The radiological impact of the CHERNOBYL ACCIDENT IN OECD COUNTRIES

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to article 1 of the Convention signed in Paris on 14th December, 1960, and which came into force on 30th September, 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April, 1964), Finland (28th January, 1969), Australia (7th June, 1971) and New Zealand (29th May, 1973).

The Socialist Federal Republic of Yugoslavia takes part in some of the work of the OECD (agreement of 28th October, 1961).

The OECD Nuclear Energy Agency (NEA) was established on 20th April 1972, replacing OECD's European Nuclear Energy Agency (ENEA) on the adhesion of Japan as a full Member.

NEA now groups all the European Member countries of OECD and Australia, Canada, Japan, and the United States. The Commission of the European Communities takes part in the work of the Agency.

The primary objectives of NEA are to promote co-operation between its Member governments on the safety and regulatory aspects of nuclear development, and on assessing the future role of nuclear energy as a contributor to economic progress.

This is achieved by:

- *encouraging harmonisation of governements' regulatory policies and practices in the nuclear field, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *keeping under review the technical and economic characteristics of nuclear power growth and of the nuclear fuel cycle, and assessing demand and supply for the different phases of the nuclear fuel cycle and the potential future contribution of nuclear power to overall energy demand;*
- *developing exchanges of scientific and technical information on nuclear energy, particularly through participation in common services;*
- *setting up international research and development programmes and undertakings jointly organised and operated by OECD countries.*

In these and related tasks, NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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LES INCIDENCES RADIOLOGIQUES
DE L'ACCIDENT DE TCHERNOBYL
DANS LES PAYS DE L'OCDE

FOREWORD

The release of radioactive material resulting from the accident which occurred in April 1986 at the Chernobyl nuclear power plant in the USSR has caused widespread environmental contamination, particularly in Europe, raising considerable concern in OECD Member countries. The reactions of national authorities have been extremely varied depending on circumstances, ranging from a simple intensification of normal environmental monitoring programmes to the application of a number of countermeasures, including restrictions on the marketing and consumption of foodstuffs.

Several lessons should be learned from this experience, and an effort directed towards better international harmonisation of the scientific bases and the concepts and measures for the protection of the public in the event of a nuclear emergency.

As a first step toward identifying areas deserving attention, the NEA has undertaken an independent assessment of the radiological impact of the Chernobyl accident and a critical review of the emergency response in Member countries. This assessment was prepared under the aegis of the NEA Committee on Radiological Protection and Public Health (CRPPH) on the basis of information officially provided by those OECD countries which are Members of the NEA. This report is published under the responsibility of the Secretary-General of OECD and does not commit Member countries.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

Figures:

Appendices:

EXECUTIVE SUMMARY

i) Introduction

On 26th April, 1986, the Chernobyl nuclear power station (USSR) suffered a major accident which was followed by a prolonged release to the atmosphere of large quantities of radioactive products. The specific features of the release favoured a widespread distribution of activity throughout the northern hemisphere, mainly across Europe. A contributing factor was the variation of meteorological conditions and wind regimes during the period of release. Activity transported by the multiple plumes from Chernobyl was measured not only in northern and in southern Europe, but also in Canada, Japan and the United States; of the NEA Member countries, only Australia remained free of contamination.

The cloud of radionuclides released from the Chernobyl reactor contained many different fission products and actinides. Although traces of these nuclides were detected in most Member countries, only a few were found in quantities which were radiologically significant. The three most important nuclides, for OECD Member countries, were iodine-131 and the two caesium isotopes, caesium-134 and caesium-137. The levels of contamination varied widely, both within and between Member countries. Within Europe, levels of total radiocaesium deposition ranged from values less than the measured cumulative deposition due to fallout from nuclear atmospheric tests, to peak values a few times higher. Of the European OECD Member countries, Portugal and Spain experienced the lowest deposition, with Austria and Scandinavia experiencing the highest.

Following the discovery of the accident at Chernobyl, monitoring for radioactive contamination was started or increased in all OECD Member countries. The data obtained from these monitoring programmes have been used to carry out assessments of the radiological impact of the accident in each Member country. In response to a request by the NEA, competent authorities from each country have supplied a summary of their assessment for incorporation in this report. The data provided comprise average and peak levels of total ground deposition for the principal radionuclides, estimates of individual and collective doses arising in the first year after the accident and information on any countermeasures taken to reduce doses.

ii) Radiological Impact of the Accident

The main exposure pathways following the accident at Chernobyl have been direct gamma irradiation from the cloud, inhalation of activity in the cloud, gamma irradiation from activity deposited on the ground, and ingestion of contaminated foods. The average individual effective dose equivalents range from a few microsieverts or less for Spain, Portugal and most of the countries outside of Europe, to about 0.7 millisieverts for Austria.

Ingestion and external gamma irradiation from deposited material are considered to be the dominant pathways of exposure, although the relative importance of each of these pathways varied considerably between Member countries. Similarly, the range of the average individual dose equivalents to the thyroid is estimated to span from a few microsieverts, or tens of microsieverts, for Spain, Portugal and the countries outside of Europe, to nearly three millisieverts for Greece.

An indication of the total radiation detriment associated with the accident in OECD Member countries may be given by the size of the collective dose received by their population. The total collective effective dose equivalent arising in the OECD area from the first year after the accident (May 1986–April 1987) is estimated to be about 70 000 man-sieverts. The total collective thyroid dose equivalent for the same period is estimated to be about 300 000 mansieverts.

The collective and average individual effective doses estimated for the various countries as a result of the Chernobyl accident can be put into perspective with other sources of exposure of the population. For example, the average individual effective dose equivalent received in Europe each year from exposure to natural background radiation is about 2 millisieverts, and the collective effective dose equivalent to the whole population of the European OECD countries is of the order of 800 000 mansieverts per year.

Another kind of information which is useful to complete the picture of the radiological impact of the accident concerns the peak values of individual dose which have been estimated in the various countries. These have been provided by each Member country in terms of average dose to individuals of the critical group, defined as a homogeneous group of population representative of the persons receiving the highest dose amongst all the population exposed. These estimates of the individual effective dose equivalents resulting from the first year of exposure/intake for the critical groups show, again, a large range of values. They vary, in fact, from a lower extreme of a few microsieverts, or tens of microsieverts, in countries outside Europe as well as in Spain and Portugal, to an upper extreme of between two and three millisieverts for the Nordic countries and Italy.

The dose values which have been mentioned so far are those actually received or committed from exposure/intake in the first year following the accident. They include consideration of the application in some countries of protective countermeasures intended to minimize the health impact of the accident on their populations. It is, therefore, interesting to have an appraisal of the effectiveness of these countermeasures in terms of dose savings achieved in the various countries. This analysis has revealed that the dose savings varied considerably, between 1 per cent and 80 per cent in the countries which took protective actions, and also that they have affected to a different degree the individual doses to critical groups and the collective doses in the various countries, depending on the different emphasis that national authorities appear to have attributed to the protection of individuals or the protection of the overall population.

iii) Accident Response

The progressive spread of contamination at large distances from the accident site has caused considerable concern in Member countries, and the reactions of national authorities to this situation have been extremely varied, ranging from a simple intensification of the normal environmental monitoring programmes, without adoption of any specific countermeasures, to compulsory restrictions concerning the marketing and consumption of foodstuffs. This variety of responses has been accompanied by significant differences in the timing and duration of application of the countermeasures.

In general, the most widespread countermeasures were those which were not expected to impose, in the short time for which they were in effect, a significant burden on lifestyles or the economy. These included advice to wash fresh vegetables and fruit before consumption, advice not to use rainwater for drinking or cooking, and programmes of monitoring citizens returning from potentially contaminated areas. In reality, experience showed that even these types of measures had, in some cases, a negative impact which was not insignificant. For example, advice to wash vegetables and fruit prompted many citizens, in some countries, to avoid altogether the consumption of these foodstuffs, which resulted in sizable economic losses due to reduced sales.

Protective actions having a more significant impact on dietary habits and imposing a relatively important economic and regulatory burden included restrictions or prohibitions on the marketing and consumption of milk, dairy products, fresh leafy vegetables and some types of meat, as well as control of the outdoor grazing of dairy cattle. In some areas, prohibitions were placed on travel to areas affected by the accident and on the import of foodstuffs from the Soviet Union and eastern European countries. In most Member countries, restrictions were imposed on the import of foodstuffs from Member as well as non-member countries.

The range of these reactions can be explained primarily by the diversity of local situations both in terms of uneven levels of contamination and in terms of national differences in administrative, regulatory and public health systems. However, one of the principal reasons for the variety of situations observed in Member countries stems from the criteria adopted for the choice and application of intervention levels for the implementation of protective actions. In this respect, while the general radiation protection principles underlying the actions taken in most Member countries following the accident have been very similar, discrepancies arose in the assessment of the situation and the adoption and application of operational radiological criteria. These discrepancies were further enhanced by the overwhelming role played in many cases by non-radiological factors, such as socio-economic, political and psychological, in determining the countermeasures.

This was particularly evident in the wide range of values adopted for the derived intervention levels (DILs), which are expressed in terms of concentrations of radionuclides in the different environmental matrices and foodstuffs. The DILs for the various exposure pathways were identical in certain countries but significantly different in others, even when environmental and socio-economical conditions were similar. These discrepancies in protective actions and intervention levels caused concern and confusion among the public, perplexities among the experts and difficulties to national authorities, including problems of loss of public credibility. Therefore, this is an area where several lessons should be learned from the accident, and an effort directed towards better international harmonisation of the scientific bases and co-ordination of concepts and measures for the protection of the public in case of emergency.

A particular problem raised by the transboundary character of the Chernobyl accident concerned its impact on the international trade of goods, particularly foodstuffs. Shortly after the deposition of contaminants in Member countries, concern was expressed regarding acceptable levels of activity in imported/exported foodstuffs. Derived intervention levels were provisionally established by the Commission of the European Communities (CEC) for the import/export of foodstuffs to and from EEC Member countries, as well as between them. The repercussions of this question were not limited to the countries directly affected by the activity deposition. Many other countries were concerned with the possible risks to their populations from food imported from Europe, and established controls and limitations on these importations. Many of these countries adopted levels of activity for the screening of imported food which were similar to those recommended by the CEC, but other countries chose to use more restrictive limits, in some cases corresponding to trivial levels of activity in foodstuffs. This was another factor of disruption in the normal commercial activities and mutual relations between countries. In order to overcome these difficulties, a significant effort is currently being made by several international organisations towards achieving a better harmonisation of criteria for the establishment of intervention levels.

iv) Conclusions

On the basis of the information officially made available by Member countries, it can be concluded that, although the radiological consequences of the accident were serious in the region surrounding the Chernobyl site, only in some countries of the OECD area did the levels of radioactive contamination resulting from the release warrant protective actions directly motivated by radiation protection considerations. On the whole, however, these consequences do not raise any major concern for the health of the population in OECD Member countries. In particular, individuals in those countries are not likely to have been subjected to a radiation dose, in terms of effective dose equivalent, significantly greater than that received from one year of exposure to the natural radiation background. As a consequence, the lifetime average risk of radiation-related harm for the individual members of the public has not been changed to any significant extent by the accident. Moreover, the impact on the populations of the OECD Member countries in terms of collective dose appears to be small in comparison with collective doses from natural background or some man-made radiation sources. The number of associated health effects (somatic and hereditary) that can be theoretically calculated from the collective dose will be very small in comparison with the natural incidence of similar effects over the next few decades. The radiation-induced health effects will not constitute a detectable addition to this natural incidence.

As is described in the report, the radiological impact of the Chernobyl accident in OECD Member countries was very uneven, but there was also considerable variation between responses in the different countries, even when they experienced similar levels of contamination. It is believed that such differences arose primarily from four factors:

1. the large emphasis given to non-radiological, non-objective criteria in the decision-making process;
2. differing levels of uncertainty on actual impacts;
3. the use of different methodologies in assessing the potential impact; and
4. the use of different assumptions and values of parameters related to environmental transfer modelling, dosimetry modelling and characteristics of the affected population groups.

There is no doubt that the Chernobyl accident, its development and the way in which its consequences have been managed have offered a number of lessons to be learned. Further improvement of emergency preparedness and public protection measures will depend on an in-depth reflection on these lessons, a process which is actively being pursued by national authorities and international organisations, including the NEA.

1. INTRODUCTION

On 26th April, 1986, Unit 4 of the Chernobyl nuclear power station, located in the Ukraine Republic of the USSR, suffered a major accident which was followed by a prolonged release to the atmosphere of large quantities of radioactive products.

The causes and circumstances of the accident, its evolution, the radiological consequences on the workers and the population living in the surroundings of the plant, the emergency actions taken by the Soviet authorities and the site decontamination and rehabilitation activities have been described in detail in the report submitted by the Soviet authorities at the Post-Accident Review Meeting organised by the IAEA in Vienna on 25th-29th August, 1986 [1], and have been further reviewed in other international and national reports [2, 3].

The specific features of the release, particularly its relatively long duration and the altitude reached by the radioactive plume, favoured a widespread distribution of activity, mainly across Europe. A contributing factor was the variation of meteorological conditions and wind regimes during the period of release. Activity transported by the multiple plumes from Chernobyl was measured not only in northern and in southern Europe, but also in Canada, Japan and the United States.

A large amount of information is already available on the distribution of the radioactive contamination produced by the release in the OECD Member countries, and reliable assessments exist of its radiological impact. The radiological consequences on the individual members of the public have been minor. Although significant collective doses have been estimated in a number of countries, they do not warrant major concerns for the general health of the population. The economic impact of the accident has been significant in some Member countries, due to the relatively high costs resulting from the restrictions applied on the sale and import of foodstuffs.

The progressive spread of contamination at large distances from the accident site has caused considerable concern in Member countries. The reactions of national authorities to this situation have been extremely varied, ranging from a simple intensification of the normal environmental monitoring programmes, without adoption of any specific countermeasures, to compulsory restrictions concerning the marketing and consumption of foodstuffs. This variety of responses has been accompanied by significant differences in the timing and duration of application of the countermeasures.

The range of these reactions can be explained primarily by the diversity of local situations, both in terms of uneven levels of contamination and in terms of national differences in criteria for the choice of intervention levels and in public health, regulatory and administrative systems. Many different approaches have also been observed in the field of communication with the public.

