# THE HEALTH IMPACT OF THE CHERNOBYL FALLOUT ON THE POPULATION OF WEST GERMANY


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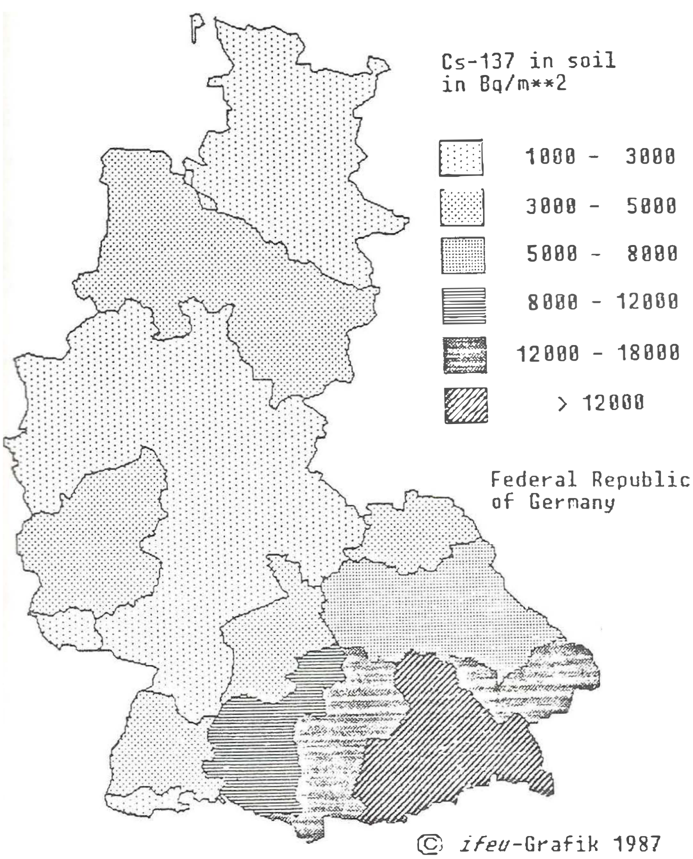
## INTRODUCTION

One and a half years after the reactor accident in the Soviet Union it is possible to assess the total Chernobyl-dose for the population in the Federal Republic of Germany [FRG]. Beside Scandinavia the FRG was one of the Western European countries with the highest radioactive fallout in May 1986. Unlike the situation in many other countries, the German public was very upset and reacted in a sensible way: the people wanted to know what countermeasures would help to reduce the dose. Once again there arose a controversial discussion about the use of nuclear energy.

**Fig.1: The $^{137}$Cs-deposition due to the Chernobyl fallout in West Germany in 1986 [Source: [6]].**




This public interest and sensitivity initiated many measurements of radioactivity in the FRG and the publication of the results. By November 1986 the authorities had registered more than 36,000 entries of data on food, soil or air contamination [1], and the number is still increasing. This data is the basis of the following assessment of the Chernobyl-dose in the FRG.

## THE RADIOACTIVE DEPOSITION IN GERMANY

In West Germany the amount of radioactive deposition was correlated with the trajectories of the radioactive plumes and the meteorological situation during its passage. In the South, especially in Southern Bavaria, it was raining heavily during the increased level of airborne radioactivity in May 1986. The washout of radionuclides resulted in a very high deposition in Southern Germany. At some places the levels of cesium-137 in soil exceeded 40,000 Bq per squaremeter.

In Munich [2] the iodine-131-deposition was about 90,000 Bq/m² and the $^{137}$Cs-deposition about 20,000 Bq/m². This is fivefold the amount of the $^{137}$Cs-fallout in West Germany due to the worldwide nuclear bomb tests from 1954 to 1966. On the other hand, the strontium-deposition related to Chernobyl was low in comparison with the atomic bomb fallout. In Munich the $^{90}$Sr-value was 210 Bq/m² according to a $^{90}$Sr/$^{137}$Cs-ratio of 1 percent.

In North Germany the fallout was considerably lower [Fig.1]: the $^{137}$Cs-deposition came to a few 1,000 Bq/m². The $^{90}$Sr/$^{137}$Cs-ratio in soil was 3.4 percent [3]. The average contamination with $^{137}$Cs, weighed according to the contaminated surfaces, was about 6,000 Bq/m² in the FRG.

