like in Chernobyl, the members of the power plant workforce and emergency services. According to the authors of the UNSCEAR report on Fukushima from autumn 2013, a total of 25,000 persons were deployed at the Fukushima Daiichi site since the beginning of the disaster.<sup>7</sup> Only about 15% of these were actually employed by TEPCO, the rest were temporary workers, volunteers or sub-contracted workers. Hardly any of them were adequately qualified to work with hazardous radioactive substances and were neither prepared nor equipped to work in a nuclear disaster area.

In its report from February 2013, the WHO reported about 23.172 workers:

- » Around 67% of these (approx. 15,500) were exposed to radiation doses of about 5 mSv during the first year of the nuclear disaster (March 2011-April 2012).<sup>8</sup> According to current WHO risk models (risk factor for cancer incidence 0.2/PSv, CI: 0.09-0.35/PSv), approximately 15 (CI: 7-17) radiation-induced excess cancer cases can be assumed for this group during the first year of the disaster, half of these fatal. The additional risk of developing cancer due to radiation for each individual worker is therefore 0.1% (CI: 0.05-0.17%).
- » In the first year of the disaster, 33% of the workers, i.e. 7,600 persons, were exposed to 30 mSv of radiation. It must be assumed that as a result of radioactive contami-

nation during deployment on the power plant site during the first year of the disaster, this group will incur around 46 (CI: 20-80) excess cancer cases, half of them fatal. The additional risk of developing cancer due to radiation for each individual worker in this group is therefore 0.6% (CI: 0.3-1.0%).

- » According to the WHO, 75 workers were exposed to radiation doses between 100 and 199 mSv. As individual dose values were not published, the expected cancer rate for this group can only be a rough estimate. The number of excess cancer cases in this group can be expected to lie somewhere between 1 and 5. The additional risk of these workers to develop cancer is therefore between 1% and 7%, depending on the level of contamination.
- » According to the WHO, 12 workers were exposed to internal radiation with individual doses ranging between 100 and 590 mSv, as well as approximately 100 mSv external radiation. As no individual dose values were published for this group, the expected cancer incidence can only be given as a rough estimate. Between 0 and 3 excess cancer cases should be expected in this group. The additional risk of these workers to develop cancer is therefore between 0 and 25%, depending on the contamination level.

To sum up the WHO data, it can be said that of the 23,172 workers deployed on the power plant site during the first year of the disaster, an estimated 28-115 are expected to develop radiation-induced cancer as a result and 14-58 will die of it.

It must be emphasized that these estimates are not only based on provisional figures from just the first year of the disaster, but they are also disputed:

- » Short-lived radioisotopes like iodine-132 or iodine-133 were not included in the estimates so that even UNSCEAR has to admit that the figure for internal contamination could be as much as 20% higher.<sup>9</sup>
- » According to UNSCEAR, even the corrected dose rates would lead to a systematic underestimation, as most radiation was no longer detectable at the actual time of measuring due to the rapid decay, for example of iodine-131.<sup>10</sup>

6 UNSCEAR. "Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session". UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. [www.un.org/Docs/journal/asp/ws.asp?m=A/68/46](http://www.un.org/Docs/journal/asp/ws.asp?m=A/68/46)

7 UNSCEAR. "Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session". UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. [www.un.org/Docs/journal/asp/ws.asp?m=A/68/46](http://www.un.org/Docs/journal/asp/ws.asp?m=A/68/46)

8 WHO. "Global report on Fukushima nuclear accident details health risks". 28.02.13. [www.who.int/mediacentre/news/releases/2013/fukushima\\_report\\_20130228/en/index.html](http://www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/index.html)

9 UNSCEAR. "Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session". UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. [www.un.org/Docs/journal/asp/ws.asp?m=A/68/46](http://www.un.org/Docs/journal/asp/ws.asp?m=A/68/46)

10 UNSCEAR. "Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - Sixtieth session". UN General Assembly Official Records, 68th session, supplement No. 46, 27.05.13. [www.un.org/Docs/journal/asp/ws.asp?m=A/68/46](http://www.un.org/Docs/journal/asp/ws.asp?m=A/68/46)



- » Moreover, the fact that organizations like the WHO and UNSCEAR rely exclusively on data provided by TEPCO certainly warrants criticism. It is a known fact that employees of a number of sub-contractors were not included in the plant operator's official figures, their data was probably not even collected.<sup>11,12</sup>
- » A number of workers complained that they had never been given a medical examination. Reports of missing, faulty or manipulated dosimeters (e.g. by encasing them in lead covers) and fake measurements have done little to enhance the credibility of the TEPCO data.<sup>13,14,15</sup>
- » The focus on the effects of radioactive iodine has meant that the health effects of radioisotopes like cesium-137, strontium-90 or plutonium have been neglected. In its Fukushima report, the WHO even assumed that internal contamination was exclusively due to iodine-131 and categorically excluded the possible incorporation of any other radioisotopes – despite the vast amount of available data showing relevant contamination and experiences gained from Chernobyl.<sup>16</sup>

The sum of these factors has resulted in the systematic underestimation of the health risk to the thousands of people exposed to radiation while working at the power plant – oftentimes without qualifications or adequate protection. Also to be taken into consideration are the tens of thousands of cleanup and decontamination workers who swept radioactive dust from rain gutters, removed contaminated soil or washed down treetops, often in perilous working conditions or even voluntarily, wearing only the simplest of face masks to protect themselves. In summary, it is safe to say that the health risks for workers exposed to radiation during the Fukushima disaster cannot be adequately assessed using the available data.