Even taking into account the objective variety of local situations, there is a widespread feeling that the range of countermeasures and intervention levels adopted in Member countries was much larger than could be justified by the above-mentioned geographical differences in contamination levels, environmental features, population habits and diets, and national regulatory approaches. This consideration also applies to the differences which have been noted in the intervention levels and the corresponding criteria for the choice of their values.

These discrepancies caused concern and confusion amongst the public, perplexities amongst the experts and difficulties to national authorities, including problems of loss of public credibility. Therefore, this is an area where several lessons should be learned from the accident, and an effort directed towards a better international harmonisation of the scientific bases and coordination of concepts and measures for the protection of the public in case of emergency.

This falls into the broad process of improvement of radiation protection response to the risk of nuclear accidents, which is currently being sponsored by several international organisations, including IAEA, WHO, OECD/NEA and CEC. The NEA Committee on Radiation Protection and Public Health (CRPPH) felt that a first step for establishing the areas where such an effort should be applied was to make an independent assessment of the radiological impact of the Chernobyl accident and a critical review of the consequent emergency responses adopted by the Member countries.

The present report is the result of this initiative of the CRPPH, and was prepared by the Agency on the basis of information supplied by the competent authorities in Member countries. The report is composed of a main text, and three appendices which give details on the information supplied by Member countries.

2. FRAMEWORK OF THE ANALYSIS

Information on radiological data and accident responses in Member countries, as well as on the intervention levels adopted, has been categorised and summarised to provide for greater ease of review. Emphasis has been placed on presenting the information in a manner which enables a satisfactory overview of the situation in Member countries, and which provides insight into the nature and underlying rationale of the responses and intervention levels. A possible framework for such an analysis is shown in Figure 1.

The **source term** for the model depicted on Figure 1 is dependent upon the accident scenario and release characteristics which generate the emergency situation. Primary considerations include the extent of advance warning of the release, the type and amount of radionuclides involved and the temporal and spatial patterns of the release.

The **response system** within a country may be characterised by four primary components: radiological impact, radiological criteria, decision-making process, and countermeasures.

The determination of the **radiological impact** is a function of the actual levels of environmental contamination, monitoring programmes and assessment methods.

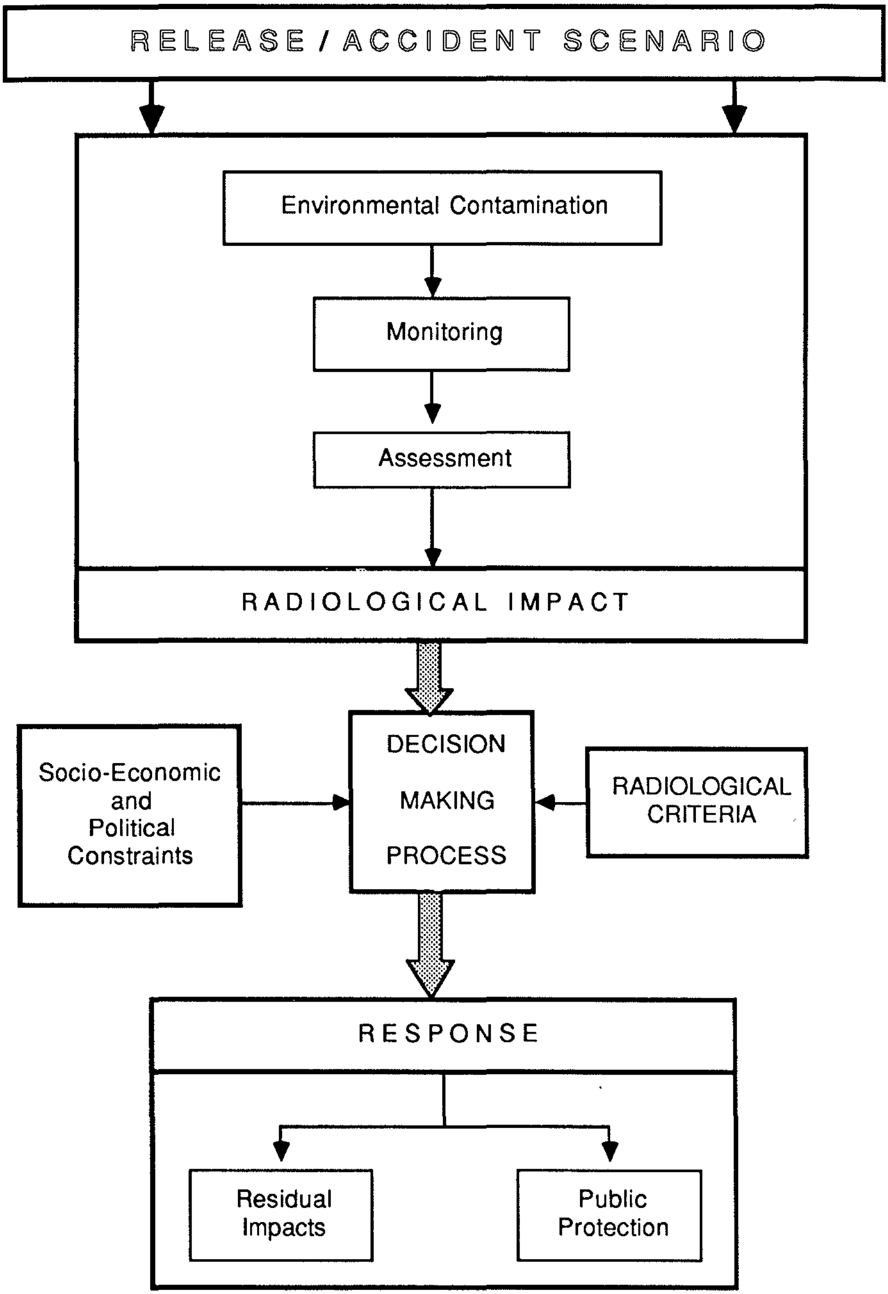
It is assumed that the routine **environmental surveillance programme** is enhanced or that **special monitoring programmes** are established in response to the detection of abnormal levels of activity or to notification by the country responsible for the release. Objects of the monitoring programmes may include the atmosphere, ground deposition (soil, vegetation), water, foodstuffs (milk/dairy products, vegetables, meat, fish, cereal/grains, fruit) and other environmental matrices (game, etc.).

Data collected on the levels of environmental contamination are required to be analysed and assessed in order to determine the radiological impact resulting from the accidental release. Key aspects of the **assessment process** include data analysis, environmental transfer models, dosimetric models and projected dose assessments.

The **decision-making process** involves an evaluation of the predicted impacts in the context of decision criteria and constraints, an identification and evaluation of alternative actions and the selection of appropriate responses. The bases for these evaluations are **radiological criteria**, which may take the form of principles, objectives, primary intervention levels of dose and derived intervention levels applied to environmental matrices and foodstuffs.

Although the use of radiological criteria can provide a quantitative basis for the selection of emergency responses, it is recognised that **socio-economic and political constraints** may form an integral part of the decision-making process and may serve to modify any such selection.

Figure 1. **CONCEPTUAL MODEL FOR ANALYSIS OF EMERGENCY RESPONSE TO THE CHERNOBYL NUCLEAR ACCIDENT**



The **outcome** of the decision-making process is represented by a set of actions enacted by the public authorities with the primary objective of restricting or minimizing exposures of members of the public. The term *countermeasures* is, for the purpose of this report, considered to convey the same meaning as *interventions, protective measures* or *protective actions*, and these four terms are used inter-changeably to denote the accident response.

The interventions may be applied to a broad range of public activities, including outdoor movement and recreation, travel or access to contaminated areas, the use of environmental matrices, the domestic marketing and consumption of foodstuffs, and the importing and exporting of foodstuffs. Measures adopted may not be limited to those directly addressed to restriction of public exposure, but may also take the form of enhanced environmental monitoring, development of public information systems, and implementation of specific recovery or compensatory programmes designed to mitigate the consequences of remedial actions taken during the accident and to restore normal living conditions.

The extent, or degree, of control associated with the various interventions is variable, and may be characterised as follows:

a) ***Passive measures*** – no direct protective measures are taken, but the development of the situation is closely watched (e.g., establishment or enhancement of monitoring programmes; issuance of public information notices);

b) ***Advisory measures*** – involve non-compulsory recommendations, and advice suggesting precautions or limitations in specific public activities;

c) ***Restrictive measures*** – involve the compulsory limitation of certain activities, *on the basis of* quantitative thresholds (e.g., food import restrictions);

d) ***Prohibitive measures*** – involve the ban on certain activities *without reference* to any quantitative threshold (e.g., ban on food imports); and

e) ***Recovery measures*** – involve the withdrawal of previously adopted protective measures, and the implementation of programmes designed to restore normal living conditions (including government compensation for economic losses to agricultural or industrial operators).

In addition, the interventions may be characterised with respect to their temporal aspects (i.e., timing and duration) and the extent of their spatial application (i.e., local, regional, national). The two primary consequences of any intervention adopted by a public authority may be characterised as those relating to **public protection** (i.e., the objectives of the countermeasure), and those relating to **disruption of normal living conditions** (i.e., the residual impacts of the countermeasure). Clearly, the adoption of a given protective measure must involve a consideration of the balance between the degree of public protection to be achieved and the extent of social, economic and psychological disruption (entailing residual risks and costs) that are introduced by the implementation of that measure.

As a contribution to the analysis of the impact of the Chernobyl accident, the present report examines in some detail two major components of the scheme described above, namely the radiological impact of the release and the accident responses adopted in Member countries.

3. RADIOLOGICAL IMPACT OF THE ACCIDENT

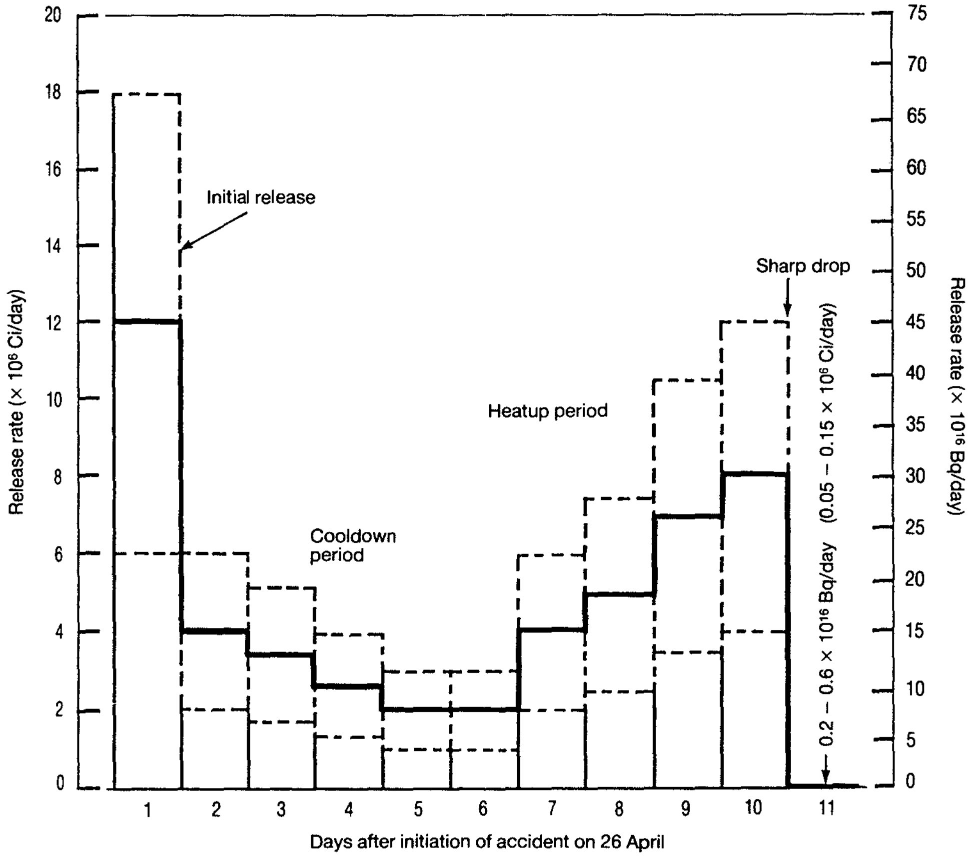
3.1. General

The accident at the Chernobyl Unit 4 reactor was characterised by two explosions and a subsequent fire, which gravely damaged the reactor and the containment building. Consequently, there was a prolonged release into the atmosphere of large quantities of radioactive material (gases, halogens and particulate matter) prior to the bringing of the release under control through a variety of mitigative measures [1, 2]. The major part of the release occurred over a period of about ten days, and was characterised by two distinct peaks in release rate (26th April and 5th May). An illustration of the daily release rate during this period is given in Figure 2. Subsequently, the release continued for many weeks at a very low rate before the destroyed reactor was finally sealed, some five months later.

During the time of the main release, a complex and varying set of meteorological conditions developed over Europe, which dispersed the cloud over a very wide area. Initially, the prevailing wind direction was to the north-west, carrying the cloud of radioactive material over the Baltic Sea into Scandinavia. After a few days, the wind direction rotated clockwise, causing the cloud to travel, both eastwards across the USSR and southwards to Turkey. During the last few days of the main release, the radioactive cloud was blown towards the south-west, over the eastern Mediterranean. The initial cloud that had been directed into Scandinavia split into three segments. One segment travelled east across the northern USSR, and was later detected in Japan and China. A second crossed over central Norway and the Norwegian Sea, to be detected later in North America. The third segment moved south-westwards over central Europe. This segment subsequently moved over northern Italy and southern France, before turning north-westwards over the United Kingdom. The radioactive material discharged toward the end of the main release travelled south over Greece, and was then turned north-west and again northwards, to Scandinavia. In doing so, it merged with the material released earlier to form a contaminated air mass covering most of Europe. Owing to the poor mixing between the atmospheres of the northern and southern hemispheres, radionuclides from Chernobyl were not detected south of the equator. Figure 3, based on plume trajectories calculated by the United Kingdom Meteorological Office [4], gives an illustration of the areas successively affected by the main body of the cloud during the period of the major release.

