The World Health Organization is a specialized agency of the United Nations with primary responsibility for international health matters and public health. Through this Organization, which was created in 1948, the health professions of some 160 countries exchange their knowledge and experience with the aim of making possible the attainment by all citizens of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life.

The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health problems of the countries it serves. The European Region has 32 active Member States,[a] and is unique in that a large proportion of them are industrialized countries with highly advanced medical services. The European programme therefore differs from those of other regions in concentrating on the problems associated with industrial society. In its strategy for attaining the goal of "health for all by the year 2000" the Regional Office is arranging its activities in three main areas: promotion of lifestyles conducive to health; reduction of preventable conditions; and provision of care that is adequate, accessible and acceptable to all.

The Region is also characterized by the large number of languages spoken by its peoples, and the resulting difficulties in disseminating information to all who may need it. The Regional Office publishes in four languages — English, French, German and Russian — and applications for rights of translation into other languages are most welcome.

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[a] Albania, Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Finland, France, German Democratic Republic, Federal Republic of Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Poland, Portugal, Romania, San Marino, Spain, Sweden, Switzerland, Turkey, USSR, United Kingdom and Yugoslavia.

Nuclear accidents — harmonization of the public health response

Nuclear accidents — harmonization of the public health response : report of a WHO meeting, Geneva, 10–13 November 1987
Copenhagen : WHO. Regional Office for Europe, 1989
EURO reports and studies ; 110
ISBN 92-890-1276-5
Nuclear Reactors — Accidents — Radioactivity — Disaster Planning — Public Health — SSR

World Health Organization
Regional Office for Europe
Copenhagen

EURO Reports and Studies 110

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Geneva
10–13 November 1987

ICP/CEH 013
Text editing by: M.S. Burgher

ISBN 92 890 1276 5
ISSN 0250-8710

PRINTED IN DENMARK

NOTE

WHO policy in respect of terminology is to follow the official recommendations of authoritative international bodies, and this publication complies with such recommendations.

Nearly all international scientific bodies have now recommended the use of the SI units (*Système international d'unités*) developed by the Conférence générale des poids et mesures (CGPM),[a] and the use of these units was endorsed by the Thirtieth World Health Assembly in 1977. The following table shows three SI-derived units used frequently in this report, together with their symbols, the corresponding non-SI units and the conversion factors.

Quantity	SI unit and symbol	Non-SI unit	Conversion factor
Radioactivity	becquerel, Bq	curie, Ci	1 Ci = 3.7×10^{10} Bq (37 GBq)
Absorbed dose	gray, Gy	rad	1 rad = 0.01 Gy
Dose equivalent	sievert, Sv	rem	1 rem = 0.01 Sv

[a] An authoritative account of the SI system entitled *The SI for the health professions* has been prepared by the World Health Organization and is available through booksellers, from WHO sales agents, or direct from Distribution and Sales, World Health Organization, 1211 Geneva 27, Switzerland.

CONTENTS

INTRODUCTION

In addition to the serious effects on the area and population close to the site, the nuclear accident at Chernobyl in 1986 resulted in very widespread contamination of the environment with radioactivity, which affected every country in Europe to a greater or lesser extent. Although considerable attention had been paid to contingency planning for accidents affecting a limited geographical area, much less emphasis had been placed on possible consequences to people and places at large distances from the source of radiation. Consequently, the countermeasures taken to protect public health in the wake of Chernobyl had to be improvised and it is not surprising that they were inconsistent and resulted in considerable public confusion and disquiet. While the actions taken by governments were, in general, more than adequate to safeguard the health of the population, the necessity of comprehensive advanced planning has been clearly realized. Such planning will ensure a more consistent and orderly response in the event of other accidents, and the effective harmonization of guidelines for action among the countries of the densely populated European Region.

From the outset, the WHO Regional Office for Europe was actively involved in the response to the accident at Chernobyl. An emergency team was assembled that collected and disseminated radiological data and public health information relating to the 32 countries of the Region. Ten days after the first release of radioactivity on 26 April, a group of senior experts was convened to advise on appropriate countermeasures, based on what was known about the radiological situation and taking into account the prevailing meteorological conditions *(1)*. Two months after the accident, a Working Group developed a first estimate of the total effective dose equivalent commitment in Europe *(2)*.

Following a resolution of the thirty-sixth session of the WHO Regional Committee for Europe (Annex 1), made in September 1986, a special project on the public health response to nuclear accidents was established. It has placed special emphasis on reviewing the experience gained from the Chernobyl accident, stimulating long-term epidemiological studies and providing guidance on a harmonized public health response system appropriate to European conditions in the event of another accident with transfrontier consequences. In September 1987 the thirty-seventh session of the Regional Committee reviewed the progress made and approved a second resolution (Annex 2), which provided further guidance to the WHO Regional Director for Europe on the direction the project should take.

To assist in the progress of the project and to assess the work done so far, 33 senior experts, with representatives of 6 international organizations, formed the Working Group on European Harmonization of Public Health Actions in Relation to Nuclear Accidents, meeting in Geneva in November 1987. A list of the participants comprises Annex 4. The main aim of the Working Group was to provide appropriate advice for the harmonization of public health measures in Europe, to minimize the possible harm to health resulting from widespread radioactive contamination following a nuclear accident. To accomplish its task, the Group reviewed the experience gained from the Chernobyl accident and recommended further essential follow-up activities.

The WHO Regional Director for Europe, Dr J.E. Asvall, opened the meeting of the Working Group. Dr B. Roos was elected Chairman and Dr T. Mork, Vice-Chairman. Dr N. Rosdahl and Dr E. Rubery were elected Co-rapporteurs and Mr J.I. Waddington served as Secretary.

RESPONSE TO CHERNOBYL

Because of the importance of learning from the experience, the Working Group decided to devote a significant amount of time to reports on the effects of Chernobyl both inside and outside the USSR, and on the action taken by national and international authorities.

The Soviet experience

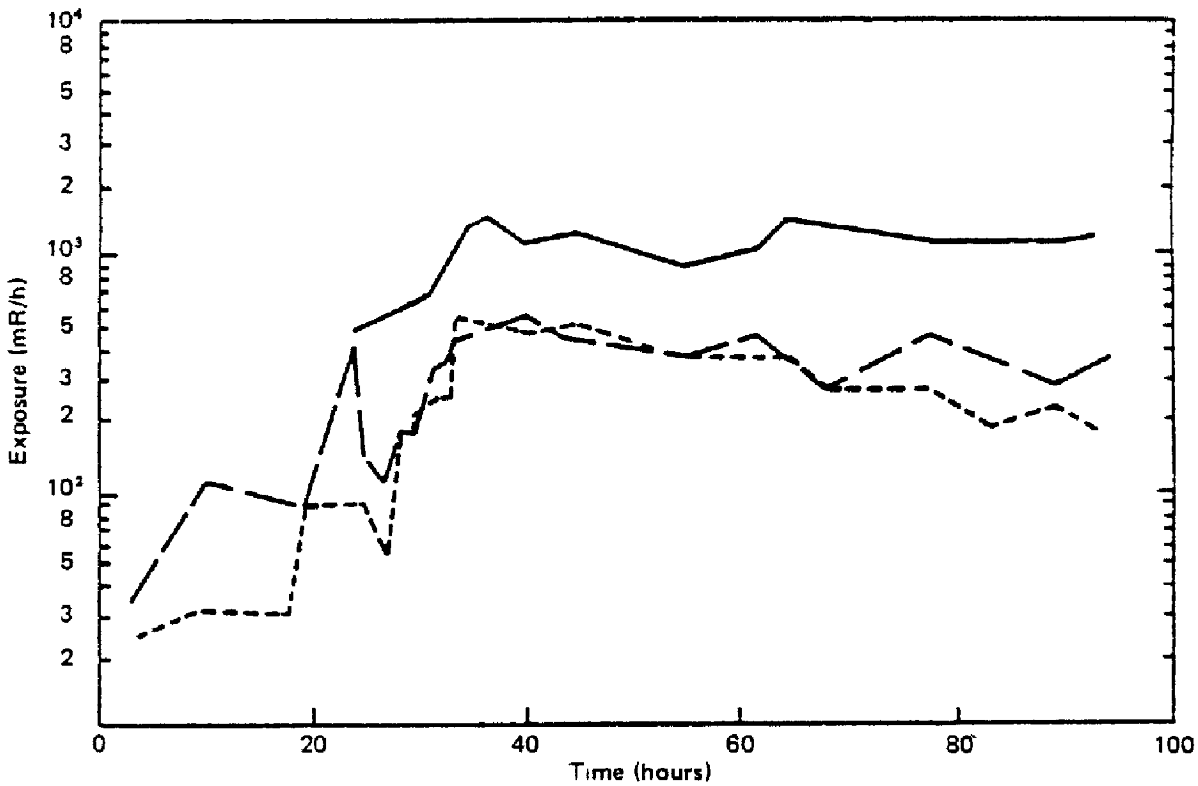
After the accident on 26 April 1986 at the No. 4 reactor at the Chernobyl site, a large quantity of radioactive products accumulated in the reactor and escaped as a radioactive cloud that spread initially to the west and north.