These regional differences resulted in considerable variations of radioactivity in food and forage. According to the region of origin, vegetables, milk or meat were contaminated very highly. In Bavaria some samples of milk contained up to 2,600 Bq of $^{131}$I per litre. In May 1986 about 18 percent of the examined Bavarian samples of milk exceeded the $^{131}$I-limit of 500 Bq/l [4]. In contrast to this, the contamination of milk in Northern Germany was much lower, only 10 Bq/l. In a similar way, vegetables were contaminated, especially leaf-vegetables. The average value of $^{131}$I in spinach reached several 1,000 Bq/kg in the first weeks. The value of lettuce was about some 100 Bq/kg. In May 1986, the mean concentration of $^{137}$Cs in lettuce was 50 Bq/kg and in beef 150 Bq/kg.

The $^{137}$Cs-concentrations in farm milk from Southern Bavaria and Northrhine-Westphalia, a state located in the middle of West Germany, are indicated in Fig. 2. During the summer, the values decreased [compared to the period immediately after the fallout] because of the lower contamination of fresh vegetables and forage on the surface. But in autumn 1986, the concentrations increased again because highly contaminated hay which had been cut in May and June was used as fodder [5].

Fig.2: The average $^{137}Cs$-concentrations in farm milk in South Bavaria and Northrhine-Westphalia in 1986/87 [Source: [6]].

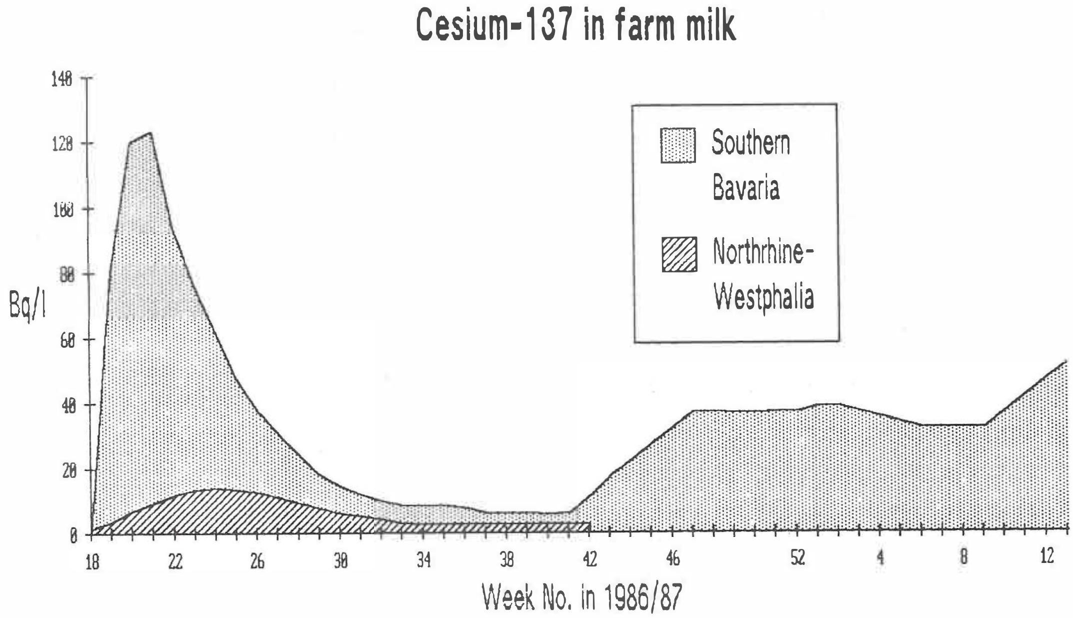



Table 1: Average $^{137}Cs$-concentrations in vegetables [in Bq/kg fresh weight] and the decrease of consumption in West Germany in May and June 1986 in comparison with the year before.

