CONTAMINATION AND RADIATION EXPOSURE IN GERMANY FOLLOWING THE ACCIDENT AT THE CHERNOBYL NUCLEAR POWER PLANT

E. ETTENHUBER, I. WINKELMANN, H.R. RÜHLE
Bundesamt für Strahlenschutz,
Berlin, Germany

XA9745821

A. BAYER, E. WIRTH, R. HAUBELT, K. KÖNIG
Bundesamt für Strahlenschutz,
München, Germany

1. RADIOACTIVE CONTAMINATION [1]

The radioactive substances released following the accident at the Chernobyl nuclear power plant were distributed by atmospheric transport over large parts of Europe. Due to dry and wet deposition processes, soil and plants were contaminated.

1.1. Activity concentrations in air

The "radioactive cloud" was first monitored on the 29th of April by near surface measurement stations; by the 30th of April the whole of southern Germany was affected. The contaminated air then spread out in both westerly and northerly directions, resulting in increased airborne radioactivity over the entire country within the following days.

1.2. Ground contamination

Airborne radionuclides were deposited on soil and plants in dry form as well as by precipitation. Locally varying depositions resulted from different activity concentrations in aerosols and very large differences in the intensity of precipitation during the passage of contaminated air masses. Rain falls were particularly heavy in Germany during the time the cloud was passing, especially south of the Danube, where on average 2,000 to 50,000 Bq of Cs-137 was deposited per square meter on soil, and in some cases even as much as 100,000 Bq per square meter. Fig. 1 illustrates Cs-137 ground contamination in the year 1986.

1.3. Local dose rate

As a consequence of the contamination of air and ground from fallout, an increase in dose rate was observed. The local dose rate and its change through time were essentially determined by the conditions as described in Section 1.2. This behaviour was particularly pronounced in the south-eastern and southern part of Germany.