As the cloud moved, it deposited radioactive material on the ground. The extent of this deposition was very uneven, both within and between Member countries. This was due, in part, to the varying distances from the source of release and, for a large part, to the presence in Europe of an unusually variable meteorological situation characterised by frequent and localised heavy precipitations. Therefore, the deposition was greatly enhanced wherever the cloud encountered rain systems. The highest levels of deposition (outside of the immediate vicinity of the Chernobyl reactor) occurred during convective storms, where the heavy rainfall and associated strong air currents (which swept material from the

Figure 2. **DAILY RELEASE OF RADIOACTIVE SUBSTANCES TO THE ATMOSPHERE DURING THE CHERNOBYL ACCIDENT (not including Noble Gases)**



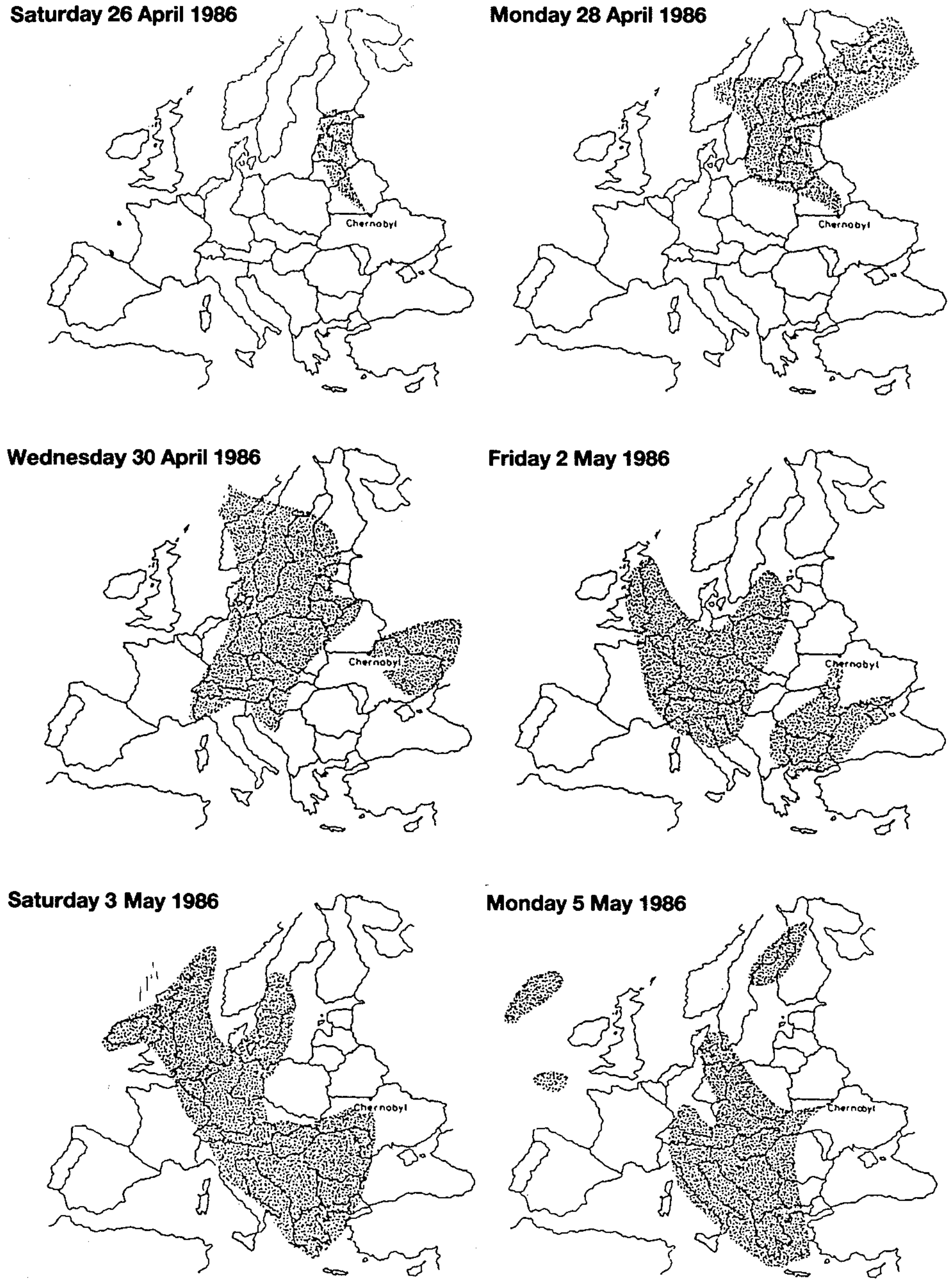
[The values shown are calculated for 6 May 1986, taking into account radioactive decay up until then. The radioactivity released on 26 April 1986 was 75-80 × 10^{16} Bq (20-22 × 10^{6} Ci). The range of uncertainty for all releases is ±50 %.]

Source: Reference (2), p. 35.

surrounding air into the clouds) were very effective in depositing airborne material in localised areas. Thus, a complex pattern of environmental contamination developed, with radionuclides from the accident being detected as far away as Japan, Canada and the United States. Of the NEA Member countries, only Australia (being in the southern hemisphere) was unable to detect enhanced environmental radioactivity which could be attributed to the Chernobyl accident.

Following the discovery of the accident at Chernobyl, monitoring for radioactive contamination was started or increased in all OECD Member countries. The measurements made depended to a large extent on the levels of contamination found. For example, where high concentrations were measured in important foods (e.g., dairy products and leafy vegetables in many countries, highland sheep in the United Kingdom, reindeer in Sweden),

Figure 3. **AREAS COVERED BY THE MAIN BODY OF THE CLOUD ON VARIOUS DAYS DURING THE RELEASE**



extensive monitoring was conducted to ensure that individuals were not exposed to undue risk of harm. On the other hand, countries such as Portugal, Iceland and others, which experienced very little contamination, had no need to take such intensive precautions. In some Member countries, where the levels of activity in some foods are still significant, parts of these monitoring programmes are still in force. Also, in order to ensure that highly contaminated foods are not being brought into Member countries from other countries, monitoring of imported foods is also carried out.

The data obtained from these monitoring programmes have been used to carry out assessments of the radiological impact of the accident in each Member country. In response to a request by the NEA, the competent authorities from each country have supplied a summary of their assessments for incorporation in this report. The data requested by the NEA comprise average and peak values of the total deposition of the principal radionuclides, estimates of individual and collective doses resulting from the first year of exposure/intake following the accident, and the effectiveness of any countermeasures taken to reduce doses. The degree of sophistication of the dose assessment provided to the NEA by each Member country depends, to a large extent, on the levels of contamination measured. Most European countries have provided detailed information for a range of nuclides and exposure pathways, whereas countries where low contamination has been observed (particularly those where the levels of activity in many foods were below detection limits) have provided only upper-bounds or qualitative statements. These dose estimates and deposition data are summarised and discussed in this chapter. A more detailed presentation of the information supplied is provided in Appendix 1. Since these assessments are progressively updated as more information becomes available, the dose estimates discussed in this chapter may not represent final evaluations; they are the best that each country could provide at this stage, based on existing information.

The dose estimates supplied by the Member countries are discussed in this chapter in the following order: collective doses; average individual doses; and individual doses to members of the critical-groups. Although it is more usual to present individual doses before collective doses, the order has been reversed here for the following reasons. Firstly, the NEA did not ask Member countries explicitly to provide average individual doses: therefore, the average doses given in this report have simply been inferred from the collective doses and population sizes. Secondly, the different sets of dose estimates have been calculated independently by each Member country: therefore, there is little uniformity in the assumptions used in the calculations. This makes the intercomparison of the doses difficult, since some apparent differences in the radiological impact of the accident on Member countries are due, in fact, to the adoption of different calculational procedures. Although these differences exist for all the dose estimates, they are particularly pronounced in the calculation of the critical-group individual doses. For these, in fact, not only are different dosimetric assumptions made in the calculations, but also the definition of what constitutes the critical group is very different between countries. Therefore, in order to enable some perspective immediately to be given to the relative impact experienced by Member countries, the collective and average doses are presented first.

3.2. Deposition Levels of Caesium and Iodine

The cloud of radionuclides released from the Chernobyl reactor contained many different fission products and actinides. Although trace quantities of many of these nuclides were detected in most Member countries, only a few nuclides were found in quantities which were radiologically significant. The three most important nuclides, for OECD Member countries, were iodine-131 and the two caesium isotopes, caesium-134 and caesium-137. These nuclides were present in the cloud at relatively high levels. Once deposited on the ground, they are quickly incorporated into foodchains. Deposited radiocaesium also provides a long-term source of direct gamma irradiation. Therefore, the levels of deposition of these three nuclides give a good indication of the radiological impact of the release on each Member country.

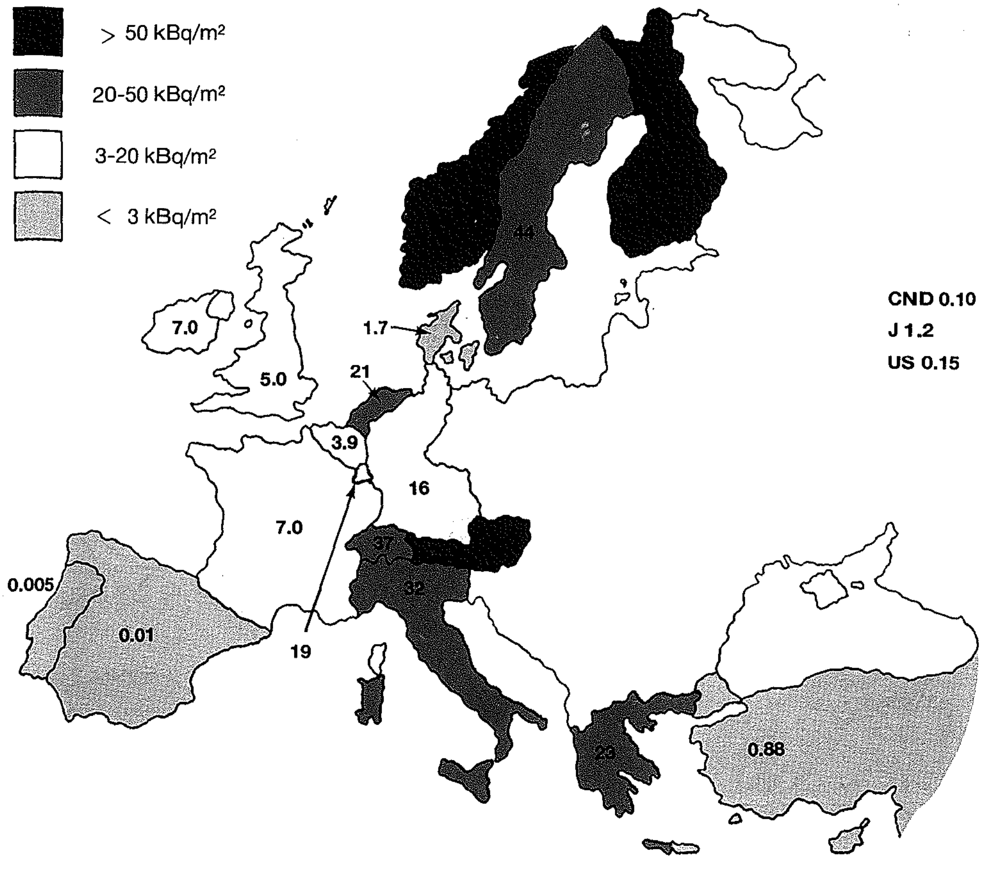
The two isotopes of radiocaesium behave very similarly in the environment and the dose delivered from the ingestion of each of them is very similar. Therefore, the deposition levels are given as those for caesium-134 and caesium-137 combined (*total caesium*), and for iodine-131 separately. The **average** levels of the total deposition (integrated deposition over the whole duration of the release) of iodine-131 and total caesium, for each Member country, are listed in Table 3.1 and shown in Figures 4 and 5. In Table 3.1 the Member countries are listed in order of decreasing average levels of caesium deposition; with a few

Table 3.1. **Average Levels of Total Deposition Following the Accident**

Country[a]	Approximate Distance from Chernobyl (km)	Average Deposition (kBq/m^2)[b]	
		Total Caesium[c]	Iodine-131
Austria	1 000-1 500	23	120
Norway	1 500-2 500	11	77
Finland	1 000-2 000	9.0	51
Sweden	1 000-2 000	8.2	44
Switzerland	1 500-2 000	8.0	37
Italy	1 500-2 500	6.5	32
FRG	1 000-1 500	6.0	16
Greece	1 000-2 000	5.3	23
Ireland	2 500-3 000	5.0	7.0[d]
Luxembourg	1 500	4.0	19
Netherlands	1 500-2 000	2.7	21
France	1 500-2 500	1.9	7.0
Denmark	1 000-1 500	1.7	1.7
UK	2 000-2 500	1.4	5.0
Belgium	2 000	1.3	3.9
Japan	9 000	0.13	1.2
Turkey	1 000-2 000	0.08	0.88
US	8 000-12 000	0.04	0.15
Canada	6 000-13 000	0.04	0.10
Spain	2 500-3 500	0.004	0.010
Portugal	3 000-3 500	0.003	0.005
Iceland	3 000-3 500	small	small
Australia	16 000	N.D.[e]	N.D.[e]

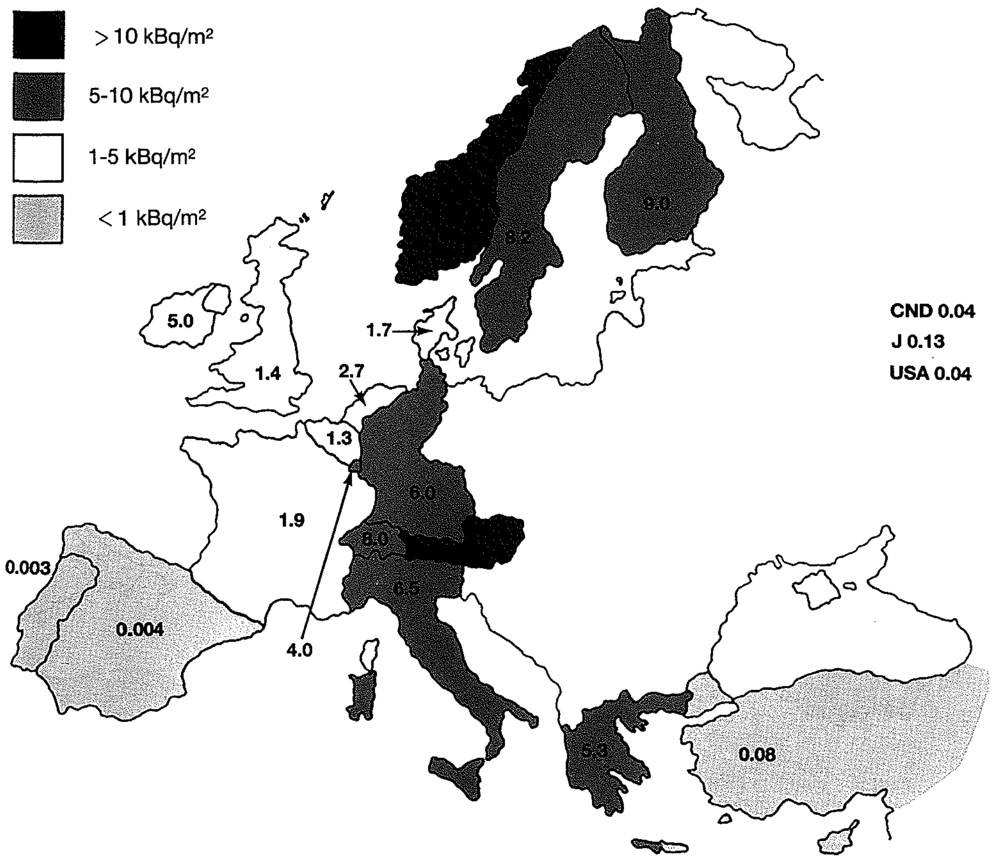
a) Countries are listed in order of decreasing average deposition of total caesium.
b) All values are given to two significant figures.
c) Caesium 137 + caesium 134.
d) Based on a limited number of measurements.
e) N.D. = Not Detected.

