Radioactivity in total diet before and after the Chernobyl reactor accident

The situation in the Federal Republic of Germany

Johannes Friedrich Diehl, Otto Frindik, and Harald Müller

Zentrallaboratorium für Isotopentechnik, Bundesforschungsanstalt für Ernährung, Engesserstrasse 20, D-7500 Karlsruhe, Federal Republic of Germany

Radioaktivität in der Gesamtnahrung vor und nach dem Reaktorunglück von Tschernobyl – Die Situation in der Bundesrepublik Deutschland

Zusammenfassung. In der Bundesrepublik Deutschland wurde Radioaktivität von Gesamtnahrungsproben (Tagesrationen Erwachsener) seit 1960 bestimmt. Die durchschnittliche Aufnahme von ^{137}Cäsium betrug 1964 8,9 Bq pro Tag (d) und Person (p) und war bis 1985 auf 0,15 Bq/d.p gefallen. Sie stieg als Folge des Reaktorunfalls von Tschernobyl 1986 auf 4,2 und 1987 auf 7,2 Bq/d.p und fiel 1988 auf 2,0 Bq/d.p. Die Aufnahme von ^{134}Cäsium, das im Fallout der Zeit vor Tschernobyl nicht meßbar war, betrug 1986 im Durchschnitt 2,0, 1987 3,0 und 1988 0,6 Bq/d.p. Die Aufnahme von ^{90}Strontium lag im selben Bereich wie in den letzten Jahren vor Tschernobyl. Die effektive Äquivalentdosis, die insgesamt aus der Ingestion von Radionukliden des Tschernobylunglücks resultieren wird (einschließlich Jod-131, auf $0,14 \pm 0,08$ mSv geschätzt.

Summary. Radioactivity in total diet samples (1-day rations of adults) has been determined in the Federal Republic of Germany since 1960. Average intake of cesium-137 was 8.9 Bq per day and per person (Bq/d.p) in 1964, 0.15 in 1985, 4.2 in 1986, 7.2 in 1987, and 2.0 in 1988. Cesium-134, not measureable in pre-Chernobyl fallout, averaged 2.0 Bq/d.p in 1986, 3.0 in 1987, and 0.6 in 1988. Intake of strontium-90 was in the same range as in the years preceding the Chernobyl accident. It is estimated that the total effective equivalent dose for adults due to ingestion of Chernobyl-released radionuclides, including iodine-131, will be 0.14 ± 0.08 mSv.

Offprint requests to: J. F. Diehl

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Introduction

In the aftermath of the reactor accident in Chernobyl on 26 April 1986, several extensive reports about the level of radioactive contamination of the environment in the Federal Republic of Germany have been issued [1–4]. Most of these are not easily accessible internationally. Only a few papers on radioactivity in specific commodities such as meat [5], milk [6], grain [7] and mushrooms [8], have appeared in scientific journals. The following account of radioactive contamination determined in total diet samples during the first few years after the Chernobyl accident enabeles a comparison to be made with the situation after the atmospheric nuclear weapons tests of the 1950s and 1960s.

Materials and methods

A system for monitoring environmental radioactivity has existed in the Federal Republic of Germany (FRG) for about 30 years. It consists of measuring stations (Meßstellen) operated by regional administrations, and lead stations (Leitstellen), operated by the Federal Government, where the data received from the measuring stations are collected and evaluated. As a lead station for radioactivity in foods, the Federal Research Centre for Nutrition maintains a data bank for radioactivity in various foodstuffs and in total diet samples reaching back to 1960.

In the following, data obtained from regional measuring stations and in our laboratory have been pooled. Gamma spectrometric determination of cesium-134 and cesium-137 and determination of strontium-90 after chemical separation have been described elsewhere [1, 9]. The total diet samples constituted one-day rations (food and drink) of adults. Before 1986 some 150 to 200 total diet samples per year were examined. In 1986 this number increased to 350, in 1987 to 620. Results for 1988 are based on 260 samples. Additional data on samples obtained in 1988 can be expected in the coming months, but it is unlikely that they will change the evaluation presented here. However, because of the incompleteness of the data base, results reported for 1988 should be considered as preliminary.

Results and discussion

Whereas radioactivity in individual food items is usually measured on raw samples, disregarding losses

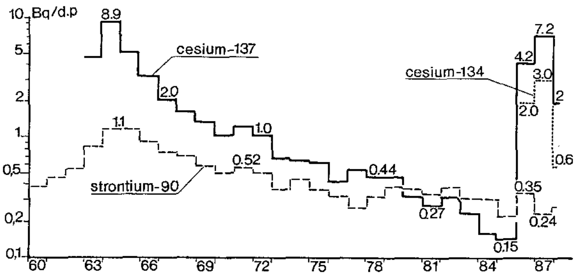

Fig. 1. Mean annual level of Cs-137, Cs-134, and Sr-90 in total diet samples (one-day portions of food and drink for adults) in the FRG since 1960. *Bq/d.p* Bq per day and per person