The nearby town of Pripyat was the first to be affected by the fallout from the cloud. The cloud contained: 8.1×10^{15} Bq strontium-90 (^{90}Sr), 270×10^{15} Bq iodine-131 (^{131}I), and 37×10^{15} Bq cesium-137 (^{137}Cs). These three were the most radiobiologically important isotopes present. A total of about 1.9×10^{18} Bq (3.5% of total radionuclides in the core) was released.

The doses to the local population varied with time during the release, but were greatest at about 48 hours after the accident.

In parts of Pripyat, the dose of gamma rays from external radiation 21 hours after the start of the release at one metre above ground was 14–120 mR/h[a] (Fig. 1). On 27 April, in the region closest to the town centre (Kourchatov Road) the external dose rose to 180–600 mR/h, with levels around 180–300 mR/h on other roads. It was predicted that the external dose rate, with the addition of the likely contribution from internal doses to the population, would rise to levels at which the USSR criteria for action would be exceeded. As a result, the people living in Pripyat and in the surrounding area were evacuated between 2 p.m. and 5 p.m. that day.

Fig. 1. Changes in the dose rate outdoors at three points in Pripyat during the first four days after the accident



Measurements of radiation in Pripyat led to the prediction of maximum doses from internal radiation of 0.1 Gy, with doses of beta radiation to the skin of 1 Gy to the critical groups. In fact, because people were advised to stay indoors, close windows and take stable iodine, the actual doses received were later expected to be 2–5 times smaller: about 15–50 mGy gamma rays and 0.1–0.2 Gy beta rays.

[a] 1 mR/h = 71.6 × 10^{-6} μC/(kg·s).

The follow-up of this population, using chromosome aberration studies carried out by the Genetic Institute of the Academy of Sciences of the USSR, confirmed these expectations. The most exposed members of the Pripyat population were people spending a lot of time outside: physicians, social workers and council workers. These formed a critical group. Mean doses to this group were estimated to be 0.13 ± 0.03 Gy (based on the results for the 93 people participating).

Since gas and aerosols continued to be released, it was decided to evacuate a larger zone around the reactor. In all, 115 000 people were evacuated, and 50 settlements, 13 000 private houses and 8000 flats were allocated to them in Kiev and Chernigov.

The basis of the action taken was a document, approved in 1983, spelling out the Soviet criteria for taking decisions to protect the public after a nuclear accident. The recommended intervention levels (Table 1) are similar to those recommended by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA). When level A is reached (when the external dose from gamma radiation is likely to exceed 0.25 Gy, or the thyroid dose is likely to exceed 0.25–0.3 Gy), the recommendation of intervention must be considered, taking account of local conditions. Doses at level B are 3–10 times higher than those at level A; such levels would make intervention essential.

Table 1. Criteria for taking decisions to protect the public following a nuclear accident

Nature of exposure	Unit of measurement	Level of exposure	
		A	B
External gamma	Gy	0.25	0.75
Internal thyroid dose from iodine	Gy	0.25–0.30	2.5
Iodine-131 in air — integrated			
Infants	(μCi·day)/litre	40.0	400.0
Adults	(μCi·day)/litre	70.0	700.0
Total iodine-131 in food	μCi	1.5	15.0
Maximum concentration iodine-131 in fresh milk or in daily food intake	μCi/litre or μCi/day	0.1	1.0
Initial iodine-131 on pasture land	μCi/m^2	0.7	7.0

Evacuation from Pripyat and other areas around Chernobyl was based upon predictions that the level A doses might be exceeded. Because of the fluctuating levels of radiation in different geographical areas, however, due to changing meteorological conditions, some people received doses above the level A; external doses of up to 0.3–0.4 Gy were received by some people in the village of Tolstyi-Les and the Kopachi villages and some others, but none of the evacuees had a dose exceeding those at level B. There is no risk of severe stochastic effects in any of the evacuated population.

On the basis of these criteria, it was clear that the most urgent necessity was to take steps to reduce doses from inhalation and external radiation. Such action was required while the cloud was being released from the reactor; action to avoid the consumption of contaminated milk and food was less urgent.

The effects of the release were felt in the European USSR far outside the Chernobyl region. To evaluate the effects of the accident throughout the USSR, the country was divided into four areas derived from its 20 economic regions (Fig. 2 and Table 2). Area 1 was Byelorussia, area 2 comprised the south-western economic region, the central economic region was area 3 and the rest of the economic regions of the USSR formed area 4 (Table 2). Although detailed monitoring results from all of the economic regions are available (Table 3), this report gives the results for the four areas.

Byelorussia has 3.6% of the population in 0.9% of the area of the USSR; the south-western region has 7.9% of the population in 1.2% of the area; the central region has 10.7% of the population in 2.2% of the area and the rest of the USSR has 77.9% of the population in 95.6% of the area.

The information used to estimate the doses to the populations in the four areas is derived from:

(*a*) gamma ray dose rate measurements of the greater part of the 160 administrative units in the USSR (these results came from the State Commission on Hydrometeorology and the Sanitary and Epidemiological Service of the Ministry of Health of the USSR);

(*b*) external radiation doses on the ground for most of the regions in the USSR for various months in 1986;

