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Nuclear catastrophe in Japan

Health consequences resulting from Fukushima

By Henrik Paulitz, Winfrid Eisenberg, and Reinhold Thiel, 6 March 2013

Since 2011, the food chain in Japan has been severely contaminated by radionuclides from Fukushima
Photo: IPPNW

German Affiliate of the International Physicians for the Prevention of Nuclear War (IPPNW)
Körtestraße 10, D-10967 Berlin. www.ippnw.de
Reinhold Thiel (V.i.S.d.P.), Henrik Paulitz, Email: paulitz@ippnw.de
www.ippnw.de/atomenergie, www.fukushima-disaster.de, www.ippnw-peace-power.net
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Summary

On 11 March 2011, a nuclear catastrophe occurred at the Fukushima Dai-ichi nuclear power plant in Japan in the wake of an earthquake and due to serious safety deficiencies. This resulted in a massive and prolonged release of radioactive fission and decay products. Approximately 20% of the radioactive substances released into the atmosphere have led to the contamination of the landmass of Japan with 17,000 becquerels per square meter of cesium-137 and a comparable quantity of cesium-134.

The initial health consequences of the nuclear catastrophe are already now, after only two years , scientifically verifiable. Similar to the case of Chernobyl, a decline in the birth rate was documented nine months after the nuclear catastrophe. Throughout Japan, the total drop in number of births in December 2011 was 4362, with the Fukushima Prefecture registering a decline of 209 births. Japan also experienced a rise in infant mortality, with 75 more children dying in their first year of life than expected statistically.

In the Fukushima Prefecture alone, some 55,592 children were diagnosed with thyroid gland nodules or cysts. In contrast to cysts and nodules found in adults, these findings in children must be classified as precancerous. There were also the first documented cases in Fukushima of thyroid cancer in children.

Table 1: Overview of the existing and expected health consequences from the Fukushima nuclear catastrophe

	Number	**Source**
Decline in live births for 2011	4362	Körblein 2013
Rise in infant mortality for 2011	75	Körblein 2013
Children with thyroid gland cysts and/or nodules in the Fukushima Prefecture alone	55,592	Fukushima Prefecture 2013
Expected incidence of cancer cases resulting from external exposure to radiation	18,950 - 41,303	IPPNW 2013
Expected incidence of cancer cases due to food intake	18,633	IPPNW 2013
Expected cases of severe illnesses among workers employed by Tepco in the nuclear facility in 2011	17,715	IPPNW 2013

The present document undertakes three assessments of the expected incidence of cancer resulting from external exposure to radiation. These are based on publications in scientific journals on soil contamination in 47 prefectures in Japan, the average total soil contamination, and, in the third case, on local dose rate measurements in the fall of 2012. Taking into consideration the shielding effect of buildings, the medical organization IPPNW has calculated the collective lifetime doses for individuals at 94,749 manSv, 206,516 manSv, and 118,171 manSv, respectively.

In accordance with the risk factors set by the European Committee on Radiation Risk (ECRR) for death caused by cancer (0.1/Sv) and the incidence of cancer (0.2/Sv), these figures translate into 18,950, 41,303, and 28,418 expected cases of cancer due to external radiation exposure in Japan.

133,832 measurement results published by the Japanese Ministry of Health were used to estimate the number of expected cases of cancer due to the consumption of contaminated food. However, a large part of the data could not be used, because instead of exact values it was only mentioned “below the maximum permitted levels”. 17,000 measurement readings could be assigned to certain prefectures, with the Fukushima region (Fukushima, Miyagi, Tochigi, and Ibaraki prefectures) showing an average total cesium contamination of 180.8 Bq/kg in the food.. Calculations indicated total cesium levels of 108.1 Bq/kg for the rest of eastern Japan, and 71.8 Bq/kg for western Japan. Due to the nature of the data it remains unclear to what extent these values are representative. Therefore it has conservatively been assumed that, in the first year following the disaster, food was on average contaminated by only half this amount of cesium.

The annual consumption of foodstuffs produced in Japan was estimated at 30,753,745 tons, and the corresponding amounts for the three defined Japanese regions was determined on the basis of their percentage of the total population. In addition, an ecological half-life period of 5 years was assumed.

According to the calculations of IPPNW, the collective lifetime dose amounted to 93,166 manSv. Correspondingly, 18,633 cases of cancer must be expected due to contaminated food intake.

The applied risk factor of 0.1/Sv, which has by now also been accepted by the World Health Organization (WHO), indicates a probable underestimation of the true risk. Recent studies point to a risk factor that is approximately twice as great, thereby resulting in a doubling of the calculated disease figures. Assuming a risk factor of 0.2/Sv, the expected incidence of cancer due to increased external radiation exposure would amount to between 37,899 and 82,606 cases, while 37,266 cancer cases would result from the intake of contaminated food.

Table 1.2: Expected incidence of cancer due to external and internal radiation exposure assuming a risk factor supported by recent findings (0.2/Sv)

	Number	Source
Expected incidence of cancer cases resulting from external exposure to radiation	37,899 – 82,606	IPPNW 2013
Expected incidence of cancer cases due to food intake	37,266	IPPNW 2013

With respect to the workers, who, according to the Fukushima operating company Tepco, were on duty in the damaged plant in 2011, IPPNW estimates on the basis of Chernobyl experiences that more than 17,000 of them will develop serious diseases.

A few of the quantitative results of this study are subject to uncertainty, because some of the original data has only been published in an imprecise form and certain calculations involved making further assumptions necessary. Nevertheless, IPPNW has deemed it necessary to present this quantitative estimate in order to show clearly the true dimension of the Fukushima nuclear catastrophe.

At present, there are numerous nuclear power plants operating at sites facing the potential risk of an earthquake all over the world. Many of them are much less able to withstand the force of an earthquake than nuclear reactors in Japan. Even a relatively weak earthquake could, at any time, trigger another nuclear catastrophe almost anywhere, in Asia, America, and also in Europe.

The nuclear accident

On 11 March 2011 at 14:46 JST, a severe earthquake triggered a catastrophic accident at the Fukushima Dai-ichi nuclear power plant in Japan. The main earthquake was followed by three heavy aftershocks at 15:08, 15:15, and 15:25.

On 6 March 2012, IPPNW published a detailed accident analysis. It concluded that the nuclear incident was caused by the earthquake in combination with serious safety deficiencies. Vital high pressure coolant injection systems failed in all three damaged blocks of the nuclear power plant independently of the subsequent tsunami. In particular, Block 1 exhibits strong evidence of coolant loss (leak) caused by the earthquake.[1]

A few months later, the official report by an investigation commission of the Japanese parliament confirmed that the tsunami was not the crucial factor behind the nuclear catastrophe, as has been claimed to this day by the nuclear industry and public authorities worldwide. The parliamentary report stresses the likelihood that the coolant loss in Block 1 was caused by the earthquake and also addresses other problems discussed by IPPNW, such as the failure of a safety valve and the inadequately diversified design of the safety systems at the nuclear plant.[2]

In the IPPNW report, it was emphasized that the high pressure coolant injection system (HPCI) exhibited a clear deviation between 15:08 and 15:10 on 11 March 2011, and that this abnormality can be chronologically correlated with one of the heavy aftershocks having a magnitude of 7.4, which was registered at 15:08.[3]

It was correspondingly stressed in the Japanese parliamentary report that the strongest vibrations were caused by an aftershock following the reactor's automatic shutdown (i.e., after 14.46) and that this can be interpreted as evidence that the loss of coolant was a result of the earthquake, which led to the worst case disaster scenario in Block 1.[4]

Experts from around the world have also stubbornly ignored the thesis of the American nuclear engineer Arnie Gundersen that the explosion in Block 3 was most probably not due to oxygen or steam, but was instead a nuclear explosion.[5]

This demonstrates that the official versions worldwide concerning the causes and the course of the nuclear catastrophe in Fukushima require correction and clarification.

Evaluating the health consequences resulting from Fukushima

Similar to how the public has been kept in the dark with respect to information on the course of the accident, there has also been an attempt to mask the health con-

[1] Paulitz, Henrik: Der Super-GAU von Fukushima. The Fukushima Disaster. Teil 1. Der Unfallablauf bis zum Eintritt der Kernschmelzen und sicherheitstechnische Schlussfolgerungen. Part 1 The course of events during the accident up until the reactor core meltdowns and conclusions relating to safety. Analyse vom 6. März 2012. Stand: 12. März 2012. Herausgegeben von der Deutschen Sektion der Internationalen Ärzte für die Verhütung des Atomkrieges, Ärzte in sozialer Verantwortung e.V. (IPPNW). Berlin. http://www.fukushima-disaster.de/fukushima_supergau_studie.pdf.

[2] The National Diet of Japan: The official report of The Fukushima Nuclear Accident Independent Investigation Commission. Executive summary. 2012. S. 17. http://www.nirs.org/fukushima/naiic_report.pdf. Last retrieved on 26.02.2013.

[3] Paulitz, Henrik: ebd. S. 26. http://www.fukushima-disaster.de/fukushima_supergau_studie.pdf.

[4] The National Diet of Japan: The official report of The Fukushima Nuclear Accident Independent Investigation Commission. Executive summary. 2012. S. 17. http://www.nirs.org/fukushima/naiic_report.pdf. Last retrieved on 26.02.2013.

[5] Gundersen, Arnie: Gundersen Postulates Unit 3 Explosion May Have Been Prompt Criticality in Fuel Pool. April 26 th, 2011. Fairewinds Associate Inc. http://www.youtube.com/watch?v=vIqbsZCKFPw . Last retrieved on 26.02.2013.

sequences of the nuclear catastrophe. It is therefore necessary to evaluate available data and findings and to make them accessible to the public.