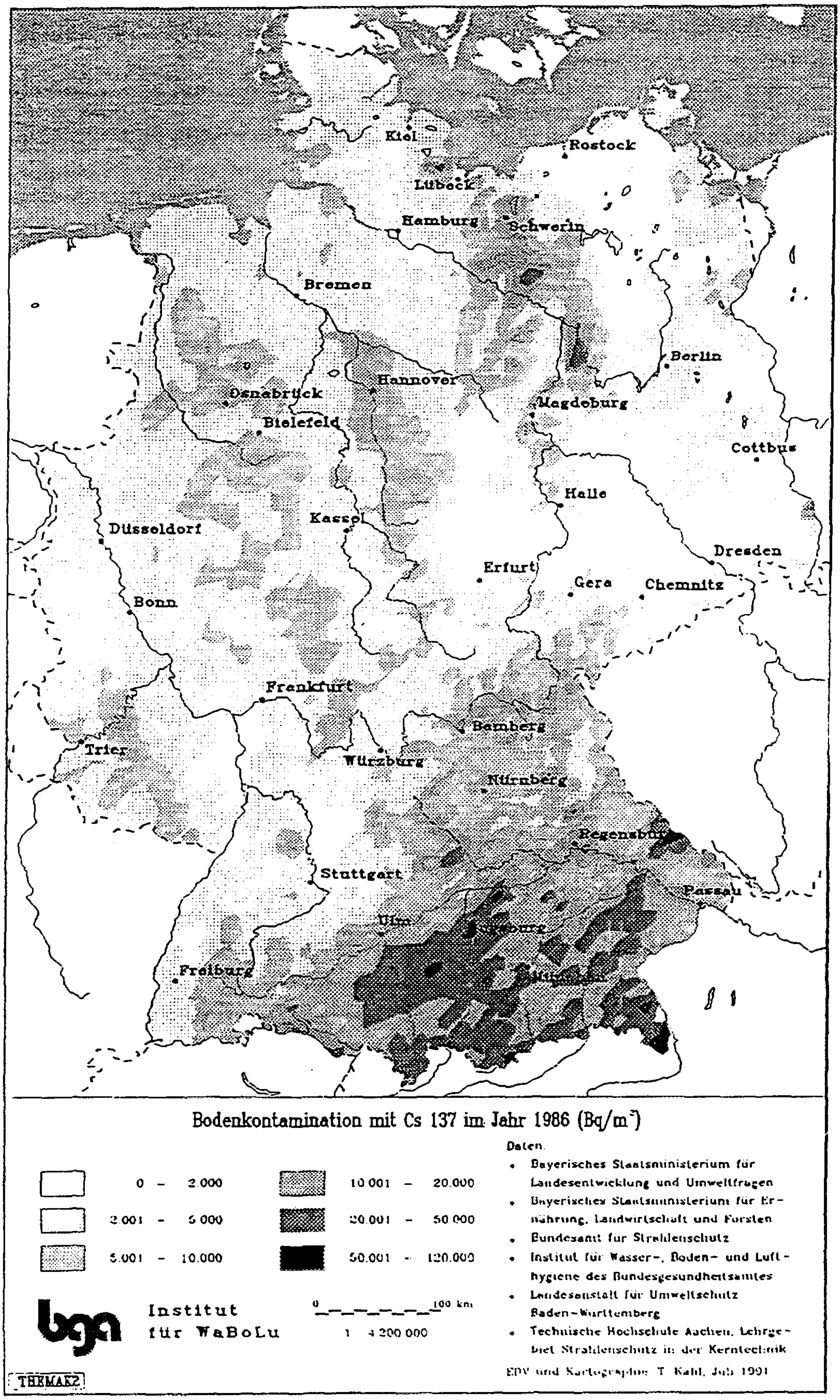

Fig 1. Ground Contamination of Cs-137 in 1986

1.4. Activity concentrations in drinking water

The contamination of drinking water by airborne radioactive substances depends primarily on the contamination of untreated rainwater used for producing drinking water. With the exception of cistern water where, depending on the dilution volume, radionuclide concentrations were measured up to the concentrations in precipitation, the mean values for all radionuclides in all other untreated water sources were below 1 Bq/l.

1.5. Specific activity in foods

Products ready for harvest in May, such as lettuce, spinach and pasture plants, showed a relatively high contamination from direct radionuclide deposition. After the I-131 specific activity had markedly decreased and caesium isotopes were still of significance, the contamination of other foodstuffs gained in importance.

Figures 2a to 2b illustrate the change of activity concentrations over time in milk. These figures show that, shortly after the radioactive cloud arrived, comparatively high I-131-activity was already measurable in milk from cows that had grazed on contaminated pastures. By the end of May, however, I-131 had almost completely disappeared from milk. Radiocaesium-activity reached a maximum approximately one month after contamination, slowly decreasing thereafter. In winter, when contaminated hay was fed to the cows, the activity was again enhanced and remained fairly constant until the next grazing season began.

Only specific pathways, such as game and mushrooms, are still of interest 10 years following the accident. In various mushroom types, more than 1000 Bq/kg of Cs-137 can still be measured in southern Bavaria. Blueberries, blackberries and wild strawberries may still be contaminated with Cs-137 at about 300 Bq/kg. Similar, high activity concentrations may also occur in game if the animals graze mainly in forest and not in agricultural areas.

2. RADIATION EXPOSURE OF THE POPULATION [2]

The contamination of air, soil, water and foods by radionuclides over various exposure pathways has led to an additional radiation exposure of the population.

2.1. Exposure from radionuclides in the air

Exposure from radionuclides in the air occurred only during the passing of the "cloud" and are considered to be insignificant in comparison to the exposure from radionuclides deposited on the ground.