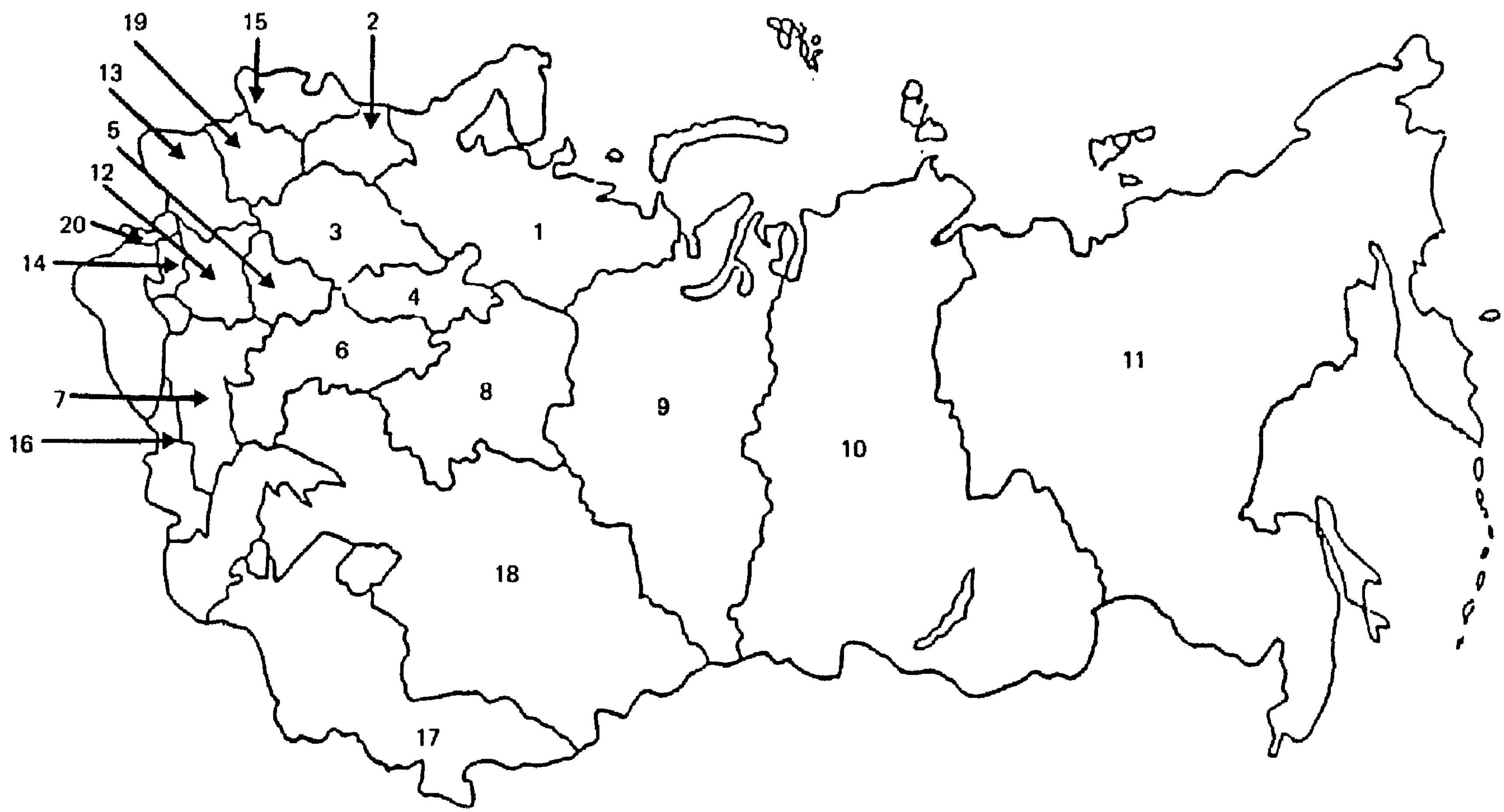
(*c*) the levels of air contamination for all radioactive products and for individual radionuclides;

(*d*) the total levels of ground contamination in each region and the level of each radionuclide;

(*e*) the concentration of ^{131}I and isotopes of cesium in water, meat and vegetables;

(*f*) food consumption data for the population from each republic and data on agricultural produce from each of the 160 administrative units;

Fig. 2. The 20 economic regions of the USSR



Note. Key in Table 2.

Table 2. Population, area and population density of the economic regions of the USSR (1986 data)

Economic region	Population (millions)			Area (km^2)	Inhabitants per km^2
	Urban	Rural	Total		
1. Northern	4.60	1.41	6.00	1 436 300	4.18
2. North-western	7.02	1.12	8.13	196 500	41.39
3. Central	24.42	5.37	29.80	485 100	61.42
4. Volga-Vyatskij	5.70	2.67	8.36	272 400	30.70
5. Central Chernozemnij	4.50	3.16	7.65	167 700	45.63
6. Povolzhskij	11.62	4.46	16.08	536 400	29.98
7. North Caucasian	9.35	6.99	16.34	356 100	45.89
8. Urals	14.82	5.16	19.98	824 000	24.25
9. West Siberian	10.32	4.04	14.36	2 427 200	5.92
10. East Siberian	6.39	2.49	8.88	4 122 500	2.15
11. Far Eastern	5.86	1.79	7.65	6 215 900	1.23
12. Donetsko-Pridneprovskij	16.96	4.61	21.57	220 900	97.64
13. South-western	11.79	10.15	21.94	269 400	81.43
14. Southern	4.95	2.54	7.49	113 400	86.03
15. Prebaltic	6.02	2.60	8.62	189 100	45.56
16. Transcaucasian	8.73	6.57	15.30	186 100	82.23
17. Central Asian	12.46	18.00	30.46	1 213 400	25.10
18. Kazakhstan	9.22	6.81	16.03	2 717 300	5.90
19. Byelorussia	6.32	3.69	10.01	207 600	48.21
20. Moldavia	1.90	2.25	4.15	33 700	123.06
Total USSR	182.93	95.85	278.79	22 191 000	12.55

Table 3. Lifetime collective effective dose equivalent commitment to the USSR (10^3 man-Sv)

Economic region	Gamma radiation from:										Total
	cloud[a]	inhalation			deposition			ingestion			
		^{131}I[b]	^{134}Cs	^{137}Cs	^{131}I[c]	^{134}Cs	^{137}Cs	^{131}I	^{134}Cs	^{137}Cs	
Northern	0.00	0 01	0.00	0.00	0.07	0 07	0.50	0.01	0.05	0 10	0.82
North-western	0.04	0.20	0.01	0.01	0.92	1.17	8.28	0.20	1.05	2.13	14.01
Central	0.17	0.77	0 01	0.02	3.83	3.60	25.40	0.60	2.60	5.49	42.49
Volga-Vyatskij	0.01	0.04	0.00	0.00	0 24	0.29	2.02	0.04	0 20	0.43	3.27
Central Chernozemnij	0.06	0.21	0.00	0.01	1.44	1.20	8.50	0.20	0 74	1.34	13.70
Povolzhskij	0.04	0 13	0.00	0.00	1 32	0.62	4.37	0.15	0 51	1.45	8.59
North Caucasian	0.02	0.07	0.00	0 00	2.40	0.19	1.31	0.24	0.46	2.84	7.54
Urals	0 02	0.15	0.00	0.00	0.84	0.59	4 19	0.15	0.44	0.87	7 27
West Siberian	0 00	0.01	0 00	0.00	0.06	0.06	0.45	0.01	0.05	0.10	0.74
East Siberian	0.00	0.00	0 00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0 01
Far Eastern	0.00	0.00	0 00	0.00	0.02	0.00	0.03	0.00	0.00	0.01	0.06
Donetsko-Pridneprovskij	0.03	0.12	0 00	0.00	3.18	0.51	3.20	0.91	1.80	11 26	21.02
South-western	1.09	1.00	0.04	0 05	14 06	4.68	29.51	3.31	5.08	21.85	80.66
Southern	0.01	0.03	0 00	0.00	0.65	0.10	0.62	0.55	0 26	1.61	3.83
Prebaltic	0.01	0.01	0.00	0.00	0.36	0.14	1.06	0.36	0.28	1.44	3.66

Transcaucasian	0.00	0.01	0.00	0.00	0.50	0.09	0.70	0 04	0.13	0.79	2.26
Central Asian	0.00	0.00	0.00	0.00	0.12	0.08	5 05	0 00	0.04	0.24	5.52
Kazakhstan	0.00	0.00	0 00	0.00	0 08	0 02	0.18	0.01	0.03	0 23	0.56
Byelorussia	0.97	1.43	0 03	0.04	8.37	5 60	39.41	1.11	8.75	40 63	106.34
Moldavia	0 01	0.02	0.00	0.00	0 89	0 16	1 17	0 10	0 25	1 60	4.19
Total USSR	2 49	4.21	0 11	0.14	39.36	19 17	135.95	7.99	22 72	94 39	326 54
			4.46			194.48			125.09		

[a] All radionuclides

[b] ^{131}I, other iodine isotopes and ^{132}Te

[c] ^{131}I and other short-lived radionuclides

(*g*) the consideration of changes in the distribution of the population between rural and urban areas in 1950–1986 in each republic;

(*h*) the levels of radiocesium and radiostrontium in agricultural products in 1964–1986.