The quantitative estimates undertaken in the present investigation are primarily based on the radioactive cesium isotopes Cs-134 and Cs-137 that were released from the nuclear power plant.

However, radioactive cesium is not the only substance posing a risk. According to the Japanese government report submitted to the IAEA in June 2011, the population of Japan was contaminated by numerous airborne radioactive isotopes. This dangerous radioactive cocktail[6] included xenon-133, cesium-134 and 137, strontium-89 and 90, barium-140, tellurium-127m, 129m, 131m, and 132, ruthenium-103 and 106, zirconium-95, cerium-141 and 144, neptunium-239, plutonium-238, 239, 240, and 241, yttrium-91, praseodymium-143, neodymium-147, curium-242, iodine-131, 132, 133, and 135, antimony-127 and 129, as well as molybdenum -99.

Birth rate decline nine months after the reactor catastrophe

According to calculations made by the Nuremberg scientist Alfred Körblein, there was a sharp decline in birth rates following the nuclear catastrophe in Fukushima (Table 2), just as was the case after Chernobyl (Table 3). In December 2011, nine months after Fukushima, Japan experienced a significant decline in births of 4.7% compared to the trend between the years 2006 to 2011 (p-value = 0.007) and 15% (p-value = 0.001) in the Fukushima Prefecture alone.[7]

In absolute numbers, this amounts to 4362 fewer live births in Japan. The corresponding number for the Fukushima Prefecture is “only” 209, which demonstrates that the consequences of Fukushima have had an effect on the whole of Japan.[8]

Table 2: Birth rate decline in December 2011 in Japan and Fukushima Prefecture[9]

Country / Region	Relative decline	Deficit of births	p-value
Japan	4.7%	4362	0.0072
Fukushima Prefecture	15.1%	209	0.0001
Official statistics. Calculations by Dr. Alfred Körblein			

[6] Government of Japan: Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety. The Accident at TEPCO’s Fukushima Nuclear Power Stations. Nuclear Emergency Response Headquarters. June 2011. www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html.

[7] Körblein, Alfred: Folgen von Fukushima. Rückgang der Geburten in Japan 9 Monate nach Fukushima. Strahlentelex 628/629. 2013.

[8] Körblein, Alfred: Email an Henrik Paulitz vom 12. Februar 2013.

[9] Körblein, Alfred: Folgen von Fukushima. Rückgang der Geburten in Japan 9 Monate nach Fukushima. Strahlentelex 628/629. 2013.

Table 3: Birth rate decline in February 1987 in various countries/regions[10]

Country / Region	Relative decline	Deficit of births	p-value
Bavaria	8.6%	839	0.0091
Southern Bavaria	11.5%	647	0.0009
Northern Bavaria	5.2%	212	0.1595
West Germany	5.0%	2539	0.0711
Austria	4.3%	299	0.0643
Italy	6.8%	2723	0.0170
Croatia	8.2%	385	0.0073
Hungary	4.2%	417	0.1000
Poland (Feb. 1987)	4.6%	2295	0.0500
Poland (Jan.- March)	4.9%	7803	0.0004
Finland	5.2%	245	0.0848
Kiev (Feb. 1987)	28.7%	817	<0.0001
Kiev (Jan. - March)	27.3%	2484	<0.0001
Official statistics. Calculations by Dr. Alfred Körblein			

Rise in infant mortality

As was the case after Chernobyl, there was a higher incidence of infant mortality following the nuclear catastrophe in Fukushima. According to Körblein, the increase amounted to 4%. The Japanese data on infant mortality show distinct peaks in the months of May and December 2011, two and nine months, respectively, after the Fukushima accident.[11] Körblein's statistics indicate a rise of 75 cases of infant death in Japan for both months.[12]

After Chernobyl, an analysis of data on early infant mortality conducted in West Germany showed the highest increases in June 1986 and February 1987 – similar time spans after the reactor catastrophe of 26 April 1986 (early infant mortality is to be understood as death within the first week after birth).

Thyroid gland abnormalities

The health authorities in the Fukushima Prefecture examined the thyroid glands of 38,114 children aged 0 to 18. The study, published in April 2012, found that 35% of the children examined had thyroid gland cysts and 1% had nodules.[13] According to this, one year after Fukushima 13,340 children in the Fukushima Prefecture had thyroid gland cysts and 381 children had thyroid gland nodules .

Dr. Hiroyuki Matsuzaki , Head of the Department of Internal Medicine at the Fukagawa Municipal General Hospital, compared these findings with a study conducted in the year 2000 examining 250 seven to fourteen-year-old children living in the Nagasaki Prefecture. Only 0.8% of these children exhibited thyroid gland cysts. In addition, he cites a work by Mazzaferri et. al. from 1993, which determined that

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[10] Körblein, Alfred: Folgen von Fukushima. Rückgang der Geburten in Japan 9 Monate nach Fukushima. Strahlentelex 628/629. 2013.

[11] Körblein, Alfred: Säuglingssterblichkeit in Japan nach Fukushima. Strahlentelex 622-623, 26, Dez. 2012. http://www.strahlentelex.de/Stx_12_622-623_S12-14.pdf. Last retrieved on 12.02.2013.

[12] Körblein, Alfred: Email an Henrik Paulitz vom 12. Februar 2013.

[13] Resident Health Management Survey of Fukushima Prefecture, 26. April 2012. http://www.pref.fukushima.jp/imu/kenkoukanri/240125shiryou.pdf. Last retrieved on 12.02.2013.

young children in the US don´t exhibit any thyroid gland deformations, but that nodules and cysts increase with age. By the age of 20, one out of ten Americans has nodules and/or cysts.[14]

At 35% of the children, the extremely high rate of thyroid gland deformities in the Fukushima Prefecture after the nuclear catastrophe indicated to Dr. Matsuzaki that “something exceptional was going on” in the thyroid gland.

On 13 February 2013, the Fukushima Prefecture reported that of a total of 133,000 children since examined, 55,592 (41.8%) already exhibit thyroid disorders.[15]

In contrast to thyroid cysts and nodules in adults, they must be regarded as pre-cancerous in children. 55,592 children are already affected in the Fukushima Pre-fecture alone.

On the same date, the administration of the Fukushima Prefecture also reported that there have been three children with thyroid cancer and seven further suspect-ed cases.[16]

Against this background and with the knowledge of what occurred after Chernobyl, Japan must expect a massive increase of thyroid cancer among children from 2015 onwards.

Estimates of cancer due to external exposure to radiation

According to the findings of a team of international researchers, soil in the western regions of Japan has been contaminated with up to 25 Bq/kg of cesium-137, whereas in eastern parts of the country, readings are usually greater than 100 becquerels. In the prefectures of Fukushima, Miyagi, Tochigi, and Ibaraki, cesium contamination in the order of 5000 Bq/kg has been reported (with far greater read-ings in the vicinity of the damaged nuclear power plant).[17]

The December 2011 publication of Yasunari et al. in the Proceedings of the Na-tional Academy of Sciences includes a diagram (fig. 3, p. 19532) indicating the av-erage levels of Cs-137 soil contamination (in Bq/kg) in the 47 Japanese prefec-tures that could be approximately determined (see Fig. 1).

The sum of the total soil activity of Cs-137 in the whole of Japan as calculated here ($3.47 \cdot 10^{15}$ Bq) can be compared with results of a study conducted by Stohl et. al. in 2012, which reports significantly greater soil contamination ($6{,}40 \cdot 10^{15}$ Bq). It indi-cates that the estimate based on Fig.1 is, by and large, a conservative one and may lead to an underestimation of the contamination.

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[14] Matsuzaki, Hiroyuki: http://1am.sakura.ne.jp/Nuclear/kou131 Matsuzaki-opinion.pdf. 19.5.2012. Quot-ed from http://www.strahlentelex.de/Stx_12_612_S01-02.pdf.

[15] Fukushima Prefecture Health Management Survey Planning Committee: 10. Bericht vom 13. Februar 2013. http://fukushimavoice-eng.blogspot.jp/2013/02/fukushima-thyroid-examination-part-4.html. Last retrieved on 03.03.2013. Vgl. (japanisch): http://www.pref.fukushima.jp/imu/kenkoukanri/250213siryou2.pdf.

[16] Hiroyuki Yamamoto: Call for Endorsement to March 11 Fukushima Action. Rundmail vom 20. Februar 2013. Vgl. auch: Ian Thomas Ash: Fukushima. Email vom 13. Februar 2013 an Alex Rosen. Unter Ver-weis auf: http://www.fnn-news.com/news/headlines/articles/CONN00240449.html. Last retrieved on 21.02.2013. Vgl. auch: http://fukushimavoice-eng.blogspot.jp/2013/02/fukushima-thyroid-examination-part-4.html. Last retrieved on 03.03.2013.

[17] Yasunari TY et. al: Cesium-137 deposition and contamination of Japanese soils due to the Fukushima nuclear accident. By Teppei J. Yasunari, Andreas Stohl, Ryugo S. Hayano, John F. Burkhart, Sabine Eckhardt and Tetsuzo Yasunarie. In: Proceedings of the National Academy of Sciences of the United States of America (PNAS). December 6, 2011. vol. 108. no. 49. p. 19530–19534. Abstract: www.pnas.org/cgi/doi/10.1073/pnas.1112058108. Last retrieved on 21.02.2013.