| | May 1986 | | June 1986 | |
|---|---|---|---|---|
| Vegetables | Consumption | Bq/kg | Consumption | Bq/kg |
| cauliflower | - 23 % | 4.9 | + 20 % | 6.9 |
| cucumber | + 137 % | 5.4 | + 41 % | 4.9 |
| kohlrabi | - 50 % | 14.2 | - 7 % | 5.7 |
| lettuce | - 70 % | 48.7 | - 13 % | 32.9 |
| carrots | - 58 % | 3.2 | + 83 % | 5.6 |
| leek | - 33 % | 34.0 | - 21 % | 24.5 |
| radish | - 73 % | 11.4 | + 3 % | 13.4 |
| celery | + 36 % | 27.7 | + 103 % | 2.5 |
| spinach | - 92 % | 170.8 | - 48 % | 63.0 |
| white cabbage | - 30 % | 54.1 | - 29 % | 29.1 |
| savory | - 45 % | 20.9 | - 28 % | 4.2 |

Table 2: Calculated radionuclide-concentrations in German food in future caused by the Chernobyl fallout. If these values were compared with measurements, the Sr- and Cs-background by the atomic bomb fallout should be taken into account. All values in milli-becquerel per kg.

| | 1988 | | | 1995 | | |
|---|---|---|---|---|---|---|
| Type of food | $^{90}Sr$ | $^{134}Cs$ | $^{137}Cs$ | $^{90}Sr$ | $^{134}Cs$ | $^{137}Cs$ |
| milk | 10 | 120 | 460 | 10 | 10 | 400 |
| beef | 2 | 190 | 700 | 1 | 20 | 590 |
| pork | 0 | 530 | 1,960 | 0 | 50 | 1,670 |
| potatoes | 30 | 320 | 1,190 | 20 | 30 | 1,010 |
| grain | 40 | 320 | 1,190 | 30 | 30 | 1,010 |
| leafy vegetables | 130 | 190 | 710 | 110 | 20 | 610 |
| root vegetables | 70 | 60 | 240 | 60 | 6 | 200 |

## COUNTERMEASURES AFTER CHERNOBYL

The national commission on radiological protection and the federal government issued limits for iodine-131 in milk and vegetables. But the control of the radioactivity in vegetables was not efficacious enough as to guarantee the observance of the limit. The limit of 500 Bq/l for milk was so high that its introduction did not reduce the population's exposure in most parts of Germany. Therefore, the state of Hesse issued its own limit for milk which was 20 Bq/l, but was opposed by the federal government and the European Economic Community [EEC].

In contrast to the official countermeasures, an information campaign, initiated by environmental associations, scientists and the mass media, succeeded and caused a change in the peoples consumption habits. Agricultural statistics indicated that the highly contaminated food was avoided by consumers to an important degree. In May 1986 the sale of spinach dropped down by 92 percent and the sale of lettuce by 70 percent (Table 1). The sale of fresh milk decreased by half in May and June, whereas the sale of uncontaminated powdered milk and homogenized milk increased rapidly.

The following dose estimation took into account these changes of the consumption habits [1]. It shows that on the average two thirds of the normal thyroid-gland dose caused by vegetables ingestion and half of the dose caused by milk ingestion could be avoided; the thyroid-gland being the most exposed organ in the first months.

## THE LONGTERM CONTAMINATION OF FOOD

In 1987 the cesium-concentrations are still high. Mushrooms, game and freshwater fish often contained several 100 Bq/kg. But the contamination of basic food was more important such as beef, pork, wheat and rye. In Fig. 3 the cesium-concentrations which are representative for West Germany in August 1987 [2] are compared with the average values in 1983 respectively 3 years before the Chernobyl fallout [3]. The high consumption rates of grain and meat lead to rather high ingestion doses in 1987.

As soon as the food which was contaminated in 1986 is off the market, the contamination will be effected exclusively by the radionuclide-transfer from the soil into the plants. In order to estimate the Cs-concentrations in future, the IFEU-institute undertook comprehensive transfer calculations [4]. The results are shown in Table 2. On an average, Cs-concentrations will be about some Bq/kg in the years to come, upward variations being possible in the highly contaminated South. Moreover, mushrooms and venison are expected to contain more cesium for the future. The Sr-values will be comparatively low. In future, most of the Sr-concentrations in food will still be caused by the fallout of the atomic bomb tests.

