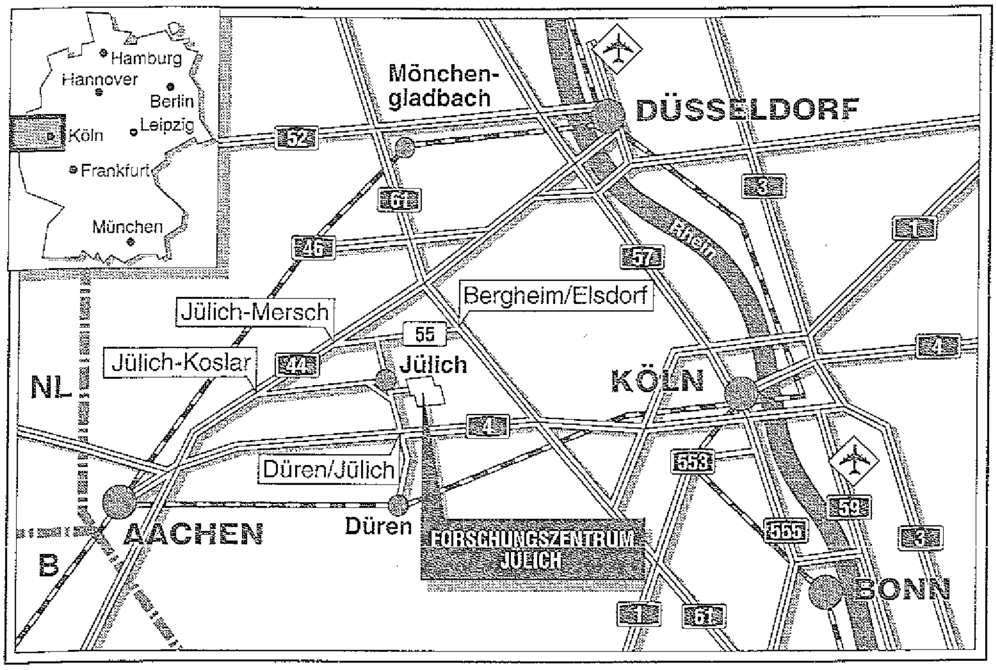
FORSCHUNGSZENTRUM JÜLICH GmbH

KFA

Abteilung Sicherheit und Strahlenschutz

Measuring Programme of the Federal Republic of Germany in Regions of Russia Contaminated by the Chernobyl Accident – Summary of the Results of the Year 1991

R. Hille K. Heinemann P. Hill



Berichte des Forschungszentrums Jülich ; 2704
ISSN 0366-0885
Abteilung Sicherheit und Strahlenschutz Jül-2704

Zu beziehen durch: Forschungszentrum Jülich GmbH · Zentralbibliothek
Postfach 1913 · D-5170 Jülich · Bundesrepublik Deutschland
Telefon: 02461/61-6102 · Telefax: 02461/61-6103 · Telex: 833556-70 kfa d

Measuring Programme of the Federal Republic of Germany in Regions of Russia Contaminated by the Chernobyl Accident – Summary of the Results of the Year 1991

R. Hille K. Heinemann P. Hill

Abstract

From May till October 1991 specialists from the Federal Republic of Germany investigated both the environmental and body burdens due to the accident of the Chernobyl nuclear power plant in the RSFSR. In the survey an area of approximately 10.000 km² extending from Tula (close to Moscow) up to Slynka at the Byelorussian border and such including regions of low and high contamination levels in the districts of Brjansk, Kaluga, Orel and Tula has been covered.

Seven measuring vans from different German institutions took part in a 3 weeks field study of dose rates and of the burden of environmental samples and foodstuffs. The results agreed fairly well with those obtained by Russian scientists.

The body content of radioactive Caesium of close to 160.000 persons has been examined. Up to 7 mobile whole-body counting laboratories have been operational with a total number of 20 counters. Each person examined received an official certificate giving the result of the measurement. Observed activity levels were generally much less and in no case higher than the annual limit of intake acceptable for professional radiation workers. Only for less than 1% of the people examined the results suggest the necessity of a further surveillance by health physicists and physicians similar to the regular medical examination professional radiation workers undergo.

Table of Contents

	page
1. Introduction	2
2. Results of the Environmental Measurements	5
3. Results of the Whole-Body Measurements	12
4. Concluding Remarks	31
Appendix : Reports	33

1 Introduction

Reports on the impacts of the reactor accident at Chernobyl in late April 1986 have been extremely contradictory as yet.

Not least, these circumstances have apparently led to considerable disquiet and concern amongst the Russian public even at a great distance from the scene of the accident.

In order to assist in informing those affected and above all to determine their actual radiation exposure, the Federal Republic of Germany took part in a measuring campaign in the regions of Bryansk, Kaluga and Tula situated to the southwest of Moscow and northeast of Kiev. For this purpose, the Federal Environmental Ministry made available funds of DM 7.1 million.

After consultation with the Radiation Protection Commission, a measuring programme was drawn up and the Research Centre Jülich entrusted with its implementation and organization. A total of 22 vehicles with 27 measuring assemblies and more than 150 staff, recruited on a voluntary basis from various institutions in the Federal Republic of Germany, were engaged in the measuring campaign lasting from mid-May to early October 1991. The measuring locations can be seen from Figures 1 and 2. Two leaflets were distributed in order to explain the situation to those persons undergoing measurements.

Environmental and food samples were measured in the first phase of the measuring programme in order to draw conclusions about the internal radiation exposure caused by foodstuffs and the external radiation present at the respective measuring locations.

More than 160,000 people were examined in the course of the subsequent whole-body measurements with the result that approx. 99 % displayed a body burden of less than 25 kBq Cs-137/134, thus demonstrating that the health of this part of the population was not endangered by food or environmental radioactivity. The following report gives a survey of the implementation of the measuring campaign and its most important results.

Fig. 1: European section of the former Soviet Union

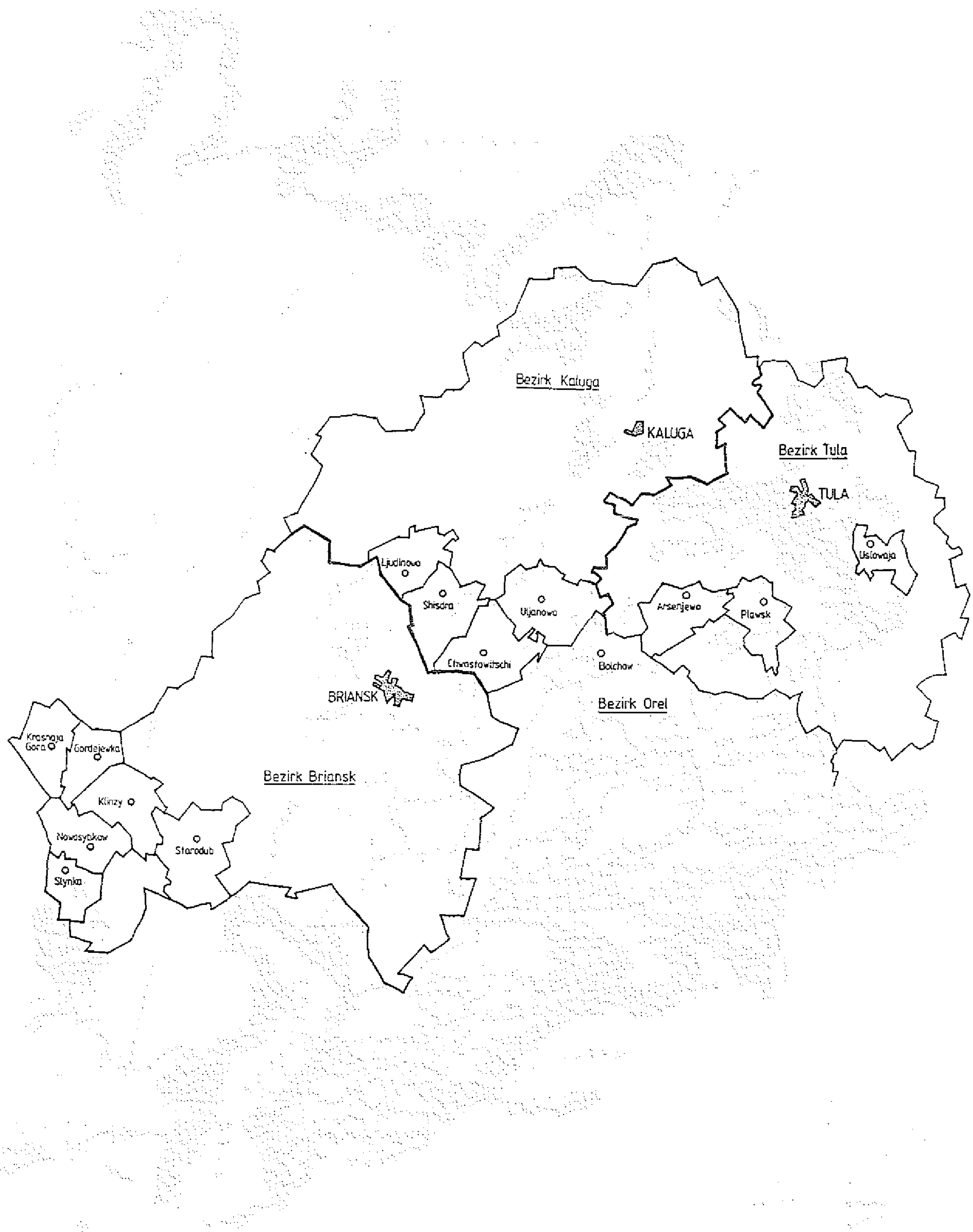


Fig. 2: Overview of the regions and administrative districts where the measuring vehicles were in operation

2 Results of the Environmental Measurements

The measuring programme of the Federal Republic of Germany in Russia, financed by the Federal Ministry of the Environment, Nature Conservation and Reactor Safety and coordinated and implemented by the KFA, began with environmental measurements in the period from 21 May to 11 June 1991. Various scientific institutions from the Federal Republic of Germany were involved with their environmental measurement vehicles and also operating personnel.

The sensitive measuring instruments were flown from the Russian military airport, Templin, north of Berlin, to Moscow and from there to the regions where they were to be employed: Tula, 200 km south of Moscow, Kaluga, 250 km southwest of Moscow, and Bryansk, 500 km south of Moscow. The measuring campaign was coordinated from Bryansk.

The measuring locations were selected by our partners on the Russian side, the National Committee for Remedying the Consequences of the Chernobyl Reactor Accident (Goskom Chernobyl). This committee also undertook to supply the detectors with liquid nitrogen, the vehicles with fuel and the German teams with board and lodging.

The environmental investigations had the following objectives:

- collecting basic data to interpret the whole-body measurements

- supplementing the whole-body measurements by measuring the external radiation

- providing factual information for the public on their uptake of radioactivity from their diet by measuring the radioactivity of their food.