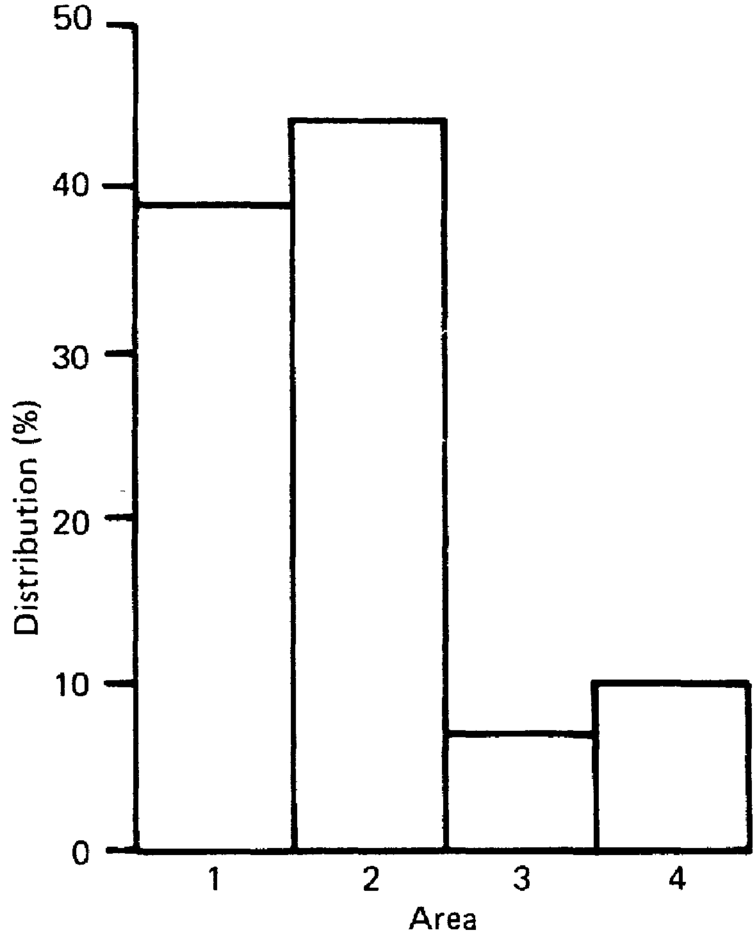
The results of the surveys made are summarized in Tables 3 and 4. The total lifetime collective effective dose equivalent commitment to the Soviet population is estimated to be 3.3×10^5 man-Sv. External doses from gamma radiation from the cloud resulted in a relatively small collective dose equivalent commitment of 2.5×10^3 man-Sv to the population of the USSR: 2.5% of the collective dose to the entire population in the first year after the accident and 0.8% of the lifetime collective dose to the entire population. The populations of areas 1 and 2 (Byelorussia and the south-western economic region) each received about 40% of the total dose, while those of areas 3 and 4 each received around 10% of the total dose (Fig. 3).

For areas close to Chernobyl, gamma radiation from the cloud was more important than for the rest of the Soviet Union because of the higher doses received by the people evacuated from the 30-km zone around the accident site.

Table 4. First-year and lifetime collective and individual effective dose equivalent commitment in the USSR via four exposure pathways

Pathway of exposure to gamma radiation	Collective dose (10^3 man-Sv)		Individual dose (μSv)		Proportion of collective dose to entire USSR population (%)	
	First year	Lifetime	First year	Lifetime	First year	Lifetime
Cloud	2.49	2.49	8.9	8.9	2.52	0.76
Inhalation	4.46	4.46	16.0	16.0	4.51	1.37
Deposition	52.00	194.50	187.0	698.0	52.60	59.60
Ingestion (produce)	39.90	125.10	143.0	449.0	40.40	38.30
Total	98.90	326.50	355.0	1171.0	100.00	100.00

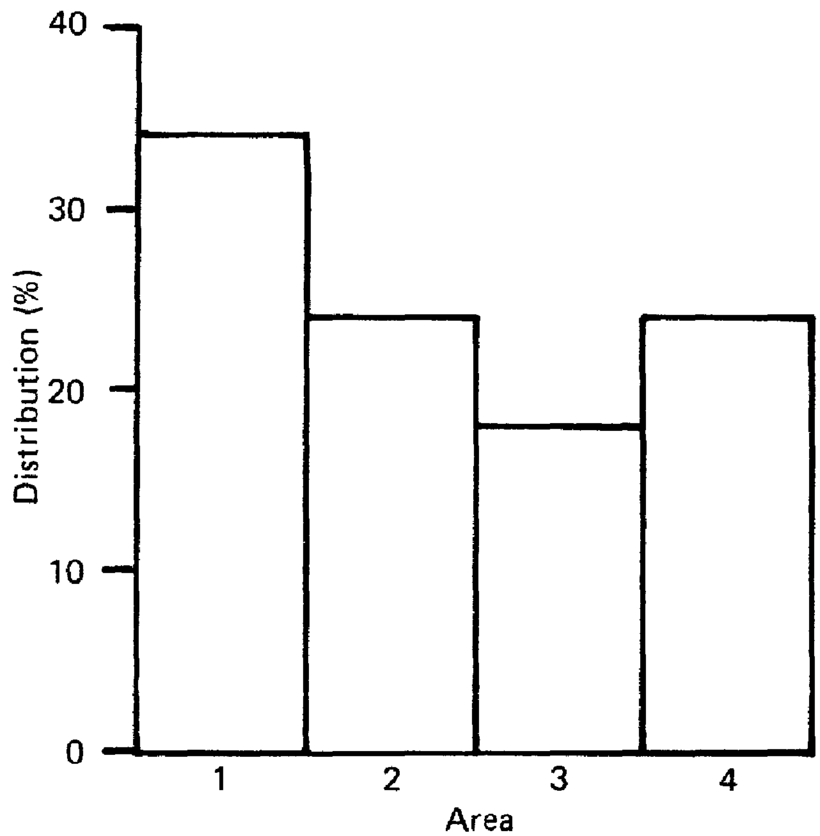
Fig. 3. Distribution in areas 1–4 of the lifetime collective effective dose equivalent commitment from gamma radiation from the cloud



Most of the problems related to radioiodine or radiocesium, as a much smaller amount of radiostrontium had been released (about 25% of the amount of radiocesium released). Further, because strontium combines with the soil relatively quickly, radiostrontium could be detected only in the 30-km evacuation zone; elsewhere the levels were indistinguishable from those already present from the fallout from nuclear weapons tests. Although radiostrontium might be detectable in some of the exposed populations within the next five years, as it accumulates with time, this radionuclide was not detectable in either human or animal tissues in 1987.

The internal exposure from inhalation was also a relatively small part of the total radiation dose received by the public (4.5% and 1.4% of the first-year and lifetime collective doses, respectively). The lifetime collective dose is predicted to be about 4.5×10^3 man-Sv. The major radionuclide involved is ^{131}I and the organ receiving the major proportion of the dose is the thyroid gland. The distribution of the lifetime collective dose in the four areas is shown in Fig. 4. The average individual whole-body dose

Fig. 4. Distribution in areas 1–4 of lifetime collective effective dose equivalent commitment from inhalation