Figure 4. · **AVERAGE VALUES OF THE TOTAL DEPOSITION OF IODINE-131 FOLLOWING THE ACCIDENT (kBq/m²)**



exceptions, the order for the average levels of iodine-131 deposition is the same. A very approximate indication of the distance of each country from Chernobyl is also given in Table 3.1. It is clear that, although the distance of a Member country from Chernobyl has influenced these deposition levels, it was by no means the overriding factor. As discussed in the introduction to this chapter, the complex meteorological conditions experienced by the cloud, particularly the occurrence of heavy rain, were very significant in determining the relative levels of deposition. Those countries, such as Austria and some Nordic countries, which experienced very heavy rainfall whilst the cloud was overhead have recorded the highest levels of deposition. Belgium and Denmark recorded lower levels of deposition and also relatively little rainfall. Even so, the average deposition levels of total caesium and iodine reported by all Member countries in Europe, with the exception of Spain and Portugal, vary by little more than two orders of magnitude. The low deposition levels in Spain and Portugal

Figure 5. **AVERAGE VALUES OF THE TOTAL DEPOSITION OF CESIUM 137 + 134 FOLLOWING THE ACCIDENT (kBq/m²)**



reflect the fact that the main body of the radioactive cloud did not disperse further westwards than the east coast of Spain before turning north, through France. Perhaps surprising are the relatively high levels, of deposition reported by Japan; there, the average deposition of iodine-131 has been reported as being similar to the value reported by the Denmark. This too is likely to have been caused by rainfall.

In Table 3.2, the **maximum** recorded total depositions (integrated over the whole duration of the release) of the nuclides considered are given, with the countries ordered in decreasing levels of maximum total caesium deposition. This ordering is not identical with that found for the average deposition levels, but generally the same trends are present. Austria, the Federal Republic of Germany, Italy and the Nordic countries recorded the highest levels of deposition, whilst Spain, Portugal and the non-European OECD countries recorded

Table 3.2. **Maximum Values of Total Deposition Following the Accident**

Country[a]	Maximum Deposition (kBq/m²)[b]		Ratio of Maximum to Average Deposition	
	Total Caesium[c]	Iodine-131	Total Caesium	Iodine-131
Sweden	190	950	23	22
Norway	>100	not given	>9	–
Italy	100	~500	~15	~16
FRG	65	160	11	10
Austria	~60	700	~2.6	5.8
Switzerland	41	180	5.1	4.9
Finland	~30	190	~3.3	3.7
Greece	28	60	5.3	2.6
Ireland	22	16	4.4	2.3
UK	20	40	14	8.0
Netherlands	~9	26	~3.3	1.2
France	7.6	not given	4.0	–
Luxembourg	7.3	~40	1.8	~2.1
Denmark	4.6	4.2	2.7	2.5
Belgium	3.0	10	2.3	2.6
Turkey	0.90	8.0	11	9.1
Japan	0.41	3.8	3.2	3.2
Iceland	0.10	small	–	–
Canada	0.065	0.24	1.5	2.4
Spain	0.041	0.09	10	9
Portugal	0.012	0.013	4	2.6
US	small	>1.9	–	>13
Australia	N.D.[d]	N.D.[d]	–	–

a) Countries are listed in order of decreasing maximum deposition of total caesium.

b) All values are given to two significant figures.

c) Caesium 137 + caesium 134.

d) N.D. = Not Detected.

very low peak levels. Japan recorded the highest levels outside Europe, as was the case for the average levels. The range of variation of the levels of total deposition in Europe, with the exception of Spain and Portugal, is again spanning about two orders of magnitude for both total caesium and iodine-131. This is almost entirely due to differences in the intensity of rainfall experienced in each Member country.

The ratios of peak deposition levels of each nuclide to the average deposition values are also given in Table 3.2 for each Member country. The variation is marked; for many countries the peak levels are no more than a few times the average levels, whilst for a few, Italy, Sweden and the United Kingdom in particular, the range of deposition is very large. This inhomogeneity of deposition is reflected in the differences between the average and critical-group individual doses discussed later in this chapter.

In order to provide some perspective on the deposition levels listed in Tables 3.1 and 3.2, some values for the cumulative deposition of caesium-137 following fallout from the nuclear weapon tests in the atmosphere are listed in Table 3.3. Within the northern

Table 3.3. **Cumulative Caesium-137 Deposition from Nuclear Weapon Tests Fallout in Some OECD Countries**

Country	Cumulative Deposition (kBq/m^2)	Reference
Austria	5.2	[1]
Denmark	2.6	[2]
Finland	1.9	[3]
Italy	5.6	[4]
UK	4.1	[5]
Northern Hemisphere	2.9	[6]
Southern Hemisphere	0.90	[6]

References:

[1] Umweltbundesamt, *Tchernobyl und die folgen für Osterreich*, Vorläufiger Bericht, novembre, 1986.

[2] Aarkrog A. et al., *Environmental Radioactivity in Denmark in 1984*, Risø-R-527, 1985.

[3] Paakola O., *Radioactivity of the Environment in Finland after the Chernobyl Accident*, Finnish Centre for Radiation Protection and Nuclear Safety, Helsinki, 1986.

[4] ENEA, *L'incidente di Chernobyl: fatti e considerazioni*, Rome, 1986.

[5] Cambray R.S. et al., *Radioactive Fallout in Air and Rain: Reports from 1962 to 1982*, Harwell, UKAEA, AERE Reports (1962-1984).

[6] UNSCEAR, *Ionizing Radiation: Sources and Biological Effects*, 1982 Report to the General Assembly of the United Nations, New York, 1982.

hemisphere, this deposition has been fairly uniform, decreasing slightly with increasing latitude. An average value for the northern hemisphere of about 3 kBq/m^2 has been estimated by UNSCEAR [5]. Generally, the deposition of caesium-134, following the accident at Chernobyl, was approximately half that of caesium-137. Therefore, comparing Table 3.3 with Table 3.1, it appears that most countries within Europe (with the exception of Spain and Portugal) experienced similar levels of deposition of total caesium to those resulting from fallout from nuclear weapon tests. However, in Austria and the Scandinavian countries the total deposition from the Chernobyl release was higher, by a factor of three or four, than that due to fallout from nuclear weapon tests. Member countries outside Europe received much less deposition of total caesium from the accident than from the weapon tests fallout.

3.3. Estimated Doses

3.3.1. *Assumptions used in the dose assessments*

The main dose pathways following the accident at Chernobyl, for OECD Member countries, have been direct gamma irradiation from the cloud (*cloud-γ*), inhalation of activity in the cloud (*inhalation*), gamma irradiation from activity deposited on the ground (*deposited-γ*), and ingestion of contaminated foods (*ingestion*). In order to use measurements of the concentration of important nuclides in the environment to estimate the individual and collective doses delivered through each of these pathways, a number of assumptions have to be made which can significantly influence the magnitude of the calculated doses. The principal assumptions are briefly summarised here; a more complete discussion is provided in Appendix 1.

The first decision that must be made is which radionuclides are contributing most of the dose from each pathway and, therefore, which nuclides will be considered in the dose assessment. Although the importance of iodine-131 and the two caesium isotopes, caesium-137 and caesium-134, was generally recognised, the account taken of other nuclides varied significantly between Member countries. This had implications, particularly, for the inhalation and cloud-γ pathways.. However, because, for most Member countries, the dose is estimated to have been dominated by the ingestion and deposited-γ pathways, the omission of nuclides other than iodine-131 and caesium will not have affected the total doses by more than a few tens of percent.

There are other decisions that have a more profound influence on the doses calculated, because they concern the deposited-γ and ingestion pathways. One set of assumptions concerns shielding effects and the resultant reduction in dose. The dose from external irradiation can be reduced by the shielding of buildings (and other surface features); if this reduction is taken into account, a value must be assigned to the efficiency of the shielding and also to the fraction of time for which an individual benefits from this shielding (usually taken to be time spent indoors). The dose from inhalation, too, can be reduced by the filtering effect of buildings, and again shielding and occupancy factors can be used to estimate the resultant reduction in dose. The reductions achieved are likely to vary between Member countries, because of the different building practices and social habits. However, the reductions assumed in the calculations are not necessarily chosen to be strictly representative; in particular, an upper-bound in dose can be calculated by ignoring the shielding afforded by buildings. The factors used in the dose estimates provided in this report range from about 0.1 (i.e., 90 per cent of the external dose removed) to 1 (i.e., no reduction considered). Thus, a factor of ten difference has been introduced into the calculated contribution of the deposited-γ (and, less importantly, inhalation) pathway to the total dose estimated by different countries.

For estimating the dose from ingestion, another set of assumptions is made. The range of foods to be considered and the amount of each food consumed by individuals need to be determined, as well as any reduction in the contamination of the food owing to preparation losses. Each of these aspects of dietary habits may actually be significantly different amongst countries, in which case the resultant differences in the calculated doses are true reflections of varying radiological consequences. However, different assumptions have also been introduced for other reasons, such as lack of data, slightly differing definitions of population groups or a need to simplify the calculational procedure. For example, mos Member countries have assumed milk to be the only significant ingestion pathway for infant (considering a *standard* infant about 6 months old), whereas the *standard* infant considere in the United Kingdom (average age 1 year) is assumed to have begun eating a range o foods, which leads to the calculation of a higher dose. Another consideration which ha resulted in the calculation of different doses is the weight which has been given to the impor and export of foodstuffs. For some countries (e.g., Greece), the importation of contaminate food is estimated to have had a significant impact on the doses. Because it is difficult t distinguish real differences in dietary habits from other assumptions, it is difficult to estimat the influence these other assumptions have had on the doses; it is likely that they hav resulted in factors of at least 2 or 3 between doses estimated by various countries.

Once radionuclides are taken into the body (whether by ingestion or inhalation), dose factors are required to convert this intake into dose. Although these dose factors are calculated using sophisticated models of human metabolism, assumptions are required in the models. Consequently, the dose factors used by Member countries are not identical. In particular, the most significant influence on the range of doses given in this report derives from the use of different sets of factor values for caesium intake in children and infants; the factors based on ICRP Publication No. 30 [6] are 2-5 times higher for these age-groups than those based on more recent models which take into account the higher metabolic rate of very young children [7, 8].

Finally, there is the problem of the variation of dose with time. Owing to its short half-life (8.5 days), the dose from iodine-131 (from all pathways) was almost completely delivered within weeks of the accident. Therefore, measurements of the environmental concentrations of this nuclide during May and June 1986 are sufficient, in principle, to calculate the full dose received by individuals in each Member country. On the contrary, the dose from caesium-137 will be delivered over a period of many years (albeit at a rapidly decreasing rate), both from ingestion and deposited-γ. Since definitive environmental measurements cannot yet be available, it is necessary to make assumptions concerning the time variation of the concentration of caesium-137 in the environment and, hence, the future exposure. There are a variety of ways of addressing this problem: the future dose can be ignored, or the environmental concentrations can be assumed to fall, remain constant or rise after a certain date according to a simple relationship, or models can be used to predict the future behaviour of caesium in the environment. The various approaches used by the Member countries for this review encompass all of these assumptions.

Collectively, these possible different assumptions can result in the estimation of dose values which are very dissimilar, even using the same set of environmental concentrations. Fortunately, many of the assumptions adopted by Member countries for the present assessment are, in fact, fairly similar. For example, most Member countries have used a shielding/occupancy factor of about 0.3 for calculating the reduction in dose from deposited-γ. However, there are some significant discrepancies, particularly with regard to the diet and range of foods considered. It is important to recognise these differences in calculational procedures when comparing the dose estimates; differences by factors of 2 or 3 need not imply a significant dissimilarity in the radiological impact experienced.