After overcoming teething troubles caused by the absence of a plan for the sequence of measuring locations, the lack of suitable maps and interpreters, and in part delayed supplies of liquid nitrogen, the measuring programme - laid down in advance by the German side - began by determining the ambient dose rate and soil contamination and examining the basic foodstuffs, such as water, milk, potatoes, bread and cereals, by gamma spectrometry as an aid for interpreting the whole-body measurements.

All foodstuff supplied by the public was measured. Each participant was given, without any recourse to Russian officials, the contamination measured for his food and a brief explanation in Russian on a specially designed form. The public were thus personally able to assess the contamination of their food. In order to cope with the great demand for food measurements, it was often necessary to work into the night without any free weekends.

A total of more than 2000 food measurements, more than 230 soil examinations and more than 500 ambient dose rate determinations were carried out. With respect to the measurements, the following general statement can be made.

The major contaminations were caused by the Cs-134 and Cs-137 nuclides. The ratio of the measured activities of Cs-137 to Cs-134 amounted to about 10:1. It was not possible to detect any contaminations above the detection limit for water and air of a few Bq/l and 1 Bq/m^3 respectively.

The measuring results are summarized in Table 1 for the three areas studied (see Figure 2) according to the range of activity values of contamination detected. As an aid to interpretation, the contamination limits laid down by the Russian Government are given in the bottom line, and these are in part below those laid down by the EC. The low measured data for the contamination of foodstuff (30 Bq/kg) given for the Bryansk region was determined by the so-called bequerel monitors used here. The highest contaminations for a food group resulted from the specimens directly provided by the grower and not bought in a shop. It became apparent that the major fraction of the measured contaminations were below the Russian contamination limit. The measured contaminations increased from the Tula region through the Kaluga region to the Bryansk region.

Table 1
Results of environmental measurements in Russia

			Contamination of foodstuffs in Bq/kg or Bq/l				
Region	Ambient dose rate (μSv/h)	Soil contamination (kBq/m^2)	Milk and milkproducts	Garden produce	Wild fruit and mushrooms[1]	Cereals and cereal products	Meat[2]
Tula	0.04-0.34	26 - 313	5- 27	5 - 133	9 - 185	9 - 68	7 - 51
Kaluga	0.08 - 0.90	2 - 552	1 - 673	2 - 377	6-10552	6 - 9	6 - 422
Bryansk	0.07 - 1.31	8 - 3946	30 - 3720	30 - 1845	30 - 15873	30 - 140	30 - 5114
Russian limits	-	-	370	592[3]	1480	370	740

1) not dried
2) without game
3) potatoes, vegetables

The external and internal radiation exposure of the population can be approximately calculated from the measured data for the ambient dose rate and the contamination of foodstuffs. The averages of the ambient dose rate and milk contamination in the three regions studied is given in Table 2. For this estimation the following assumptions are made:

- The measured ambient dose rate is, as a first approximation, equal to the external radiation exposure outdoors.

- The population spend two-thirds of their time indoors and the ambient dose rate there is lower by a factor of 10 than that outside the house.

- Everybody incorporates per day the activity contained in a litre of milk.

Under these assumptions, the external and internal radiation exposures are obtained, also shown in Table 2. It can be seen that the external radiation exposure in all three areas studied exceeds that of the inner radiation exposure on average by a factor of at least 2.

Table 2:

Ambient dose rate and milk contamination and the resulting internal and external radiation exposure

	Average of		External radiation exposure	Internal radiation exposure
Region	Ambient-dose rate (μSv/h)	Milk contamination (Bq/l)	(mSv/a)	(mSv/a)
Tula	0.19	9.3	0.7	0.04
Kaluga	0.28	46	1.0	0.23
Bryansk	0.36	131	1.3	0.67

A comparison of our measured data with Russian measured data, taking the example of soil contamination, shows good agreement. The Russian measured data are taken from maps of soil contamination generally available and the German data are averages from the individual measurements. They are compiled in Table 3. Apart from this comparison, a number of individual samples were also measured in parallel by German and Russian scientists. In this case, the deviation was also within the error limit.

Table 3:
Comparison of soil contaminations

	soil contamination	
Region	Russian studies	Averages of the individual German measurements
Tula	1 - 5 Ci/km^2 = 37 - 185 kBq/m^2	106 kBq/m^2
Kaluga	1 - 5 Ci/km^2 = 37 - 185 kBq/m^2	137 kBq/m^2
Bryansk	5 - 15 Ci/km^2 = 185 - 555 kBq/m^2	249 kBq/m^2

Individual samples were taken to Germany and examined for strontium 90 and iodine 129. These analyses were intended to answer particular questions, such as: Are there other dose-relevant nuclides, apart from the caesium contaminations detected by gamma spectrometry? Do increased iodine 129 concentrations occur which, together with the isotopic ratio I-129: I-131, enable the thyroid dose to be reconstructed?

The strontium analyses, summarized in Table 4, were carried out in the laboratories of the participating environmental measuring teams; mainly in Jülich. The iodine analyses in Table 5 were carried out by Dr. Handl, Lower Saxony Institute of Radioecology, Hanover, using neutron activation analysis.

The strontium analyses deal mainly with soil samples, but grass, wild fruits and cereals were also investigated. The soil samples are divided into worked (arable) and unworked soils (pasture, meadows). Even though the picture is not very uniform, nevertheless it is striking that the ratio of the radioactivity concentration of Cs-137 : Sr-90 is smaller for arable land than for meadows and pasture. This may be related to the fact that the more mobile strontium has already migrated out of the sampling layer to a greater extent in the case of the unworked soils.

Only individual values are available for the foodstuffs and a systematic evaluation is therefore very difficult. Even if the values of the dose factors are considered, it can be seen from the ratio of the Cs-137 : Sr-90 activity concentrations that Cs-137 is the more dose-relevant nuclide.

The iodine analyses shown in Table 5 comprise 8 individual samples of soils with different uses and compositions. The I-129 concentrations are naturally low. The isotopic ratio of I-129 to stable I-127 is between 10^{-6} and 10^{-7} and is elevated in comparison to the normal value in Europe of 10^{-8}. The nuclide I-129 itself only provides a negligible contribution to the radiation exposure. It will probably be very difficult to draw any conclusions about I-131 on this basis or indeed to reconstruct the thyroid dose. The activity ratio of Cs-137 : I-129 is given for comparison.

Table 4:

Evaluation in Germany of environmental samples from Russia for Sr-90

sample type	Location	Region/ district	Nuclid (Bq/kg)		activity ratio Cs-137:Sr-90	Remarks
			Cs-137	Sr-90		
Soil	Smotrova-Buda	Klincy	$7.6 \cdot 10^2$	$1.4 \cdot 10^1$	54	Meadow
Soil	Pobeda	Klincy	$1.1 \cdot 10^3$	$2.3 \cdot 10^1$	48	
Soil	Olchovka	Klincy	$2.5 \cdot 10^3$	$3.6 \cdot 10^1$	69	
Soil	Pervoya Maya	Klincy	$7.0 \cdot 10^2$	$2.0 \cdot 10^1$	35	Meadow
Soil	Pervoya Maya	Klincy	$2.3 \cdot 10^3$	$9.2 \cdot 10^0$	250	Memorial, Cs:Sr ratio unusually large
Soil	Pravlitchi	Klincy	$9.9 \cdot 10^1$	$4.1 \cdot 10^0$	24	Meadow
Soil	Guta-Koretskaya	Klincy	$7.3 \cdot 10^3$	$6.9 \cdot 10^1$	106	
Soil	Dolina	Klincy	$4.7 \cdot 10^3$	$5.0 \cdot 10^1$	94	Pasture
Soil	Dolina	Klincy	$5.7 \cdot 10^3$	$5.9 \cdot 10^1$	97	Pasture
Soil	Lovatyanka	Klincy	$7.5 \cdot 10^3$	$1.5 \cdot 10^2$	50	Meadow
Soil	Korenyevo	Klincy	$4.3 \cdot 10^3$	$6.3 \cdot 10^1$	68	Pasture 0-5 cm
Soil	Korenyevo	Klincy	$8.0 \cdot 10^1$	$1.4 \cdot 10^1$	57	Pasture 5-10 cm
Soil	Uscherpya	Klincy	$1.9 \cdot 10^3$	$2.6 \cdot 10^1$	73	
Soil	Veprin	Klincy	$7.7 \cdot 10^3$	$8.8 \cdot 10^1$	87	
Soil	Lopatni	Klincy	$1.6 \cdot 10^2$	$5.4 \cdot 10^0$	30	Pasture
Soil	Roshny	Klincy	$3.0 \cdot 10^3$	$2.7 \cdot 10^1$	111	
Soil	Korenyevo	Shisdra	$2.9 \cdot 10^3$	$5.0 \cdot 10^1$	58	High hill
Soil	Voylova	Ludinovo	$1.1 \cdot 10^3$	$1.0 \cdot 10^1$	111	Pasture
Soil	Guljovka	Klincy	$2.1 \cdot 10^3$	$3.8 \cdot 10^1$	55	Cs:Sr ratio
Soil	Turosna	Klincy	$1.2 \cdot 10^3$	$1.4 \cdot 10^2$	8.6	unusually small
Soil	Star Kolkhoz	Uzlovaya	$2.3 \cdot 10^2$	$6.9 \cdot 10^0$	33	Arable land
Soil	Tsashitastrani Kolkhoz	Uzlovaya	$2.9 \cdot 10^2$	$1.4 \cdot 10^1$	21	Arable land
Soil	Butyrki	Uzlovaya	$1.6 \cdot 10^2$	$1.1 \cdot 10^1$	14	Arable land
Soil	Raccbet Kolkhoz	Uzlovaya	$3.3 \cdot 10^2$	$2.1 \cdot 10^1$	16	Arable land
Soil	Kalinina Kolkhoz	Uzlovaya	$3.6 \cdot 10^2$	$2.5 \cdot 10^1$	14	Arable land
Soil	Red Flag Kolkhoz	Uzlovaya	$4.6 \cdot 10^2$	$2.2 \cdot 10^1$	21	Arable land
Soil	Bocxod	Uzlovaya	$4.2 \cdot 10^2$	$2.0 \cdot 10^1$	21	Arable land
Soil	Bestruchovo State Farm	Uzlovaya Uzlovaya	$2.7 \cdot 10^2$	$1.6 \cdot 10^1$	17	Arable land
Soil	C4D Kolkhoz	Uzlovaya	$3.6 \cdot 10^2$	$1.7 \cdot 10^1$	21	Arable land
Soil	Afanasovo	Ulyanovo	$3.3 \cdot 10^3$	$1.8 \cdot 10^1$	180	Party Headauarters
Soil	Sorokino	Ulyanovo	$1.3 \cdot 10^3$	$6.1 \cdot 10^0$	220	Pasture
Soil	Dudorovski	Ulyanovo	$1.2 \cdot 10^3$	$8.3 \cdot 10^3$	149	Pasture
Soil	Kzyin	Ulyanovo	$2.0 \cdot 10^3$	$1.1 \cdot 10^0$	1768	Pasture, Cs:Sr ratio unusually large
Soil	Vyesniny	Ulyanovo	$2.4 \cdot 10^3$	$1.0 \cdot 10^1$	237	Pasture
Soil	Krapivna	Ulyanovo	$2.6 \cdot 10^3$	$8.4 \cdot 10^0$	312	Playing field
Soil	Krapivna	Ulyanovo	$2.7 \cdot 10^3$	$1.1 \cdot 10^1$	249	School playing field
Grass	Korenyevo	Shisdra	$1.1 \cdot 10^3$	$2.2 \cdot 10^2$	5	
Grass	Korenyevo	Shisdra	$9.8 \cdot 10^2$	$6.9 \cdot 10^1$	14	High hill
Grass	Dolina	Klincy	$7.0 \cdot 10^1$	$1.0 \cdot 10^2$	0,07	unussually Cs:Sr ratio, should be >1
Bilberries	Veprin	Klincy	$2.8 \cdot 10^3$	$5.0 \cdot 10^0$	560	