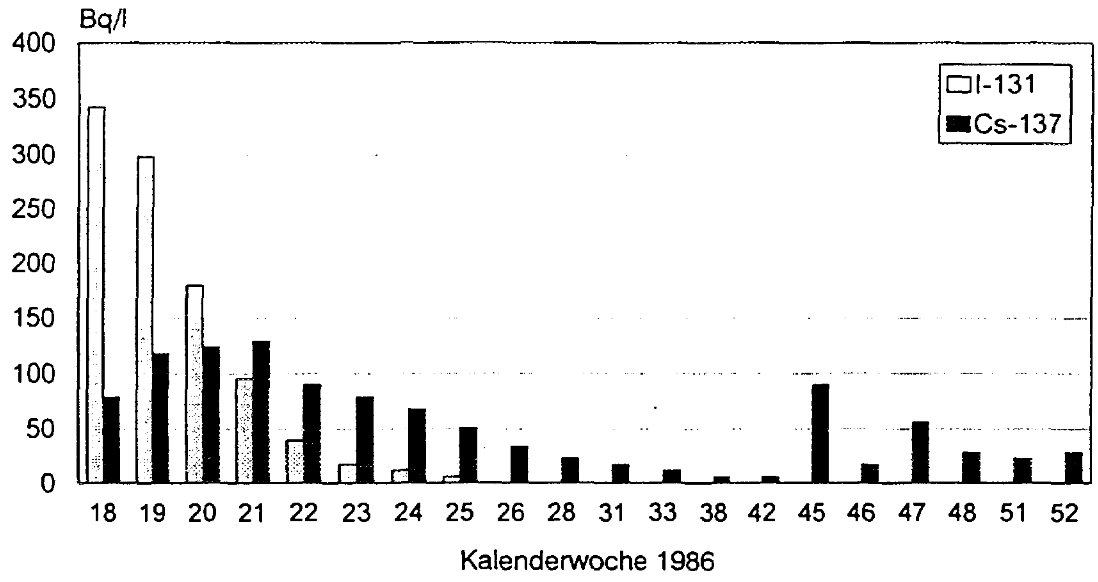

Fig 2a. Mean specific activity of I-131 and Cs-137 in milk (South Bavaria) in 1986

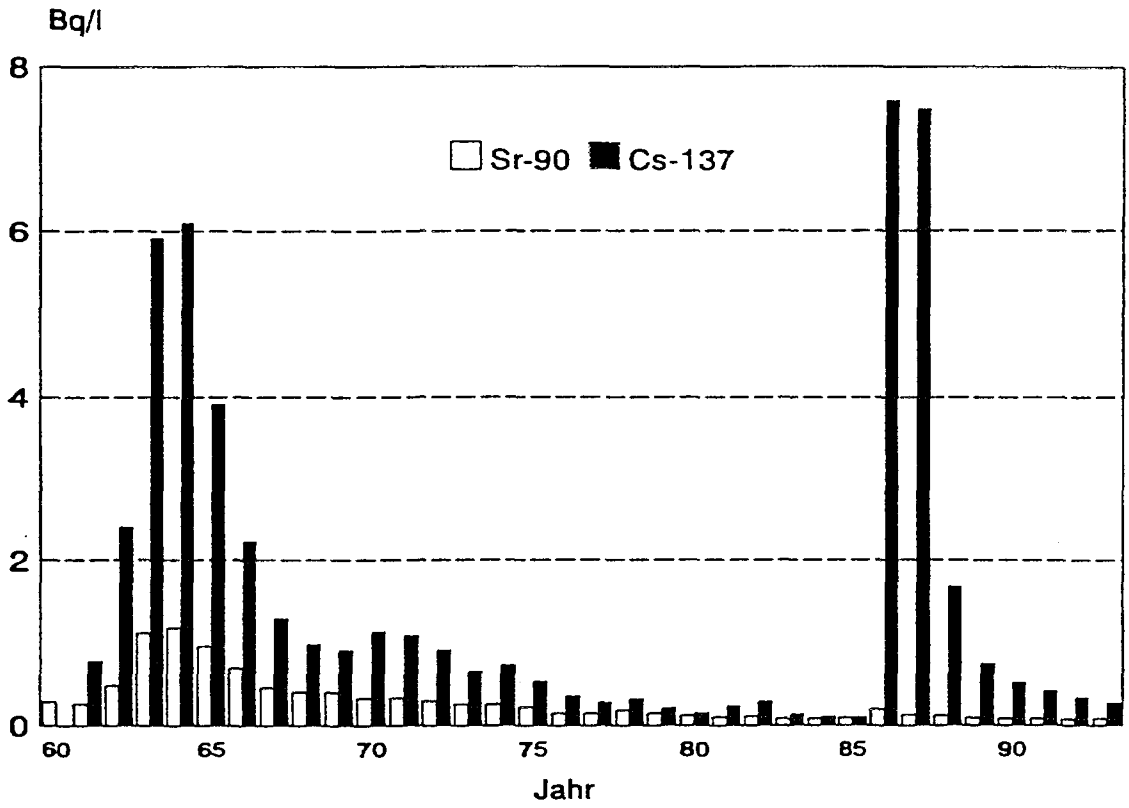

Fig 2b. Mean specific activity of Sr-90 and Cs-137 in milk (Germany)

2.2. Exposure from radionuclides deposited on the ground

For estimating the exposure from radionuclides deposited on the ground, such influential factors as the place and length of residence, shielding, wash-off from buildings and concrete ground surfaces as well as the migration of radionuclides into deeper layers of soil must be considered. As shown in Table Ia, exposure estimates performed by the SSK (Commission on Radiological Protection) have led to the compilation of values for typical contaminated areas.