3.3.2. *Collective dose estimates*

Collective effective and collective thyroid dose equivalents committed by the first year of exposure/intake following the accident have been calculated by each Member country for three representative age-groups. These age-groups are *infants* (assumed by most Member countries to be 0-1 year old), *children* (the average age assumed by most countries lies between 5 and 10 years) and *adults* (generally assumed to be young adults of about 20 years in age). The collective dose estimates take account of the reductions in dose achieved by any countermeasures taken. The collective effective dose equivalents for each age-group and countries are listed in Table 3.4. Since the collective dose is strongly influenced by both population size and the amount of deposition, the countries are listed in alphabetical order. The corresponding collective thyroid dose equivalents are listed in Table 3.5. The populations of each Member country are also given in the Tables as an aid to interpreting the doses. As discussed in the previous section, undue significance should not

Table 3.4. **Collective Effective Dose Equivalent Estimates for the First Year[a]**

Country[b]	Population $(\times 10^6)$	Collective Effective Dose Equivalent (man Sv)[c,d]			
		Total	Infants	Children	Adults
Australia	16	–	–	–	–
Austria	7.4	4 900	42	490	4 400
Belgium	10	400	22	85	290
Canada	25.5	63	0.49	8.4	54
Denmark	5.2	140	4.9	27	110
Finland	4.9	2 500	44	320	2 100
France	55	1 300	67	280	920
FRG	61	18 000	4 000[e]		14 000
Greece	9.8	3 600	48	630	3 000
Iceland	0.24	small		small	
Ireland	3.5	370	55	37	280
Italy[f]	56.6	28 000	300	4 100	23 000
Japan	120	780	17	160	600
Luxembourg	0.37	45	0.50	4.7	40
Netherlands	14.5	950	40	150	750
Norway	4.2	700	72	130	500
Portugal	9.3	58	2.0	12	44
Spain[g]	37.7	not assessed		not assessed	
Sweden	8.3	1700	33	160	1 500
Switzerland	6.5	1 400	13	130	1 300
Turkey	52	830	20	150	660
UK[h]	56.6	2 100	120	510	1 800
US	239	not assessed		not assessed	
Grand Total	~795	~68 000	~12 000[e]		~55 000

a) These estimates do not generally include the possible contributions from consumption of imported contaminated food.
b) Countries are listed in alphabetical order.
c) These doses are the sum of doses received from external exposure and doses committed from the intake of radionuclides in the period May 1986-April 1987.
d) All doses are given to two significant figures.
e) Total for infants and children.
f) The dose estimates are average values between independent evaluations made by two different national bodies.
g) Owing to the low deposition levels observed, it was not considered useful to calculate collective doses.
h) The sum of collective doses for the different age groups does not equal the total collective dose given in the table, for the reasons given in Appendix 1.

be attributed to factors of two or three difference between dose estimates. The total collective effective dose equivalent to the population of OECD Member countries arising from exposure/intake during the first year following the accident (May 1986–April 1987) is estimated to be about 70 000 mansieverts. The total collective thyroid dose equivalent for the same period is estimated to be about 300 000 mansieverts. Although the influence of the size of the population on the collective doses is clear from the Tables, the impact of the variation of deposition between countries is also evident (compare, for example, the collective effective doses for the United Kingdom and Italy).

Table 3.5. **Collective Thyroid Dose Equivalent Estimates for the First Year**

Country[a]	Population (x 10^6)	Collective Thyroid Dose Equivalent (man Sv)[b,c]			
		Total	Infants	Children	Adults
Australia	16	–	–	–	–
Austria	7.4	17 000	680	2 600	14 000
Belgium	10	3 100	190	820	2 100
Canada	25.5	95	6.8	45	43
Denmark	5.2	330	18	75	240
Finland	4.9	4 500	130	900	3 400
France	55	7 400	670	2 100	4 600
FRG	61	91 000	33 000[d]		58 000
Greece	9.8	27 000	760	8 000	19 000
Iceland	0.24	small	small		
Ireland	3.5	1 800	810	250	790
Italy[e]	56.6	120 000	2 400	28 000	85 000
Japan	120	8 200	210	2 400	5 600
Luxembourg	0.37	160	3.7	31	120
Netherlands	14.5	5 800	350	1 300	4 100
Norway	4.2	1 900	78	160	1 600
Portugal	9.3	150	9.0	43	100
Spain[f]	37.7	not assessed	not assessed		
Sweden	8.3	3 500	57	410	3 000
Switzerland	6.5	8 500	120	1 400	7 000
Turkey	52	5 300	310	1 800	3 300
UK[g]	56.6	11 000	1 900	5 300	9 400
US	239	3 000	not assessed		
Grand Total	~ 795	~ 320 000	~ 97 000[d]		~ 220 000

a) Countries are listed in alphabetical order.

b) These doses are the sum of doses received from external exposure and doses committed from the intake of radionuclides in the period May 1986-April 1987.

c) All doses are given to two significant figures.

d) Total for infants and children.

e) The dose estimates are average values between independent evaluations made by two different national bodies.

f) Owing to the low deposition levels observed, it was not considered useful to calculate collective doses.

g) The sum of collective doses for the different age groups does not equal the total collective dose given in the table, for the reasons given in Appendix 1.

The ratios between the collective thyroid dose equivalent and collective effective dose equivalent estimates, for each age-group, are listed in Table 3.6. Here a marked variation is apparent. The ratios for the total doses range from about 2 for Canada, Denmark, Finland and Sweden, to 11 for Japan. Presumably, some of the differences are due to the variety of levels of caesium and iodine-131 deposition throughout Member countries and, more significantly, to the variability of the countermeasures taken by the countries. For example, in the absence of countermeasures and assuming an all-milk diet for infants, the rate of thyroid or effective collective dose would be expected to be about an order of magnitude higher for infants than for adults. This is clearly what appears in the case of

Table 3.6. **Ratio of Collective Thyroid Dose Equivalents to Collective Effective Dose Equivalents, for Doses in the First Year**

Country[a]	Ratio			
	Total	Infants	Children	Adults
Australia	–	–	–	–
Austria	3.5	16	5.4	3.2
Belgium	7.8	8.5	9.7	7.1
Canada	1.5	14	5.4	0.8
Denmark	2.4	3.7	2.8	2.3
Finland	1.8	3.0	2.8	1.6
France	5.8	10	7.6	5.0
FRG	5.1	8.3[b]		4.1
Greece	7.6	16	13	6.4
Iceland	–	–	–	–
Ireland	5.0	15	6.7	2.8
Italy	4.2	8.0	6.9	3.7
Japan	11	12	15	9.3
Luxembourg	3.6	7.4	6.6	3.2
Netherlands	6.1	8.8	8.8	5.5
Norway	2.6	1.1	1.2	3.1
Portugal	2.7	4.5	3.6	2.3
Spain	–	–	–	–
Sweden	2.1	1.7	2.5	2.0
Switzerland	6.1	9.3	11	5.5
Turkey	6.4	16	12	5.0
UK	5.2	16	10	5.2
US	–	–	–	–

a) Countries are listed in alphabetical order.
b) Average for infants and children.

Canada. On the other hand, for those countries which undertook specific countermeasures to reduce the dose to infants (e.g., milk bans or advice for infants to be fed from powdered milk), this difference in the ratio between infants and adults has been strongly reduced (e.g., in Finland, Italy, Switzerland). However, the ratio is also fairly similar for other countries where countermeasures were not taken, for example Denmark and Japan. It is clear that differing assumptions regarding diet and the modelling of future doses have also had an important influence on the doses calculated.

3.3.3. *Average individual dose estimates*

The NEA did not ask Member countries to provide average individual dose estimates directly. Instead, indicative average individual doses have been derived from the collective dose estimates. These indicative individual doses were obtained for each country by dividing the total collective dose by the population of the country; no account was taken of the age structure of the population. They are, therefore, not strictly applicable to any particular age-group, but are, however, good indicators of the radiological impact of the accident at Chernobyl on the majority of individuals in each Member country. The average individual effective dose equivalents resulting from exposure/intake during the first year following the accident are listed in Table 3.7, with the countries ordered in terms of decreasing average total caesium deposition. They are also shown in Figure 6. The doses range from a few microsieverts or less for Spain, Portugal and most of the countries outside of Europe, to about 0.7 millisieverts for Austria. Generally, the doses correspond in relative magnitude to the amount of caesium deposition. Deviations from this are likely to be due to three major causes: the relative location of areas of higher deposition in relation to the population and agricultural land (this is particularly significant in countries such as Norway where much of the land is not heavily exploited); the countermeasures taken to reduce exposures (for

Table 3.7. **Average Individual Effective Dose Equivalent Estimates for the First Year**

Country[a]	Average Individual Effective Dose Equivalent (mSv)[b,c]	Percentage Pathway Contribution (%)			
		Inhalation	Deposited-γ	Ingestion	Cloud-γ
Austria	0.65	7	19	74	< 1
Norway	0.17	not assessed			
Finland	0.50	3	25	72	< 1
Sweden	0.20	5	47	47	< 1
Switzerland	0.22	2	23	74	< 1
Italy[d]	0.49	7	17	77	< 1
FRG	0.30	12	47	40	1
Greece	0.37	15	7	78	< 1
Ireland	0.11	< 1	14	84	< 1
Luxembourg	0.12	8	29[e]	63	–
Netherlands	0.066	7	53	40	< 1
France	0.023	–	30[e]	70[f]	–
Denmark	0.027	3	7	91	< 1
UK	0.037	3	14	82	< 1
Belgium	0.040	35	46	18	< 1
Japan	0.0065	13	68	19	< 1
Turkey	0.016	3	30	65	3
US	not assessed	not assessed			
Canada	0.0025	1	38	60	< 1
Spain[g]	not assessed	not assessed			
Portugal	0.0062	–	–	100	–
Iceland	< 0.001	not assessed			
Australia	–	–	–	–	–

a) Countries are listed in order of decreasing average total caesium deposition.

b) These doses are calculated by dividing the total collective effective dose equivalents given in Table 3.4 by the respective populations. They take no account of the age structure of each population, and so should not be applied to a particular age-group.

c) All doses are given to two significant figures.

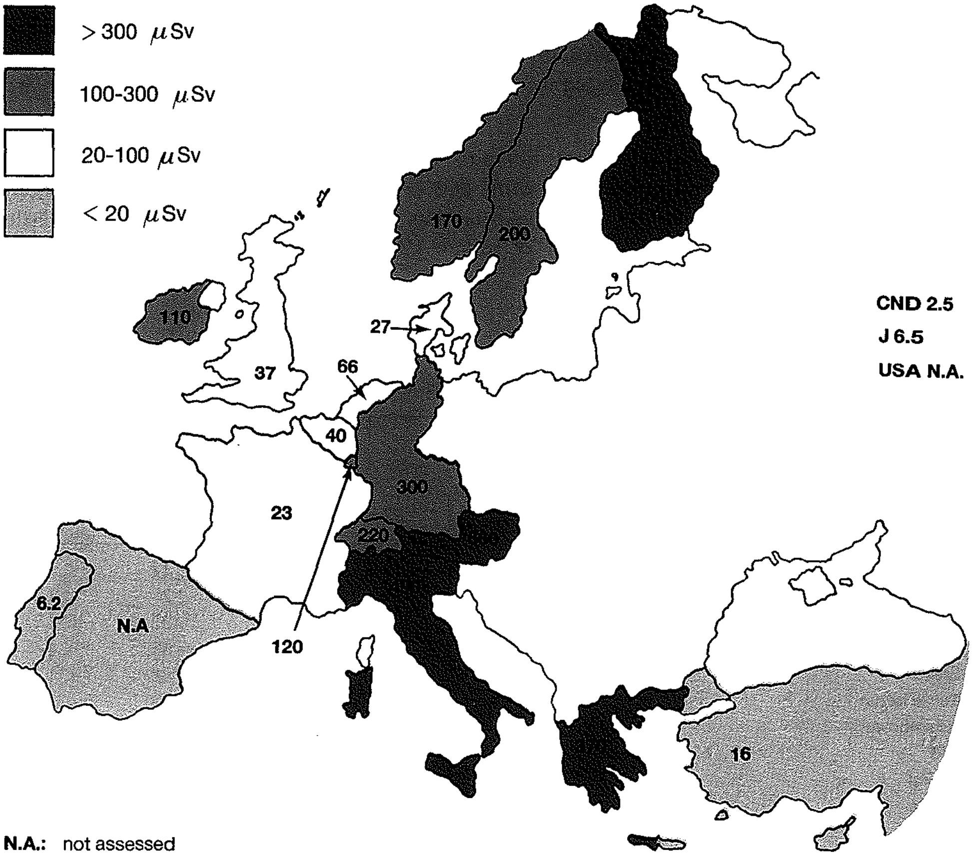
d) The dose is estimated from the average value between independent collective dose evaluations made by two different national bodies.

e) Includes the contribution from cloud-γ

f) Includes the contribution from inhalation.

g) Owing to the low deposition levels observed, it was not considered useful to calculate collective doses. Therefore, no average dose estimate is given.

Figure 6. **AVERAGE INDIVIDUAL EFFECTIVE DOSE EQUIVALENTS (microsieverts)**



example, Austria, Norway and the Federal Republic of Germany estimate they achieved a considerable dose-saving); and differences in the assumptions underlying the dose calculations.

The percentage pathway contributions to the average individual effective dose equivalents are also listed in Table 3.7. Generally, ingestion and external gamma irradiation from deposited material (deposited-γ) are considered to be the dominant pathways, although the relative importance of each of these pathways varies considerably between Member countries. Whether or not countermeasures were implemented within a country will obviously have a significant impact on the relative contributions of the various pathways (i.e., in most instances the countermeasures taken will have reduced the ingestion dose). However, this is clearly not the sole factor influencing the relative contribution of each pathway. For example, Belgium and Japan took no special countermeasures, but the contribution of ingestion to the estimated average effective dose equivalent is much less than that from deposited-γ for both these countries. Such dissimilarities are likely to be due to different assumptions adopted in the calculations. This is shown clearly in the relative contributions of the inhalation pathway for Belgium and cloud-γ pathway for Turkey, respectively: these are very much higher than for other countries. Some discrepancies are explained in Appendix 1.