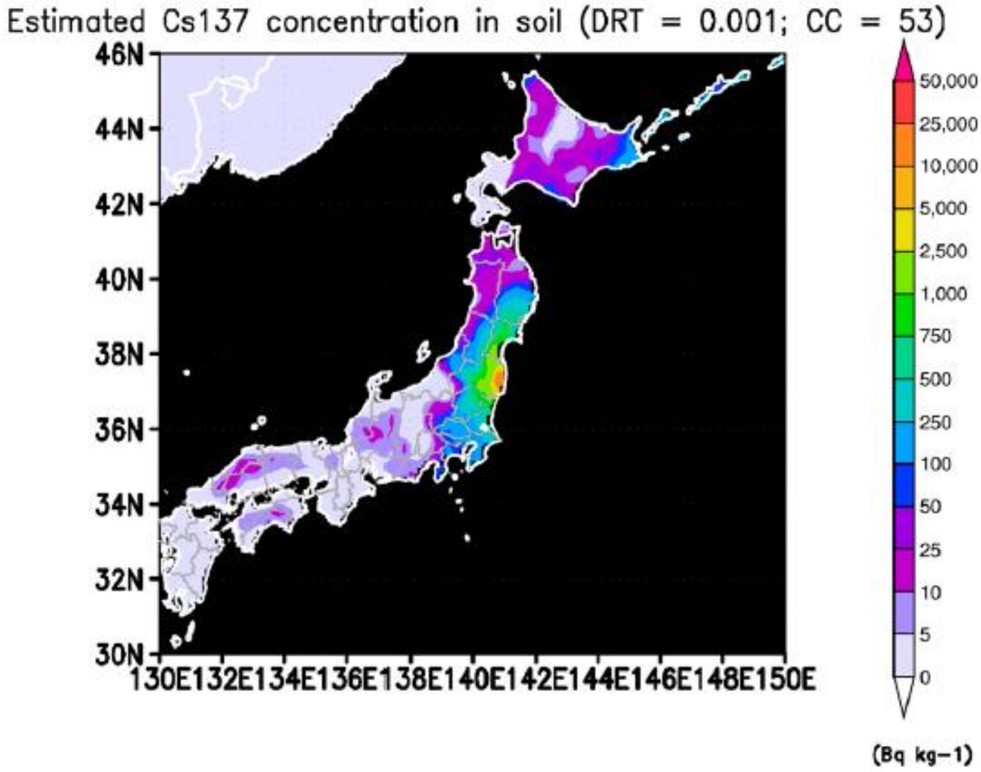

Fig. 1: Soil concentration of cesium-137 in Japan (Bq/kg) resulting from the nuclear catastrophe in Fukushima[18]

On the basis of data from this study, the average Cs-137 soil contamination per square meter (Bq/m2) was calculated for each prefecture.[19] In determining the average local dose rate, contamination by cesium-134 was also taken into consideration in addition to that by cesium-137. According to informations from the Nuclear and Industrial Safety Agency of Japan (NISA), the Fukushima nuclear power plant released 1.2 times more Cs-134 than Cs-137.[20,21] Taking the shorter half-life of Cs-134 (2 years) into account, the average soil contaminations from Cs-134 and Cs-137 were assumed to be at comparable levels (1:1 ratio) for the whole of the first year following Fukushima.[22]

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[18] Yasunari TY et. al: Cesium-137 deposition and contamination of Japanese soils due to the Fukushima nuclear accident. By Teppei J. Yasunari, Andreas Stohl, Ryugo S. Hayano, John F. Burkhart, Sabine Eckhardt and Tetsuzo Yasunarie. In: Proceedings of the National Academy of Sciences of the United States of America (PNAS). December 6, 2011. vol. 108. no. 49. p. 19530–19534. Abstract: www.pnas.org/cgi/doi/10.1073/pnas.1112058108. Last retrieved on 21.02.2013.

[19] Für die Umrechnung der spezifischen Aktivität pro kg Boden (Bq/kg) in die Aktivität pro Fläche (Bq/m2) wurde eine 5 cm dicke, kontaminierte Erdschicht mit einem spezifischen Gewicht von 1 g/cm3 angenommen.

[20] "A preliminary estimate made by the Nuclear and Industrial Safety Agency of Japan (NISA) indicated that 160 PBq of 131I, 18 PBq of 134Cs and 15 PBq of 137Cs were spewed into the atmosphere between 11 and 16 March 2011." Vgl. Nobuyuki Hamada, Haruyuki Ogino, Yuki Fujimichi: Safety regulations of food and water implemented in the first year following the Fukushima nuclear accident. Journal of Radiation Research (2012) 53 (5): 641-671. doi: 10.1093/jrr/rrs032 First published online: July 22, 2012. http://jrr.oxfordjournals.org/content/53/5/641.full.pdf+html. Last retrieved on 22.02.2013.

[21] Vgl. auch Tokyo Electric Power Company: Estimation of the released amount of radioactive materials into the atmosphere as a result of the accident in the Fukushima Daiichi Nuclear Power Station (Estimation made as of May 2012). May 24, 2012. http://www.tepco.co.jp/en/press/corp-com/release/betu12_e/images/120524e0201.pdf. Last retrieved on 22.02.2013.

[22] Integral(exp(-tau*t)) von t=0 bis t=1 (Jahr), mit tau=ln(2)/HWZ. Ergebnis: HWZ/ln(2)*(1-exp(ln(2)*1/HWZ) bzw. mit HWZ=2 (Jahre): Faktor 0,845. 1,2*0,845 ergibt in etwa 1.

Table 4: Determining the collective doses in the Japanese prefectures from external radioactive contamination resulting from the release of radiocesium

	Area [sq.km]	Population [number]	Cs-137* [Bq/kg]	Avg. local dose limit [mSv/a]	Collective dose [manSv]
A) Fukushima, Miyagi, Tochigi, and Ibaraki Prefectures					
Fukushima Prefecture	13,782	1,960,523	2500	8.000	15,684
Miyagi Prefecture	6862	2,326,957	1200	3.840	8936
Tochigi Prefecture	6408	1,993,479	400	1.280	2552
Ibaraki Prefecture	6096	2,946,020	500	1.600	4714
Subtotal	33,148	9,226,979			
B) Eastern Japan excluding Fukushima, Miyagi, Tochigi, and Ibaraki					
Hokkaidō region					
Hokkaidō Prefecture	83,456	5,475,783	50	0.160	876
Tōhoku region (excl. Fukushima and Miyagi)					
Akita Prefecture	11,612	1,061,773	50	0.160	170
Aomori Prefecture	9606	1,349,294	50	0.160	216
Iwate Prefecture	15,279	1,302,645	500	1.600	2084
Yamagata Prefecture	9323	1,151,685	250	0.800	921
Kantō region (excl. Ibaraki and Tochigi)					
Chiba Prefecture	5157	6,195,643	250	0.800	4957
Gunma Prefecture	6363	1,992,143	50	0.160	319
Kanagawa Prefecture	2416	9,075,075	100	0.320	2904
Saitama Prefecture	3797	7,211,316	250	0.800	5769
Tokyo Prefecture	2187	13,228,912	250	0.800	10,583
Chūbu region (only 5 prefectures)					
Shizuoka Prefecture	7780	3,731,717	25	0.080	299
Aichi Prefecture	5163	7,428,769	10	0.032	238
Gifu Prefecture	1598	2,064,888	20	0.064	132
Nagano Prefecture	13,562	2,130,448	5	0.016	34
Yamanashi Prefecture	4465	851,345	20	0.064	54
Subtotal	181,764	64,251,436			
C) Western Japan					
Kyūshū region (southern Japan)					
Fukuoka Prefecture	4976	5,088,063	5	0.016	81
Saga Prefecture	2440	843,302	5	0.016	13
Nagasaki Prefecture	4095	1,406,959	5	0.016	23

Komamoto Prefecture	7405	1,807,798	5	0.016	29
Ōita Prefecture	6339	1,185,179	5	0.016	19
Miyazaki Prefecture	7735	1,125,902	5	0.016	18
Kagoshima Prefecture	9188	1,689,291	5	0.016	27
Okinawa Prefecture	2276	1,412,753	5	0.016	23
Shikoku region					
Ehime Prefecture	5678	1,414,316	10	0.032	45
Kagawa Prefecture	1876	989,320	5	0.016	16
Kōchi Prefecture	7105	751,142	10	0.032	24
Tokushima Prefecture	4146	775,421	5	0.016	12
Chūgoku region					
Hiroshima Prefecture	8479	2,849,619	10	0.032	91
Okayama Prefecture	7113	1,936,593	5	0.016	31
Shimane Prefecture	6708	706,848	10	0.032	23
Tottori Prefecture	3507	581,597	5	0.016	9
Yamaguchi Prefecture	6112	1,430,338	5	0.016	23
Kinki region					
Shiga Prefecture	4017	1,417,291	5	0.016	23
Mie Prefecture	5777	1,838,629	5	0.016	29
Kyōto Prefecture	4613	2,627,571	10	0.032	84
Nara Prefecture	3691	1,389,066	5	0.016	22
Ōsaka Prefecture	1897	8,865,882	5	0.016	142
Wakayama Prefecture	4726	986,604	5	0.016	16
Hyōgo Prefecture	8393	5,571,822	5	0.016	89
Chūbu region (only 4 prefectures)					
Niigata Prefecture	12,583	2,345,660	100	0.320	751
Toyama Prefecture	4248	1,082,248	5	0.016	17
Ishikawa Prefecture	4185	1,163,071	5	0.016	19
Fukui Prefecture	4189	799,104	10	0.032	26
Subtotal	153,497	54,081,389			
Total					**63,166**
Contamination data by Yasunari et. al. 2011, calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein					

The dose coefficient for gamma radiation in the soil amounts to 1.5E-15 (Sv/s)/(Bq/m²) for Cs-134 and 5.3E-16 (Sv/s)/(Bq/m²) for Cs-137. The conversion factors to calculate the average increased local dose rate (mSv/a) due to Fukushima amount to 47.3 (mSv/a)/(MBq/m²) for Cs-134 and 16.7 (mSv/a)/(MBq/m²) for

Cs-137.[23] The collective first year dose for each prefecture was calculated by taking population figures into account. For the whole of Japan, the result was a dose of 63,166 manSv - for the first year (see Table 4).