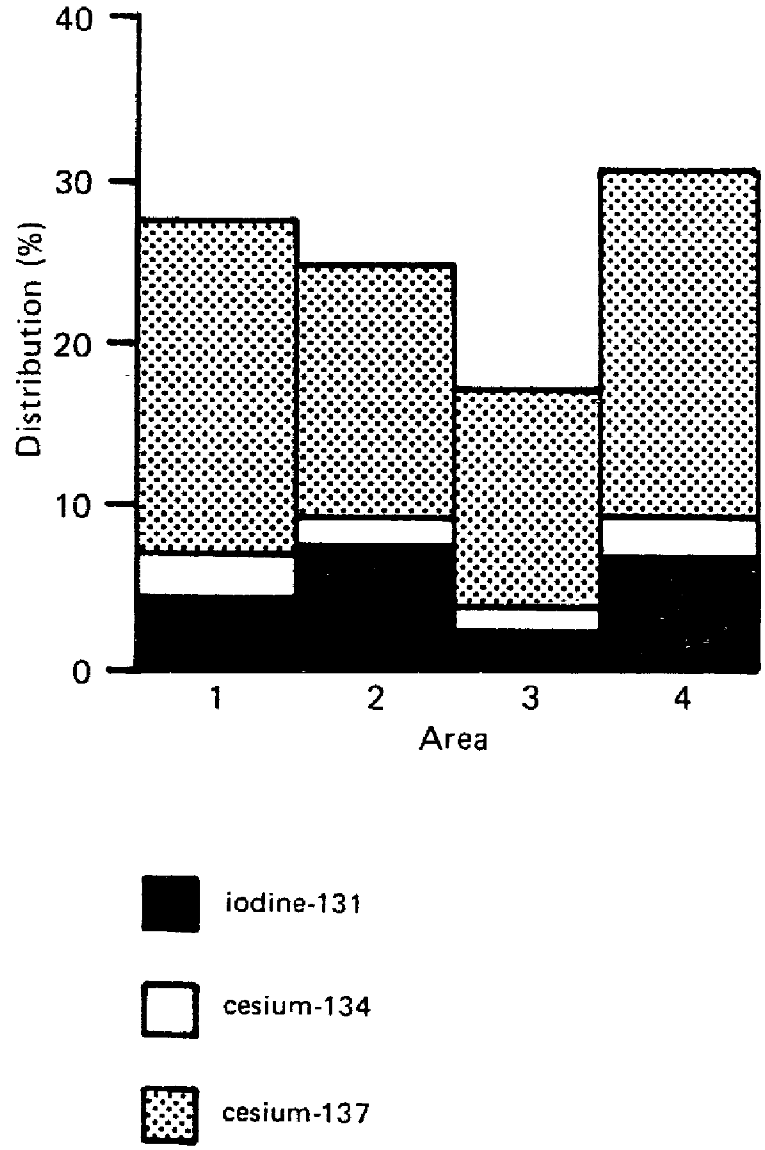


equivalent in Byelorussia (area 1) from this factor was about 4.3 mGy for infants aged 1 year, 3.7 mGy for children aged 10 years and 5.0 mGy for adults. Doses to children in other areas were substantially lower.

The lifetime gamma ray dose from deposition will be about 59.6% of the total lifetime collective dose; ^{137}Cs contributes 70% of this total dose estimate and ^{134}Cs 10% (Fig. 5). Account was taken in the calculations of possible fluctuations in the distribution of the population. A collective effective dose equivalent commitment of 1.9×10^5 man-Sv is predicted, made up of radiocesium and radioiodine.

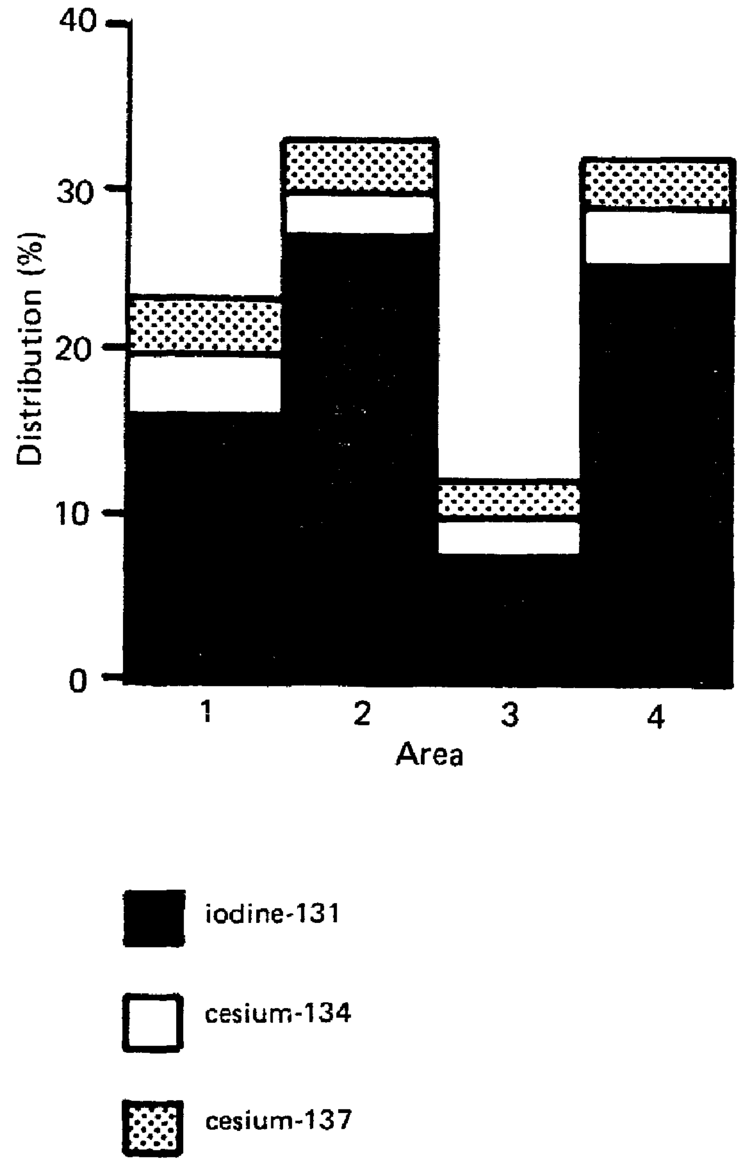
Gamma ray doses from deposition in the first year after the accident were predicted to be 5.2×10^4 man-Sv (15.9% of the total lifetime dose); the radionuclide composition of these doses is shown in Fig. 6. These exposures are 2–3 times lower than those initially predicted, owing to the

Fig. 5. Distribution in areas 1–4 of the lifetime collective effective dose equivalent commitment from gamma radiation from deposition



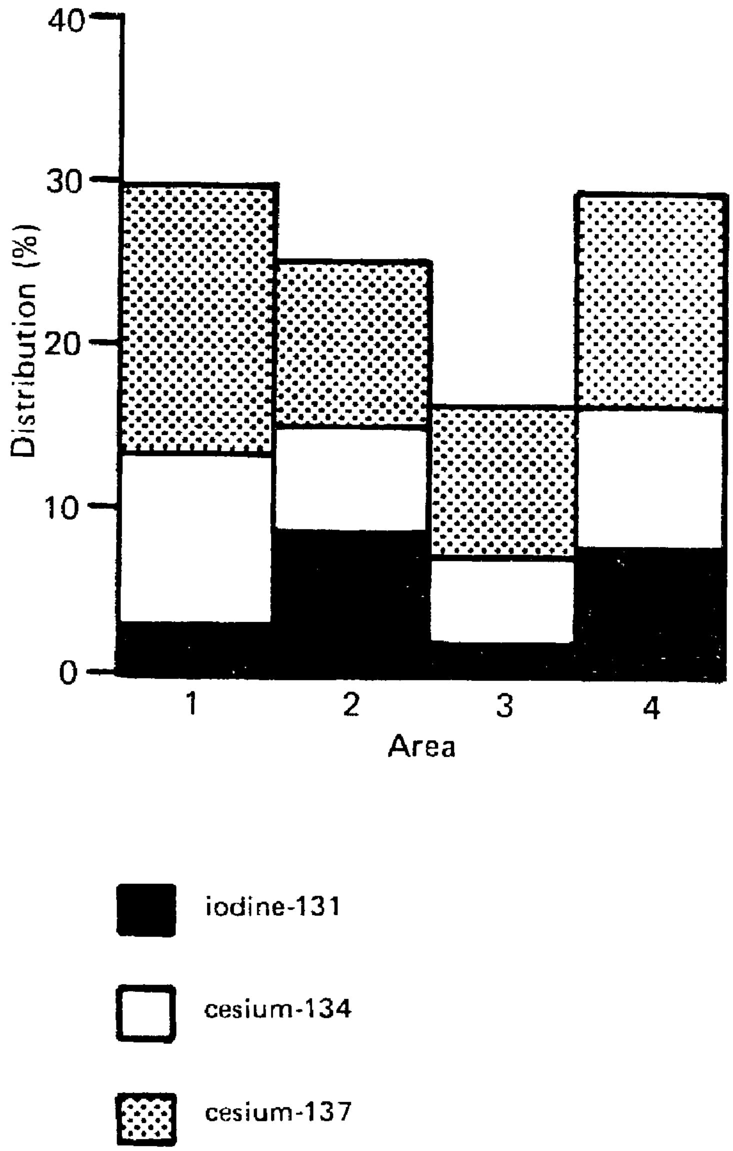
decontamination procedures followed, which included asphalting, and spreading gravel, sand or soil over contaminated areas. Six thousand dwellings have been decontaminated. In some areas, the productivity of the land has been limited.