Table 4 (cont.):
Evaluation in Germany of environmental samples from
Russia for Sr-90

sample type	Location	Region/ district	Nuclid (Bq/kg) Cs-137	Sr-90	activity ratio Cs-137:Sr-90	Remarks
Edible boletus	Veprin	Klincy	$5.0 \cdot 10^4$	$2.0 \cdot 10^0$	24500	dried
Mushrooms	Klincy	Klincy	$2.7 \cdot 10^4$	$4.9 \cdot 10^0$	55200	dried
Jam	Veprin	Klincy	$1.4 \cdot 10^3$	$6.2 \cdot 10^0$	227	
Barley	Pavlitschi	Klincy	$0.83 \cdot 10^1$	$2.9 \cdot 10^1$	0.29	unussually Cs:Sr ratio, should be >1
Rye	Olchovka	Klincy	$2.9 \cdot 10^1$	$4.8 \cdot 10^0$	6.6	
Rye	Guta-Koretskaya	Klincy	$5.7 \cdot 10^1$	$7.7 \cdot 10^0$	7	

Table 5:
Iodine 129 analyses of 8 soil samples

		Contamination				
sampling location	soil type	Cs-137 (Bq/kg)	I-129 (Bq/kg)	I-127 (Bq/kg)	Activity ratio Cs-137:I-125	Isotopicratio I-129:I-127 x 10^{-7}
Olchovka	Arable land	2.5 • 103	2.7±0.4	1.2±0.2	$9.3 \cdot 10^5$	3.6±0.4
Guta-Koretskaya	Arable land	$7.3 \cdot 10^3$	3.8±0.6	0.6±0.1	$1.9 \cdot 10^6$	1.1±0.6
Uscherpya	Arable land	$1.9 \cdot 10^3$	2.9±0.5	0.7±0.1	$6.5 \cdot 10^5$	6.5±0.5
Lopatni	Pasture	$1.6 \cdot 10^2$	2.2±0.2	0.6±0.05	$7.3 \cdot 10^4$	6.0±0.2
Roshny	Arable land	$3.0 \cdot 10^3$	2.9±0.2	2.6±0.2	$1.0 \cdot 10^6$	1.8±0.3
Korenyevo	Meadow	$2.9 \cdot 10^3$	1.8±0.2	1.2±0.1	$1.6 \cdot 10^6$	2.4±0.2
Woylovo	Pasture	$1.1 \cdot 10^3$	2.6±0.4	0.8±0.1	$4.2 \cdot 10^5$	5.0±0.4
Turosna	Arable land	$1.2 \cdot 10^3$	2.8±0.4	1.0±0.1	$4.3 \cdot 10^5$	4.6±0.4

3 Results of the Whole-Body Measurements

The second phase of the measuring programme consisting of whole-body measurements lasted from July to September 1991. The following German institutions provided persononnel for this programme:

- Research Centre Jülich
- Central Institute of Nuclear Research, Rossendorf
- Federal Civil Defence Office and its associated early warning stations, Bonn
- Nuclear Auxiliary Services, Eggenstein
- Technical Control Board for Saxony, Dresden-Chemnitz
- Hahn-Meitner Institute, Berlin
- Federal Agency for Materials Research, Berlin
- Research Centre Geesthacht
- Brenk Systemplanung, Aachen
- other institutions and private individuals.

Three semitrailers with 4 measuring assemblies each and 4 box-type delivery vans with 2 measuring assemblies each were employed for the whole-body measurments. This permitted flexible operation. The delivery vans enabled measurements to be carried out at localities with populations ranging from several hundred to a few thousand even if the roads were not suitable for heavy vehicles, and the semitrailers were parked in towns where they remained stationary for up to a few weeks thus permitting a high throughput.

It was to be expected that in 1991, i.e. 5 years after the accident, the detectable incorporation of the population would only consist of the gamma-emitters Cs-137 and Cs-134. Even in 1990 we had only been able to detect these radionuclides with the whole-body counter at the Research Centre Jülich for reactor personnel on duty in block 4 of the Chernobyl power station on the night of the accident. On the basis of the environmental and food measurements, an appreciable contamination of the population with Sr-90 and Pu-139 was ruled out.

An important criterion for selecting the measuring systems was therefore sufficient detection sensitivity for the isotopes Cs-137 and Cs-134 in a short measuring time appropriate for the measuring task. It should be possible to detect a Cs activity of 1 kBq in the human body with a measuring time of 1 minute. This requirement was not only fulfilled by spectroscopic, nuclide-resolving measuring systems but also by simpler systems with plastic scintillators. We therefore decided on a mixed concept. Apart from spectroscopic systems, instruments operating radiometrically with plastic scintillators were employed which required knowledge of the isotopic composition of the incorporated activity. This mixed system enabled, on the one hand, cost savings since the instruments operating radiometrically were considerably cheaper and more mobile, and on the other hand more efficient spectrometric measuring systems were available for more complicated measurements. The lighter QBM1 monitors[1)] were employed on the small, mobile vans whereas the heavy instruments of the Fastscan (Canberra, NaI detector) and H 13010 type (Herfurth, plastic scintillator) were installed on the semitrailers. Plans of the vehicle interiors are shown in Figure 3.

The vans were used in towns in order to reach kindergartens, factories, offices, schools and suburbs. In the country, they were used to take measurements in villages, small towns, collective farms, state farms, convalescent homes and holiday camps. The semitrailers were stationed exclusively in administrative centres. They were usually parked at hospitals or health centres. Table 6 gives an overview of the localities visited by the measuring vehicles (see also Figure 2).

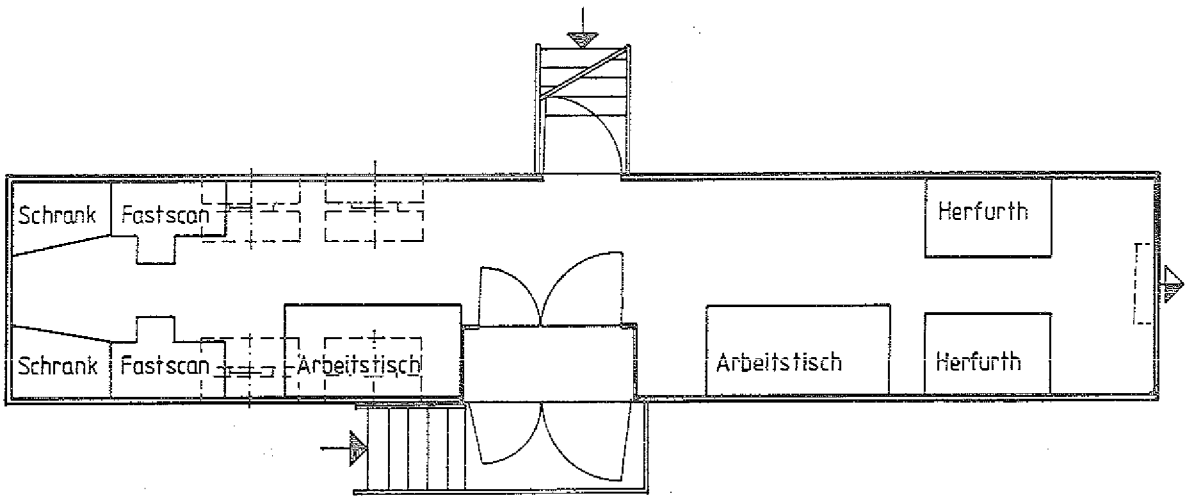
Table 6:

Overview of the localities visited by the measuring vehicles during the measuring campaign

Region	District	Vehicles	Period
Bryansk	Gordejevka	1 semitrailer	07.08. - 06.09.1991
	Klincy	1 semitrailer	21.06. - 15.08.1991
		2 delivery vans[1)]	20.06. - 13.09.1991
		2 delivery van	25.09.1991
	Krasnaja Gora	1 semitrailer	08.09. - 26.09.1991
	Novosybkov	1 semitrailer	12.09. - 26.09.1991
	Slinka	1 semitrailer	16.08. - 12.09.1991
	Starodub	2 delivery vans	16.09. - 24.09.1991
Kaluga	Chvastovitschi	1 semitrailer	13.08. - 09.09.1991
		1 delivery van	13.08. - 05.09.1991
	Ludinovo	1 semitrailer	19.06. - 25.07.1991
		2 delivery vans	17.06.1991
		4 delivery vans	18.06.1991
		1 delivery van	19.06. - 25.07.1991
	Shisdra	1 semitrailer	29.07. - 11.08.1991
		1 delivery van	27.07. - 12.08.1991
	Uljanovo	1 semitrailer	09.09. - 23.09.1991
		1 delivery van	06.09. - 19.09.1991
Orel (Orjol)	Bolchov	1 delivery van	23.09. - 27.09.1991
Tula	Arsenjevo	1 delivery van	24.08. - 26.09.1991
	Plavsk	1 delivery van	31.07. - 23.08.1991
	Uslovaja	1 semitrailer	23.06. - 03.08.1991
		1 delivery van	21.06. - 29.07.1991

1) occasionally just one van

1) Quick Body Monitor, Nuclear Enterprises, Edinburgh, UK



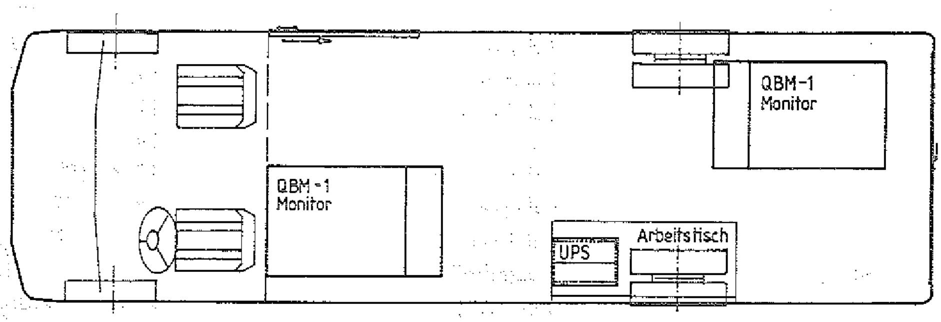


Figure 3: Interior of the semitrailer (top) and the box-type delivery van (bottom)

For intercalibration puposes, a comparative measurement was carried out with a whole-body phantom made available by our Russian partners from the Scientific Research Institute for Hygiene at Sea of the Ministry of Health of the former USSR which had already successfully participated in an IAEA inter comparison1) and which had also been used to calibrate the Russian measuring assemblies. Human beings of different weight and size can be simulated in a standing, lying or sitting position using individual polyethylene bricks 1 kg in weight. Two tubes with a Cs-137 standard were embedded in each brick in order to simulate the distribution of caesium in the body.