As people do not spend all of their time outdoors and because of the shielding effect of buildings, it has been assumed that the population was only exposed to 50% of the outdoor dose, thereby being exposed to a total of 31,583 manSv. In accordance with a decision made by the German Commission on Radiological Protection (SSK) following Chernobyl, it has been assumed that the lifetime dose corresponds to three times the first-year dose. Thus, the lifetime dose for the Japanese amounts to 94,749 manSv (see Table 5).

Applying the risk factor set by the European Committee on Radiation Risk (ECRR) for cancer mortality of EAR (excess absolute risk)/Sv = 0.1/Sv (or 10%/Sv) and for the incidence of cancer of EAR/Sv = 0.2/Sv (20%/Sv), the number of expected deaths due to cancer is 9475, and that of expected incidence of cancer is 18,950.

The risk factor of 0.1/Sv, which has recently been adopted by the World Health Organization (WHO), poses the likelihood of an underestimation of the risk. More recent studies indicate a risk factor higher by a factor of 2, thereby necessitating doubling the figure for the calculated incidence of cancer.[24,25]

If one assumes a doubling of the risk factor, one should expect 18,950 deaths due to cancer (mortality) and 37,899 cases of cancer (incidence).

Table 5: Expected incidence of cancer in Japan due to external radioactive contamination resulting from the release of radiocesium (Var. 1)

External collective dose for the first year – outdoors [manSv]	63,166
Effective dose (50% due to shielding) [manSv]	31,583
Lifetime dose (3 x 1-year dose) [manSv]	**94,749**
Expected cancer deaths (mortality), with EAR/Sv=0,1/Sv (DDREF=1)	9475
Expected cases of cancer (incidence)	**18,950**
Expected cancer deaths (mortality), with **EAR/Sv=0,2/Sv** (DDREF=1)	18,950
Expected cases of cancer (incidence)	**37,899**

A second estimate of expected cases of cancer from external radiation exposure was undertaken on the basis of data compiled by the research team of Dr. Andreas Stohl from the Norwegian Institute for Air Research. It concluded that on 20 April 2011, 36.6 Petabecquerel[26] (PBq) of cesium-137 was released from the Fukushima nuclear plant, of which 6.4 PBq (approx. 18%) was deposited on Japanese soil (see Fig. 2).[27]

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[23] Umrechnung in mSv/a: 8760 h/a*3600 s/h = 31.5 Mio s/a. Dosisfaktor Cs-137: DF= 5,3E-16 Sv/s*Bq/m² = 5,3E-16*31.5E6*1000 mSv/Sv*1000 Bq/kBq = 5,3*31,5E-4 = 0,0167 (mSv/a)/(kBq/m²) = 16,7 (mSv/a) / (MBq/m²). Entsprechend für Cs-134: DF= 16,7*15/5,3= 47,3 (mSv/a) / (MBq/m²).

[24] Bauer S, Gusev BI, Pivina LM, Apsalikov KN, Grosche B. Radiation exposure due to local fallout from Soviet atmospheric nuclear weapons testing in Kazakhstan: solid cancer mortality in the Semipalatinsk historical cohort, 1960-1999. Radiat Res. 2005 Oct;164(4 Pt 1):409-19. PubMed PMID: 16187743. http://www.ncbi.nlm.nih.gov/pubmed/16187743. Last retrieved on 04.03.2013.

[25] Körblein A, Hoffmann W. Background radiation and cancer mortality in Bavaria: an ecological analysis. Arch Environ Occup Health. 2006 May-Jun;61(3):109-14. PubMed PMID: 17672352.

[26] Peta steht für Billiarde, 10 hoch 15: 1.000.000.000.000.000.

[27] Stohl A et. al.: Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. By A. Stohl, P. Seibert, G. Wotawa, D. Arnold, J. F. Burkhart, S. Eckhardt, C. Tapia, A. Vargas, and T. J.

According to this study, Japan was contaminated with an average of 16,939 Bq/m2 Cs-137. Taking into account contamination by Cs-134, the increased average local dose rate due to Fukushima is calculated at 1.084 mSv/a. Multiplied by the population figure of Japan, this results in a collective first year dose of 137,677 manSv outdoors and of 68,839 manSv accounting for the shielding effect of buildings (see Table 6).

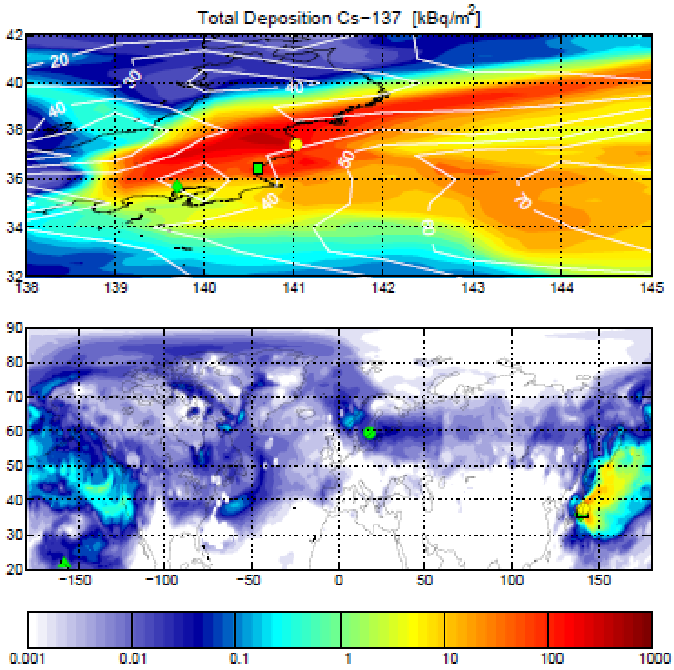

Fig. 2: Deposition of cesium-137 resulting from the nuclear catastrophe at Fukushima up to 20 April 2011. The top diagram shows Japan (yellow circle: Fukushima nuclear power plant, green rhombus: Tokyo), the bottom diagram shows the worldwide spread of the radioactive particles (green circle: Stockholm)[28]

A calculated lifetime dose (triple the first-year dose, see above) amounting to 206,516 manSv results in 20,652 expected deaths from cancer and 41,303 expected cases of cancer based on ECRR risk factors.

If, on the basis of new findings, one assumes a risk greater by a factor of 2, calculations indicate 41,303 expected deaths from cancer and 82,606 expected cases of cancer (see Table 6).

An alternative third estimate of anticipated cases of cancer due to external radiation exposure is derived from the work of Annette Hack and Thomas Dersee[29], who

Yasunari. In: Atmos. Chem. Phys., 12. p. 2313–2343. 2012. http://www.atmos-chem-phys.net/12/2313/2012/acp-12-2313-2012.pdf. Last retrieved on 21.02.2013.

[28] Stohl A et. al.: Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. By A. Stohl, P. Seibert, G. Wotawa, D. Arnold, J. F. Burkhart, S. Eckhardt, C. Tapia, A. Vargas, and T. J. Yasunari. In: Atmos. Chem. Phys., 12. p. 2313–2343. 2012. http://www.atmos-chem-phys.net/12/2313/2012/acp-12-2313-2012.pdf. Last retrieved on 21.02.2013.

[29] Dersee ist Herausgeber des deutschsprachigen Informationsdienstes „Strahlentelex“.

conducted measurements of local dose lrates in the fall of 2012, one-and-a-half years after the beginning of the nuclear catastrophe.[30]

Table 6: Expected incidence of cancer in Japan due to external radioactive contamination resulting from the release of radiocesium (Var. 2)

Population of Japan [number]	127,000,000
Land area of Japan [sq. km.]	377,835
Total amount of released cesium-137 [PBq]	36.6
Cesium-137 contamination of Japan [PBq]	6.4
Cäsium-137 contamination of Japan [Bq]	6.40E+15
Cs-137 [Bq/m2]	16,939
Average increased local dose limit of Cs-134/Cs-137 [mSv/a]	1.08
External collective 1-year dose (outdoors) [manSv]	137,677
Effective dose (50% due to shielding) [manSv]	68,839
Lifetime dose (3 x 1-year dose) [manSv]	**206,516**
Expected cancer deaths (mortality), with **EAR/Sv=0.1/Sv** (DDREF=1)	20,652
Expected cases of cancer (incidence)	**41,303**
Expected cancer deaths (mortality), with **EAR/Sv=0.2/Sv** (DDREF=1)	41,303
Expected cases of cancer (incidence)	**82,606**
Contamination data by Stohl et. al. 2012, calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein	

On the basis of a total of 37 24-hour daily average values, i.e. continuous measurements in 5-minute intervals for 37 days, the average local dose rates in the second year were calculated for the Fukushima region, the rest of eastern Japan, and for western Japan (see Table 7).