## 3.2 Health effects on the general public

Unlike workers who were and are still exposed to high levels of radiation, the larger part of the Japanese public was exposed to smaller doses, mainly from contaminated food, water, soil and air. Nonetheless, by far the greatest number of actual health effects is to be expected in this group due to its size. This can be illustrated with an example: if the UNSCEAR figures are used, Japan's population of 127 million people will be exposed to a lifetime dose of around 48,000 Person-Sievert (PSv), the majority of which will affect the population in the most heavily contaminated prefectures. By applying the risk factor 0.2/PSv (CI: 0.09-0.35) proposed in the BEIR VII report, which is now even used by the WHO, the estimated total number of radiation-induced cancer cases in Japan is 9,600 (CI: 4,300-16,800), around half of which will be fatal.

This figure is even higher if the dose calculations of the WHO Fukushima report are used. The WHO assumes that the individual dose in the first year of the nuclear disaster was about 3-25 mSv for the population in the most heavily contaminated areas (just under 1 million people), and 0.316 mSv (CI: 0.1-1 mSv) for the remaining population (about 126 million people).<sup>17</sup>

Depending on the factor used to calculate lifetime dose (double or triple the first-year dose), one arrives at a collective lifetime dose of 110,000-165,000 PSv. Using the cancer incidence risk factor of 0.2/PSv (CI: 0.09-0.35), around 9,900-57,000 additional cancer cases can be expected for the whole of Japan. Other calculation models that apply the higher risk factor of 0.4/PSv for cancer incidence arrive at a figure between 22,000 and 66,000 cancer cases.<sup>18</sup> Recent epidemiological studies suggest that this risk factor more reliably reflects the actual cancer risk than the lower risk factor applied in the BEIR VII report.<sup>19</sup>

Irrespective of which dose estimates, lifetime dose calculations or risk factors one is inclined to believe – there can be no doubt that the radioactivity released through the Fukushima nuclear disaster will result in a significant number of cancer cases in Japan – leukemia, lymphoma and solid tumors – while the individual cases will not be attributable to Fukushima or any other singular cause. No mass screenings or special prevention programs are planned for the general public, with the exception of regular thyroid tests for children in Fukushima Prefecture.

11 Hackenbroch V et al. "A Hapless Fukushima Clean-Up Effort". Der Spiegel, 05.04.11. [www.spiegel.de/international/world/a-hapless-fukushima-clean-up-effort-we-need-every-piece-of-wisdom-we-can-get-a-754868-2.html](http://www.spiegel.de/international/world/a-hapless-fukushima-clean-up-effort-we-need-every-piece-of-wisdom-we-can-get-a-754868-2.html)

12 Sato J, Tada T. "TEPCO fails to submit dose data on 21,000 Fukushima plant workers". The Asahi Shimbun, 28.02.13. <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201302280086>

13 Sato J et al. "TEPCO subcontractor used lead to fake dosimeter readings at Fukushima plant". The Asahi Shimbun, 21.07.12. <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201207210069>

14 McCurry J. "Life as a Fukushima clean-up worker". The Guardian, 06.03.13. [www.theguardian.com/environment/2013/mar/06/fukushima-clean-up-radiation-public-criticism](http://www.theguardian.com/environment/2013/mar/06/fukushima-clean-up-radiation-public-criticism)

15 "TEPCO subcontractor tries to underreport workers' radiation exposure". Kyodo News, 21.07.12.

16 WHO. "Global report on Fukushima nuclear accident details health risks". 28.02.13, S. 48-49. [www.who.int/mediacentre/news/releases/2013/fukushima\\_report\\_20130228/en/index.html](http://www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/index.html)

17 WHO. "Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami based on a preliminary dose estimation". 2013. S. 39. [www.who.int/iris/bitstream/10665/78218/1/9789241505130\\_eng.pdf](http://www.who.int/iris/bitstream/10665/78218/1/9789241505130_eng.pdf)

18 Paulitz H et al. "Auf der Grundlage der WHO-Daten sind in Japan zwischen 22.000 und 66.000 Krebserkrankungen zu erwarten" IPPNW, 14.03.13. [www.ippnw.de/commonFiles/pdfs/Atomenergie/Fukushima/Fukushima\\_Erwartete\\_Krebserkrankungen\\_Japan\\_mit\\_WHO-Daten.pdf](http://www.ippnw.de/commonFiles/pdfs/Atomenergie/Fukushima/Fukushima_Erwartete_Krebserkrankungen_Japan_mit_WHO-Daten.pdf)