The reference measurement was carried out with 2 phantoms of 70 kg (standard human being) and 12 kg (small child approx. 3 years) at one of our Fastscan counters. Agreement between our measured data and the reference activities was very excellent. The burden of the small child was only overestimated by about 8 % and the deviation for the standard human being was even smaller at just 3 %. Both the Herfurth monitors and QBM-1 monitors were calibrated in Russia using real people being contaminated by incorporated Cs-activities of more than 100 nCi (as determined with a Fastscan system) as phantoms.

The measuring campaign was guided by the project management in Germany. The operating experience was continuously evaluated there and used to modify the instruments and procedure. A coordination group was set up in Bryansk in the office of the Goskom Chernobyl (National Committee for Remedying the Consequences of the Chernobyl Reactor Accident) of the Russian Federation in order to guide and supervise operations on site and was particularly involved in the following tasks:

- liaison office with the project management in Jülich
- liaison staff with the Goskom Chernobyl
- preparation of operations in the regions and districts
- contacts to permanent Russian agencies and the press
- catering for the measuring personnel
- instrument servicing, counselling and if necessary training the measuring staff to use the instruments
- vehicle servicing
- contacts to Russian scientific establishments
- contact to the German Embassy in Moscow
- transportation of measuring personnel between Moscow and and the operating areas
- public information.

---

1) R.V. Griffith et al.
'IAEA-USSR Whole Body Counter Intercomparison', Proc. Eigth Int. Congress of the International Radiation Protection Association, May 17-22, 1992, Montreal, P. 1027-1030

A well equipped office belonging to the Goskom in the centre of Bryansk was made available for the coordination staff. This integration into the offices of our Russian partners promoted cooperation. Bryansk proved to be a suitable site since it was situated at the centre of the operating area with good transport routes to Moscow. The measuring staff in each of the three districts of Tula, Kaluga and Bryansk formed one measuring team consisting, depending on the situation in the operating areas, of 4 - 10 members, some of whom were able to speak enough Russian so that it was possible to communicate with the population in every measuring vehicle. Our colleagues from the former East Germany (e.g. ZfK Rossendorf) were of great assistance in this respect.

The planned daily throughput for the semitrailers amounted to 200 persons/day. This goal was exceeded by far and as a rule a daily throughput of 500 persons was reached (peak value 820 persons on July 4, 1991 in Ludinovo).

The goal for the vans was a daily throughput of 100 persons/day. During the operating period the standard number was closer to 300 persons/day (peak value 562 persons/day on August 8, 1991 in the Chvastovitchi rural district). This rate was only possible since the crew voluntarily worked much longer than planned to cope with the great demand.

All those examined were given a certificate of the measurement results in Russian (Figure 4). Our Russian partners received a carbon copy of this certificate (generally the health authorities in the rural districts). We kept a carbon copy in Germany for our own purposes. Russian assistants helped us to fill in the numbered forms, recorded the personal details required and entered the measuring date. Not only the weight of the person was recorded but also their height. The record number, year of birth, weight, height and a class identification code (see Table 7) were included in the data sets at the time of measurement.

Table 7: Division into classes of the persons measured

B	babies	0 - 3 years
K	children	3 - 12 years
J	juveniles	12 - 18 years
F	women	over 18 years
M	men	over 18 years

The measured data were entered on the certificate by the measuring staff and authenticated by a rubber stamp (particularly important in Russia!) and signature. At the same time the measured data were evaluated according to three categories.

The breakdown of the categories can be seen from Table 8. A differentiation was made between adults and children. The limits for children were selected in such a way that for 5- to 12-year-olds the same dose corresponded to the limits for adults.

Table 8:
Division of the measured data into categories

	adults	children
category 1	up to 7 kBq	up to 4 kBq
category 2	up to 25 kBq	up to 15 kBq
category 3	over 25 kBq	over 15 kBq

In determining the limits between the categories we proceeded according to a simple model, although alternatives are undoubtedly available. The values were based on the dose limits from recent Russian legislation. This results in a limit between the first and second category of an annual dose of 1 mSv and between the second and third category an annual dose of 5 mSv. The external radiation burden and internal radiation exposure are thus combined. We kept to the rule of thumb frequently employed in radiation protection - external radiation exposure twice as high as internal - in order to set the limits given in Table 8. On the basis of the German Radiation Protection Ordinance it was assumed that in the case of continuous uptake by ingestion for adults an equilibrium activity of 1000 kBq corresponds to a dose burden of 50 mSv. A value of 35 kBq thus actually resulted for the boundary between the second and third category. However, in order to filter out more heavily exposed persons and to cover uncertainties due to the simple modelling we set the limit at 25 kBq. Slightly different limits could result if other dose factors specified in the literature are used[2)]. We are aware that at many locations the ratio of 2:1 for external and internal radiation exposure is not valid. Ratios of 3:1 were also determined in Germany. This ratio may even be reversed on soils with high transfer factors. However, we also considered it important that within the framework of this measuring campaign uniform limits should be used in all cases. Different limits at various locations would undoubtedly have been more accurate, but if we had been unable to explain the situation to the public in this simple manner then we would only have caused confusion.

Measurements in the first category do not give any cause for concern; measurements in the second category are also completely safe but in this case we recommend the public to limit their intake of food known to be highly contaminated (e.g mushrooms, game, meat). The values in the third category do not in any case exceed the permissible limits of activity intake in the Federal Republic, i.e. they were in a range corresponding to the dose values permissible for persons professionally

2) e.g. A.S. Keverling Buisman, From Body Burden to Effective Dose Equivalent - a Compilation of Data for the Evaluation of Whole Body Counter Measurements, ENC-116, April 1982

exposed to radiation in the Federal Republic[3]. We are of the opinion that this group of persons should be treated as persons professionally exposed to radiation. In particular, repeated meàsurements and an annual medical check-up are recommended.

In order to achieve our goal, namely of informing the Russian public about their true radiation exposure and thus reducing unnecessary fears, as many people as possible had to be measured. Our minimum goal was therefore to examine 100,000 persons. We expected that of a population of about 300,000 in the operating areas every third person would take part in the measuring campaign. Our expectations were clearly exceeded and at the end of the measuring campaign 163,000 people had been measured. This is due, above all, to the willingness of the measuring staff to work overtime, and the suitability and serviceability of the measuring technology. However, our success was also due to the fact that our campaign was readily accepted by the public so that in some areas more than 70 % of the population made use of our services. We operated in more than 110 settlements in a total of 14 administrative districts in the four regions of Bryansk, Kaluga, Oryol (Orel) and Tula. The proportion of measurements in the individual districts relative to the total number of persons examined can be seen in Figure 5. Almost 50 % of the measurements were undertaken in the Bryansk district where the greatest number of measuring assemblies were deployed. Almost 32 % of the measurements were made in the Kaluga district, which can be attributed to the great interest on the part of the public and the excellent organization by the Russian partners. The number of measured persons in the Tula district was considerably less than in Kaluga. The town of Bolchov in the Orel district was only included in the measuring programme at the last moment. The fraction of 0.9 % of the total measurements is certainly a remarkable success in view of the fact that the van only operated for one week in this area.

Figure 6 gives a survey of the whole-body burden in the three regions of Tula, Kaluga and Bryansk on the basis of measurements of 2000 persons in each region. It can be seen that the town of Uslovaya, typical of the Tula region, is clearly least contaminated. The town of Shistra, representing the Kaluga region, is in the medium range, whereas Klincy in the Bryansk region is most heavily polluted. In Uslovaya all values are in the first category; in Shistra the first and second categories are found; whereas in Klincy a small fraction is also included in the third category.

Upon closer inspection of the individual regions, the Bryansk region seems to be of particular interest due to its generally higher values.

In Figure 7 the results from three further towns in this region are shown: Novosibkov, Krasnaya-Gora and Zlynka. It can be seen that the values for a relatively high fraction of the samples of about

---

3) The anual limit of intake (ALI) from ingestion of a 10:1 Cs-137/Cs-134 mixture is in the range of $4 \cdot 10^6$ Bq. Assuming continuous uptake this corresponds to body burdens of about $1 \cdot 10^6$ Bq under equilibrium conditions. The highest measured body burden of 290 kBq amounts to appr. 30 % ALI. External dose is neglected in this estimate.

2000 persons each fall into the third category. In Novosibkov this involves about 2 % (40 persons) in Krasnaya-Gora about 4 % (80 persons) and in Zlynka about 6 % (120 persons). The highest value measured was approximately 290,000 Bq.

Figures 8 - 10 show the distribution of all measured persons between the 3 categories in the administrative districts of the Tula, Kaluga and Bryansk regions. A total of less than 1 % of those examined belong in the third category and thus display values requiring further monitoring.

In the Tula region (Figure 8) practically all data are in the first category. Of the almost 19,000 persons measured in Uslovaya, just 3 persons had a somewhat higher whole-body activity allocated to the second category. In Arsenyevo and Plavsk approximately 5,000 and 4,000 persons respectively were measured, none of these data were allocated to a higher category.

Figure 9 shows the results of the four administrative districts in the Kaluga region. The fraction of measured data in the second category ranges from 0.2 % in Ludinovo to 3.8 % in Chvastovitchi. Values in the third category represented an exception. In Ludinovo just 9 measured values out of approximately 25,000 were in the third category, in Chvastovitchi 21 from almost 10,000, in Ulyanovo 4 from more than 8,000 and in Shistra 0 from almost 10,000.