2.3. Exposure due to the inhalation of contaminated air

Exposure from the inhalation of contaminated air did not contribute significantly to the overall effective dose. Inhalation doses, as estimated by the SSK for the area south of the Danube, are shown in Table Ib. Values north of the Danube are a factor of 2 to 10 lower than those shown in Table Ib and are up to a factor of 2 higher in the pre-alpine area.

2.4. Exposure due to the ingestion of contaminated foods

Exposure estimates of ingested amounts of contaminated foods are accompanied by uncertainties. For example, the origin of foods bought, and thus the amount of their contamination, is often unknown to the consumer. Similarly, individual eating habits may have changed. In a representative inquiry, taken in May 1986, about two thirds of those questioned had changed their eating habits with regard to fresh vegetables and lettuce, possibly resulting in reduced dose.

Exposure of the population from the ingestion of radionuclides in foods was determined by whole body measurements performed on reference groups and the internal dose accumulated since 1986 was calculated from these measurements. In the population of southern Germany (as calculated from

TABLE Ia. CUMULATIVE EFFECTIVE DOSE BY EXTERNAL IRRADIATION [2]

	"representative Cs-137-contamination"	cumulative external radiation exposure (mSv)					
					infant		adult
area	(Bq/m_)	1 year	5 years	lifetime	1 year	5 years	lifetime
pre-alpine region	32 000	0.3	0.6	1.5	0.2	0.5	1.3
south of the Danube	16 000	0.15	0.3	0.8	0.1	0.25	0.7
north of the Danube	4 000	0.04	0.08	0.2	0.03	0.07	0.2

TABLE Ib. DOSE DUE TO INHALATION (SOUTH OF THE DANUBE) [2]

Inhalation doses	infant	adult
effective dose (in mSv)	0.03 - 0.07	0.02 - 0.04
thyroid dose (in mSv)	0.45 - 1.2	0.35 - 0.7

TABLE Ic. MEAN EFFECTIVE DOSE DUE TO INGESTION [2]

area	mean effective dose due to ingestion (mSv)	
	1 year	lifetime
pre-alpine region	0.25	0.6
south of the Danube	0.15	0.4
north of the Danube	0.08	0.2

representative measurements taken in the Munich area) the internal dose early in 1996 amounted to about 0.12 mSv for women and to about 0.18 mSv for men.

SSK estimates (Table Ic) contain mean values for the first post-accident year as well as over the entire lifetime for men, women and children in the pre-alpine area and regions south and north of the Danube. In addition to ceasium-137, other radionuclides deposited are also included. However, owing to dietary habits, 80% of values deviate from mean values by more than a factor of 3.

2.5. Total exposure

According to SSK estimates, persons who were infants at the time of the accident received a total mean effective dose within the 12 months following the accident via the various pathways of 0.17 mSv (north of the Danube), 0.35 mSv (south of the Danube), and 0.65 mSv (prealpine region).

3. COMPARISON OF EXPOSURES TO NATURAL RADIATION [1]

The sum of external and internal exposures from natural radioactive substances results in a mean value of about 2.4 mSv/yr in Germany (Fig.3), although this value varies between 1 and 10 mSv per year. During the course of a lifetime (70 years), this type of exposure would accordingly result in an effective lifetime dose between 70 and 700 mSv.