19 Thiel et al. "Gefahren ionisierender Strahlung: Ergebnisse des Ulmer Expertentreffens vom 19. Oktober 2013". IPPNW, 15.01.14. [www.ippnw.de/strahlung](http://www.ippnw.de/strahlung)

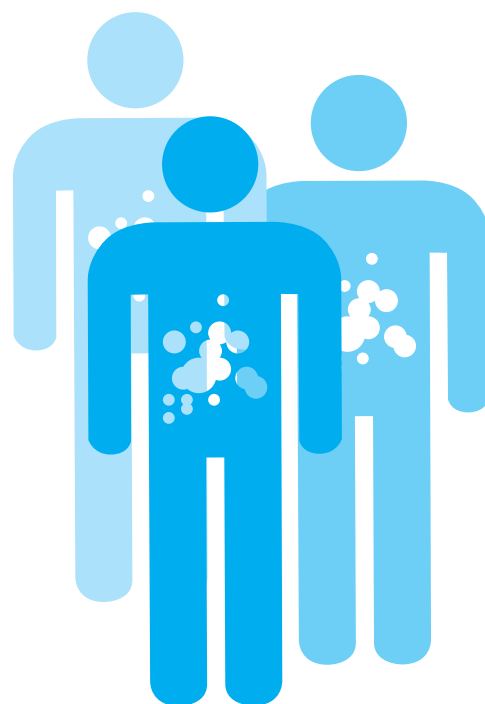


It must be noted that the calculation of disease rates and health effects is based on a great number of assumptions, such as the source term, the ingestion of radioactive particles in food and certain risk-relevant behaviors.<sup>24</sup> The calculations in this chapter are based on dose calculations by the WHO and estimates of collective lifetime doses by UNSCEAR. It has already been shown that this information is so fraught with uncertainties and subject to systematic underestimation that the collective doses and with it the number of cancer cases and deaths are likely to be several times higher. Reasons for this include:

- » The total amount of radioactive particles that were released is probably far greater than the numbers used for the WHO and UNSCEAR reports (see chapter on atmospheric emissions).
- » Exposure of the population in the 20-km zone prior to and during evacuation was not included in dose estimates.<sup>25</sup>

- » The quantity and choice of food samples for calculating internal radiation doses was inadequate or biased (see chapter on radioactive contamination of food).
- » The independence of the authors of both reports is questionable. IAEA representatives wrote essential sections of the WHO report, even though the agency's main aim is the promotion of nuclear energy around the world.<sup>26</sup>

Calculations of health risk can naturally only be as accurate as the assumptions they are based upon. An assessment based on data of questionable objectivity, selective sampling, biased data and the misappropriation of relevant information does not provide an acceptable basis for health policy recommendations.



25 WHO. "Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami". 23.03.12. [http://www.who.int/ionizing\\_radiation/pub\\_meet/fukushima\\_dose\\_assessment/](http://www.who.int/ionizing_radiation/pub_meet/fukushima_dose_assessment/)

26 IAEA. "Atoms for Peace". 1957. [www.iaea.org/About](http://www.iaea.org/About)



## 4 Thyroid screening in Fukushima Prefecture

An increase in thyroid cancer is to be expected in the regions affected by radioactive iodine contamination. According to UNSCEAR, the thyroid glands of infants in Fukushima Prefecture were exposed to a dose of 15-83 mGy in the first year of the nuclear disaster, “as much as one half of which arose from the ingestion of radioactivity in food.”<sup>1 2</sup> In comparison, the average annual thyroid dose from natural background radiation is normally 1 mGy.<sup>3</sup> These dose calculations are, of course, just estimates, as actual doses depend on a number of dietary and habitual variables, individual exposure well as specific health factors. As radioactive fallout does not stop at prefectural borders and radioactive iodine was found in milk, seafood, meat, drinking water, vegetables and rice, infants in other parts of the country were also affected. It is estimated that in the first year of the nuclear disaster, infants in the rest of Japan received an average thyroid dose of 2.6-15 mGy. UNSCEAR estimates the collective lifetime thyroid dose for the whole of Japan to be

112,000 Person-Gy.<sup>4</sup> If the Dose and Dose Rate Effectiveness Factor (DDREF) of 0.009/pGy from the BEIR-VII report is applied to calculate the number of expected thyroid cancer cases due to radioactivity from the nuclear disaster in Japan, one arrives at the number of 1,000 excess cases.<sup>5</sup> In view of the numerous problems with the UNSCEAR data that have already been addressed above, it is safe to assume that this figure is actually far too low.

To monitor the development of thyroid cancer cases in the affected population, the Fukushima Medical University (FMU) initiated the Fukushima Health Management Survey. This prospective study is the largest scientific investigation of long-term effects of the Fukushima nuclear disaster and warrants a brief analysis.