In the Bryansk region (Figure 10) there were 6 major areas of operation (administrative districts). On average 88 % of the measured results were in the first category, 10 % in the second and 2 % in the third. As shown in Fig. 10, these fractions varied considerably amongst the individual districts. The town of Klincy, where at 43,000 the greatest number of persons were measured, is one of the more weakly contaminated areas, whereas Gordeyevca with almost 4 % of the approx. 5,000 measurements in category 3 was the most highly contaminated rural district.

Table 9 shows all the results again in a tabular form.

Table 10 lists all cases where Cs-137/134 activities of more than 150 kBq were recorded. This mainly involves older men; women hardly occur in this group. A cumulation of high burdens can be distinguished particularly in Koshany in the Krasnaya Gora district and in Ushcherpya in the Klincy area.

Table 11, in contrast, covers all cases where the highest specific activities were determined. It becomes apparent that the contaminations are also fairly high in Unetcha in the Klincy area. The proportion of women in this table is also greater, which is understandable since they are often smaller and lighter than men.

The age distribution of specific activities measured is shown in fig. 11 for two villages in the district of Klincy. The highest burdens are single cases only and observed mainly for the elderly. Some of them have little money left to spent on contamination free foodstuffs from the state owned shops and hence rely on food being produced by themselves. A few younger people showing enhanced values fish in contaminated waters, hunt or collect mushrooms and berries. Obviously some age groups are missing in the measurements done in those villages. This reflects the migration of workers as well as children being in summer holiday camps.

Table 12 shows a dosimetric evaluation of our measurements in the district of Klincy. Using a dose factor of 0.040 mSv/kBq a internal doses for adults (20 years and older) have been calculated. All locations included in our measuring programme yielding an 1991 average annual internal dose of 0.2 mSv/a and more are listed in the table. Results less than the limit of detection (LOD) have been included with the value of the LOD in the calculation of the mean. All measured Cs-activities have been assumed to be due to a continual intake through ingestion. Locations of measurement were normally surrounded by smaller settlements whose population took part in the programme, too. A number of measurements acceeding the actual number of inhabitants (given according to Russian sources) might result. Numbers given for Roshny also include measurements taken at closeby Kusnez.

Table 13 shows a dosimetric evaluation of results obtained for people in category 3. The calculated 1991 annual doses are given in column 6 for three more highly contaminated localities in the Klincy area. Dose factors of 0.04 mSv/kBq·a were used for adults and 0.072 mSv/kBq·a for children (5 - 15 years).

Table 13 also provides data on the full lifetime irradiation dose. An attempt was made here to reconstruct the average total dose of the population from the measured body burden based on the activity curve as measured for a group of persons in the Berchtesgarden region since 1986. It can be seen that even in these highly contaminated areas the ingestion lifetime irradiation dose is between 0.1 and 0.2 Sv and thus in the range of professional exposure to radiation. The total dose from internal and external radiation exposure can be estimated with the aid of the ambient dose rate measurements from the first phase. Column 8 in Table 13 shows the average external radiation exposure in the three selected localities. By comparing Column 8 with Column 6, these results permit a more accurate determination of the ratio of internal to external radiation exposure for these localities. It can be seen that the ratio of 1:2 for persons in category 3 assumed by us is actually only a rough approximation.

Figure 4: Certificate issued concerning the incorporation measurements

ИЗМЕРИТЕЛЬНАЯ ПРОГРАММА ФЕДЕРАТИВНОЙ РЕСПУБЛИКИ ГЕРМАНИЯ 1991 г.

СЕРТИФИКАТ

измерений накопления радиоактивных веществ в организме

№ протокола 028452

1. Фамилия .... 6. Место жительства

2. Имя .... Область ....

3. Отчество .... Район ....

4. Пол (муж.- 1, жен.- 2) .... Пункт ....

5. Дата рождения .... (день,месяц,год) 7. Вес человека (кг) ....

8. Дата радиометрии .... (день,месяц,год)

Измеренная у Вас активность составляет ....нКи(....................Бк)

☐ - Это содержание радиоактивных веществ безопасно.

☐ - Это содержание радиоактивных веществ несколько выше, но не дает повода к беспокойствию.

☐ - Это содержание радиоактивных веществ указывает на необходимость повторного измерения через 3 месяца.

(печать) .... (подпись)

MESSPROGRAMM DER BUNDESREPUBLIK DEUTSCHLAND 1991

BESCHEINIGUNG

über die Messung der Inkorporation von radioaktiven Stoffen

Protokoll Nr. 028452

1. Фамилия / Name .... 6. Место жительства / Wohnort

2. Имя / Vorname .... Область / Gebiet ....

3. Отчество / Vatersname .... Район / Kreis ....

4. Пол (муж.- 1, жен.- 2) / Geschlecht(männl.-1,weibl.-2) .... Пункт / Ort ....

5. Дата рождения / Geburtsdatum .... (день,месяц,год) (Tag,Monat,Jahr) 7. Вес человека (кг) / Gewicht(kg) ....

8. Дата радиометрии / Meßdatum .... (день,месяц,год) (Tag,Monat,Jahr)

Измеренная у Вас активность составляет ....нКи(....................Бк)
Ihr Meßwert beträgt nCi Bq

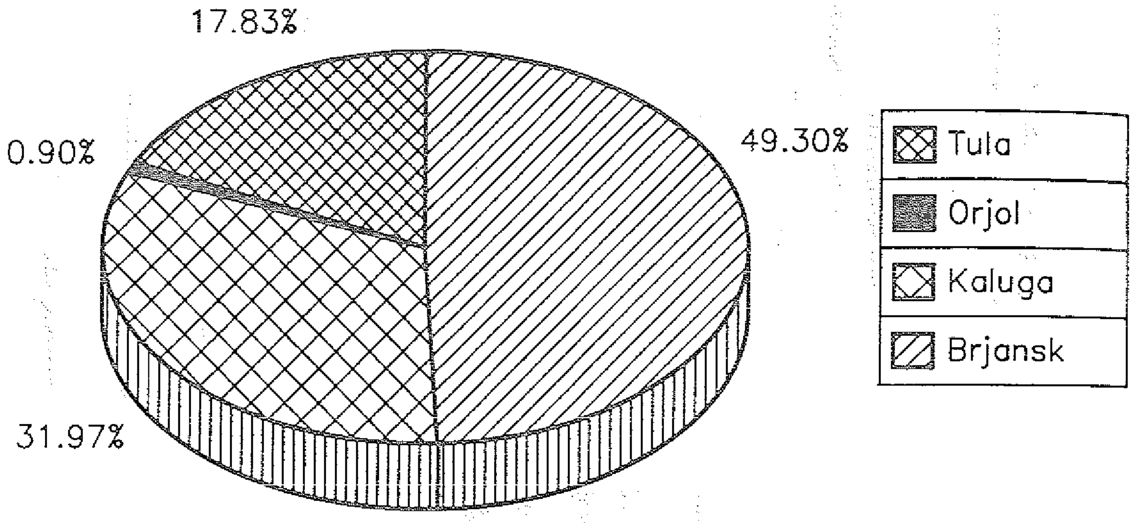
☐ - Dieser Wert ist unbedenklich.

☐ - Dieser Wert ist etwas erhöht, aber nicht besorgniserregend.

☐ - Dieser Wert bedeutet, daß eine Wiederholungsmessung in 3 Monaten erforderlich ist.

(Stempel) .... (Unterschrift)

Protokoll Nr. der vorherigen Messung: .....



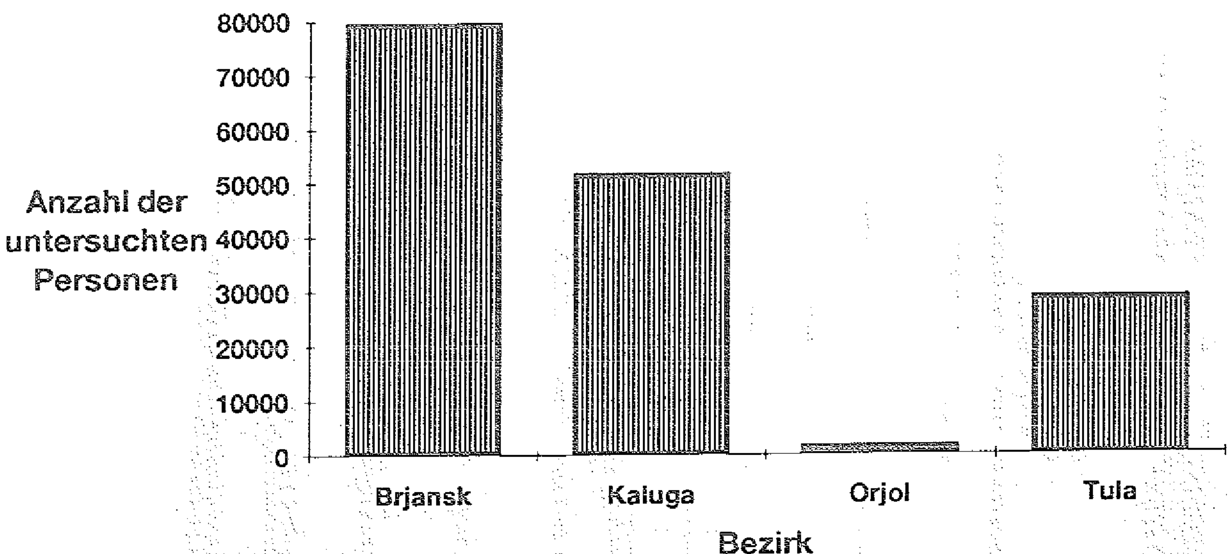


Figure 5: Total number of persons measured, distributed between the individual districts

Aktivitätsverteilung in der russischen Bevölkerung
im Zeitraum Juli/August 1991 (jeweils etwa 2000 Personen)

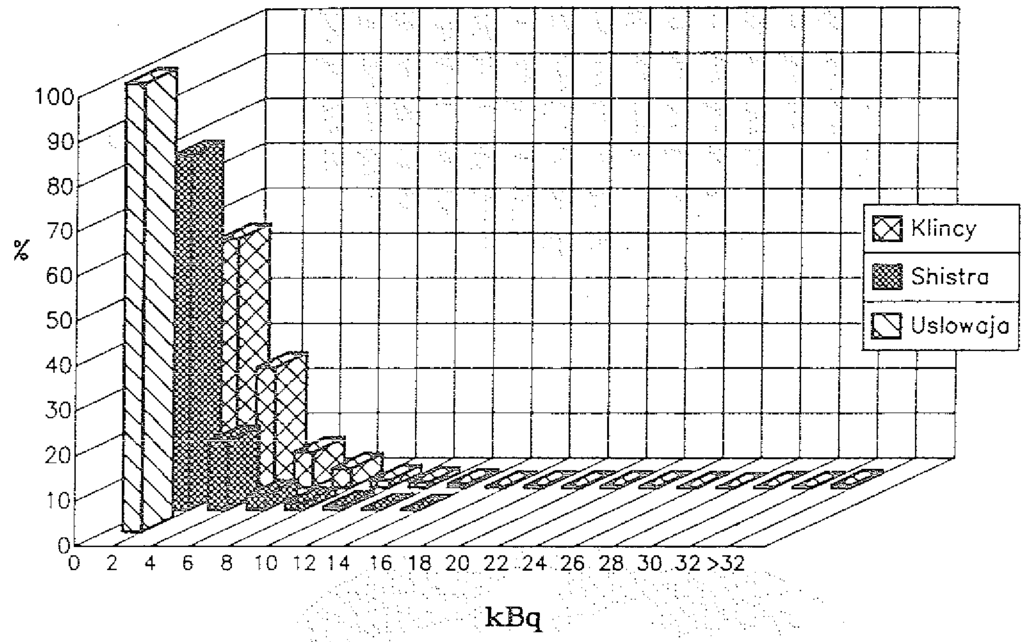


Figure 6: Whole-body burden of the populaton in the three regions of Tula, Kaluga and Bryansk with the example of one town from each of these regions.