Table 7: Average local dose rate (LDR) in various regions of Japan 1.5 years after the nuclear catastrophe (Fall 2012)

	Background radiation before Fukushima (LDR)* [µSv/h]	Average LDR measured in Fall 2012 [µSv/h]	Average LDR increased by Fukushima in Fall 2012 [µSv/h]
Fukushima region	0.072	0.192	0.120
Rest of eastern Japan	0.069	0.126	0.057
Western Japan	0.082	0.153	0.071
Measurement data by Hack/Dersee 2012, calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein *Data from MEXT for terrestrial radiation incl. an assumed average cosmic radiation of 0.034 µSv/h (0.3 mSv/a)			

[30] Annette Hack, Thomas Dersee: Folgen von Fukushima. Durchhalteparolen und falsche Strahlenmessungen. Tabelle 1. Messungen der Ortsdosisleistungen in Japan im Herbst 2012. Strahlentelex Nr. 622-623. 2012. S. 4. http://www.strahlentelex.de/Stx_12_622-623_S01-09.pdf. Last retrieved on 22.02.2013.

According to information provided by the Japanese Ministry of Science and Technology (MEXT), the terrestrial background radiation in Tokyo before the Fukushima nuclear catastrophe was registered at 0.036 µSv/h.[31] The values obtained for the individual prefectures were averaged for the Fukushima Region (0,038 µSv/h), for the rest of eastern Japan (0,035 µSv/h), and for western Japan (0,047 µSv/h).

In addition to these values, there was exposure from cosmic radiation measured at 0.034 µSv/h (0.3 mSv/a).[32] The average values for terrestrial radiation calculated for the three regions of Japan on the basis of the MEXT data were correspondingly increased. This resulted in local dose rates before Fukushima amounting to 0.072 µSv/h, 0.069 µSv/h, and 0.082 µSv/h, respectively, as presented in Table 7.

Values were considerably higher even in the second year after the Fukushima nuclear catastrophe – around 0.120 µSv/h in the Fukushima Region, 0.057 µSv/h in the rest of eastern Japan, and 0.071 µSv/h in western Japan. It is remarkable that these figures indicate an elevated local dose rate in western Japan anyhow amounting to around 60% of the higher local dose rate in the Fukushima region.

As represented in Table 8, the average local first-year dose rates resulting from Fukushima were calculated making the presumably conservative assumption that they were 25% greater than the increased local second-year dose rates. Multiplying this figure by the number of inhabitants results in the outdoors collective doses for the three observed regions, which have to be reduced considerably due to the shielding effect of buildings (a factor of 2 is assumed).

This approach is a conservative one, as measurements of the local dose rates were at times carried out in the relatively well-shielded upper floors of hotels:[33]

> *"In evaluating exposure levels, it must be noted that hotels nowadays are typically built as Western-style high-rises. An overnight stay in one of the upper floors means that tourists will experience considerably less radiation exposure at a level around 0.1 µSv/h (i.e. the 6th floor of the Richmond Hotel in Fukushima City). This greatly lowers the average daily dose. Exposure levels in the open, in the numerous one and two story traditional Japanese buildings, and during excursions through the countryside are, to some extent, considerably higher (see Tables 1 and 2) and correspond to those experienced by the local population."*

This results in lifetime collective doses of 18,237 manSv for the Fukushima Region, 60,456 manSv for the rest of eastern Japan, and 63,395 manSv for western Japan. The sum for the whole of Japan amounts to 142,089 manSv. Employing the ECRR risk factors, calculations indicate 11,817 deaths due to cancer (mortality) and 23,634 expected cases of cancer (incidence).

If, on the basis of new findings, one assumes that the risk is greater by a factor of 2, calculations indicate 28,418 deaths due to cancer (mortality) and 56,835 expected cases of cancer (incidence).

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[31] Iori Mochizuki: Radiation back ground level was 0.036 µSv/h in Tokyo before 311. Fukushima Diary. December 24th, 2012. http://fukushima-diary.com/2012/12/radiation-back-ground-level-was-0-036-%CE%BCsvh-in-tokyo-before-311. Last retrieved on 22.02.2013.

[32] Wikipedia: Background radiation. http://en.wikipedia.org/wiki/Background_radiation. Last retrieved on 27.02.2013.

[33] Annette Hack, Thomas Dersee: Folgen von Fukushima. Durchhalteparolen und falsche Strahlenmessungen. Tabelle 1. Messungen der Ortsdosisleistungen in Japan im Herbst 2012. Strahlentelex Nr. 622-623. 2012. S. 4. http://www.strahlentelex.de/Stx_12_622-623_S01-09.pdf. Last retrieved on 22.02.2013.

Table 8: Expected incidence of cancer in Japan due to external radioactive contamination on the basis of measured increased local dose rates (Var. 3)

	Fukushima Region	**Rest of Eastern Japan**	**Western Japan**	**Japan Total**
Population	9,226,979	64,251,436	54,081,389	127,559,804
Second-year local dose l rates [µSv/h]	0.192	0.126	0.153	
Second-year increased local dose rates due to Fukushima [µSv/h]	0.120	0.057	0.071	
First-year increased local dose rates due to Fukushima (25% higher as in second year) [µSv/h]	0.150	0.072	0.089	
First-year increased local dose l rates due to Fukushima [mSv/h]	1.318	0.627	0.781	
First-year external collective dose - outdoors [manSv]	12,158	40,304	42,263	
Effective dose (50% due to shielding) [manSv]	6079	20,152	21,132	
Lifetime dose (3 x 1-year dose) [manSv]	**18,237**	**60,456**	**63,395**	**142,089**
Expected cancer deaths (mortality), with **EAR/Sv=0.1/Sv** (DDREF=1)	1824	6046	6339	14,209
Expected cases of cancer (incidence)	**3647**	**12,091**	**12,679**	**28,418**
Expected cancer deaths (mortality), with **EAR/Sv=0.2/Sv** (DDREF=1)	3647	12,091	12,679	28,418
Expected cases of cancer (incidence)	**7295**	**24,183**	**25,358**	**56,835**
Measurement data by Hack/Dersee 2012, calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein				

Table 9: Expected cases of cancer due to external radiation exposure

Data source	**Expected cases of cancer (incidence) according to ECRR risk factor**	**Expected cases of cancer (incidence) risk according to newer findings**
Yasunari et. al. 2011	18,950	37,899
Stohl et. al. 2012	41,303	82,606
Hack/Dersee 2012	28,418	56,835
Calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein		

Table 9 provides an overview of the results of the three methodological approaches, which take into account the various risk factors to estimate the occurrence of cancer due to external exposure to radiation. It shows that 20,000 to 80,000 patients with cancer should be anticipated.

Incidence of cancer due to radiation exposure from food

Levels of agricultural production for the year 2010, including fisheries and aquaculture, can be found in the 2012 Statistical Handbook of Japan issued by the Ministry of the Interior. [34] In light of Japan's extremely high dependence on imports for agricultural products [35] and an only slight decrease in the own production after Fukushima, this investigation has assumed that the Japanese annual food consumption is 80% of food production in 2010 (30.753.745 t).

"Corrected" measurements of radionuclides in food samples taken from 19 March 2011 to 31 March 2012, which were published by the Japanese Ministry of Health, were used to calculate the average level of contamination in foodstuffs after Fukushima.[36] Most of these measurement readings of 133,832 food samples from all over Japan could not be evaluated, because the measured values are not given, but it is only declared that maximum permitted levels were not exceeded. More than 17,000 measurement readings could be sorted according to Japanese prefectures. These showed that for the Fukushima region (Fukushima, Miyagi, Tochigi, and Ibaraki prefectures) food samples had an average level of total cesium contamination of 180.8 Bq/kg. Total cesium contamination for the rest of eastern Japan was calculated at 108.1 Bq/kg, and 71.8 Bq/kg for western Japan (see Table 10).

Due to the nature of the data it remains unclear if these underlying values are representative. Therefore it has been conservatively estimated that foodstuff on average was contaminated with only half this amount of cesium for the first year after Fukushima. This results in 90.4 Bq/kg total cesium for the Fukushima region, 54.0 Bq/kg for the rest of eastern Japan, and 35.9 Bq/kg for western Japan (see Table 12).

[34] Für die Berechnung wurden 80% der japanischen Produktionsmengen von 2010 zugrunde gelegt. Quelle: Ministry of Internal Affairs and Communications. Statistics Bureau, Director-General for Policy Planning (Statistical Standards) and Statistical Research and Training Institute: Statistical Handbook of Japan 2012. Chapter 5 Agriculture, Forestry and Fisheries. Table 5.2 Agricultural Production. Table 5.3 Production Volumes of Meat, Milk and Eggs. Table 5.6 Production by Fishery Type and Species http://www.stat.go.jp/english/data/handbook/c05cont.htm. Last retrieved on 17.02.2013.

[35] Hanns Günther Hilpert: Japans Agrarimport - Ein Überblick. http://www.dijtokyo.org/doc/dij-jb_12-hilpert.pdf. Last retrieved on 21.02.2013.

[36] Ministry of Health, Labour and Welfare: Corrected Test results of radionuclide in foods sampled since 19 March 2011 to 31 March 2012 (PDF:10,034KB) (Excel 2007:14,479KB) http://www.mhlw.go.jp/english/topics/2011eq/xls/20110319_20120331.xlsx. Last retrieved on 20.02.2013.