The study was initiated by the controversial Japanese scientist Shunichi Yamashita, known among other things for his advice to the people of Fukushima to smile more, as this would minimize the effects of radiation, as well as for trivializing the effects of ionizing radiation on health, contrary to scientific knowledge.<sup>6</sup> Perhaps even more critically, he was instrumental in preventing the distribution of iodine tablets in his role as consultant to the responsible emergency authority - a decision that he later reco-

1 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami”. 02.04.14, S. 9, Paragraph 30. [www.unscear.org/docs/reports/2013/13-85418\\_Report\\_2013\\_Annex\\_A.pdf](http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf)

2 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami”. 02.04.14, S. 87, Tabelle 10. [www.unscear.org/docs/reports/2013/13-85418\\_Report\\_2013\\_Annex\\_A.pdf](http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf)

3 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami”. 02.04.14, S. 86, Paragraph 211. [www.unscear.org/docs/reports/2013/13-85418\\_Report\\_2013\\_Annex\\_A.pdf](http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf)

4 UNSCEAR., “Sources, effects and risks of ionizing radiation – UNSCEAR 2013 Report; Volume I – Report to the General Assembly – Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami”. 02.04.14, S. 198, Tabelle C16. [www.unscear.org/docs/reports/2013/13-85418\\_Report\\_2013\\_Annex\\_A.pdf](http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf)

5 National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). “BEIR VII report, phase 2: Health risks from exposure to low levels of ionizing radiation”. 2006, S. 279, Tabelle 12.5. [www.nap.edu/openbook.php?record\\_id=11340&page=8](http://www.nap.edu/openbook.php?record_id=11340&page=8)

6 Yamashita, S. “Rede vom 21.03.11”. <https://www.youtube.com/watch?v=UOgaBUDFeb4>



gnized as wrong.<sup>7</sup> In this light, the results of a study led by him must be viewed critically due to a probable lack of objectivity. In 2012, it also became known that the international nuclear lobby organization IAEA had financial relations with the Fukushima Medical University, which casts further doubt on the study's scientific neutrality.<sup>8</sup> Parent organizations in Fukushima also criticized the hasty and superficial nature of FMU thyroid exams, which lasted no longer than 2-3 minutes, the practice of withholding ultrasound images from the children's families and the fact that general practitioners had received written warnings not to perform follow-up examinations of children taking part in the study or to provide secondary opinions. Children living outside the prefecture were excluded from the study, as were a large numbers of children whose parents had left the prefecture after the onset of the disaster. Despite such criticism, the Fukushima Prefecture thyroid study is the world's most extensive study of radioactively contaminated children and warrants discussion. The FMU study comprises two separate parts: the preliminary baseline screening and the full-scale screening.

#### 4.1 Preliminary baseline screening

Preliminary baseline screening was carried out between October 2011 and March 2014 to determine the thyroid cancer prevalence, i.e., the natural frequency of thyroid cancer in the pediatric population of Fukushima Prefecture. At the time of the nuclear meltdowns, around 360,000 children between the ages of 0 and 18 were living in the prefecture. Japan's Ministry of Health puts the annual rate of new cases (incidence) of thyroid cancer in children under 19 in Japan at 0.35 per 100,000.<sup>9</sup> In a population of 360,000 children, one could therefore expect about one new case of thyroid cancer per year to be diagnosed either because the illness exhibited symptoms or due to incidental findings. A known phenomenon is the so-called 'screening effect', whereby healthy subjects who would normally not have become symptomatic until much later are diagnosed at an early stage of the disease as a result of mass screenings. It can be assumed that in the three and a half years of the baseline study, the cancer incidence would actually have been higher than the 3-4 statistically predicted cases. It was expected that these additional cases would be diagnosed at a very early stage and therefore present no acute danger for the patient.

The actual picture presented by the baseline study, however, was altogether different: the ultrasound tests of 537 of the children showed such abnormal results that fine needle aspiration biopsy was required. Microscopic analysis resulted in a total of 116 suspected cases of cancer. A large majority of these were found to be malignant, and based on the limited information available, 101 children required surgery mostly because of metastasis, large tumor size, or tumor's proximity to other vital structures. In surgery, one case was found to be a benign lesion, while cancer was confirmed in 100 cases (97 papillary thyroid carcinoma and 3 poorly differentiated thyroid carcinoma).<sup>10</sup> Awkward questions about the possible causes of such an unexpected high rate of malignant thyroid cancer were already asked by the end of the preliminary baseline study.

#### 4.2 Full-scale screening

Full-scale screening is the second phase of thyroid screening and was begun in April 2014. It involves a follow-up thyroid ultrasound examination of the children from the baseline study plus a baseline thyroid ultrasound examination of children born shortly after the nuclear disaster. The target group is therefore slightly larger than that of the baseline study. The aim is to examine these children every 2 years up to the age of 20, then every 5 years for the rest of their lives. Full-scale screening involved the thyroid ultrasound examination of 381,261 children, of which 236,595 (62.1%) were examined between April 2014 and December 2015. Validated results are only available for 220,088 children (57.7%) at this time. 157 children required fine-needle aspiration biopsy because of lesions found on ultrasound examination. Microscopic analyses resulted in a total of 51 new suspected cases of cancer. 16 of the children required surgery, mostly because of metastasis, large tumor size, or tumor's proximity to other vital structures, and papillary thyroid carcinoma was confirmed in all cases.<sup>11</sup>

Thus, the total number of children with confirmed thyroid cancer is now 116 (February 2016). All of them required surgery, some for metastasis, large tumor size, or tumor's proximity to other vital structures. A further 50 children have been diagnosed with suspected thyroid carcinoma. They are still awaiting surgery.