Fig 6. Distribution in areas 1–4 of the first-year collective effective dose equivalent commitment from gamma radiation from deposition



Internal doses from ingested radionuclides over the first year were predicted to be 4.0×10^4 man-Sv, or 12.2% of the total lifetime dose. The distribution of these doses between radiocesium and radioiodine is shown in Fig. 7.

Fig. 7. Distribution in areas 1–4 of the first-year collective effective dose equivalent commitment from ingestion



The reduction in doses is due to steps taken to prevent contaminated milk from entering the food supply, and to reduce levels of contamination in milk by not putting cows to pasture and by processing and importing milk. It is estimated (by comparing dose levels in people in the parts of the country where milk was not controlled because of a smaller degree of contamination) that these countermeasures reduced doses by 5–20 times.

During 1986–1987, more than 300 000 measurements of levels of radiocesium in people were carried out, using whole-body monitoring. In almost 80% of cases, levels less than 1000 Bq were detected; levels 10–15 times greater had been forecast. For the country as a whole, ^{134}Cs and ^{137}Cs made up 13% and 20%, respectively, of the ingestion dose in the first year.

The lifetime collective effective dose equivalent commitment from ingestion was predicted to be 1.3×10^5 man-Sv, about 38% of the expected dose (Fig. 8). This was made up of radiocesium and radioiodine. The calculations used coefficients for the transfer of ^{137}Cs to the main types of agricultural produce between 1964 and 1986 derived from data on this radionuclide in fallout from tests of nuclear weapons. This gave a half-life for ^{137}Cs in milk of 8.4 years. The calculations assumed that food intake patterns remained the same but allowed for some relative growth of the population in various regions. These assumptions might lead to slightly underestimated doses because of the present trends of increasing meat and milk consumption and falling potato and bread consumption.

Lifetime doses can be more accurately estimated once the full value of the planned controls on agricultural production and technical measures, including prophylactic measures, can be assessed. In 1986 and 1987 in the contaminated areas in Byelorussia, the Ukraine and the Russian Soviet Federative Socialist Republic, a series of agricultural, biological and chemical measures were taken, including deep ploughing and the use of mineral fertilizers (phosphorus and lime), which reduced the uptake of the radionuclides released by the plant. These actions are estimated to have resulted in first-year exposures 1.5–3 times smaller than predicted. This relatively small gain is about what can reasonably be expected for cesium.

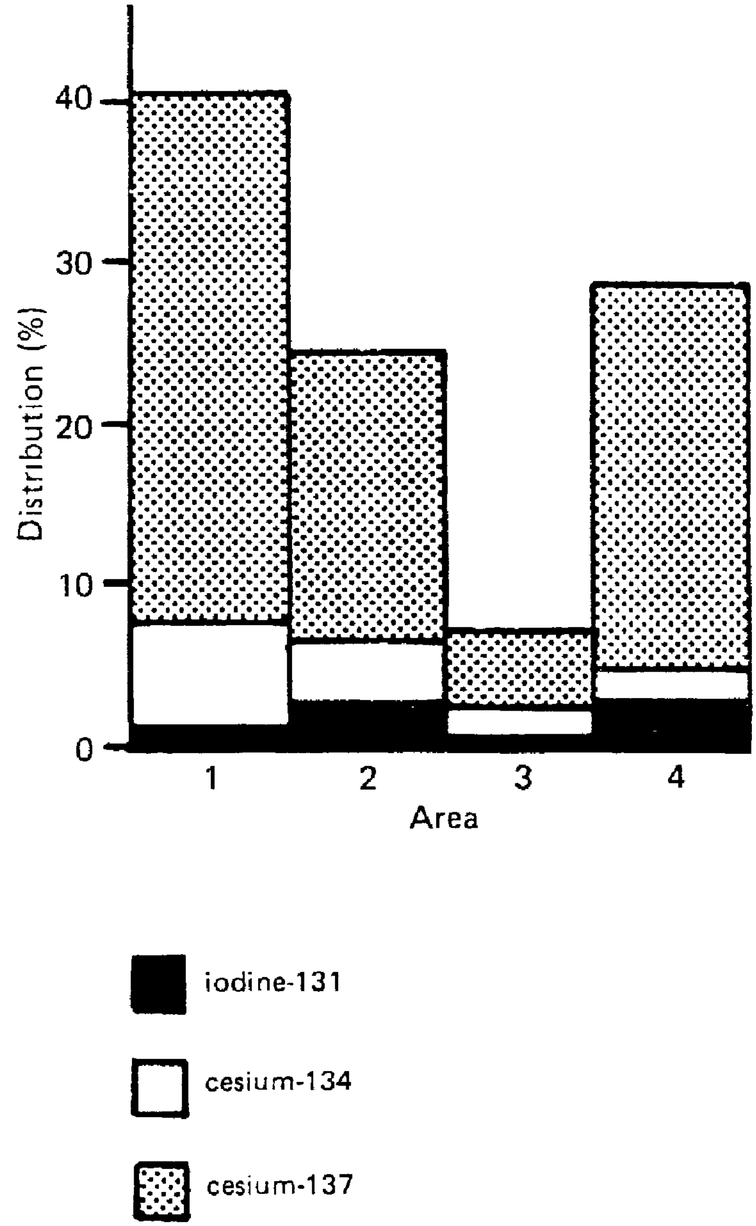
Other countermeasures included the burial of contaminated soil and vegetation in long-term radioactive waste disposal sites. Food with unacceptable contamination levels (above 3700 Bq/litre or 3700 Bq/kg) was destroyed or held until the radioactivity fell to acceptable levels.

In relation to exposure to radioiodine, iodine prophylaxis and restrictions on the consumption of cows' milk were used to reduce the doses to the thyroid gland. Sometimes milk could be reprocessed into milk products, reducing levels of radioactivity sufficiently to permit consumption. Some people, however, did not take the proffered advice on avoiding contaminated milk, particularly farmers with their own cows. This was considered inevitable.

In addition to these urgent actions, and on the basis of predictions of likely effects, a series of prophylactic measures were taken to reduce significantly the level of internal and external radiation received.

The average predicted individual lifetime dose to the population of the USSR from the accident had been calculated to be about 1.2 mSv. This meant that doses were likely to rise only 2% above background radiation levels in the USSR, on average. About 60% of the dose would be from

Fig. 8. Distribution in areas 1–4 of the lifetime collective effective dose equivalent commitment from ingestion



external gamma radiation, 1% from inhalation and 38% from internal irradiation. In general, internal and external irradiation made approximately equal contributions to the first-year dose in areas at long distances from the accident.

Special centres were set up for the medical follow-up of the exposed population. A special register of exposed people was to be made, including about 1 million people, of whom about 216 000 were children. All were receiving relevant laboratory tests. A further group of 32 000 people, of whom 12 000 were children, were from the evacuated zone. Their health was to be compared with that of a control population.

The follow-up so far has demonstrated that the countermeasures reduced exposures. Pregnant women and children were evacuated to health spas during the summer months. Although the women had been advised that termination of pregnancy was not necessary, some, particularly those in the early stages of pregnancy, chose to have abortions.

In the most heavily contaminated parts of the Gomelskaya, Kievskaya, Bryanskaya and Mogilevskaya regions, therefore, doses were generally similar to those in the surrounding area: 10–15 mSv including the dose — less than 50% of the total — from internal exposure to radiocesium. Only about 0.5–1% of the people examined received more than 50 mSv through internal exposure. Further countermeasures are expected to reduce doses even further in subsequent years.

Conclusions

The consequences of the accident must be carefully followed up. Work was still underway to discover the measures that had been most effective in reducing doses.