The corresponding individual average thyroid dose equivalents are given in Table 3.8, with the countries ordered in terms of decreasing average iodine-131 deposition. Again, the percentage pathway breakdown is also given. For these doses, there is little correspondence between the amount of iodine-131 deposition and the dose. This is

Table 3.8. **Average Individual Thyroid Dose Equivalent Estimates for the First Year**

Country[a]	Average Individual Thyroid Dose Equivalent (mSv)[b,c]	Percentage Pathway Contribution (%)			
		Inhalation	Deposited-γ	Ingestion	Cloud-γ
Austria	2.3	37	6	57	< 1
Norway	0.43	not assessed			
Finland	0.92	68	< 1	32	< 1
Sweden	0.42	53	23	23	< 1
Switzerland	1.3	14	4	82	< 1
Italy[d]	2.0	17	3	81	< 1
Greece	2.8	11	1	88	< 1
Netherlands	0.40	27	10	63	< 1
Luxembourg	0.43	29	< 1	71	< 1
FRG	1.5	40	9	51	< 1
Ireland	0.52	3	< 1	97	< 1
France	0.13	–	< 1	100[e]	< 1
UK	0.19	8	3	89	< 1
Belgium	0.31	80	7	13	< 1
Denmark	0.064	33	3	65	< 1
Japan	0.068	41	6	53	< 1
Turkey	0.10	12	6	81	< 1
US	0.013	–	–	100	–
Canada	0.0037	17	< 1	83	< 1
Spain[f]	not assessed	not assessed			
Portugal	0.017	–	–	100	–
Iceland	small	not assessed			
Australia	–	–	–	–	–

a) Countries are listed in order of decreasing average iodine-131 deposition.

b) These doses are calculated by dividing the total collective thyroid dose equivalents given in Table 3.5 by the respective populations. They take no account of the age structures of each population, and so should not be applied to a particular age-group.

c) All doses are given to two significant figures.

d) The dose is estimated from the average value between independent collective dose evaluations made by two different national bodies.

e) Includes inhalation.

f) Owing to the low deposition levels observed, it was not considered useful to calculate collective doses. Therefore, no average dose estimate is given.

probably because countermeasures to reduce thyroid doses from ingestion of iodine-131 (such as milk and leafy vegetable bans) were relatively simple and, being short-term, they were cheap to implement. However, variations in the calculational procedures adopted are also apparent, particularly with respect to the estimates of percentage contributions from each of the major pathways. For example, most Member countries estimated the contribution from deposited- γ to be small, whereas the contribution by this pathway to the total dose for Sweden was estimated to be nearly one quarter. Similarly interesting is the range of contributions estimated for inhalation; there is clearly no consensus in the calculational procedures used for this pathway. Some of these differences are discussed in Appendix 1.

In considering these individual dose estimates, it should be recognised that they are based on measured environmental concentrations, assumed dietary habits, and models of the behaviour of radionuclides in the environment and in man. The results of recent large-scale whole-body measurement programmes in some countries indicate that the dose estimates provided in this report may be a little high. This is not surprising, for a number of reasons. For example, there is a natural tendency, when calculating *best estimate* doses, to err slightly on the cautious side, in order to avoid under-estimating doses. Another reason is that the theoretical evaluations based on food concentrations and assumed intake rates cannot take into account the changes many people made to their dietary habits in the first few months following the accident. When these whole-body measurement programmes have been completed, it is likely, therefore, that several OECD Member countries will revise their average individual dose estimates downwards; it is not expected that any country will revise these dose estimates upwards.

The collective and average individual effective doses given in Tables 3.4 and 3.7 can be put into perspective with other sources of radiation exposure of the population. For example, the average individual effective dose received by citizens of Europe each year from exposure to natural background radiation is about 2 millisieverts. The fluctuations of the annual dose around this average are extremely large throughout Europe, with the actual values varying by more than an order of magnitude. The collective effective dose equivalent to the whole population of the European OECD countries from natural background radiation is of the order of 800 000 mansieverts per year.

3.3.4. *Critical-group individual dose estimates*

Although the calculation of average individual and collective doses involved many assumptions which led to differences in dose estimates between Member countries of probably factors of 3 or so, thus making it necessary to use caution when comparing the doses, the influence of the assumptions made on the estimates of critical-group doses is far greater. The most important assumption is the definition of the critical group, and a wide range of definitions has been used here. Some Member countries have identified a real subset of their population as being more highly exposed, and performed the calculations using the known habits and situation of these people. Such critical-group estimates are deemed to be *best estimates.* Other Member countries have defined a theoretical critical group with extreme habits and exposure. It is unlikely that any such highly exposed individuals exist in practice, and so the doses calculated represent a deliberate over-estimate of the highest doses received. Such theoretical dose calculations are useful in situations where the most highly exposed group of individuals is not easily identified and the theoretical dose can be shown to be of no concern. However, it is not usually appropriate to compare this kind of theoretical dose directly with critical-group doses based on a known group of individuals.

The intercomparison of the *realistic* critical-group doses also requires some qualification. The size of population group chosen for a given critical group can have a very strong influence on the doses calculated. The choice of a very small group comprising a few highly exposed individuals will enable the calculation of doses which are representative of the exposure of all the individuals within that group. The disadvantage is that a large number of such small, highly exposed groups may exist, each with slightly different habits, and it may be difficult to identify the group most at risk without performing separate calculations for each group. The choice of a larger critical group can overcome this problem, with the drawback that the habits and exposures of the individuals within the group will be more inhomogeneous. The critical-group doses calculated using this group will therefore tend to be representative of the average doses in a large group rather than to be true *critical*-group

Table 3.9. **Critical Group Individual Effective Dose Equivalent Estimates for the First Year[a]**

Country[b]	Critical Group Effective Dose Equivalent (mSv)[c,d]			Assumed Critical Group
	Infants	Children	Adults	
Sweden	2.3	2.6	2.5	Identified Group of 2 000-4 000
Norway	2.5	2.3	2.1	Not Known
Italy	3.2	3.2	2.6	Hypothetical Group
FRG	1.2	0.8	0.8	Identified Group of 200 000
Austria	0.82	0.98	1.2	Identified Group of 200 000
Switzerland	1.4	1.7	2.0	Identified Group of 10 000
Finland	0.92	0.93	0.95	Identified Group of 670 000
Greece	0.27	0.44	0.36	Whole Population
Ireland	0.37	0.32	0.32	Hypothetical Group
UK	1.2	1.1	1.0	Hypothetical Group
Netherlands	0.16	0.10	0.06	Whole Population
France	0.21	0.087	0.049	"East France"
Luxembourg	0.12	0.12	0.12	Whole Population
Denmark	0.081	0.050	0.023	Whole Population
Belgium	0.26	0.20	0.12	Hypothetical Group
Turkey	0.19	0.12	0.081	Identified Group of 40 000
Japan	0.057	0.038	0.020	Hypothetical Group
Iceland	not assessed			Not assessed
Canada	0.0042	0.0053	0.0066	Residents in Vancouver
Spain	0.071	0.053	0.034	Hypothetical Group
Portugal	0.030	0.020	0.010	Hypothetical Group
US	0.020	0.0050	0.0050	Residents in Washington State
Australia	–	–	–	–

a) These estimates do not generally include the possible contribution from consumption of imported contaminated food.

b) Countries are listed in order of decreasing maximum total caesium deposition.

c) These doses are the sum of the doses received from external exposure and doses committed from the intake of radionuclides in the period May 1986-April 1987.

d) All doses given to two significant figures.

doses. It is important to bear these points in mind when considering the critical-group individual dose estimates provided by each Member country.

The committed effective dose equivalents to individuals of the critical group resulting from exposure/intake during the first year following the accident (May 1986–April 1987) are listed in Table 3.9, for each age-group. The effect of any countermeasures introduced by countries is taken into account in these dose estimates. Also indicated on the Table are the assumptions made regarding the nature of the critical group: whether hypothetical, real small group or real large group. The countries are ordered in terms of decreasing maximum total caesium deposition. The doses fall into at least two distinct groups: those with values of about 1 mSv or more, and those with values of about 0.1 mSv or less. Generally, those countries which recorded the highest caesium deposition also estimated the highest critical group doses. There is no uniformity in the relative sizes of the doses predicted for each age-group; this is due both to the influence of the countermeasures and to differences in the assumed habits of each age-group. However, for no country is the maximum difference in dose between age-groups greater than a factor of four, and, for the most part, this factor is only about two or less.

The contributions to the critical-group individual doses by different pathways and nuclides are listed in Table 3.10. There is general agreement concerning the contributions of

Table 3.10. **Contributions by Pathway and Nuclide to the Critical Group Individual Dose Estimates for the First Year**

A) Percentage Pathway Contribution (%)

Pathway	Age Group		
	Infants	Children	Adults
Cloud-γ	$< 1^a$	$< 1^a$	$< 1^b$
Inhalation	0-29	0-16	0-15
Deposited-γ	0-57[c]	0-88	1-88
Ingestion	32-98[d]	18-98	19-97[e]

B) Percentage Nuclide Contribution (%)

Nuclide	Age Group		
	Infants	Children	Adults
Iodine 131	8-80	5-50	4-37
Caesium 134 + 137	22-90	32-94	46-96
Other[f]	0-29	0-18	0-23

a) The contribution from cloud-γ for Ireland was 3%.
b) The contribution from cloud-γ for Ireland and Turkey was 3%.
c) The contribution from deposited-γ for Sweden was 88%.
d) The contribution from ingestion for Sweden was 11%.
e) The contribution from ingestion for the US was 5%.
f) The upper ends of the ranges are uncertain, because some countries provided no nuclide breakdown for the deposited-γ pathway; the highest percentage contribution estimates could be up to a factor of two greater than the values given here.

cloud- γ and inhalation to the total dose. However, the ranges of percentage contributions made by the two most important pathways, ingestion and deposited- γ, are very large. This is partly a reflection of the countermeasures taken in some states, and is partly due to different calculational assumptions. Similarly, for the relative contributions of nuclides, there is a consensus that iodine-131 and the two caesium isotopes are responsible for most of the dose, but there is no agreement on their relative contributions.

3.4. Effect of Countermeasures

Following the discovery of the accident at Chernobyl, a number of the OECD Member countries took actions which were intended to minimise the health impact of the accident on their population. In deciding on a given protective measure, many considerations must be taken into account, such as the economic and health impact of the countermeasure, the likely health detriment incurred by not acting, the ease with which the countermeasure can be implemented, etc. Some of these aspects are discussed in Chapters 4 and 5 of this report. However, it is interesting to consider in this Chapter the connections between countermeasures and dose-saving. Basically, a countermeasure may be taken primarily to reduce either individual dose or collective dose (although, in practice, any countermeasure will influence both). For example, a ban on leafy vegetables from a particular region within a country, which had been subject to very high deposition, is primarily a countermeasure designed to reduce the dose received by individuals living in that region. A decision to ban all

Table 3.11. **Percentage of the Collective Effective Dose for the First Year Saved by Countermeasures**

Country[a]	Percentage Saved (%)			
	Total	Infants	Children	Adults
Austria	50	53	50	50
Finland	7.2	12	11	6.3
France	very small			
FRG	30[b]	–	–	–
Greece	23	25	17	24
Italy[c]	18	53	33	15
Luxembourg	7.5	17	13	6.6
Netherlands	15	43	23	12
Norway	32	29	28	33
Sweden	15	0	3.0	17
Switzerland	1.0	50	0	0
Turkey	12	0	18	11
UK	1.0	< 1.0	1.0	1.0

a) Countries are listed in alphabetical order. Only countries where some countermeasures have been adopted are indicated.

b) Overall estimate. No information is available on dose savings for different age groups, but it is assumed that countermeasures adopted for infants and children have been fully implemented.

c) These estimates are the average values between independent evaluations made by two different national bodies.

milk with caesium concentrations above a specified low level (i.e., a level that will affect milk produced throughout a greater part of the country) is intended to reduce the collective dose received by the population of the country.

The recommendations of ICRP Publication No. 40 [9]) and IAEA Safety Series No. 72 [10] stress the primary importance of individual dose reduction in the definition of countermeasures. However, as it appears from some of the actions taken by Member countries following the accident at Chernobyl, concern was not limited to the dose to individuals of the critical groups. Competent authorities from Member countries have provided the NEA with an estimate of the doses saved by any countermeasures implemented. In considering these savings, it is interesting to observe which countries have placed importance on reducing the collective dose and which have concentrated on reducing the individual doses to those most a risk.

Estimates of percentage dose saved by the countermeasures implemented in each Member country are listed in Tables 3.11 and 3.12, for the collective effective dose equivalents and collective thyroid dose equivalents, respectively, and in Table 3.13 for the critical-group individual doses. Again, these percentage savings refer to doses resulting from exposure/intake in the first year following the accident. The dose savings for each age-group are listed. Austria, the Federal Republic of Germany and Norway estimate the highest collective effective dose savings, with a reduction in total dose between 30 per cent and 50 per cent. Austria also estimates the highest critical-group dose savings (64 per cent-80 per cent) and the highest collective thyroid dose savings (68 per cent-85 per cent).

Table 3.12. **Percentage of the Collective Thyroid Dose for the First Year Saved by Countermeasures**

Country[a]	Percentage Saved (%)			
	Total	Infants	Children	Adults
Austria	70	85	70	68
Finland	58	71	57	58
France	very small			
FRG	60[b]	–	–	–
Greece	36	39	22	40
Italy[c]	55	81	66	47
Luxembourg	38	39	39	38
Netherlands	24	30	23	23
Norway	19	28	47	14
Sweden	8.1	0	1.2	9.1
Switzerland	4.5	77	0	0
Turkey	19	0	16	22
UK	< 1	< 1	< 1	< 1

a) Countries are listed in alphabetical order. Only countries where some countermeasures have been adopted are indicated.

b) Overall estimate. No information is available on dose savings for different age groups, but it is assumed that countermeasures adopted for infants and children have been fully implemented.

c) These estimates are the average values between independent evaluations made by two different national bodies.

Table 3.13. **Percentage of the Critical-Group Individual Effective Dose for the First Year Saved by Countermeasures**

Country[a]	Percentage Saved (%)		
	Infants	Children	Adults
Austria	80	72	64
Finland	16	2.1	5.0
France	not given		
FRG	~ 50[b]		not given
Greece	25	17	23
Italy	36	27	10
Luxembourg	12	13	6.9
Netherlands	36	23	14
Norway	33	15	19
Sweden	0	1.9	2.7
Switzerland	38	0	0
Turkey	0	37	9.0
UK	14	19	23

a) Countries are listed in alphabetical order. Only countries where some countermeasures have been adopted are indicated.

b) Average for infants and children.