At this point it should be noted that although thyroid cancer is generally considered a cancer with favorable outcome, such a diagnosis is always a personal tragedy for the patients and their families. Following surgery, which of course always involves a

7 "Authorities jump gun on iodine pills / Premature distribution risked ill effects on health, depleted emergency supplies". The Yomiuri Shimbun, 22.03.11. <http://www.nationmultimedia.com/2011/03/21/headlines/Authorities-jump-gun-on-iodine-pills-30151398.html>

8 MOFA. "Practical arrangements between Fukushima Medical University and the International Atomic Energy Agency on Cooperation in the area of human health". 15.12.12. [http://www.mofa.go.jp/policy/energy/fukushima\\_2012/pdfs/fukushima\\_iaea\\_en\\_06.pdf](http://www.mofa.go.jp/policy/energy/fukushima_2012/pdfs/fukushima_iaea_en_06.pdf)

9 Katanoda K et al. "An updated report of the trends in cancer incidence and mortality in Japan". Jpn J Clin Oncol. 43(5):492-507, May 2013. [www.ncbi.nlm.nih.gov/pubmed/23493744](http://www.ncbi.nlm.nih.gov/pubmed/23493744).

10 Fukushima Medical University. "Final Report of Thyroid Ultrasound Examination (Preliminary Baseline Screening)". 31.08.15. <http://fmu-global.jp/?wpdmdl=1222>

11 Fukushima Medical University. "The 22nd Prefectural Oversight Committee Meeting for Fukushima Health Management Survey". 15.02.16. <http://fmu-global.jp/survey/proceedings-of-the-22nd-prefectural-oversight-committee-meeting-for-fukushima-health-management-survey>



certain degree of risk itself, patients have to endure lifelong follow-up examinations, permanent medication with thyroid hormones, regular visits to the doctor, blood tests and both clinical and sonographic examinations. There is also the perpetual fear of a relapse, metastasis or renewed tumor growth. Thus, there is no justification for treating thyroid cancer lightly.

Particularly alarming is the fact that 16 new proven carcinoma cases have developed in the period between the first and the second round of screenings. The incidence of other thyroid lesions also increased: while the incidence of thyroid nodules and cysts in the first screening was 48.5%, the incidence for such changes in the second screening was 59.3%. This means that in the second screening, cysts and nodules were found in 36,408 children that had not exhibited thyroid anomalies in the first screening. In 348 children, these lesions were so unusual that further examinations were required. A further 782 children with small cysts or nodules in the first screening exhibited such rapid growth rates of these lesions at a follow-up examination that further evaluation had to be initiated. In the years to come, the families of these children must live in fear of their child developing cancer. They blame themselves and are tormented by the question of why more was not being done to protect their children.

The data from full-scale screening now allows for a calculation of the incidence, i.e. the number of new cases per year. Unfortunately, because the authorities are withholding data related to newly diagnosed cases of thyroid cancer, the exact period of time between the first and second screenings are not known for the individual cancer case. If the time between the two screenings was 2 years as scheduled, then we can assume an incidence of 3.6 new cases per year among 100,000 children. Prior to the Fukushima nuclear meltdowns, the annual incidence of thyroid cancer among children in Japan was 0.35 per 100,000 children. This ten-fold increase in the incidence of thyroid cancer in children can no longer be explained by the so-called 'screening effect'.

### 4.3 Screening summary

The number of children that were not examined suggests that the increased incidence of thyroid cancer could be even higher. More than 67,000 children from Fukushima Prefecture who were exposed to radiation were not included in the study and more than 160,000 are still on the waiting list for full-scale screening. A further cause for alarm is that children living outside Fukushima Prefecture are not being systematically examined or screened – although it is generally known that radioactive fallout containing iodine-131 occurred as far away as the northern districts of Tokyo and hundreds of thousands of additional children were exposed to increased radiation levels in the first days and weeks of the nuclear disaster and not screened. Without mass screenings it will not be possible to establish a

causal link between excess cancer cases and radiation exposure, and cancer cases may have delayed diagnosis with worsened outcomes.

At this point it is important to remember that the authorities, against better judgment, did not distribute iodine tablets to protect the population from the harmful effects of iodine-131. The report by the Japanese parliament's Independent Investigation Committee states that "although the positive effects of administering stable iodine and the proper timing were fully known, the government's nuclear emergency response headquarters and the prefectural government failed to give proper instructions to the public."<sup>12</sup> It is also difficult to understand why, on April 19, 2011, the Japanese government raised the permissible level of radiation exposure of children to 3.8 µSv per hour (equivalent to about 20 mSv per year with an average exposure of 14 hours per day).<sup>13</sup> Following protests by parent organizations, scientists and doctors, the government withdrew the new guideline on May 27, 2011 and returned to the old standard of 0.2 µSv/hour (equivalent to about 1 mSv/year).<sup>14</sup> In the first weeks and months of the disaster the change in standard will have certainly contributed to children in the affected areas being exposed to higher doses of radiation.