## THE RESULTS OF DOSE ESTIMATION

Average consumption rates and dose coefficients based on the ICRP-30-model [4] were used to calculate the radiation dose of the German population. Since the effective dose definition of ICRP is controversial, for example it only takes into account cancer mortality and not cancer incidences, the different organic doses were also calculated by IFEU. In Table 3 the results are shown for some organs. In total, the thyroid gland dose exceeds the other doses because short living $^{131}$I effected mainly the thyroid gland. The total dose amounts to 3.1 mSv [319 mrem], 1.8 mSv [180 mrem] resulting from the first year.

The effective dose integrated over the next 50 years was estimated 1.4 mSv [140 mrem]. In 1986 the effective dose was 0.22 mSv. In 1987, the effective dose is approximately 0.13 mSv in FRG.

An important result is the fact that 75 percent of the time-integrated effective dose was caused by the external gamma radiation of cesium in the soil. This external dose already contains a reduction factor of 0.19 for the radiation screening of the soil and of the buildings during the stay inside.

## THE CHERNOBYL RISK IN WEST GERMANY

Integrated over the following 50 years, the collective dose will be 86,000 man-Sv in FRG, thus disproving other estimations carried out by the National Radiation Protection Board. Morrey, et al. [5] valued only 78,000 man-Sv corresponding to the collective dose for the whole area of EEC. In consideration of the German collective dose which already exceeds this value, the real dose of EEC must be much higher. On the other hand, Jens Scheer's collective dose assessment for West Germany [6], which ranges from 90,000 to 720,000 person Sv, seems to be too high.

On the basis of the new estimate, a total risk of 4,700 - 14,000 additional cancers in FRG can be expected, the calculation relying upon Bertell's risk coefficients [7] which are 549 - 1,648 cancers [including the nonfatal cases] per 10,000 person Sv. These values are essentially higher than the risk value of ICRP which concluded 100 fatal cancers per 10,000 persons Sv [13]. Meanwhile it seems that Bertells estimations which used the linear dose-response-model are far more realistic than ICRP. Different actual studies refused the old ICRP-risk-values and used new ones which exceed them by the manifold. For its calculations, the German risk study about nuclear reactors used 260 - 502 fatal cancers [8]. The US-Department of Energy took a value of 230 fatal cancers for its Chernobyl - report [9]. And the German Commission on Radiological Protection no longer excludes a possible risk value of up to 500 fatal cancers per 10,000 person Sv [10]. All these values lie in the range of Bertell's estimation and verify the validity of it. Therefore the risk estimation of 4,700 - 14,000 additional cancers in FRG is quite realistic, though the values are not conclusive enough as to back up an epidemiological proof.

## CONSEQUENCES

Whereas the information campaign of environmental associations and scientists had an important impact on the consumer's habits, the countermeasures of the federal government failed in reducing the collective dose substantially. First of all, this is a consequence of the official contamination limits for food which are far too high and thus contravene the first aim of countermeasures: the reduction and minimization of the collective dose and therefore the number of additional cancers.

**Fig.3:** The representative radiocesium-concentrations in German food 3 years before [1983] and 1 year after Chernobyl [August 1987]. The two scales differ by a factor of 30 [Source: [7] and [7]].