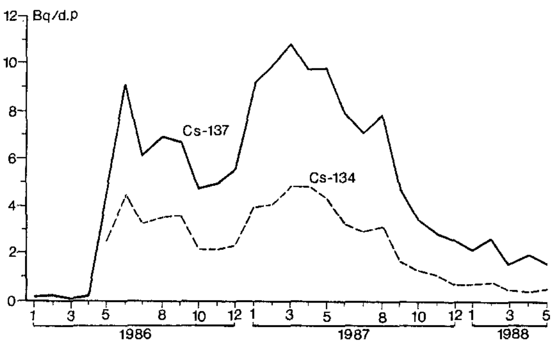

Fig. 2. Mean monthly level of Cs-137 and Cs-134 in total diet samples in the FRG from January 1986 until May 1988. *Bq/d.p* Bq per day and per person

due to culinary preparation, data obtained from ready-to-eat total diet samples reflect the actual intake of radioactivity by man, and are therefore of particular interest. For representation in the figures, all results obtained on total diet samples in various regions of the FRG in one year (Fig. 1) or in one month (Fig. 2) were averaged. While intake of Sr-90 in 1986 and 1987 was within the range observed in previous years, intake of Cs-137 in 1987 almost reached the peak value of 1964 which had resulted from the atmospheric nuclear bomb tests. Cs-134, not measurably present in the bomb fallout, accompanied Cs-137 in the deposition from Chernobyl in the ratio of 1:2. Due to the shorter half-life of Cs-134, the ratio decreased to about 1:3 in early 1988. The steep increase of the level of both cesium isotopes in May 1986 (Fig. 2) was mostly due to the surface contamination of field-grown vegetables and the contamination of meat and milk of cattle kept outdoors. The decline between May and October 1986 can be explained as the result of vigorous plant growth in the summer months which diluted the level of contamination initially present. The new increase during the winter months of 1986/87 was partly due to increased radiocesium levels in meat and milk which resulted from the feeding of hay and silage harvested in May/June 1986. The gradual disappearance of uncontaminated pre-Chernobyl food supplies from the market also contributed to this increase. Staple foods consumed in 1986 were mostly from the harvest of 1985; only when the pre-Chernobyl supplies of grain, potatoes, and frozen and canned foods were largely exhausted, was the peak of 11 Bq Cs-137 and 5 Bq Cs-134 per day reached in March 1987 (Fig. 2).

The steep decline since then indicates that contamination from the Chernobyl accident is disappearing faster from the food chain than the contamination caused by atmospheric nuclear tests. This is not surprising since Chernobyl caused essentially a single input of radioactivity into the biosphere, whereas the fallout deposition from nuclear weapons tests continued for many years after the 1963 test-stop agreement between the Soviet Union and the United States.

Regional and local differences in the amounts of radioactive material deposited in the Federal Republic of Germany after the Chernobyl accident were considerable (roughly a factor of 10 between Northern Germany and the most highly contaminated areas south of the River Danube) while much less difference was seen in total diet samples. Even farm families nowadays buy much of their food in supermarkets, where products originating from many parts of Europe and from overseas are offered. As a result, radioactivity levels in total diet samples from Southern and Northern Germany differed only by a factor of two. The pooling of data on which the figures are based is therefore justifiable.

The internal radiation exposure caused by the dietary intake of these radionuclides (Table 1) can be calculated using generally accepted dose conversion factors, as previously explained [1]. The table also contains previously published data [1] for I-131, a short-lived radionuclide which was of importance only during the first few weeks after the Chernobyl accident. Data for Sr-90 are not included in the table, because Sr-90 exposure after the accident was not greatly different from the 10-year period before the accident (Fig. 1).

Some other radionuclides released from the Chernobyl reactor (such as Ru-103) were detectable in foods soon after the accident, but these have not con-

Table 1. Annual ingestion of radionuclides (as Bq per year and person) and resulting effective equivalent dose (in mSv) for adults

Year	Cs-137		Cs-134		I-131		Total dose (mSv)
	Bq/a · p	mSv	Bq/a · p	mSv	Bq/a · p	mSv	
1986	1533	0.0215	730	0.0146	235	0.003	0.039
1987	2628	0.0368	1095	0.0219	–	–	0.059
1988	730	0.0102	219	0.0044	–		0.015

tributed significantly to the total radiation exposure. It should be noted that the effective equivalent dose refers to the life-time exposure caused by the ingestion of the radionuclides under discussion, not to exposure in one year.

Taking into account all radionuclides and the predictable intake in 1989 and following years, it can be estimated that the total effective equivalent dose caused by ingestion of radionuclides released from Chernobyl will be about 0.14 mSv for adults. Depending on eating habits and geographic location within the Federal Republic of Germany actual exposures may vary considerably. An estimate of this variability can be obtained from the standard deviations associated with the mean values shown in Fig. 2. For instance the Cs-137 value for the month of March 1987 ($n = 57$) is 11.04 ± 6.96 Bq/d.p, for April 1987 ($n = 59$) 9.86 ± 5.92 Bq/d.p, and for May 1987 ($n = 70$) 9.90 ± 5.08 Bq/d.p. If we attach the same variability to the total effective equivalent dose we obtain 0.14 ± 0.08 mSv. Only in very exceptional cases (consumption of unusually high amounts of game and of cesium-accumulating species of wild mushrooms) are exposures of higher than 0.40 mSv conceivable.

To put these results in perspective, it may be useful to recall that the daily intake of radioactivity from natural sources (K-40, C-14, H-3, U-234, Th-228 and others) is in the range of 150 to 200 Bq/person. This results in an annual internal radiation exposure of 0.38 mSv/person [2] or 1.14 mSv during the 3-year period of 1986–1988, a value 8 times higher than the 0.14 mSv caused by the Chernobyl accident.

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