In summary, it can be said that mass screenings can contribute to documenting the incidence of thyroid carcinoma and result in treatment at an earlier stage with more likely positive outcomes.

In view of the experience of Chernobyl, it is incomprehensible that, apart from thyroid screenings, there have been no other mass screenings of children in the contaminated prefectures. Evaluation and screening for other radiation induced conditions such as solid tumors, leukemia, lymphoma as well as non-cancer health effects like cataracts, endocrine and cardiovascular diseases and genetic consequences of radiation exposure should have been or could still be undertaken. Extensive research by independent scientists is necessary to quantify the true extent of the disease burden on the affected population.

12 The National Diet of Japan. "The official report of The Fukushima Nuclear Accident Independent Investigation Commission of the National Diet of Japan". 05.07.12. [http://www.nirs.org/fukushima/naic\\_report.pdf](http://www.nirs.org/fukushima/naic_report.pdf)

13 MEXT. "Notification of interim policy regarding decisions on whether to utilize school buildings and outdoor areas within Fukushima Prefecture". 19.04.11. [www.mext.go.jp/english/incident/1306613.htm](http://www.mext.go.jp/english/incident/1306613.htm)

14 MEXT. "Immediate Measures toward Reducing the Radiation Doses that Pupils and Others Receive at Schools, etc. in Fukushima Prefecture". 27.05.11. [http://radioactivity.mext.go.jp/en/important\\_imformation/0001](http://radioactivity.mext.go.jp/en/important_imformation/0001)



## 5 Consequences of the nuclear disaster on the non-human biota

In addition to the effects on humans in contaminated areas, a closer look should also be taken of the effects of increased radiation on the non-human biota, i.e. plants and animals. Plants and animals belong to the same ecosystem as humans and have numerous interdependencies with us, the most obvious being the fact that our diet consists almost entirely of animal and plant products. But apart from this, we co-exist in a complex symbiosis with numerous species and are therefore also affected by changes in these complex systems. Also, we may be able to learn more about the effects of chronic exposure to low-dose radiation from its effects on plants and animals. As many living organisms have a more rapid generational turnover than humans, genetic effects can be easily observed and investigated both *in vitro* and *in vivo*. The investigation of the non-human biota is therefore an important aspect in the analysis of the consequences of a nuclear disaster. During the last five years, several scientific papers have addressed the morphological, genetic and physiological effects of ionizing radiation on the non-human biota in Fukushima, the most relevant of which will be discussed in this chapter.

In 2015, for example, the research group around Watanabe found a significant correlation between radiation dose and morphological abnormalities in native Japanese fir trees in the contaminated area around the wrecked power plant.<sup>1</sup> The closer the trees were to the wrecked reactor, the more pronounced were the changes, suggesting a dose-effect correlation. Temporal progression could also be observed, as the most serious mutations of main shoots were found on trees that began growing in spring 2012, i.e. one year after the onset of the nuclear

disaster. As trees live and grow their entire lives in one place, they provide us with an excellent demonstration of local effects.

This is not the case with animals that run free and are therefore unsuitable for demonstrating local effects. However, the lycaenid butterfly, a native species that spends its entire life within an extremely limited radius was evaluated for radiation impacts. In a study in 2012, Hiyama et al. were able to demonstrate a significant increase in pathologies that was directly proportional to the radioactive contamination of the food source: reduced body and wing size, greater number of morphological mutations and increased mortality rate (18.5%).<sup>2</sup> Laboratory examinations confirmed the radiation-induced increase in genetic mutations and morphological changes in the butterflies.<sup>3</sup> It was also found that later generations of butterflies exhibited higher mutation rates than the first generation. This suggests that mutations can be passed on and accumulate over generations.<sup>4</sup>

In well-designed studies, larger animals can also be an important source of information. Murase et al. observed a species of goshawk that tend to return to their same nest year after year. The goshawks were studied before and after the Fukushima nuclear disaster up to 100-120 kilometers from the Fukushima site. Murase et al. found that the bird's reproductive capacity was directly proportional to the level of radiation measured di-

1 Watanabe Y. et al. "Morphological defects in native Japanese fir trees around the Fukushima Daiichi Nuclear Power Plant". *Sci. Rep.* 5, 13232. <http://dx.doi.org/10.1038/srep13232>

2 Hiyama A et al. "The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly". *Nature Scientific Reports* 2, Art 570 (2012). [www.nature.com/articles/srep00570](http://www.nature.com/articles/srep00570)

3 Møller AP, Mousseau TA. « Low-dose radiation, scientific scrutiny, and requirements for demonstrating effects". *BMC Biol.* 2013 11:92. <http://bmcbiol.biomedcentral.com/articles/10.1186/1741-7007-11-92>