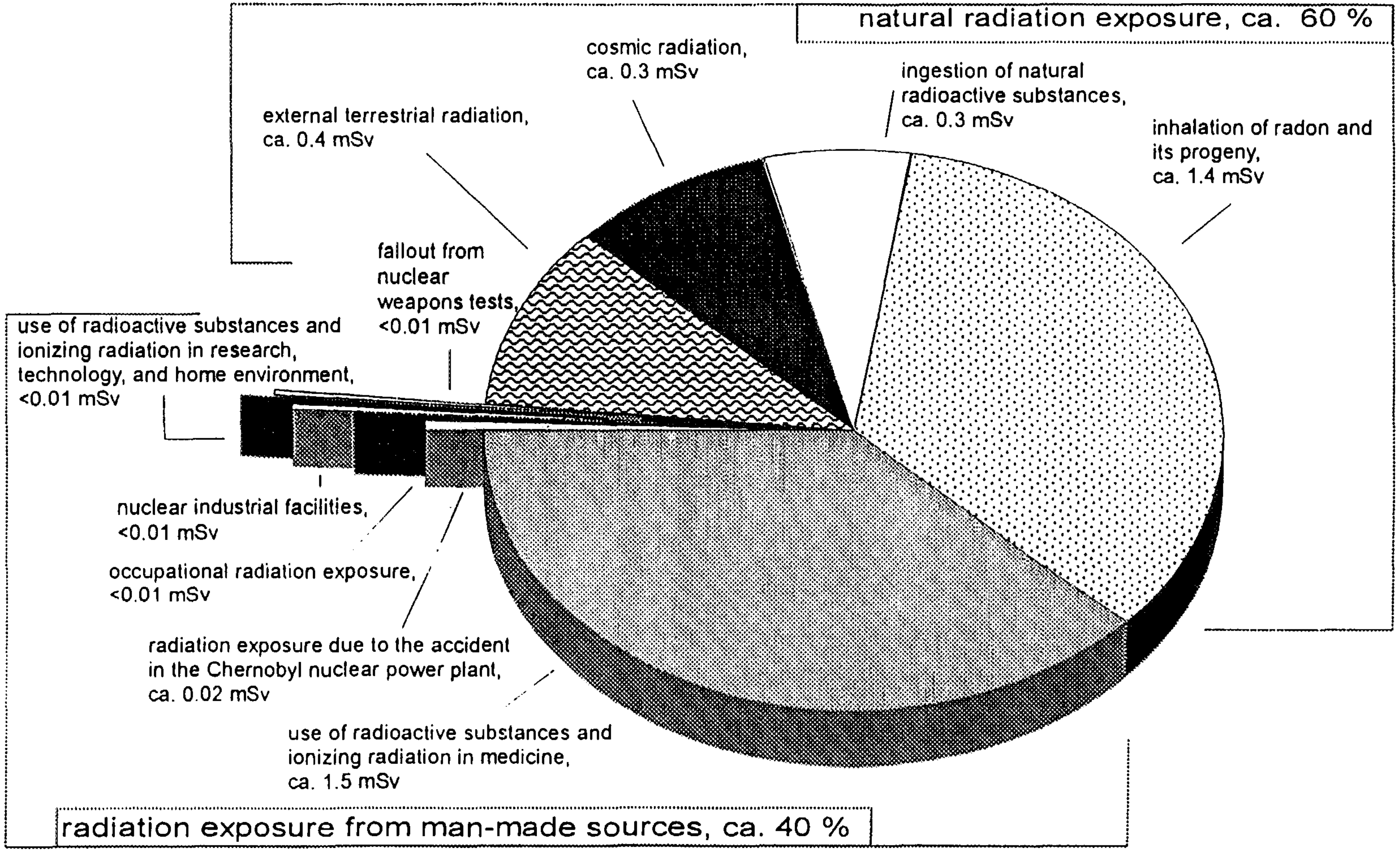

Fig 3. Contributions to the mean effective dose of the population of Germany in 1993

As compared to the values estimated in Chapter 3, it follows that the additional mean effective dose of 0.35 mSv during the first post-accidental year for children living south of the Danube corresponds to about 15% of the mean annual dose caused by natural radiation sources. In some pre-alpine regions, the values are about twice as high. The total mean dose during the 50 years following the reactor accident to this same group of persons (estimated at about 1.3 mSv) corresponds to about 1% of the mean dose from natural radiation sources over an entire lifetime. Here, again, dose values may be twice as high in some pre-alpine areas.

References

[1] A. BAYER, E. WIRTH, R. HAUBELT, K. KÖNIG, E. ETTENHUBER, I. WINKELMANN, H. RÜHLE
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[2] Zehn Jahre nach Tschernobyl, Information der Strahlenschutzkommission zu den radiologischen Auswirkungen und Konsequenzen insbesondere in Deutschland
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