Aktivitätsverteilung in der russischen Bevölkerung
im Zeitraum August/Sept. 1991 (jeweils etwa 2000 Personen)

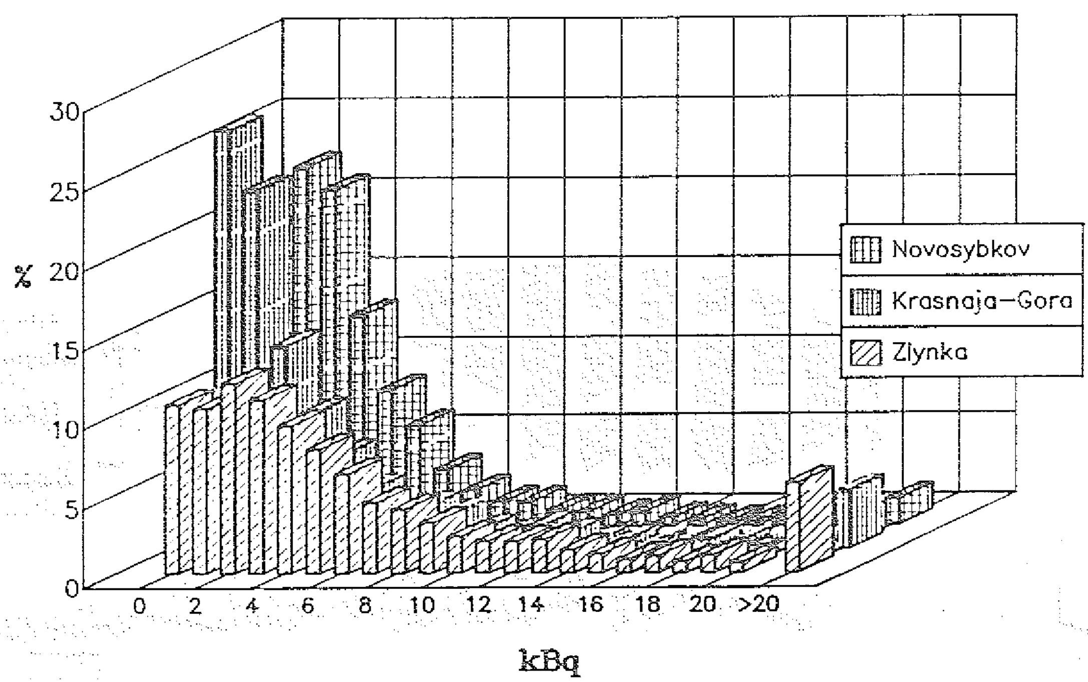


Figure7: Whole-body burden of the population of three towns in the Bryansk region

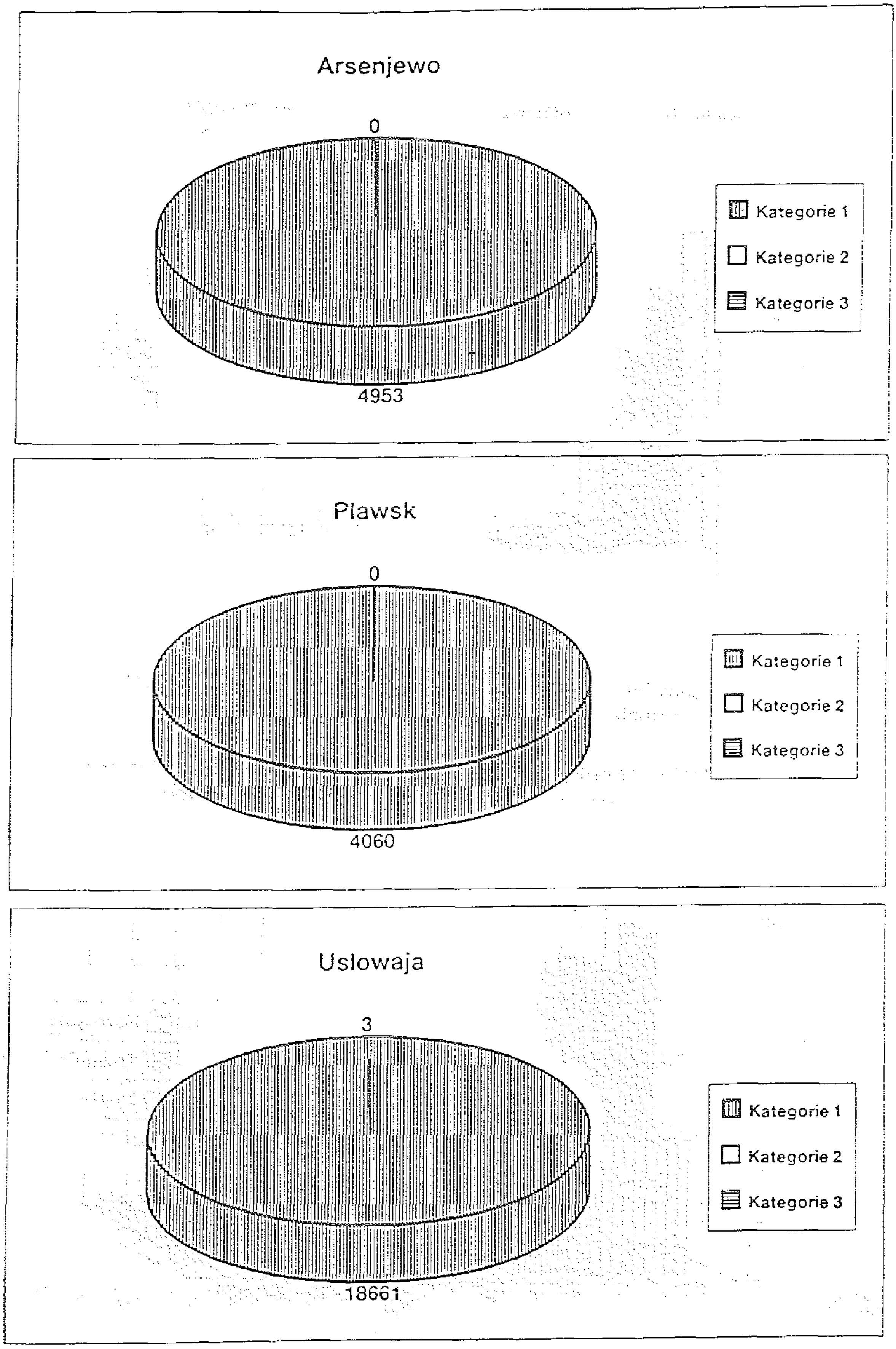


Figure 8: Percentage distribution of all persons measured in the Tula region between the three data categories.

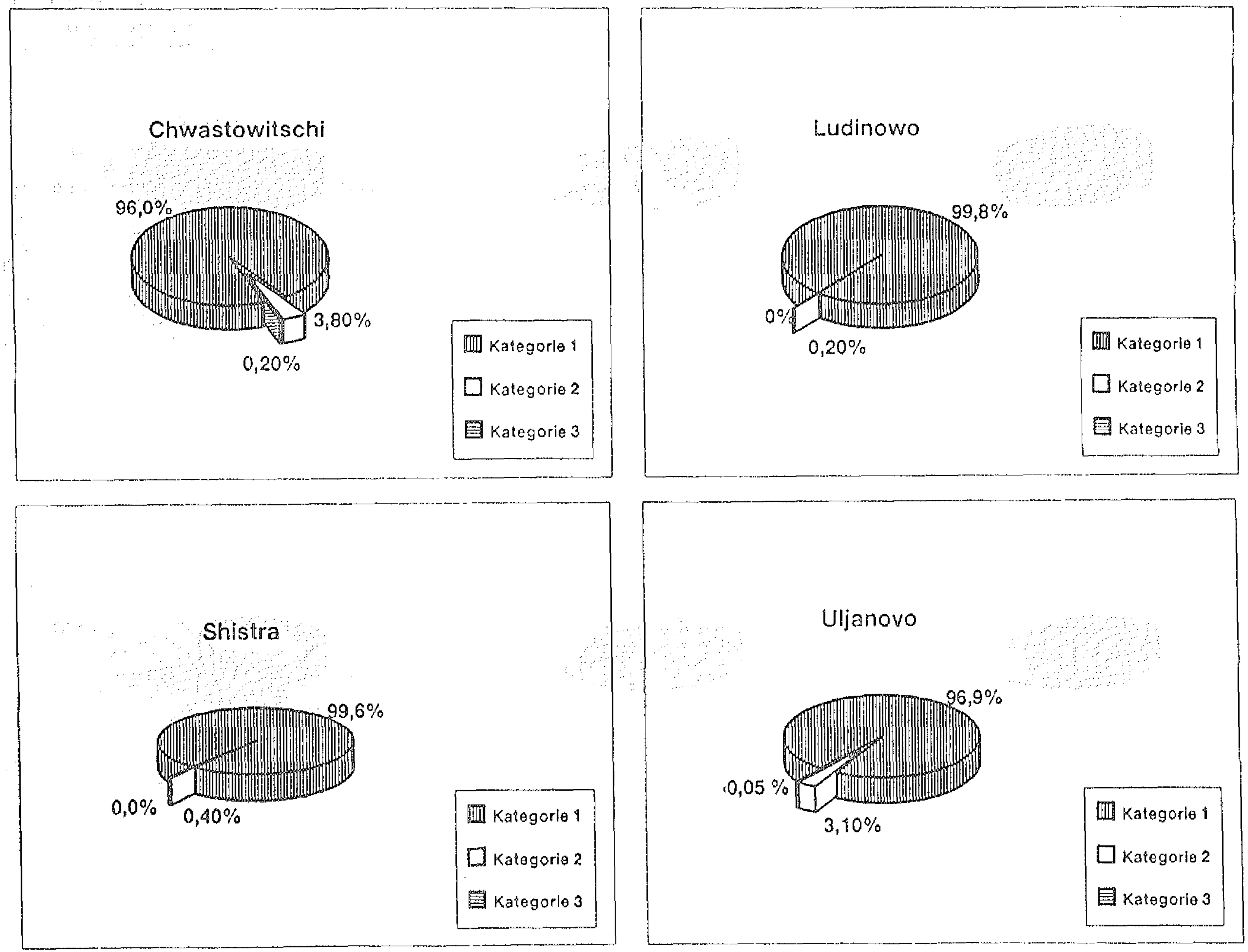


Figure 9: Percentage distribution of all persons measured in the Kaluga region between the three data categories.