4 Taira W et al. "Fukushima's Biological Impacts: The Case of the Pale Grass Blue Butterfly". *J Hered* (2014) 105 (5): 710-722.



rectly beneath the nest.<sup>5</sup> These results indicate that radiation has an effect on the bird's germ line. Overall success of birds leaving the nest dropped from pre-Fukushima rates of 79% to 55% in 2012 and 50% in 2013 which may be related to the level of radioactive substances in their food. There was also an overall reduction in the number of birds, butterflies and cicadas proportional to the ambient radiation of the study area.<sup>6 7</sup>

A study of primates in the contaminated areas is even more significant in terms of the possible inferences about the effects on humans. In April 2012, pathological blood counts were found in wild monkeys in the Fukushima forests about 70 kilometers from the nuclear plant. As a control group, a monkey population about 400 kilometers north of Fukushima was also analyzed. While the concentration of radioactive cesium in the muscles of Fukushima monkeys was found to be between 78 and 1,778 Bq/kg, cesium concentrations in the control group were below the detectable level. In the Fukushima monkeys, the reduction in the number of red and white blood cells was directly proportional to the cesium concentration in the muscles, so that a dose-effect correlation can be assumed.<sup>8</sup>

It would be unscientific to draw direct conclusions about the effects of ionizing radiation for humans from such plant- and animal-studies. Nonetheless, the research findings cannot be disregarded, particularly regarding the question of genetic and transgenerational effects of radiation. In this respect, animal models with their rapid generational succession can help us fill knowledge gaps and attain a better understanding of the complex interaction between ionizing radiation and living tissue in general, and the DNA of germ line cells in particular. Thus, the investigation of the non-human biota in Fukushima is a field of research that could provide a wide range of important findings in the future.

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5 Murase K et al. „Effects of the Fukushima Daiichi nuclear accident on goshawk reproduction“. Sci. Rep. 2015, 5. <http://dx.doi.org/10.1038/srep09405>

6 Mousseau TA et al. „Genetic and Ecological Studies of Animals in Chernobyl and Fukushima“. Journal of Heredity, Volume 105, Issue 5. S. 704-709.

7 Aliyu AS et al. „An overview of current knowledge concerning the health and environmental consequences of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident“. Environ. Internat. 85 (2015) 213-228. <http://cricket.biol.sc.edu/chernobyl/papers/Sadiq-et-al-EI-2015.pdf>

8 Ochiai K et al. „Low blood cell counts in wild Japanese monkeys after the Fukushima Daiichi nuclear disaster“. Nature Scientific Reports 2014;4:5793. <http://www.nature.com/srep/2014/140724/srep05793/pdf/srep05793.pdf>



## 6 Outlook

From the findings cited above it is clear that the nuclear catastrophe of Fukushima is still not under control and the process of dealing with the consequences for humans and the environment has only just begun. At the same time, basic information about the source term and the contamination of soil, ocean and foods is still being disputed between the nuclear lobby and its institutions on one side and independent scientists and physicians on the other, even five years after the onset of the disaster. The health effects for occupationally exposed workers and the general public are being systematically played down by the nuclear industry and their lobby organizations such as the IAEA or UNSCEAR. With eloquent statements and palliative reports, particularly on the part of the Japanese authorities, persistent attempts are undertaken to end all discussion about the Fukushima nuclear disaster.

It must be clearly stated that the discussion is far from over. According to TEPCO, every day, approximately 300 tons of radioactive wastewater flow into the sea.<sup>1</sup> Decontamination efforts have stalled and are being continuously countered by recontamination. The decontamination of mountain ranges, forests and fields has proven to be impossible, even for a country like Japan. The authorities optimistically assume a 'shielding effect' due to the washout of radionuclides in the ground and leaching of radioactive particles into deeper layers of soil, but forget to account for the increased exposure of the public through radi-

oactive cesium-137 in the groundwater and food chain.<sup>2</sup> It will take decades and cost many billions of tax dollars to salvage the radioactive materials from the wrecked reactor blocks.<sup>3</sup> The half-life of cesium-137 is about 30 years. This means that relevant amounts of radiation will remain in fields, pastures and forests for the next three hundred years and more. The fact that the forests of southern Germany are still radioactively contaminated 30 years after Chernobyl is a case in point.

It would be unscientific to formulate a concluding statement about the long-term effects of a nuclear disaster just five years after it began, especially as the main issues are cancer and cardiovascular disease which take years and decades to manifest themselves. But this is precisely what the Japanese authorities, IAEA and UNSCEAR are attempting to do by stating that there will be no 'relevant' or 'discernible' radiation effects in the exposed population. What people in the affected areas need is credible information, guidance and support, not deception, manipulated studies and false hopes. Organizations like the IAEA are not motivated to protect the health of the population; their interests lie largely in protecting the profits and political influence of the nuclear industry in Japan and the world. While the Japanese nuclear power sector has generated immense profits with its aging reactors for decades, the cost of the extensive decontamination and clean-up attempts in Fukushima will be shouldered by generations of Japanese taxpayers – a majority of which now have grave doubts about nuclear power. In Japan,

1 Tsukimori O, Hamada K. „Japan government: Fukushima plant leaks 300 tpd of contaminated water into sea | Reuters“. Reuters, 07. 08.13. <http://www.reuters.com/article/2013/08/07/us-japan-fukushima-water-idUSBRE9760AU20130807>.