Table 10: Average values for contamination of food in Japanese prefectures on the basis of available absolute measurement values from the Ministry of Health (19 March 2011 - 31 March 2012)

Region or prefecture	Area [sq. km]	Population [number]	Total cesium [Bq/kg]	Standard deviation (number of measurements)
A) Fukushima, Miyagi, Tochigi, and Ibaraki prefectures				
Fukushima Prefecture	13,782	1,960,523	322.8	1698.1 (6249)
Miyagi Prefecture	6862	2,326,957	118.7	180.3 (1506)
Tochigi Prefecture	6408	1,993,479	200.5	426.9 (757)
Ibaraki Prefecture	6096	2,946,020	81.3	236.3 (2287)
Total for "Fukushima region"	**33,148**	**9,226,979**		
Average for "Fukushima region"			**180.8**	**106.9**
B) Eastern Japan excluding Fukushima, Miyagi, Tochigi, and Ibaraki				
Hokkaidō region				
Hokkaidō Prefecture	83,456	5,475,783	13.5	37.7 (123)
Tōhoku region (excl. Fukushima and Miyagi)				
Akita Prefecture	11,612	1,061,773	59.3	118.7 (106)
Aomori Prefecture	9606	1,349,294	8.3	13.2 (68)
Iwate Prefecture	15,279	1,302,645	123.2	243.3 (760)
Yamagata Prefecture	9323	1,151,685	26.9	51.1 (1618)
Kantō region (excl. Ibaraki and Tochigi)				
Chiba Prefecture	5157	6,195,643	76.4	216.2 (720)
Gunma Prefecture	6363	1,992,143	140.1	224.3 (462)
Kanagawa Prefecture	2416	9,075,075	164.9	343.3 (235)
Saitama Prefecture	3797	7,211,316	253.9	289.9 (1692)
Tokyo Prefecture	2187	13,228,912	213.1	336.0 (96)
Chūbu region (only 5 prefectures)				
Shizuoka Prefecture	7780	3,731,717	75.2	115.5 (708)
Aichi Prefecture	5163	7,428,769	102.9	122.3 (8)
Gifu Prefecture	1598	2,064,888	89.8	79.3 (70)
Nagano Prefecture	13,562	2,130,448	155.3	276.6 (22)
Yamanashi Prefecture	4465	851,345	118.4	114.9 (28)
Total for rest of eastern Japan	**181,764**	**64,251,436**		
Average for rest of eastern Japan			**108.1**	**70.4**
C) Western Japan				
Kyūshū region (southern Japan)				
Fukuoka Prefecture	4976	5,088,063	no value*	

Saga Prefecture	2440	843,302	no value	
Nagasaki Prefecture	4095	1,406,959	no value	
Komamoto Prefecture	7405	1,807,798	no value	
Ōita Prefecture	6339	1,185,179	no value	
Miyazaki Prefecture	7735	1,125,902	no value	
Kagoshima Prefecture	9188	1,689,291	no value	
Okinawa Prefecture	2276	1,412,753	no value	
Shikoku region				
Ehime Prefecture	5678	1,414,316	no value	
Kagawa Prefecture	1876	989,320	no value	
Kōchi Prefecture	7105	751,142	no value	
Tokushima Prefecture	4146	775,421	no value	
Chūgoku region				
Hiroshima Prefecture	8479	2,849,619	no value	
Okayama Prefecture	7113	1,936,593	no value	
Shimane Prefecture	6708	706,848	50.9	33.6 (72)
Tottori Prefecture	3507	581,597	no value	
Yamaguchi Prefecture	6112	1,430,338	no value	
Kinki region				
Shiga Prefecture	4017	1,417,291	no value	
Mie Prefecture	5777	1,838,629	66.8	43.2 (24)
Kyōto Prefecture	4613	2,627,571	no value	
Nara Prefecture	3691	1,389,066	no value	
Ōsaka Prefecture	1897	8,865,882	no value	
Wakayama Prefecture	4726	986,604	no value	
Hyōgo Prefecture	8393	5,571,822	no value	
Chūbu region (only 4 prefectures				
Niigata Prefecture	12,583	2,345,660	97.7	100.2 (90)
Toyama Prefecture	4248	1,082,248	no value	
Ishikawa Prefecture	4185	1,163,071	no value	
Fukui Prefecture	4189	799,104	no value	
Total for western Japan	**153,497**	**54,081,389**		
Average for western Japan			**71.8**	**23.8**
Average of the prefecture averages			**120.2**	

Data from the Japanese Ministry of Health, calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein

* “no value” means that for these prefectures measured values were not published, but it was only declared that maximum permitted levels were not exceeded, which cannot be evaluated.

The ecological half-life period of cesium-137 for plant and animal products is in the range of 4 to 6 years. After the Chernobyl reactor catastrophe, it was ascertained that ecological half-life periods were somewhat longer than previously (1965 to 1985). The variability for the time response in fish is very pronounced and cannot be determined without knowledge of the respective specific local conditions. Ecological half-life periods for cesium-137 in the upper levels of topsoil (0-10 cm) are estimated to be between 30 and 300 years, which means that in this case the decrease in activity is primarily determined by radioactive decay (the physical half-life period).[37]

On this basis, the present study has taken the ecological half-life period for Cs-134 and Cs-137 in foodstuffs to be 5 years. This results in an effective half-life of 1.43 years for Cs-134 and 4.3 years for Cs-137 (see Table 11).

Table 11: Ingestion factors and effective half-life periods

Ingestion factor Cs-134 [Sv/Bq]	1.9E-08
Ingestion factor Cs-137 [Sv/Bq]	1.3E-08
Physical half-life period Cs-134 [a]	2
Assumed ecological half-life period Cs-134 [a]	5
Effective half-life period Cs-134 [a]	1.43
Physical half-life period Cs-137 [a]	30
Assumed ecological half-life period Cs-137 [a]	5
Effective half-life period Cs-137 [a]	4.3
Calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein Remark: Effective half-life period: 1/T(eff.) = 1/T(phys.) + 1/T(eco.)	

The annual consumption level of foodstuffs produced in Japan was estimated to be 30,753,745 tons. The corresponding levels for the three defined Japanese regions were calculated on the basis of their percental share of the total population (see Table 12).

According to these assumptions, the total collective lifetime dose for Japan amounts to 93,166 manSv. Employing the ECRR risk factors, calculations indicate 9,317 deaths due to cancer (mortality) and 18,266 expected cases of cancer (incidence).

If, on the basis of new findings, one assumes that the risk is greater by a factor of 2, calculations indicate 18,633 expected deaths from cancer (mortality) and 37,266 expected in cases of cancer (incidence).

This estimation of the health consequences resulting from contaminated food intake is subject to significant uncertainties. The question therefore arises as to what extent the analyzable data published by the Japanese Ministry of Health is truly representative for the average contamination levels in the various prefectures for the first year.

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[37] Pröhl G, Fiedler I, Klemt E, Zibold G, Ehlken S: Erfassung ökologischer Halbwertszeiten von Sr-90 und Cs-137 in terrestrischen und aquatischen Ökosystemen. Herausgegeben vom Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU). Schriftenreihe Reaktorsicherheit und Strahlenschutz. BMU-2004-640. 2004. http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/schriftenreihe_rs640.pdf. Last retrieved on 27.02.2013.

Table 12: Expected cases of cancer on the basis of Japanese Ministry of Health measurement values (suitable for evaluation) of foodstuffs

	"Fukushima region"	Rest of eastern Japan	Western Japan	Japan - Total
Population [number]	9,226,979	64,251,436	54,081,389	127,559,804
Population [%]	7.2	50.4	42.4	
Assumed quantity ingested [t/a]	2,224,558	15,490,556	13,038,631	30,753,745
Average value total cesium [Bq/kg]	180.8	108.1	71.8	
Assumed average value total cesium (50%) [Bq/kg]	90.4	54.0	35.9	
Cs-134 [Bq/kg]	45.2	27.0	18.0	
Cs-137 [Bq/kg]	45.2	27.0	18.0	
First-year collective dose Cs-134 [manSv]	1911	7952	4447	
First-year collective dose Cs-137 [manSv]	1307	5441	3043	
Collective dose Cs-134 [manSv] (lifetime)	3938	16,388	9166	
Collective dose Cs-137 [manSv] (lifetime)	8084	33,639	21,950	
Total collective dose [manSv]	**12,022**	**50,028**	**31,116**	**93,166**
Total cancer deaths (mortality) with **EAR/Sv=0.1/Sv** (DDREF=1)	1202	5003	3112	9317
Total cases of cancer (incidence)	**2404**	**10,006**	**6223**	**18,633**
Total cancer deaths (mortality) with **EAR/Sv=0.2/Sv** (DDREF=1)	2404	10,006	6223	18,633
Total cases of cancer (incidence)	**4809**	**20,011**	**12,446**	**37,266**
Data from the Japanese Ministry of Health, calculations by Henrik Paulitz/IPPNW, in consultation with Dr. Alfred Körblein				

Digression: Selected information on the contamination of foodstuffs

In order to better understand the assumptions made in the previous section on the contamination of foodstuffs, this study will now review details on publications concerning the measurement programs.