These high percentage dose savings for both critical-group doses and collective doses indicate that, although some countermeasures were undertaken specifically to prevent exposure to those individuals and organs most at risk, generally the countermeasures taken were not strongly biased towards this purpose. The percentage dose savings estimated by Greece, Luxembourg and the Netherlands are also similar for collective and critical-group effective doses, whilst for Sweden the percentage collective dose savings are estimated to be significantly higher than those for the critical-group individual doses. However, other Member countries, such as the United Kingdom, estimate considerably higher percentage savings for the critical-group individual doses than for the collective doses.

In considering these estimates of dose savings, attention must also be paid to the assumptions made concerning the critical group. Luxembourg and the Netherlands assumed that no one group of individuals was significantly more at risk than the general population. Therefore, the percentage dose savings for collective and individual doses would be bound to be similar. On the other hand, the United Kingdom critical group is a hypothetical group of individuals assumed to have very extreme habits and to live in areas with significantly above-average contamination. The influence of any countermeasures on such an extreme group is, therefore, likely to be far more pronounced than on the (real) general population. These observations suggest that the choice of whom to protect when introducing countermeasures is partly influenced by the pattern of the environmental contamination. Where the concentrations in the environment vary greatly throughout a country, the potential arises for one group of individuals to be significantly more at risk than the general population; in such circumstances the need to protect this critical group is clear. However, for small countries with fairly uniform environmental contamination, it would seem more useful to seek to reduce the collective dose.

3.5. Potential Health Effects

According to standard practice, an appraisal of the health detriment (number of excess cancers and cancer fatalities) which could result from the exposure of a population to a given dose can be derived by multiplying the collective dose by the *risk-factors* established by the UNSCEAR [11] and the ICRP [12]. These risk factors express the predicted excess numbers of various cancer types and cancer fatalities in a group of individuals exposed to a unit radiation dose.

This approach is valid on the cautious assumption, taken by the ICRP as the basis for its recommendations [12], that the probability of health effects due to radiation exposure is linked to the dose by a linear relationship without threshold. Only on this assumption can the collective dose be taken as proportional to the number of detrimental health effects. The calculation of health effects from collective dose estimates provides, therefore, the theoretical maximum number of such effects that could be expected to arise in the exposed population within a few decades following the exposure. The effects calculated with these assessments are purely statistical, and cannot be attributed to any identified individuals. It should also be recognised that the concept of collective dose has been developed by the ICRP essentially as a tool for the analysis of alternative protection options in the process of optimization of radiation protection, rather than for absolute health detriment appraisals.

For the above reasons, the estimates of collective health detriment are primarily intended to be used in the planning of radiation protection provisions for the design and operation of a nuclear installation. They are not very meaningful in the appraisal of the radiological impact of an accident, where more realistic estimates are required.

Moreover, the calculation of potential health effects due to the Chernobyl accident would be characterised by great uncertainties due to a combination of the following sources of error:

a) The collective dose estimates provided by Member countries are affected by large uncertainties due to the intrinsic limitations in the data bases and the assessment methods available; and

b) The radiation risk estimates concerning the population groups exposed to the Hiroshima and Nagasaki atomic explosions in 1945 (which were one of the principal bases for the extablishment of the current risk factors) are presently being subjected, by the competent international bodies, to a critical review which is expected to lead to some changes in the values of the risk factors.

This may explain the range of different estimates of the number of health effects associated with the Chernobyl accident which have been issued by several international and national organisations.

Considering the scientific and technical reasons given above and the appropriateness of avoiding a further contribution to this variety of theoretical estimates, the present report does not include a calculation of the potential health effects from the Chernobyl accident.

4. ACCIDENT RESPONSE

4.1. Countermeasures

A detailed survey has been conducted of the protective measures adopted in Member countries in response to the Chernobyl accident. A compilation of the information which has been made available to the NEA is provided in Appendix 2. Only information officially transmitted to the Agency by the competent authorities of Member countries has been used in this analysis.

The types of intervention adopted have been grouped into the following categories:

a) Environmental monitoring;
b) Public information;
c) Control of outdoor public activities;
d) Control of use of water;
e) Control of use of milk and dairy products;
f) Control of use of vegetables, fruit and grains;
g) Control of use of meat and fish; and
h) Others.

To the extent possible, the degree of accident response has been qualified according to the classification given in Chapter 2 (i.e., advice, restriction, prohibition). For each country where interventions have been adopted, the timing, duration of application and spatial extent of the countermeasures have been indicated, where known. In addition, explanatory notes, including attempts to identify the basis or rationale for the measures, have been provided for each intervention type. A summary matrix describing the state of adoption of countermeasures in the different countries is presented in Table 4.1.

Accident response in Member countries ranged from the application of no specific protective measures up to comprehensive bans on marketing, consumption and importing of foodstuffs. In general, the most widespread countermeasures were those which were not expected to impose, in the short time for which they were in effect, a significant burden on lifestyles or the economy. These included advice to wash fresh vegetables and fruit before consumption, advice not to use rainwater for drinking or cooking, and programmes of monitoring citizens returning from potentially contaminated areas. In reality, experience showed that even these types of measures had, in some cases, a negative impact which was not insignificant. For example, advice to wash vegetables and fruit prompted many citizens, in some countries, to avoid altogether the consumption of these foodstuffs, which resulted in sizable economic losses due to reduced sales.

Protective actions having a more significant impact on dietary habits and imposing a relatively important economic and regulatory burden included restrictions or prohibitions on the marketing and consumption of milk, dairy products, fresh leafy vegetables and some types of meat, as well as control of the outdoor grazing of dairy cattle. In some cases, restrictions were placed on travel to areas affected by the accident and on the import of foodstuffs from the Soviet Union and eastern European countries. In most Member countries, controls, in the form of restrictions, were imposed on the import of foodstuffs from Member as well as non-member countries.

Following the first indications that the Chernobyl event was a major accident involving a large-scale release of contaminants, all Member countries intensified their normal programmes of environmental monitoring and many instituted special monitoring programmes. The situation was complicated by the fact that there was initially considerable uncertainty as to the precise characteristics and spatial distribution of the radioactive plumes, and also that existing emergency monitoring protocols appeared to be tailored to respond to the release from a well-defined, local source, which was not the case. Therefore, considerable initial effort had to be made to identify areas of elevated deposition of contaminants prior to determining whether the actual activity levels required some form of intervention.

Control of outdoor public activities, aimed at restricting the exposure of the public arising from inhalation of activity in air or from direct irradiation by the plume or by deposited activity, was only sparsely applied in Member countries. Such measures were mostly expressed as regional advice, and were generally adopted in response to uncertainty about the level of environmental contamination.

The principal consideration of countermeasures in most Member countries was aimed at restricting public exposures arising from the consumption of water and foodstuffs. The occurrence of high deposition following rainfall led to advice, for some remote areas where there was a dependence on fresh rainwater for drinking or cooking, to avoid consumption of rainwater. The most widespread initial concern was over the contamination of fresh milk arising from the consumption of contaminated grass by dairy animals, thus placing young children, in particular, at risk from the intake of radioiodine. Thus, many Member countries adopted countermeasures, in the form of advice or prohibitions, concerning the outdoor grazing of dairy cattle. In northern Europe, where dairy cattle were still indoors, such measures were implemented to keep cattle indoors and fed on stored fodder. In other parts of Europe, where cattle were already grazing outdoors, interventions were invoked to return them to their stables and provide them with stored fodder. The degree of impact of this type of measure was thus very variable from country to country.

In addition to the control of grazing cattle, a variety of protective actions were adopted in relation to the consumption of milk and dairy products. Such actions ranged from advice to limit consumption by the general population to prohibitions on consumption by infants and children in more heavily contaminated regions of some countries. In some cases, contaminated milk was destroyed, in others, milk was converted into dairy products, such as cheese and butter, which were then stored with the assumption that sufficient radioactive decay of the short-lived radionuclides would occur over the period of storage. It was noted that greater concentrations of radioiodine and radiocaesium occurred in the milk of sheep and goats as compared to dairy cattle, primarily due to the particular diet and grazing habits of sheep and goats.

Table 4.1. **Summary Matrix of Responses to the Chernobyl Nuclear Accident in OECD Member Countries**

Response[b]		AUS	A	B	CND	DK	SF	F	FRG	GR	IS	IRL	I	J	L	NL	N	P	E	S	CH	TR	UK	US
		Country[a]																						
A. ENVIRONMENTAL MONITORING	1. Intensify/expand monitoring activities	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
B. PUBLIC INFORMATION	1. Establish means for issuance of public information	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
C. OUTDOOR PUBLIC ACTIVITIES	1. Control outdoor activities		A		X		A		A[c]												X	A		
	2. Monitor people/vehicles from contaminated areas		Y			Y	Y	Y	Y	Y		Y			Y	Y		Y	Y	Y		Y	Y	Y
	3. Control travel to contaminated areas		A				A		A			A			A	A	A		A	A			A	A
	4. Clean transport vehicles at border points		A			A	A		A							A						A		
D. WATER	1. Control rainwater use for drinking or household purposes		A		A		A		A	A	X		A	A	A	A	A			A	A	A	A	A
	2. Control rainwater use for watering cows		A				A															A		
	3. Filter rainwater before drinking													A										
	4. Control rainwater use in saunas						A																	
E. MILK AND DAIRY PRODUCTS	1. Control grazing of dairy cattle		P	A		P	A		A	A			P		P	P				A		P/A[d]		
	2. Control marketing & consumption of cow milk/dairy products		R/A[e]				R		R	R			R			R/A[e]	R			R	A	R		
	3. Control marketing & consumption of sheep/goat milk		R/A[e]							A			R			R	A				A	A		
	4. Control marketing & consumption of sheep/goat cheese		P							P			P			P	R			R	A	P/A[g]		
	5. Control import of milk/dairy products	[h]	R	R[i]	R	R[i]	R	R[i]	R[i]	R[i]		R[i]	R[i]	R	R[i]	R[i]	R	R[i]	R[i]	R[i]	R	R[i]	R[i]	R
F. VEGETABLES, FRUIT AND GRAINS	1. Control consumption of fresh leafy vegetables		A						A[c]	A			A			A				A	A	A		
	2. Wash fresh vegetables prior to consumption		A	A		A			A	A		A	A	A	A	A				A	A	A		
	3. Control consumption of non-cultivated plants & mushrooms		A				A		A							A				A				
	4. Control domestic marketing of leafy vegetables		P					P[j]	R				P		P	R/P	P			R				
	5. Control import of vegetables, fruit and grains	[h]	R	R[i]	R	R[i]	R	R[i]	R[i]	R[i]		R[i]	R[i]	R[k]	R[i]	R[i]	R	R[i]	R[i]	R[i]	R	R[i]	R[i]	R
	6. Control agricultural practices						A													A				

G. MEAT AND FISH	1. Control domestic marketing of animal thyroids									P			P		P	P								
	2. Control domestic marketing of lamb/sheep		R							R						R	R			R	R		R	
	3. Control domestic marketing of beef/horse meat		R														R							
	4. Control domestic marketing of reindeer meat						A										R			R				
	5. Control domestic marketing of game						A									A				R				
	6. Control consumption of freshwater fish						A									A	P			A	R^l			
	7. Control hunting of game											A				A			A	A				
	8. Control imports of meat	h	R	R^i	R	R^i	R	R^i	R^i	R^i		R^i	R^i	R	R^i	R^i	R	R^i	R^i	R^i	R	R^i	R^i	R
H. OTHERS	1. Government compensation for agricultural losses		Y				Y		Y	Y			Y			Y	Y			Y		Y	Y	
	2. Controls on the changing of industrial air filters		A	A			A		A	A			A		A	A				A	A			
	3. Control the use of sewage sludge for soil amendment		P				R								R					R	R			
	4. Administer stable iodine		X		X		X^m	X	X	X					X	X			X	X	X	X		X

Matrix key:

A = Advice
R = Restriction
P = Prohibition
X = Explicit advice against need for specific action
Y = Action taken

Notes:

a) See Chapter 9 for key to Member country acronyms.
b) For detailed description of response, see Appendix 2.
c) Some States gave advice. No official national advice.
d) Prohibition progressively phased-out; followed by advice; limited to Trace region.
e) Including advice not to drink fresh cow milk from farms.
f) Restriction on marketing of sheep/goat milk; advice to avoid consumption of sheep/goat milk.
g) Prohibition on consumption (1 week); and advice against marketing goat cheese (8 weeks).
h) Surveillance of imports; no specific restrictions imposed.
i) Including a temporary prohibition on imports from Eastern European countries.
j) Temporary measure in one department (Haut Rhin), for spinach only.
k) Restriction limited to vegetables only.
l) Concerned only Lake Lugano.
m) Except for nationals travelling to within 50 km of Chernobyl.

Activity deposition on growing vegetables was also an initial source of concern, as reflected by the actions taken relating to marketing and consumption of vegetables. Countermeasures ranged from simple advice to wash fresh, leafy vegetables prior to consumption, up to prohibitions on the marketing and consumption of some vegetables (e.g., all leafy vegetables in Italy, spinach in parts of France and the Netherlands).

Initial concern and adoption of countermeasures related to consumption of water and foodstuffs were primarily in response to high levels of iodine-131 activity. Later, as levels of the short-lived iodine-131 decreased, attention focussed on the presence of longer-lived radionuclides, in particular caesium-137 and -134, in foodstuffs. Environmental monitoring activities were then focussed to assess the accumulation and impact of long-lived contaminants in the long-term. In response to this concern, control of marketing and consumption was extended to stored milk products, and to meat and fish. Such measures were later further extended to include game, reindeer, and other specific foodstuffs, a reflection of the longer-term cycling of radionuclides such as caesium-137 in the environment.

Countermeasures concerning the import of foodstuffs were adopted in virtually all Member countries, entailing a considerable economic impact. Initially, several countries invoked prohibitions on the import of foodstuffs from the Soviet Union and eastern European countries, largely in response to uncertainty over the actual levels of contamination in those countries. Later, restrictions on imports from both Member and non-member countries were adopted, although there were variations in the relevant intervention levels used by the different countries for the screening of foodstuffs activity.

In addition, a variety of other actions were applied sparsely throughout the OECD European countries, and included recommendations on specific agricultural practices, control of the changing of industrial air ventilation filters, recommendations on the washing of vehicles and roads and development of government compensation programmes for agricultural losses. Most Member countries established a variety of mechanisms for dissemination of information to the public (e.g., new releases, telephone *hotlines*). However, problems became evident in overloading of telephone services, issuing of contradictory information or advice and, in general, lack of public comprehension of events and their meaning.