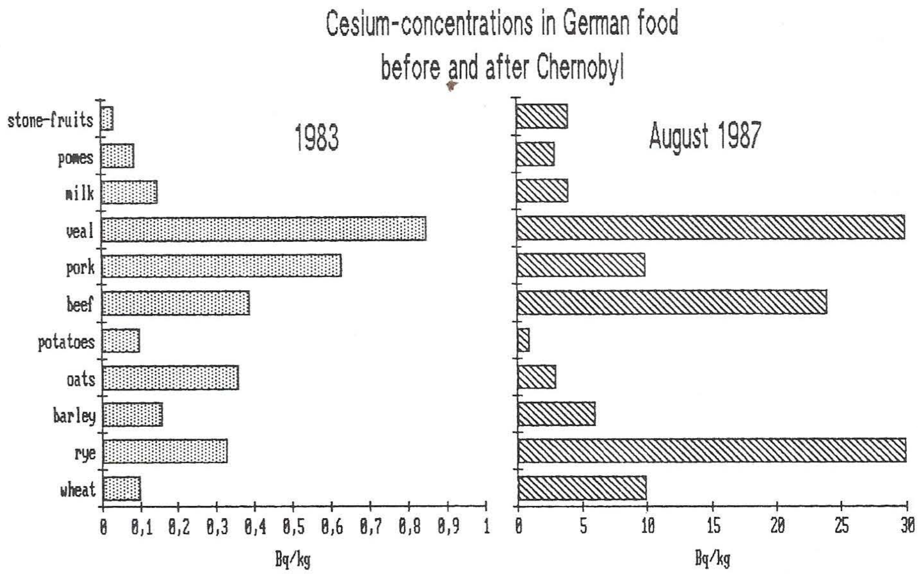



**Fig.4:** The total radiation doses for the following 50 years caused by the Chernobyl fallout in West Germany

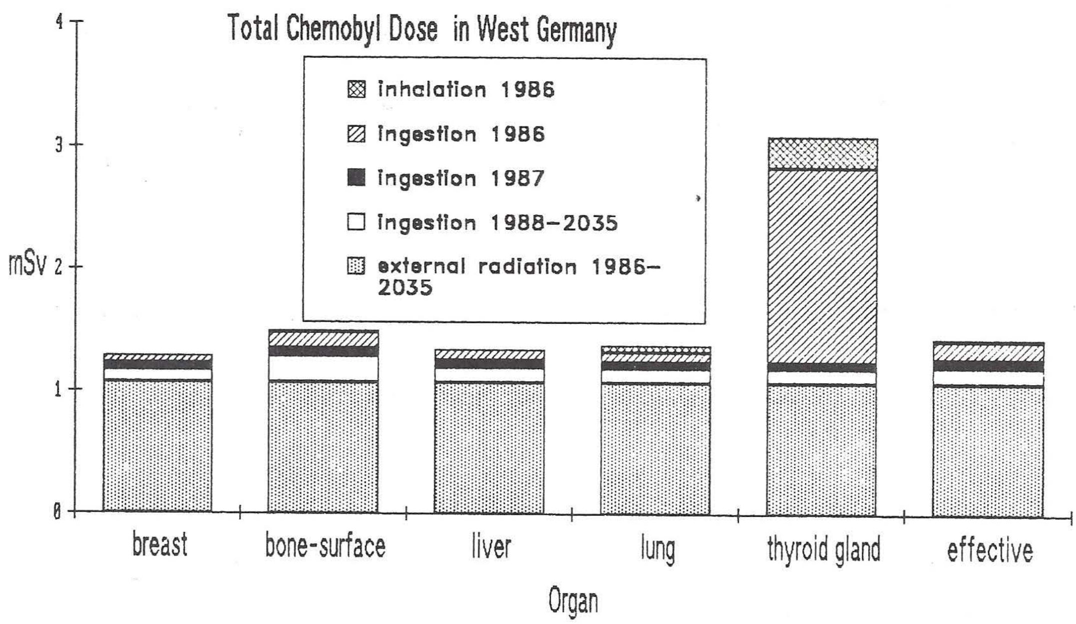



**Table 3:** Radiation doses for some organs and the effective dose in West Germany due the reactor accident of Chernobyl. *(all values in mrem).*

| Exposure pathway | Time period | organ: breast | bone surface | lung | thyroid | effective dose |
|---|---|---|---|---|---|---|
| Ingestion | 1986 | 6.7 | 13.2 | 7.8 | 158.8 | 14.8 |
| Inhalation | 1986 | 0.2 | 0.4 | 5.8 | 26.0 | 1.7 |
| External radiation | 1986 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 |
| Ingestion | 1987 | 5.3 | 6.5 | 6.1 | 6.2 | 7.2 |
| External radiation | 1987 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 |
| Ingestion | 1988-2035 | 10.6 | 21.9 | 11.6 | 11.5 | 13.3 |
| External radiation | 1988-2035 | 95.6 | 95.6 | 95.6 | 95.6 | 95.6 |
| **Total dose** | | **129.7** | **149.0** | **138.2** | **309.1** | **143.9** |

This is important in consideration of the attempt by EEC to establish new radioactivity limits for the next reactor accident. The proposed values are even higher than the existing EEC limits which were introduced after Chernobyl (see Table 4). The new limits would obstruct the goal of minimization of artificial radiation exposure.