On 18 April 2011, the Japanese Ministry of Science and Technology (MEXT) published data on iodine and cesium contamination of vegetables from the Fukushima Prefecture outside of the evacuation zone. The data indicate a wide range of values for Cs-137 far above 10,000 Bq/kg, above 100,000 Bq/kg, and even above 1,000,000 Bq/kg. The peak values reached 2,650,000 and 2,879,000 Bq/kg of Cs-137.[38]

Around 100 kilometers south of the damaged nuclear power plant, the Ibaraki Prefecture administration discovered spinach, which it reported to be contaminated

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[38] MEXT: Readings of dust sampling. Readings of environmental monitaring samples（Weed）. April 18, 2011. http://eq.wide.ad.jp/files_en/110418dust_1000_en.pdf. Last retrieved on 20.02.2013.

with up to 1931 Bq/kg of radiocesium. Most of the other vegetable samples were similarly contaminated, to a greater or lesser extent. A reading of parsley found 2110 Bq/kg of Cs-137. Shiitake mushrooms, which are consumed in large amounts in Japan, registered 8000 Bq/kg of Cs-137. Lesser amounts of radiation were found in lettuce, onions, tomatoes, strawberries, wheat, and barley.[39]

According to the Japanese Atomic Information Forum, the Fukushima Prefecture acknowledged in November 2011 that radiation values for rice from the city of Date (not far from the prefecture capital of Fukushima City and more than 50 km away from the nuclear power plant) surpassed the safety limit of 500 becquerels of radiocesium per kilogram (Bq/kg). Rice was measured with up to 1050 Bq/kg.[40]

A report by the International Atomic Energy Agency (IAEA) from 19 March 2011 states that Japanese authorities measured radioactive iodine in milk from the Fukushima Prefecture. On 16 March, up to 1510 Bq/kg were detected, thereby exceeding the Japanese maximum levels for marketing five times. Information on cesium contamination was not provided.

According to the provisional regulations set by the Japanese Ministry of Health, meat products from the Fukushima, Tochigi, Miyagi, and Iwate prefectures could still not be sold even in January 2012, because of radioactive contamination.[41]

In December 2012, the Ministry of Agriculture (MAFF) disclosed that since April 2012, the generally applicable contamination limit of 100 Bq/kg for foodstuff would only be mandatory for meat as of 20 September 2012. Until then, apparently on account of the high contamination levels found in beef, the limits were maintained at 500 Bq/kg.[42]

> *"While the new regulation setting out the maximum limit of 100 Bq/kg for general foods came into force on April 1st, 2012, as the transitional measure, the maximum limit of 500 Bq/kg still had applied to beef until September 30."*

On 2 July 2012, the Japanese Ministry of the Environment (MOE) released information on the contamination of freshwater and marine fish in the winter period of 2011/2012. It found the highest level of cesium contamination in freshwater fish (a kind of goby fish in the Mano River) in the Fukushima Prefecture with 2600 Bq/kg.[43]

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[39] "Ibaraki Prefecture Agricultural Products Test Results", Ibaraki Prefectural Government, August 8th, 2011. Quoted from: Alex Rosen: Effects of the Fukushima nuclear meltdowns on environment and health. February 16th, 2012. University Clinic Düsseldorf, Department of General Paediatrics. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/FukushimaBackgroundPaper.pdf. Last retrieved on 20.02.2013.

[40] Japanese Atomic Information Forum: Cesium detected from more Fukushima rice. Earthquake Report No. 276. November 29th, 2011. http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1322541949P.pdf. Last retrieved on: 18.02.2013.

[41] TEPCO: Current Status of Fukushima Daiichi Nuclear Power Station. January 27, 2012. www.tepco.co.jp/en/nu/fukushima-np/f1/images/f12np-gaiyou_e_3.pd. Quoted from: Alex Rosen: Effects of the Fukushima nuclear meltdowns on environment and health. February 16th, 2012. University Clinic Düsseldorf, Department of General Paediatrics. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/FukushimaBackgroundPaper.pdf. Last retrieved on 20.02.2013.

[42] Ministry of Agriculture, Forestry and Fisheries (MAFF): Questoins and answers on rice, meat and eggs, milk, dairy products, mushrooms, and edible wild plants. December 19, 2012. http://www.maff.go.jp/e/quake/press_120613-faq-yasai.html. Last retrieved on 20.02.2013.

[43] GRS: Environmental impact caused by the nuclear power accident at Fukushima Daiichi nuclear power station. November 26, 2012. http://fukushima.grs.de/sites/default/files/Environmental_effect_20121126.pdf. Last retrieved on 20.02.2013.

Since 2011, the Ministry of the Environment has been regularly monitoring contamination in the rivers of Fukushima. According to information released on 18 February 2012, analyses of these rivers clearly indicated a steady increase in the amount of radiocesium found in sand and sediments.[44] A continued increase in the contamination of freshwater fish could therefore be expected.

In June 2011, the Japanese Ministry of Agriculture and Fisheries (MAFF) also referred to the high levels of radiocesium found in freshwater fish in the rivers of Fukushima Prefecture. For instance, 2100 Bq/kg were found in masu salmon (Oncorhynchus masou) from the Mano River, 2500 Bq/kg in Japanese dace (Tribolodon hakonensis) from the Mano River, and 620 to 1310 Bq/kg in ayu (Plecoglossus altivelis) from the Abukuma River.[45]

On 22 May 2012, the Japanese Ministry of Science (MEXT) published the results of its own study, according to which the seawater in the Bay of Tokyo was 6 times more contaminated with radiocesium than before the nuclear catastrophe in Fukushima.[46]

In June 2011, the Japanese Ministry of Agriculture and Fisheries (MAFF) reported findings that the radiocesium level in flatfish off the Japanese east coast continued to rise despite decreasing contamination of seawater. This could be attributable to the fish's habitat on the sea floor. Samples from 13 June 2011 measured levels of 360 Bq/kg radiocesium in slime flounder (Microstomus achne), 680 Bq/kg in stone flounder (Kareius bicoloratus), and 340 Bq/kg in spotted halibut (Verasper variegatus). A species of greenling (Hexagrammos otakii), a scavenger bottom-dwelling fish, showed levels of radiocesium reaching 1780 Bq/kg, while 890 Bq/kg were read in the deep sea codfish (Physiculus maximowiczi).[47]

Digression: "24,000 additional cases of cancer in Japan to be expected"

In May 2012, the Nuremberg scientist Dr. Alfred Körblein undertook the first rough estimate of expected cases of cancer due to external and internal radiation exposure.[48]

> *"The effective first-year dose [see WHO report] was set at 10 to 50 millisieverts for the 20 to 30 kilometer zone, and from 1 to 10 millisieverts for all other areas. If one assumes an average value of 10 millisieverts, the collective dose in the first year for a population of around 2 million would be 20,000 manSv. . Employing the risk factor set by the European Committee on Radiation Risk (ECRR) for cancer mortality rates of EAR/Sv = 0.1/Sv (or 10%/Sv) and for the incidence of cancer of EAR/Sv = 0.2/Sv (20%/Sv) results in 20,000 manSv × 0.2 /Sv = 4000 cases of*

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[44] GRS: Environmental impact caused by the nuclear power accident at Fukushima Daiichi nuclear power station. November 26, 2012. http://fukushima.grs.de/sites/default/files/Environmental_effect_20121126.pdf. Last retrieved on 20.02.2013.

[45] Physikblog. Juni 2011. http://fukushima.physikblog.eu/discussion/19/radioaktivitaet-in-der-nahrung-gefaehrliche-verharmlosung-eines-ernsten-problems/p4. Last retrieved on 20.02.2013. Unter Verweis auf: MAFF: http://www.jfa.maff.go.jp/j/kakou/kensa/index.html

[46] GRS: Environmental impact caused by the nuclear power accident at Fukushima Daiichi nuclear power station. November 26, 2012. http://fukushima.grs.de/sites/default/files/Environmental_effect_20121126.pdf. Last retrieved on 20.02.2013.

[47] Physikblog. Juni 2011. http://fukushima.physikblog.eu/discussion/19/radioaktivitaet-in-der-nahrung-gefaehrliche-verharmlosung-eines-ernsten-problems/p4. Last retrieved on 20.02.2013. Unter Verweis auf: MAFF: http://www.jfa.maff.go.jp/j/kakou/kensa/index.html

[48] Körblein, Alfred: Mitteilung vom 25. Mai 2012. Vgl. http://www.strahlentelex.de/Stx_12_610_S01-02.pdf. Last retrieved on 20.02.2013.

cancer due to radiation exposure in the first year alone. The lifetime dose would presumably be three times as high. This would result in an expected 12,000 additional cases of cancer for Fukushima alone. The figure for the whole of Japan could possibly be twice as high. A number of epidemiological studies, for example on nuclear facility workers or in Kazakhstan, where the population was exposed to a high level of radiation exposure from Soviet nuclear weapons testing, have nonetheless resulted in higher relative risks with a ERR/Sv of approximately 1/Sv. A spontaneous cancer mortality rate of 25% indicates a EAR/Sv of 0.25/Sv and not 0.1/Sv for cancer mortality. For this reason, the estimate cited above is still relatively cautious (conservative)."

Illness and mortality among employees at the Fukushima nuclear facility

According to Tepco, the operator of the nuclear power plant, 18,846 people worked at the facility between March and November 2011.[49]

Tepco has only provided data on contamination levels in workers with readings over 100 mSv.(50) Thus, there is no information on all of the workers who, according to Tepco, were exposed to less than 100 mSv. The present estimate therefore relies on knowledge gathered in the wake of the 1986 nuclear catastrophe in Chernobyl concerning the so-called liquidators (cleanup workers).[50]

According to the victim association of Chernobyl liquidators, by 1992 some 70,000 of the approximately 800,000 liquidators were invalids (8.75%) and 13,000 (1.6%) dead.[51] On the 19th anniversary of the catastrophe, the Ukrainian Embassy in Paris reported that 94% of the liquidators were ill.[52] On the basis of various studies, Yablokov estimated that by 2005 (19 years after Chernobyl) some 112,000 to 125,000 had already died (14.8%).[53]

Applying these statistics to the figure of 18,846 workers in the Fukushima nuclear facility cited by Tepco, 302 mortalities and 1649 cases of severe illness could be expected by the year 2017. By 2030, at the latest, 2789 workers will have died and 17,715 will become severely ill, most long before 2030.