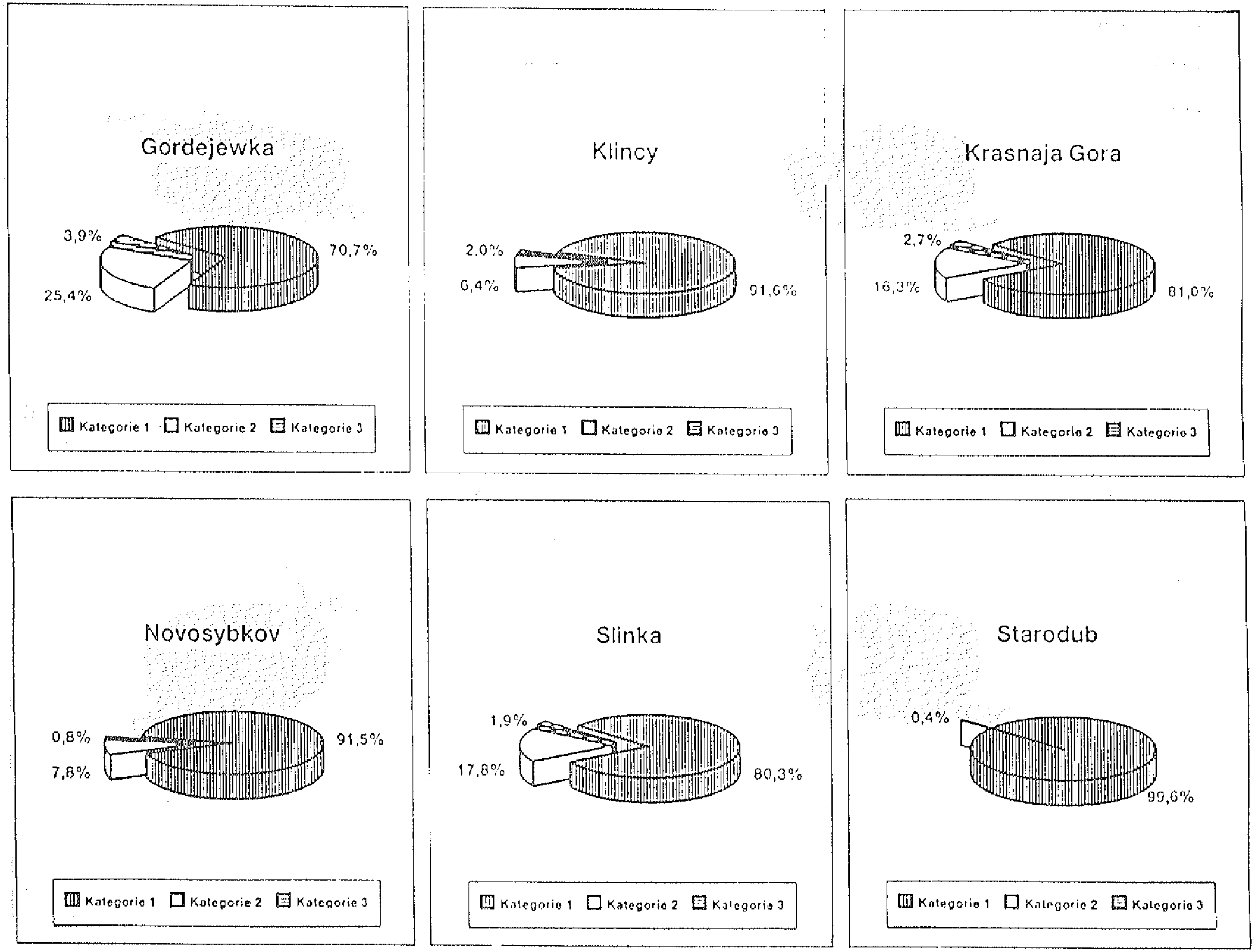


Figure 10: Percentage distribution of all persons measured in the Bryansk region between the three data categories

Table 9
Survey of the data from the 1991 measuring campaign
(top: no. of results in the individual categories
bottom: percentage distribution between the categories)

Region	District	Category 1	Category 2	Category 3	Total
Bryansk	Gordeyevka	4879	1752	270	6901
Bryansk	Klincy	43024	3029	924	46977
Bryansk	Krasnaya Gora	5727	1151	193	7071
Bryansk	Novosybkov	5422	461	45	5928
Bryansk	Slinka	6677	1476	162	8315
Bryansk	Starodub	5124	20	0	5144
Kaluga	Chvastovitchi	9554	377	21	9952
Kaluga	Ludinovo	25189	42	9	25240
Kaluga	Shistra	9939	43	0	9982
Kaluga	Ulyanovo	8136	259	4	8399
Orel	Bolchov	1446	1	0	1447
Tula	Arsenyevo	4953	0	0	4953
Tula	Plavsk	4060	0	0	4060
Tula	Uslovaya	18661	3	0	18664
		152791	8614	1628	163033
Bryansk		70853	7889	1594	80336
Kaluga		52818	721	34	53573
Orel		1446	1	0	1447
Tula		27674	3	0	27677
					0
Russia		152791	8614	1628	163033

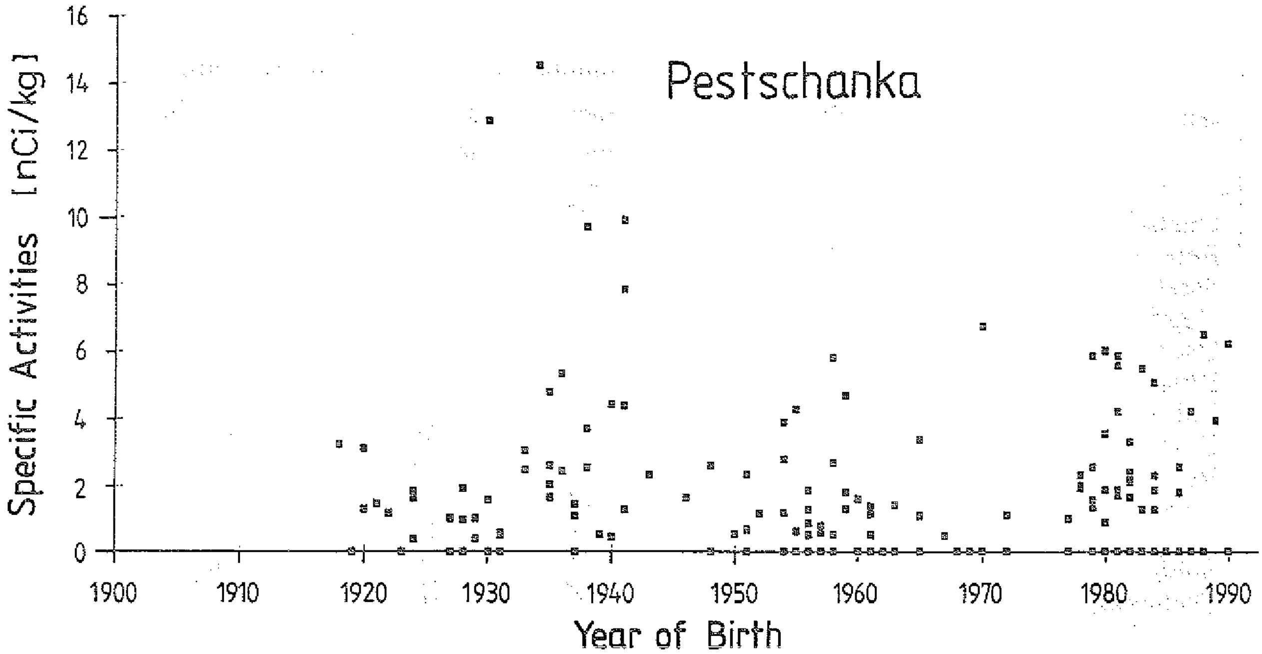
Region	District	Category 1	Category 2	Category 3
Bryansk	Gordejevka	70.7 %	25.4%	3.9 %
Bryansk	Klincy	91.6 %	6.4 %	2.0 %
Bryansk	Krasnaya Gora	81.0 %	16.3 %	2.7 %
Bryansk	Novosybkov	91.5 %	7.8 %	0.8 %
Bryansk	Slinka	80.3 %	17.8 %	1.9 %
Bryansk	Starodub	99.6 %	0.4 %	0.0 %
Kaluga	Chvastovitchi	96.0 %	3.8 %	0.2 %
Kaluga	Ludinovo	99.8 %	0.2 %	0.0 %
Kaluga	Shistra	99.6 %	0.4 %	0.0 %
Kaluga	Ulyanovo	96.9 %	3.1 %	0.0 %
Orel	Bolchov	99.9 %	0.1 %	0.0 %
Tula	Arsenjevo	100.0 %	0.0 %	0.0 %
Tula	Plavsk	100.0 %	0.0 %	0.0 %
Tula	Uslovaya	100.0 %	0.0 %	0.0 %
Bryansk		88.2 %	9.8 %	2.0 %
Kaluga		98.6 %	1.3 %	0.1 %
Orel		99.9 %	0.1 %	0. %
Tula		100.0 %	0.0 %	0.0 %
Total		93.7 %	5.3 %	‹ 1.0 %

Table 10
List of cases in which Cs-137/134 activity of more than 150 kBq was detected.
The data are rounded off to 2 significant digits

District	Place of residence	Year of birth	sex	Activity [nCi]	[kBq]
Krasnaya Gora	Nikolajewka	1931	m	7700	290
Slinka	Sennoje	1937	m	7500	280
Gordejevka	Koshany	1955	m	7200	270
Klincy	Uscherpya	1944	w	6200	230
Klincy	Uscherpya	1930	m	6200	230
Gordejevka	Smjaltsch	1926	m	6200	230
Klincy	Uscherpya	1944	w	5800	210
Klincy	Roschny	1939	m	5500	200
Klincy	Beresovka	1923	m	5300	200
Gordejevka	Koshany	1930	m	5100	190
Klincy	Unetscha	1935	m	5000	180
Klincy	Saretschje	1933	m	4300	160
Gordejevka	Koshany	1933	m	4200	150
Krasnaya Gora	Nikolajevka	1930	m	4200	150
Klincy	Uscherpya	1940	m	4100	150

Table 11
List of cases in which specific Cs-137/134 activities of more than 2500 Bq/kg were detected.
The data are rounded off to 2 significant digits.