The decontamination measures taken in the USSR had reduced the doses to the population by a factor of 2–3; keeping dust levels down also reduced exposures.

Iodine prophylaxis had been very effective, particularly in reducing exposures from the gas and aerosols released from the reactor.

Agreed standards are an essential basis for the control of different types of food. Controls on foodstuffs can reduce internal doses by a factor of 10. Methods and principles need to be developed for taking and assaying samples in a standard way, and for careful monitoring of the situation.

In the event of a nuclear accident, it is important to isolate the highly contaminated inner zone, to evacuate populations when necessary and to follow up radiation exposures in human beings.

Survey of responses from other countries

Following the Chernobyl accident, all the countries of the European Region took a number of actions to safeguard the health of their populations. In almost all countries, these actions consisted of a combination of an increase in radiological monitoring and some form of control of food. In addition, some countries acted to protect surface water supplies and to reduce exposures to radioiodine.

The variety of actions recommended by national authorities, which were usually given wide national and international publicity, created a certain degree of confusion in the public, who often could not understand why neighbouring countries applied different measures. As a result, the authorities responsible for radiation protection and public health at national and subnational levels lost some credibility. For this reason, after the immediate post-accident period, a review of the range of actions carried out in different countries, taking account of the rationale behind the different national decisions, was clearly an important priority.

At an early stage, the member countries of the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA/OECD) asked the Agency to make such a review. This study was carried out in late 1986 and early 1987 and resulted in a report issued in 1987 *(3)*. The WHO Regional Office for Europe complemented this study in July 1987 by carrying out a similar survey for the remaining countries of the Region, using the same format as far as possible.

The data collected from OECD member countries showed that, although the countries used similar methods to protect public health (such as controlling the food supply and restricting grazing), their criteria for deciding when action was necessary differed significantly. For example, the intervention levels for ^{131}I in dairy products ranged from 10 Bq/litre to 2000 Bq/litre. In other foods, intervention levels for ^{134}Cs and ^{137}Cs varied from 50 Bq/kg to 8900 Bq/kg. Wide variations were also encountered in action levels for other public health measures taken, such as controlling outdoor activities and advising the restriction of the grazing of dairy cattle.

The WHO review of the situation in other European countries also identified considerable variations in response. Detailed dose estimates of the kind made for OECD countries were not available for most of the others. As a result, the evaluation was primarily based on more qualitative considerations of the radiological situation.

In general, all the countries responded to the accident in quite similar ways. Differences in response could often be explained by differences in the radiological situation and local food production and customs. Table 5 summarizes the public health responses to the Chernobyl accident in most of the countries of the Region, and in four countries outside it.

During the first weeks, when ^{131}I was the most important radionuclide contributing to the internal dose, the most common types of intervention were the control of the use of foodstuffs, with milk, other dairy products and leafy vegetables being the main concerns. Later, when ^{134}Cs and ^{137}Cs dominated as contributors to the internal dose, meat and fish needed to be controlled.

In other types of intervention, countries took different actions. In three eastern European countries, for example, people were advised to keep their

Table 5. Summary of responses to the Chernobyl nuclear accident in 32 countries

Country	Intensification or expansion of environmental monitoring activities	Establishing means to issue public health information	Rain-water		
			Control of use for drinking or household purposes	Control of use for watering cattle	Control of use in saunas
European Member States					
Austria	Y	Y	A	A	
Belgium	Y	Y			
Bulgaria	Y	Y			
Czechoslovakia	Y	Y			
Denmark	Y	Y			
Finland	Y	Y	A	A	A
France	Y	Y			
German Democratic Republic	Y	Y			
Germany, Federal Republic of	Y	Y	A		
Greece	Y	Y	A		
Hungary	Y	Y			
Iceland	Y	Y	X		
Ireland	Y	Y			
Israel	Y	Y			
Italy	Y	Y	A		

Luxembourg	Y	Y	A	
Malta	Y	Y		
Netherlands	Y	Y	A	
Norway	Y	Y	A	
Poland	Y	Y		
Portugal	Y	Y		
Romania	Y	Y	A	A
Spain	Y	Y		
Sweden	Y	Y	A	
Switzerland	Y	Y		
Turkey	Y	Y	A	A
United Kingdom	Y	Y	A	
Yugoslavia	Y	Y	A	A
Other countries				
Australia	Y	Y		
Canada	Y	Y		
Japan	Y	Y	A	
United States of America	Y	Y	A	

Note. A = advice; P = prohibition; R = restriction; X = explicit advice against the need for specific action; Y = action taken.

Source: *The radiological impact of the Chernobyl accident in OECD countries (3)* and data from the survey conducted by the WHO Regional Office for Europe.

Table 5 (contd)

Country	Outdoor public activities			
	Control of outdoor activities	Monitoring of people/vehicles from contaminated areas	Control of travel to contaminated areas	Cleaning of transport vehicles at borders
European Member States				
Austria	A	Y	A	A
Belgium				
Bulgaria		Y		A
Czechoslovakia				
Denmark		Y		A
Finland	A	Y	A	A
France		Y		
German Democratic Republic		Y		A
Germany, Federal Republic of	A[a]	Y	A	A
Greece		Y		
Hungary		Y		A
Iceland				
Ireland		Y	A	
Israel			A	
Italy				
Luxembourg		Y	A	

Malta				
Netherlands		Y	A	A
Norway			A	
Poland	A			
Portugal		Y		
Romania	A	Y		A
Spain		Y	A	
Sweden		Y	A	
Switzerland	X			A
Turkey	A	Y		A
United Kingdom		Y	A	
Yugoslavia	A	Y		
Other countries				
Australia				
Canada	X			A
Japan				
United States of America		Y	A	

[a] Some states gave advice, no official national advice

Table 5 (contd)

Country	Milk and dairy products				
	Control of grazing of dairy cattle	Control of marketing and consumption of cow's milk/ dairy products	Control of marketing and consumption of sheep's/ goat's milk	Control of marketing and consumption of sheep's/ goat's cheese	Contol of import of milk/dairy products
European Member States					
Austria	P	R/A[a]	R/A[b]	P	R
Belgium	A				R[c]
Bulgaria	P/A	R	R/A	R/A	
Czechoslovakia	A	R	R	P	
Denmark	P				R[c]
Finland	A	R			R
France					R[c]
German Democratic Republic		R			
Germany, Federal Republic of	A	R			R[c]
Greece	A	R	A	P	R[c]
Hungary	P/A	A	R		
Iceland					
Ireland					R[c]
Israel					
Italy	P	R	R	P	R[c]

Luxembourg	P				R[c]
Malta					R
Netherlands	P	R/A[a]	R	P	R[c]
Norway		R	A	R	R
Poland	P	R	R	R	R
Portugal					R[c]
Romania	P/A	R	R	R	
Spain					R[c]
Sweden	A	R		R	R[c]
Switzerland		A	A	A	R
Turkey	P/A[d]	R	A	P/A[e]	R[c]
United Kingdom					R[c]/A
Yugoslavia	A	R/A	R/A	R	R
Other countries					
Australia					R[f]
Canada				R	
Japan					R
United States of America					R

[a] Including advice not to drink fresh cow's milk from farms

[b] Restriction on marketing of sheep's/goat's milk, advice to avoid consumption of sheep's/goat's milk

[c] Included a temporary prohibition on imports from eastern European countries.

[d] Prohibition progressively phased out; followed by advice limited to Thrace region.

[e] Prohibition on consumption (1 week), and advice against marketing goat's cheese (8 weeks).