Whereas the ingestion dose could in principle be reduced by countermeasures the external radiation from the soil cannot be avoided. As follows from the represented calculations, the external dose is the main contribution to the total accident dose in distant areas like West Europe. Consequently an efficacious minimization of radiation dose would only be possible if new nuclear accidents were prevented.

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## REFERENCES


[1] Diehl J.F., et al., *Radioactivity in Food Chernobyl and the Consequences*, Report of the Bundesforschungsanstalt für Ernährung, BFE-R-86-04, Karlsruhe, 1986 [in German]

[2] Gesellschaft für Strahlen und Umweltforschung, *Environmental Radioactivity and Radiation Exposure by the Chernobyl Accident*, GSF-Report No. 16/86, Neuherberg, 1986 [in German]

[3] Kirchner G., Department of Physics at the University of Bremen, private communication

[4] Schmidt M., et al., *The Consequences of Chernobyl*, Institute for Energy and Environmental Research Heidelberg, IFEU-Report No.43, 1986 [in German]

[5] Schmidt M., et al. *The Cesium-Soil and Grass Contamination in Southern Germany and the feeding in Winter* 1986/87, IFEU-Report No. 45, Heidelberg, 1986 [in German]

[6] Schmidt M., [Ed.], *The Radiation Risk of Chernobyl, Three Studies of the IFEU-Institute about the Previous and Future Consequences of the Reactor Accident*, IFEU-Report No. 49, Heidelberg, 1987 [in German]

[7] Bundesgesundheitsamt, Report about the Radiation Exposure, monthly since December 1986 [in German]

[8] Bundesministerium des Inneren, *Environmental Radioactivity and Radiation Exposure*, Annual Report 1983, Bonn, 1986

[9] D.Noßke et al., "Dose coefficients for the Inhalation and Ingestion of Radionuclide Compounds," *Bundesgesundheitsamt*, ISH-Report No. 63, 1985

[10] Morrey M. et al., *A Preliminary Assessment of the Radiological Impact of the Chernobyl Reactor Accident on the Population of the European Community*, EEC-Commission, Doc. No. 2948/86 EN, 1986

[11] Scheer J., "How many Chernobyl fatalities?" *Nature* 326, 1987, 449

[12] Bertell R., *Handbook for Estimating Health Effects from Exposure to Ionizing Radiation*, 2nd Edition, Toronto, 1986

[13] Steinhauer C., Matzerath C., *Results of the German Risk Study for Nuclear Power Plants - Part B: Long Distance Modelling and Estimation of the Stochastical Somatic Effects*, Annual Meeting of Nuclear Engineering 1987, Karlsruhe [in German]

[14] Science 236, 1987, 658

[15] Strahlenschutzkommission, *The Impacts of the Accident in Chernobyl on the Federal Republic of Germany*, SSK-Publication No.7, Stuttgart, 1987


**Table 4: The EEC-limits for radiocesium in imported food which were introduced in May 1986 compared with the new limits of the proposed EEC regulation for the next nuclear accident [date: October 1987].**

| | | | |
|---|---|---|---|
| **old limits** | | | |
| milk products and baby food | 500 Bq/l | $^{131}I$ | in May 1986 |
| fruits, vegetables | 350 Bq/kg | $^{131}I$ | [recommended] |
| milk products and baby food | 370 Bq/kg | $^{134/137}Cs$ | since June 1986 |
| **proposed limits** | | | |
| milk products and baby food | 500 Bq/kg | all isotopes of I, Sr | |
| | 20 Bq/kg | Pu and transurans | |
| | 1,000 Bq/kg | other radionuclides like Cs | |
| water | 400 Bq/kg | I, Sr | |
| | 10 Bq/kg | Pu etc. | |
| | 800 Bq/kg | Cs etc. | |
| other food | 3,000 Bq/kg | I, Sr | |
| | 80 Bq/kg | Pu etc. | |
| | 1,250 Bq/kg | Cs etc. | |