Kreis	Wohnort	Jahrgang	Ge-schl.	Spezifische Aktivität [nCi/kg]	[Bq/kg]
Krasnaja Gora	Nikolajevka	1931	m	130	4800
Gordejevka	Koshany	1955	m	120	4300
Gordejevka	Smjaltsch	1926	m	95	3500
Klincy	Unetscha	1935	m	91	3400
Klincy	Uscherpya	1944	w	89	3300
Klincy	Saretschje	1913	m	84	3100
Klincy	Uscherpya	1944	w	83	3100
Klincy	Saretschje	1918	w	80	3000
Slinka	Sennoje	1937	m	79	2900
Klincy	Beresowka	1923	m	79	2900
Klincy	Roschny	1939	m	76	2800
Klincy	Uscherpya	1917	w	74	2700
Krasnaja Gora	Nikolajevka	1930	m	72	2700
Gordejevka	Koshany	1930	m	71	2600
Klincy	Unetscha	1920	m	71	2600
Klincy	Unetscha	1933	w	68	2500



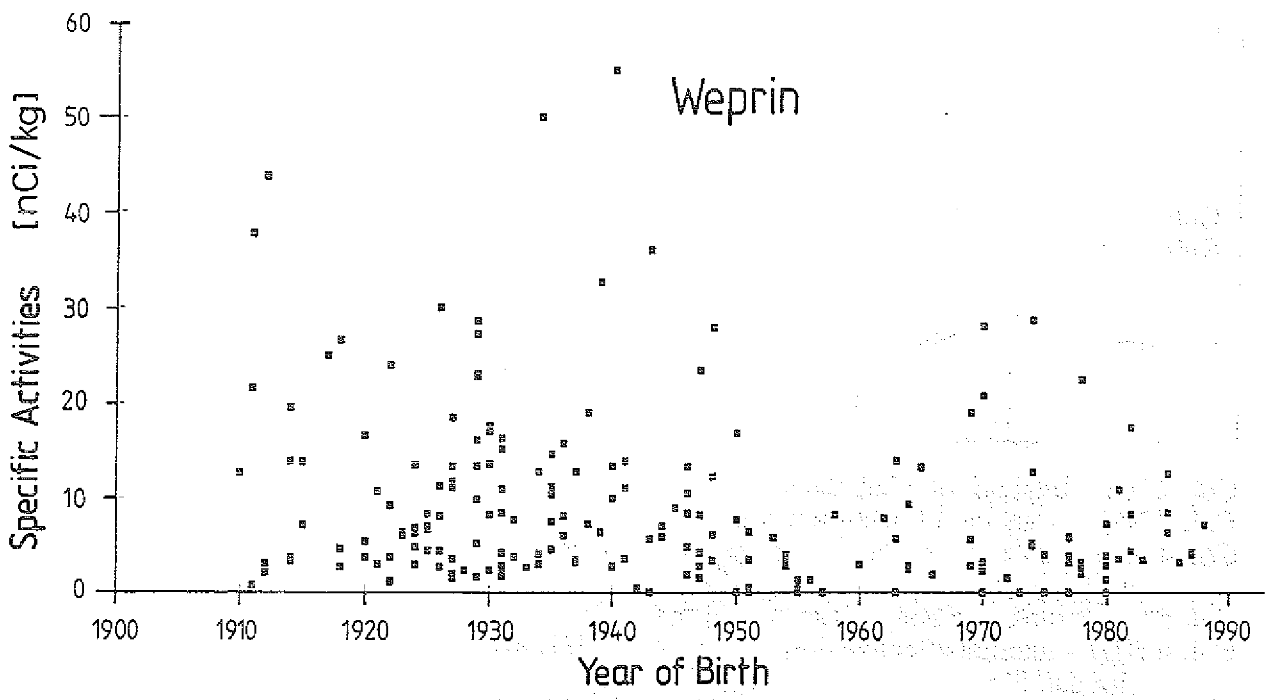


Figure 11: Age distribution of specific activities given for two locations of measurement in the district of Klincy

Table 12:
Average annual internal dose of adults in some villages of Klincy district 1991

settlement	number of inhabitants	number of measurements total	adults	average annual internal dose of adults 1991 [mSv/a]
Unetscha	258	230	203	1.7
Beresovka	216	100	99	1.3
Saretschje	220	131	106	1.1
Veprin	246	199	164	0.99
Uscherpya	1262	906	733	0.72
Blisna	130	71	69	0.65
Tulukovschina	312	248	180	0.55
Guta-Koretskaya	434	467	346	0.52
Roshny	819	757	538	0.52
Lopatni	1029	688	518	0.38
Teremoschka	222	308	112	0.29
Subbovitschi	171	41	35	0.27
Olchovka	1291	959	675	0.26
Pestschanka	314	173	99	0.20

Table 13:
Results from some localities in the Bryansk region, Klincy district

1 Locality	2 Inh.	3 NM	4 NM3	5 AM3	6 AID	7 ILD	8 AED
Lopatni	1029	688	35 m	48	1.9	86	0.95
			19 f	41	1.6	114	
			3 c	21	1.5	202	
Guta Koretskaya	434	467	35 m	45	1.8	81	2.1
			20 f	40	1.6	112	
			1 c	22	1.6	212	
Unetscha	258	230	48 m	72	2.9	130	(2.5)
			71 f	57	2.3	199	
			6 c	19	1.4	183	

Col. 2 Inh. - total no. of inhabitants
Col. 3 NM - total no. of measurements
Col. 4 NM3 - total no. of measurements in the 3rd category
m = men, w = women, c = children
Col. 5 AM3 - average body burden (kBq) in cat. 3
Col. 6 AID - internal effective dose in mSv year 1991, average for cat. 3
Col. 7 ILD - internal effective dose, accident-related lifetime irradiation dose, mSv, average for cat. 3
Col. 8 AED - external effective dose, mSv year, average of the ambient dose rate

The values in brackets are uncertain.

4. Concluding Remarks

The measuring campaign carried out by the Federal Republic in 1991 has achieved its aim since it earned widespread recognition both amongst the Russian public and also from Russian experts. The hope that this measuring campaign succeeded in providing objective information for the public on the present radiation risk and in this way reduced unfounded fears has been confirmed by the information we have received from Russia. A climate of trust has been created and the psychological wellbeing of many people has improved. It is hoped that this will be associated with a consolidation of the social structure and an improvement in public health in Russia.

Measurements carried out in the districts of Bryansk, Kaluga, Orel and Tula contaminated by the reactor accident at Chernobyl on the radionuclides incorporated by the public provided data indicating that over 99 % of cases are within a completely safe range. There is no risk to the health of this proportion of the population from their food or environmental activity. Whole-body measurements of more than 25 kBq Cs-137/134 were only found for less than 1 % of the measurements. The elevated values were mainly found in te Bryansk district, in a region close to the Byelorussian Border. In all cases the 1991 pollution was smaller than that permitted for persons professionally exposed to radiation in the Federal Republic of Germany. These values therefore do not represent an acute health risk. However, the more heavily contaminated group should be monitored in the same way as persons professionally exposed to radiation. This means, in particular, the implementation of regular repeated measurements and accompanying medical check-ups.

In agreement with environmental measurements, apart from Cs-137, Cs-134 and nuclides of natural origin, no further gamma-emitting incorporations were determined in the population. Due to experience with environmental measurements, it was not necessary to determine Sr-90 in humans.

A dose reconstruction in order to determine the total burden since the accident is hardly possible from the data gathered in this single measuring campaign alone and cannot go beyond extremely rough estimates of averages. It is therefore indispensable to evaluate and collect into a data bank all data gathered in the affected areas in connection with the Chernobyl reactor accident. An appropriate method would be to incorporate our measured data into Russian data banks (Obninsk, Moscow).

It would be useful to continue this measuring campaign in coming years and indeed necessary with respect to fluctuations over time. In Russia, it would be appropriate to concentrate on the Kaluga and Bryansk regions. Not least with respect to the problems of dose reconstruction, more emphasis should be placed on scientifc aspects. The means, in particular, improved coordination between environmental and whole-body measurements including the measuring facilities of the Russian partners. The environmental measurements should not be implemented in a campaign prior to the main phase but should rather accompany the entire measuring operation. In selected cases and/or at selected locations, medical methods of examining the radiation exposure (e.g. blood tests) should be included by way of example.

All our assistance can only be regarded as an encouragement towards self-help. In the long term our goal must be to integrate our Russian colleagues on site so that they will also enjoy the confidence expressed by the population in our work. Our 1991 measuring campaign was only the first step in this direction.

Appendix: Reports

Environmental measurements:

K.-H. Schneider
'Meßprogramm der Bundesrepublik Deutschland Umweltradioaktivität des Umweltmeßwagens des Forschungszentrums Jülich GmbH vom 25. Mai 1991 bis 12. Juni 1991
ASS-Bericht Nr. 0535, Jülich, September 1991

K. Heinemann
'Meßprogramm der Bundesrepublik Deutschland - Ergebnisse der Umweltmessungen in Rußland in der Zeit vom 25. Mai 1991 bis 12. Juni 1991'
KFA-Bericht Jül-2531, Jülich, October 1991

Incorporation measurements:

P. Hill, R. Hille
'Meßprogramm der Bundesrepublik Deutschland- Ergebnisse der Ganzkörpermessungen in Rußland in der Zeit vom 17. Juni bis 4. Oktober 1991'
KFA-Bericht Jül-2610, April 1992, ISSN 0366-0855

P. Hill, R. Hille
'Radiation Exposure due to Incorporation of Radionuclides in two selected Places of the RSFSR Five Years after the Chernobyl Accident'
Proc. Eigth Int. Congress of the International Radiation Protection Association, May 17-22, 1992, Montreal, p. 277-280

P. Hill, R. Hille
'Whole-Body Monitoring of Post-Chernobyl Body Burdens in Russia' Proc. of the FS-SFRP Seminar 'Umweltauswirkungen Kerntechnischer Anlagen', September 15-18, 1992, Fribourg, in print

E. Finke, P. Hill, R. Hille, P. Sauermann
'Radiation Exposure of the Population in Russia after the Reactor Accident at Chernobyl-Evaluation of the 5-year-Dose Equivalent Commitments in the Districts of Kaluga and Brjansk'
Proc. of the FS-SFRP Seminar 'Umweltauswirkungen Kerntechnischer Anlagen', September 15-18, 1992, Fribourg, in print

and references given therein .

FORSCHUNGSZENTRUM JÜLICH GmbH

KFA

Jül-2704
Dezember 1992
ISSN 0366-0885