The total numerical ratio of cleanup workers deployed after Chernobyl (an estimated 800,000) to the 18,846 workers cited above for Fukushima would indicate that far more people were and still are involved in the Japanese cleanup operations in highly contaminated areas. If one takes into consideration the necessary activities outside the nuclear power plant, the figure cited above should be considered a low-end estimate.

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[49] Wiedergegeben nach: Strahlenschutzkommission (SSK): Zusammenfassung und Bewertung der Jahrestagung 2012. der Strahlenschutzkommission: Ein Jahr nach Fukushima - eine erste Bilanz aus der Sicht der Strahlenschutzkommission. Stellungnahme der Strahlenschutzkommission. Verabschiedet in der 257. Sitzung der Strahlenschutzkommission am 05./06. Juli 2012. S. 6. http://www.ssk.de/SharedDocs/Beratungsergebnisse_PDF/2012/Klausurtagung2012.pdf?__blob=publicationFile. Last retrieved on 22.02.2013.

[50] Liquidatoren waren meist junge Soldaten, die während und nach der Katastrophe zur Eindämmung des Unglücks gezwungen wurden.

[51] Vgl. Strahlentelex 138-139/1992, S. 8, GUS: Bereits 13.000 tote Liquidatoren.

[52] IPPNW/GFS: Gesundheitliche Folgen von Tschernobyl. 25 Jahre nach der Reaktorkatstrophe. April 2011. S. 25. http://www.ippnw.de/commonFiles/pdfs/Tschernobyl_Studie_2011_web.pdf. Last retrieved on 26.02.2013.

[53] Yablokov, Alexej: Mortality after the Chernobyl Accident. In: Ann N Y Acad Sci, 2009 Nov;1181:192-216.

Digression: Health consequences of Chernobyl

In order to comprehend the possible scenario awaiting Japan in terms of illness and fatalities, it is reasonable to recall the consequences of the 1986 nuclear catastrophe in the Ukrainian Chernobyl power plant.

After Chernobyl, rates for infant mortality and perinatal mortality increased in many European countries. Existing studies indicate many thousands of infant deaths in Europe as a result of Chernobyl.[54,55]

In addition, genetic and teratogenic damage (birth defects) significantly rose in a number of European countries. The total extent of genetic damage can only be roughly estimated. With reference to a report by UNSCEAR, one arrives at between 12,000 and 83,000 children from the Chernobyl region born with genetic damage and some 30,000 to 200,000 genetically damaged children worldwide.[56]

Thyroid cancer is omnipresent among adults and children since the fourth year after the catastrophe. According to a WHO prognosis, more than 50,000 people who were four-years-old or less at the time of the catastrophe will be afflicted with thyroid cancer in the Belarusian region of Gomel alone. Extending this prognosis to all age groups (including young people and all adult age groups) who were living in the Gomel region at the time of the reactor catastrophe, the incidence of thyroid cancer for just this region is far greater than 100,000.[57] Malko arrives at a figure of around 240,000 additional cases of cancer, including leukemia, for the whole of Europe.[58]

The number of non-cancer diseases also rose dramatically according to information from the Ukrainian Ministry of Chernobyl Affairs: For example diseases affecting the endocrine system including diabetes mellitus type I, the nervous system, the circulatory system, digestive organs, the skin and subcutaneous tissues, the skeleton, and the muscular system .[59]

As has been previously mentioned, 112,000 to 125,000 liquidators already died before 2005.[60]

The World Health Organization (WHO), however, has attempted to play down the figures. Almost 20 years after the reactor catastrophe, the WHO reported in Sep-

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[54] IPPNW/GfS: Gesundheitliche Folgen von Tschernobyl. 20 Jahre nach der Reaktorkatastrophe. April 2006. S. 5. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/Gesundheitliche_Folgen_Tschernobyl.pdf. Last retrieved on 12.02.2013.

[55] Vgl. Körblein A, Küchenhoff H. Perinatal mortality in Germany following the Chernobyl accident. Radiat Environ Biophys. 1997 Feb; 36(1):3-7. Diverse unveröffentlichte Berechnungen von A. Körblein für Polen, Italien, Finnland, Schweden und Norwegen.

[56] IPPNW/GfS: Gesundheitliche Folgen von Tschernobyl. 20 Jahre nach der Reaktorkatastrophe. April 2006. Tabelle auf S. 5. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/Gesundheitliche_Folgen_Tschernobyl.pdf. Last retrieved on 12.02.2013.

[57] Edmund Lengfelder, Christine Frenzel: 20 Jahre nach Tschernobyl. Erfahrungen und Lehren aus der Reaktorkatastrophe. Otto Hug Strahleninstitut MHM. Informationen. Februar 2006.

[58] Malko, M.V: Assessment of Chernobyl malignant Neoplasms in European Countries. 2007. http://www.physiciansofchernobyl.org.ua/eng/Docs/Malko.pdf. Last retrieved on 12.02.2013.

[59] IPPNW/GfS: Gesundheitliche Folgen von Tschernobyl. 20 Jahre nach der Reaktorkatastrophe. April 2006. Tabelle auf S. 6. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/Gesundheitliche_Folgen_Tschernobyl.pdf. Last retrieved on 12.02.2013.

[60] Yablokov, Alexej: Mortality after the Chernobyl Accident. In: Ann N Y Acad Sci, 2009 Nov;1181:192-216.

tember 2005 that only 4000 fatalities could be expected.[61] The WHO based its finding, in part, on an almost ten-year-old study by E. Cardis et. al. published in 1996.[62] However, the original article, in fact offers an estimate of almost 9000 fatalities due to cancer and leukemia for the Chernobyl region.[63] Taking into consideration the dose exposure spans given by E. Cardis et. al. and the long-term exposure of the population of the Chernobyl region under study, calculations indicate up to 22,000 fatalities.[64] Within this context, it should be noted that the so-called Chernobyl region, namely the particularly heavily contaminated areas of the Ukraine, Belarus, and Russia, is sparsely inhabited.

The radionuclides released from Chernobyl spread over the whole of Europe and throughout the whole northern hemisphere. As such, the so-called TORCH Report (The Other Report on Chernobyl) of 2006 came to the conclusion that a total of 30,000 to 60,000 additional cancer fatalities can be anticipated.[65]

Alexej Yablokov, President of the Center for Russian Environmental Policy and member of the Russian Academy of Sciences, has arrived at very much higher figures. He does not employ the usual method of risk estimation based on dose effect calculations. Instead, he uses the so-called Balance Method, which entails comparing data on the state of health of a population (morbidity and mortality) from highly contaminated radioactive areas with data on the state of health from “clean” areas. With this method, the former environmental advisor to Russian President Boris Yeltsin arrives at a figure of 1.44 million deaths worldwide and, if prenatal mortalities are included, the number rises to 1.6 million.[66] Furthermore, Yablokov refers to American and Canadian experts who have calculated the total number of expected fatalities as a result of Chernobyl and have arrived at an estimate between 900,000 and 1.8 million people worldwide. These figures include future fatalities, as the nuclides from Chernobyl continue to remain in the biosphere.[67]

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[61] ÄrzteZeitung: WHO rechnet mit 4000 Toten als Folge von Tschernobyl. 6. September 2005. http://www.aerztezeitung.de/medizin/fachbereiche/sonstige_fachbereiche/umweltmedizin/article/370597/who-rechnet-4000-toten-folge-tschernobyl.html. Last retrieved on 12.02.2013.

[62] E. Cardis, L. Anspaugh, V.K. Ivanov; I.A. Likhtariov, K. Mabuchi, A.E. Okeanov, A.E. Prsyazhniuk: Estimated long term health effects of the Chernobyl accident. In: One Decade After Chernobyl. Summing up the Consequences of the Accident. Proceedings of an International Conference, Vienna, 1996. STI/PUB/1001, IAEA, Vienna, 1996, Vienna.

[63] IPPNW/GfS: Gesundheitliche Folgen von Tschernobyl. 20 Jahre nach der Reaktorkatastrophe. April 2006. Tabelle auf S. 74. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/Gesundheitliche_Folgen_Tschernobyl.pdf. Last retrieved on 12.02.2013.

[64] IPPNW/GfS: Gesundheitliche Folgen von Tschernobyl. 20 Jahre nach der Reaktorkatastrophe. April 2006. Tabelle auf S. 75. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/Gesundheitliche_Folgen_Tschernobyl.pdf. Last retrieved on 12.02.2013.

[65] Fairlie, Ian; Sumner, David: Der andere Bericht über Tschernobyl (TORCH: The Other Report on Chernobyl). Berlin, Brüssel, Kiew, April 2006. Im Auftrag von Rebecca Harms, MEP. Greens/EFA in the European Parliament. http://www.chernobylreport.org/summary-de.pdf. Last retrieved on 12.02.2013.

[66] Jablokow, Alexej: Tschernobyl: Wie viele sind ums Leben gekommen? IPPNW-Kongress „25 Jahre Tschernobyl. Zeitbombe Atomenergie. Atomausstieg jetzt!“, Berlin, Urania, 8.-10. April 2011. http://www.tschernobylkongress.de/fileadmin/user_upload/pdfs/jablokov_opferzahlen_tschernobyl.pdf. Last retrieved on 01.03.2013.

[67] Yablokov, Alexej: Ein zweites Tschernobyl rückt näher. Alexey Jablokow über die Folgen von Tschernobyl und die „Nuklearisten“ von heute. IPPNW-Forum 125. März 2011. S. 20. http://www.ippnw.de/commonFiles/pdfs/Forum/forum125_20-21-22.pdf. Last retrieved on 12.02.2013.