[f] Surveillance of imports; no specific restrictions imposed

Table 5 (contd)

Country	Vegetables, fruit and grains					
	Control of consumption of fresh, leafy vegetables	Washing fresh vegetables prior to consumption	Control of consumption of non-cultivated plants and mushrooms	Control of domestic marketing of leafy vegetables	Control of import of vegetables, fruit and grains	Control of agricultural practices
European Member States						
Austria	A	A	A	P	R	
Belgium		A			R[a]	
Bulgaria	A	A	A	R		
Czechoslovakia		A		R		
Denmark		A		R[a]		
Finland			A		R	A
France				P[b]	R[a]	
German Democratic Republic						
Germany, Federal Republic of	A[c]	A	A	R	R[a]	
Greece	A	A			R[a]	
Hungary		A				
Iceland						
Ireland		A			R[a]	
Israel				R		
Italy	A	A		P	R[a]	

Luxembourg		A		P	R[a]	
Malta					R	
Netherlands	A	A	A	R/P	R[a]	
Norway				P	R	
Poland	A	A		R	R	
Portugal					R[a]	
Romania		A				
Spain					R[a]	
Sweden	A	A	A	R	R[a]	A
Switzerland	A	A			R	
Turkey	A	A			R[a]	
United Kingdom					R[a]	
Yugoslavia	A	A	A	R	R	A
Other countries						
Australia					R[d]	
Canada				R		
Japan		A			R[e]	
United States of America					R	

[a] Included a temporary prohibition on imports from eastern European countries

[b] Temporary measure in one region (Haut Rhin), for spinach only.

[c] Some states gave advice, no official national advice.

[d] Surveillance of imports, no specific restrictions imposed

[e] Limited to vegetables.

Table 5 (contd)

Country	Meat and fish							
	Control of domestic marketing of animal thyroids	Control of domestic marketing of lambs/sheep	Control of domestic marketing of beef and horse meat	Control of domestic marketing of reindeer meat	Control of domestic marketing of game	Control of consumption of freshwater fish	Control of hunting of game	Control of imports of meat
European Member States								
Austria		R	R					R
Belgium								R[a]
Bulgaria		R	R					
Czechoslovakia								R
Denmark								R[a]
Finland				A	A	A		R
France								R[a]
German Democratic Republic								
Germany, Federal Republic of								R[a]
Greece	P	R						R[a]
Hungary								
Iceland								
Ireland							A	R[a]
Israel								

Italy	P							R[a]
Luxembourg	P							R[a]
Malta								
Netherlands	P	R			A	A	A	R[a]
Norway		R	R	R		P		R
Poland		R				R		
Portugal								R[a]
Romania								
Spain							A	R[a]
Sweden		R		R	R	A	A	R[a]
Switzerland		R				R[a]		R
Turkey								R[a]
United Kingdom		R						R[a]
Yugoslavia	P	R			R		A	
Other countries								
Australia								R[b]
Canada								R
Japan								R
United States of America								R

[a] Included a temporary prohibition on imports from eastern European countries.

[b] Surveillance of imports; no specific restrictions imposed

Table 5 (contd)

Country	Government compensation for agricultural loss	Controls on the changing of industrial filters	Control of the use of sewage sludge for soil amendment	Administration of stable iodine
European Member States				
Austria	Y	A	P	X
Belgium		A		
Bulgaria				
Czechoslovakia		A		X/Y[a]
Denmark				
Finland	Y	A	R	X[b]
France				X
German Democratic Republic		A		X
Germany, Federal Republic of	Y	A		X
Greece	Y	A		X
Hungary		A		
Iceland				
Ireland				
Israel				
Italy	Y	A		
Luxembourg		A	R	X
Malta				

Netherlands	Y	A		X
Norway	Y			
Poland				X[c]/Y
Portugal				
Romania				X[d]/Y
Spain				X
Sweden	Y	A	R	X
Switzerland		A	R	X
Turkey	Y			X
United Kingdom	Y			
Yugoslavia			R	X
Other countries				
Australia				
Canada				X
Japan				
United States of America				X

[a] Advice against action to general population; action taken only with regard to the staff of sheep farms.

[b] Except for nationals travelling within 50 km of Chernobyl.

[c] Some regions gave advice; no official national advice

[d] Surveillance of imports, no specific restrictions imposed

children indoors during the first week after the accident. Most countries found such advice unnecessary.

Further, countries differed significantly in the derived intervention levels set for drinking-water and foods. The various reasons for adopting the intervention levels for foods, however, should be borne in mind. In some instances, these levels were set to protect particularly vulnerable groups within a population (such as infants, in relation to radioiodine in milk), while in others they were intended for general application to the whole population. In yet other cases, they were primarily applicable to international trade, as were the levels provisionally adopted in May 1986 by the European Communities. Acceptable levels of ^{131}I also depended on the likely duration of the presence of the cloud. The longer this period, the lower the acceptable level.

An attempt was made to assess the value of the various protective measures within the OECD countries in terms of the averted dose. A similar assessment could not be made for the other countries, owing to the lack of information on levels of contamination. In all European countries, however, the percentages of the collective effective first-year dose averted by the various protective measures were likely to differ considerably. Within the OECD countries, the averted collective effective first-year dose for critical groups was considered to range from virtually 0% to 80%. Similarly, evaluations from the same group of countries indicate that, for whole populations, the averted collective effective dose might range from 1% to 50% in one country. The percentage of dose averted was also likely to vary according to the degree of contamination. A country with very little contamination did not need to take action or avert any dose, while a heavily contaminated country needed to take several actions and might consequently avert a high percentage of the potential dose.

Iodine prophylaxis

Following a nuclear accident, the fuel rods in a reactor core may release radioactive isotopes of iodine as a gas or in radioactive particles. Local populations exposed to the cloud given off can receive doses of radioiodine through the inhalation of gaseous or particulate radioiodine in the air, the ingestion of contaminated food and drink, external irradiation from the cloud or ground deposition, or absorption through skin and mucous membranes.

Most radioisotopes of iodine have half-lives of days rather than years; therefore exposure is usually a problem only in the first few weeks after an accident. In general, inhaled or ingested iodine is rapidly taken up from the lungs and intestines and preferentially concentrated in the thyroid gland. The thyroid may also, of course, receive a radiation dose externally or internally from other radionuclides released from the cloud. Iodine also concentrates, to a lesser extent, in the salivary and mammary glands, parts of the gastrointestinal tract and the placenta. The concentration of iodine in milk is also greater than the average level in the tissues. As a result, the amount of radioiodine in an accidental release will frequently be a critical factor in determining the need for action to protect the local population; the predicted dose to the thyroid will usually be a decisive factor in the decision-making process.

The short-lived isotopes of radioiodine usually responsible for most of the predicted dose to the thyroid have high specific activities; therefore, the concentration in the thyroid gland can be reduced if the body is loaded with stable iodine before the circulating radioiodine is concentrated there. Of course, iodine prophylaxis provides no protection from external irradiation of the thyroid gland or from internal irradiation from other radionuclides than iodine.

The Chernobyl accident resulted in the estimated release of about 7.3 MCi ^{131}I and probably up to 2.0 MCi of other radioisotopes of iodine between 26 April and 6 May 1986. The WHO Regional Office for Europe surveyed the advice given in countries on iodine prophylaxis after the accident; 19 countries responded to the questionnaire (Annex 3). In addition to the USSR, Poland, Romania and the Slovak Socialist Republic in Czechoslovakia — which border on the most affected part of the USSR — advised stable iodine for certain groups in their populations. Ten other countries (and the Czech Socialist Republic) gave specific advice against prophylaxis. Some advised its use for people travelling to areas close to Chernobyl. Five countries gave no specific advice *(3)*.

USSR

Within the USSR, the long duration of the release (over 10 days) meant that repeated doses of stable iodine had been necessary for people living close to the site of the accident. As soon as it was realized that radioactivity was being released and the gamma radiation rate was rising above background levels, the decision was made to distribute potassium iodide (KI). At that stage, the concentration of radioiodine in the release was not known.

The adult dose was one tablet of 125 mg KI; this was given three or four times during the release. Children under 10 years old received half the adult dose. Prophylaxis was claimed to have reduced thyroid doses by 95–97%. Smaller doses were less effective, and larger ones only increased the blocking by a small fraction and were not worthwhile.

Within the USSR, 5.4 million people, of whom 1.7 million were children, were given stable iodine. The Soviet authorities felt that many did not really need to take the tablets; everyone living in Kiev, for example, received them, although this was found to be unnecessary. The authorities'