2 MAFF. „Towards the recovery and restoration of the Great East Japan Earthquake disaster area“. MAFF Topics, Dezember 2011. [http://www.maff.go.jp/j/pr/aff/1112/mf\\_news\\_00.html](http://www.maff.go.jp/j/pr/aff/1112/mf_news_00.html)

3 „IAEA calls for improvements at Japan's Fukushima plant“. BBC News Asia, 22.04.13. <http://www.bbc.co.uk/news/world-asia-22246464>.



a huge system of deception has been installed to protect the nuclear power industry. Undesirable reports can be declared a 'betrayal of state secrets' and are punishable by law.<sup>4</sup>

Public debate on Fukushima should not be focused on profits, power and political influence of the nuclear industry, but center around the situation and health of the affected population – those who lost everything, who fear for their health and that of their children, who ask nothing more than a life without fear of radiation. The risks to the health of the Japanese population must be investigated by independent scientists, positively excluding any undue influence by the nuclear industry and their political supporters. Extensive studies are required to understand the public health consequences, to identify diseases at an early stage and improve preventive measures for future generations by learning more about the effects of ionizing radiation. The debate on the health effects of the Fukushima nuclear disaster is about far more than the principle of independent research and taking a stand against the influence of powerful lobby groups. It is about the universal right of every human being to health and life in a healthy environment.

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4 Sieg L, Takenaka K. "Japan secrecy act stirs fears about press freedom, right to know". Reuters, 24.10.13. <http://www.reuters.com/article/2013/10/25/us-japan-secrecy-idUSBRE99N1EC20131025>.





**Recommendations  
from IPPNW and PSR**



## Recommendations from IPPNW and PSR

### For Japan:

- » The people affected by the nuclear disaster and their human right to health and life in a healthy environment should be at the center of all discussions and policy decisions. To this end, adequate involvement of affected groups in decision-making processes must be ensured.
- » All people involved with the nuclear disaster clean-up who might have been or will be exposed to radioactivity must be equipped with reliable dosimeters and be regularly examined by independent physicians. This also applies to employees of subcontractors, temporary workers and volunteers. Nuclear reactor operators such as TEPCO must no longer influence the studies and data.
- » The Japanese government must create and maintain registries similar to those created by the Soviet Union after Chernobyl that cover all groups that have been exposed to radiation as a result of the Fukushima nuclear catastrophe. This applies to:
  - » All evacuees from the contaminated areas and those still living in contaminated areas
  - » Workers at the power plant site and those who work on clean-up and decontamination
- » Residents from contaminated regions must be allowed the right to decide whether they will return to their homes with some radioactivity still present or choose to move to non-contaminated areas. Financial and logistical support of their decision must be provided.
- » The forced resettlement of evacuated people in contaminated regions must be stopped. In particular, people should not be pressured by the withdrawal of financial assistance if they do not want to return to their contaminated former homes.
- » Epidemiological research on the effects of the nuclear disaster must be ensured, and regular free health checks and treatment must be provided for the affected population. The health risks for the Japanese people should be assessed by independent scientists who do not have conflicting interests with the nuclear industry or its political supporters.
- » Because much of the fallout covered the Pacific Ocean, systematic research on the effects on marine life must be conducted jointly by Japanese and international marine research institutes including the United States.
- » Reporting and research on the consequences of the nuclear disaster in Japan must not be hindered by state repression such as the controversial new Japanese law, “the Act on the Protection of Specially Designated Secrets”.
- » Japan shut down all its nuclear power plants after the meltdowns at Fukushima and for several years has managed without nuclear power. Now, the nuclear lobby is trying to bring the reactors back online against the will of the majority of the Japanese population. Japan should permanently shut down all of its 50 nuclear power plants and instead invest in renewable, sustainable energy production. The country has enormous potential for solar power, wind power, hydropower, geothermal energy, as well as energy conservation and efficiency measures.
- » Until then, the enormous influence of the nuclear lobby on Japanese politics and the rampant corruption and collusion between politics, power plant operators and regulators must be investigated and effectively stopped so that disasters like Fukushima can be prevented in the future.



### For Europe and the United States:

- » There are still almost 300 nuclear reactors in Europe and the United States with an average age of 30 to 40 years.
- » IPPNW and PSR urge all States with nuclear power plants to begin closure and decommissioning of reactors and to move to sustainable renewable energy and energy efficiency. There is a broad global consensus that fossil fuels cannot and should not play any role in the energy production of the future. But nuclear is not an acceptable alternative.
- » **IPPNW and PSR recommend that a global energy transition towards 100% renewable energy, coupled with energy efficiency and conservation and the decentralization of energy production should be the only reasonable political consequence of the nuclear disasters at Chernobyl and Fukushima.**



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