4.2. Intervention Levels

4.2.1. *General*

Intervention levels are quantitative values (e.g., dose, radionuclide concentration) used as a threshold for initiating a given set of countermeasures. ***Primary intervention levels*** (PILs) are specified in terms of projected dose to individuals over a given time period. Secondary, or ***derived intervention levels*** (DILs), are usually specified as the concentration of activity of a given radionuclide within a given environmental matrix or foodstuff, which, on the basis of specific assumptions on transfer to humans, corresponds to a dose to individuals equivalent to the relevant primary intervention level. In this way, DILs can be compared directly to measurements of activity levels in the environment or in foodstuffs and used to provide a quick determination of the need for intervention.

The basic ICRP recommendations of 1977 [12] and the Basic Safety Standards for Radiation Protection issued by IAEA/WHO/ILO/NEA in 1982 [13] stipulate that the establishment of criteria for remedial actions for the protection of the public in the event of a nuclear accident and the definition of the corresponding intervention levels are the responsibility of national authorities, due to the variety of administrative, social and environmental conditions existing in the various countries. An extreme interpretation of this concept would have as a consequence that differences in practice may develop between Member countries, particularly in the establishment of intervention levels. This may give rise to problems in case of accidents having transfrontier consequences, causing unnecessary concern and confusion in the affected countries, as has been shown by the experience of the Chernobyl accident.

In order to counteract this potential trend, a significant effort towards a more consistent approach to emergency response had been made during the past few years by several international organisations, namely the ICRP, the IAEA, the WHO, and the CEC, in order to develop an international consensus on criteria for the protection of the public in the event of a nuclear accident. This resulted, prior to the Chernobyl accident, in a set of recommendations which constituted a reasonably well-developed international basis for emergency response [9, 10, 14, 15, 16].

As a result, the general radiation protection principles which were underlying the actions taken in most Member countries during the Chernobyl accident have been very similar. However, discrepancies arose amongst Member countries in the assessment of the situation and the adoption and application of operational radiological criteria. These discrepancies were further enhanced by the overwhelming role played in many cases by non-radiological factors, such as socio-economic, political and psychological, in determining the countermeasures.

4.2.2. *Derived intervention levels*

One of the principal aspects of the variety of criteria and responses observed in the various countries was the wide range of values adopted for the derived intervention levels. A summary of the DILs adopted by each Member country for iodine-131 and radiocaesium (caesium-137 and -134) is provided in, respectively, Table 4.2 and Table 4.3. These data have been provided by the competent authorities in Member countries. The DILs have been tabulated for drinking water, milk/dairy products, vegetables, meat and other exposure pathway components (fruit, cereals, forage, sewage sludge used in agriculture, etc.). The effective dates of adoption of the intervention levels are also provided.

As can be observed from Tables 4.2 and 4.3, the DILs for the various exposure pathways were identical in certain countries but significantly different in others, even when environmental and socio-economic conditions were not substantially different. For example, the DIL values for radioiodine adopted to control the consumption of milk varied between 125 and 2 000 Bq/L; in one country a level as low as 10 Bq/L was adopted for restricting the import of milk. For radiocaesium (caesium-137 and -134) in milk, DIL values ranged from 50 to about 9 000 Bq/L. Similar broad ranges are evident in the adoption and application of DILs for vegetables and meat.

Part of these apparent discrepancies can be explained by differences in the intended application of the DILs. Some of the higher values represent peak activity concentration levels applicable to short periods of time. On the other hand, in some countries, lower DILs

Table 4.2. **Summary of Derived Intervention Levels: Iodine-131[a]**

Country[b]	Pathway (Bq/L or Bq/kg)					
	Drinking Water	Milk/Dairy Products	Vegetables	Meat	Other	Date adopted
A		370[c]	185			2/5/86
N		1 000	1 000	1 000		
SF	2 000	2 000				2/5/86
S		2 000	300; 5 000[d]	300		2/5/86
CH[e]						
I		560[f]	560[f]	560[f]		1971
GR		125[g]	90[h]			26/5/86 (CEC)
NL		500[i]	1 000[j]			2/5/86
L		500	250			
FRG		500	250			
F[e]						
IRL[e]						
UK	11 000[k]	2 000[l]	110 000[m]		160 000[m,n]	3/86 (NRPB-DL10)
B		500[o]	1 000[p]			2/5/86
DK[e]						
J	110	220	7 400			
TR[e]						
US	1.5[q]	560[r]			1 850[s]	1982 (milk, forage)
CND	10	10 ; 40[t]	70	70	70[u]	5/86 (all but water)
E		125[g]	90[h]		90[h,u]	26/5/86 (CEC)
P		125[g]	90[h]		90[h,u]	26/5/86 (CEC)
IS[e]						
AUS[e]						
CEC		125[g]	90[h]		90[h,u]	26/5/86

a) A detailed examination of intervention levels currently is being conducted by the NEA as a separate study.
b) Member countries are listed in order of decreasing *average deposition of radioiodine* (see Table 3.1). See Chapter 9 for key to Member country acronyms.
c) Value replaced by 185 Bq/L on 21/5/1986.
d) Value stated as import limit (2-15 May).
e) No official DILs.
f) Attention Level, based on activity over a 7-day period; Emergency Level cited as 10 times the Attention Level.
g) CEC recommendation of 26 May 1986; Replaced the 16 May recommendation of 250 Bq/L (kg), which had replaced the 6 May recommendation of 500 Bq/L (kg); For control of imports/exports.
h) CEC recommendation of 26 May 1986; Replaced the 16 May recommendation of 175 Bq/kg, which had replaced the 6 May recommendation of 350 Bq/kg; For control of imports/exports.
i) Value replaced by 125 Bq/L on 23/5/1986.
j) Value replaced by 250 Bq/kg on 23/5/1986.
k) Lower DERL*, based on activity over a 2-day period; Value of 3 700 Bq/L used for activity over a 7-day period.
l) Lower DERL* (peak concentration), for fresh milk only.
m) Lower DERL* (peak concentration).
n) Lower DERL* (peak concentration) for fruit.
o) Initial value (2-15 May); Was 250 Bq/L from 15-25 May, and 125 Bq/L after 25 May.
p) Initial value (2-15 May); Was 500 Bq/kg from 16-25 May, and 250 Bq/kg after 25 May.
q) US EPA derived level for the Chernobyl accident.
r) US FDA PAG** for marketing of foodstuffs.
s) US FDA PAG for animal forage.
t) Manufactured dairy products (Bq/kg).
u) Fruit (fresh weight).

* DERL = Derived Emergency Reference Level.
** PAG = Protective Action Guide.

Table 4.3. **Summary of Derived Intervention Levels: Total Caesium** (^{137}Cs + ^{134}Cs)[a]

Country[b]	Pathway (Bq/L or Bq/kg)					
	Drinking Water	Milk/Dairy Products	Vegetables	Meat	Other	Date adopted
A		185[c]; 300	110[c]; 175	185[c,d]; 300[e]		
N		370[f]	600[f]	600[f]; 6 000[g]	370[h]	20/6/86
SF		1 000		1 000[i]	1 000[j]	22/5/86
S		300[k]	300[k]; 10 000[l]	300[k]	300[m]	15/5/86
CH		370[n]	600[n]	600[n]	600[n]	8/9/86
I		250[o]; 370[p]	250[o]; 600[p]	250[o]; 600[p]		1971; 31/5/86 (CEC)
FRG		370[p]	600[p]	600[p]		31/5/86 (CEC)
GR		370[p]	600[p]	600[p]		31/5/86 (CEC)
IRL		370[p]	600[p]	600[p]		31/5/86 (CEC)
L		370[p]	600[p]	600[p]		31/5/86 (CEC)
NL		370[p]	600[p]	600[p]		31/5/86 (CEC)
F		370[p]	600[p]	600[p]		31/5/86 (CEC)
DK		370[p]	600[p]	600[p]		31/5/86 (CEC)
UK	51 000[q]	3 600[r]; 370[p]	190 000[s]; 600[p]	1 000[t]; 600[p]	280 000[u]	3/86 (DERL); 31/5/86 (CCE)
B		370[p]	600[p]	600[p]		31/5/86 (CEC)
J[v]						
TR		370	600	600		31/5/86
US	90[w]	8 900[x]				1982 (Milk)
CND	50	50; 100[y]	300	300	300[z]	5/86 (Except Water)
E		370[p]	600[p]	600[p]		31/5/86 (CEC)
P		370[p]	600[p]	600[p]		31/5/86 (CEC)
IS[v]						
AUS		100[t]	100[t]	100[t]	100[t,aa]	5/86
CEC		370	600	600	370[h]	31/5/86

a) A detailed examination of intervention levels currently is being conducted by the NEA as a separate study.
b) Member countries are listed in order of decreasing average deposition of total caesium (^{137}Cs + ^{134}Cs) (see Table 3.1). See Chapter 9 for key to Member country acronyms.
c) For ^{137}Cs only.
d) Pork and poultry; Applicable value for other types of meat is 370 Bq/kg.
e) Value for pork and poultry; Value of 600 Bq/kg for other meat.
f) Replaced original value of 300 Bq/L(kg) on 20/6/1986.
g) Reindeer and game meat (20/11/1986).
h) Infant food (Bq/kg).
i) Beef and pork.
j) Grains and cereals.
k) Replaced the 2/5/86 value of 1 000 Bq/L(kg).
l) Value stated as import limit (2-15 May).
m) Marketing limit for game.
n) Notification levels only; Countermeasures dependent on dose assessment.
o) Attention Level, for 1-year period of exposure; Emergency Level cited as 10 times the Attention Level.
p) CEC Regulation; For control of imports/exports.
q) Lower DERL*, based on activity over a 2-day period; Value of 15 000 Bq/L (^{137}Cs) used for activity over a 7-day period.
r) Lower DERL* (peak concentration), for fresh milk only.
s) Lower DERL* (peak concentration).
t) Screening reference level for consumption and marketing.
u) Lower DERL* (peak concentration), for fruit.
v) No official DILs.
w) US EPA derived level for the Chernobyl accident.
x) US FDA PAG** for marketing of milk/milk products.
y) Manufactured dairy products (Bq/kg).
z) Fruit (fresh weight).
aa) Cereals, fruit, nuts/seeds, fish.

* DERL = Derived Emergency Reference Level.
** PAG = Protective Action Guide.

have been adopted to apply as average values over extended periods. Some values are intended to be applied to exposures of the most exposed age category of a critical group (often infants), while others are intended for application to adults of an average population.

In some cases, the above-mentioned discrepancies in DILs may be explained, at least in part, by diversities in the primary intervention levels of dose adopted by the national authorities. For example, in a few countries, questions were raised as to whether the management of this situation should be made within the context of emergency provisions or by using radiation protection criteria similar to those applied to the control of normal operating conditions, in view of the relatively low levels of population exposure, the large distance from the source of release and the relative stability of the contamination in the long term. This created uncertainties in the choice and application of appropriate levels of action.

In other cases, differences in the DILs can be accounted for in terms of objective diversities in environmental features and living and dietary habits. However, it is apparent that dissimilarities in assessment methodology, including environmental transfer and dosimetric modelling, as well as the influence of non-quantifiable, socio-economic and political constraints, may have played a major role in creating the perception of unwarranted discrepancies in the adoption of DILs and their application.

A particular problem raised by the transboundary character of the Chernobyl accident concerns its impact on the international trade of goods, particularly foodstuffs. Shortly after the deposition of contaminants in Member countries, concern was expressed regarding acceptable levels of activity in imported/exported foodstuffs. Derived intervention levels were provisionally established by the Commission of the European Communities (CEC) for the import/export of foodstuffs to and from EEC Member countries, as well as between them [17, 18]. Relatively low values were selected for the control of radiocaesium, namely 370 Bq/L in milk and 600 Bq/kg in other foodstuffs. The retention of these DILs has been prolonged due to the issue of the future marketing of preserved or stored foodstuffs. It is recognised, however, that these DILs have not been formulated solely on radiological protection grounds, but their choice was largely influenced by other, non-radiological factors. The impact of this question was not limited to the countries directly affected by the activity deposition. Many other countries were, in fact, concerned with the possible risks to their populations from food imported from Europe, and established controls and limitations on these importations. Many of these countries adopted levels of activity for the screening of imported foods which were similar to those recommended by the CEC, but other countries chose to use more restrictive limits, in some cases corresponding to trivial levels of activity in foodstuffs. This was another factor of disruption in the normal activities and mutual relations between countries.

In order to overcome these difficulties, a significant effort is currently being made by several international organisations towards achieving a better harmonisation of criteria for the establishment of intervention levels. Some of these organisations, particularly the CEC and the UN Food and Agriculture Organisation (FAO), are concentrating their action on the attempt to achieve an international consensus on a set of reference values of activity concentration in foodstuffs to be used to regulate international trade in case of foodstuffs contamination due to a nuclear accident.

5. SOME LESSONS TO BE LEARNED FROM THE CHERNOBYL ACCIDENT

5.1. General

As was previously described, the radiological impact of the Chernobyl accident in Member countries was very uneven, but there was also considerable variation between responses in the different countries, even when they experienced similar levels of contamination. It is believed that such differences arose primarily from four factors: 1) the large emphasis given to non-radiological, non-objective criteria in the decision-making process; 2) differing levels of uncertainty on actual impacts; 3) the use of different methodologies in assessing the potential impact; and 4) the use of different assumptions and values of parameters related to environmental transfer modelling, dosimetry modelling and characteristics of the affected population groups.

Non-radiological criteria have been influential in determining many of the countermeasures adopted in Member countries. Differing levels of uncertainty on the actual impacts are closely related to the spatial and temporal variations in activity deposition. Given this uncertainty, enhanced by the difficulty to characterise the source term and by the problems resulting from transboundary contamination, it was difficult to apply uniformly consistent responses which matched countermeasures to specific impacts. The use of different methodologies, employing diverse sets of assumptions on the critical parameters, also led to the adoption of dissimilar responses. In many cases, different assumptions on environmental processes and attributes of the affected groups were used in the dose assessment models, often yielding significantly dissimilar conclusions as to the need of specific protective actions. However, it is not readily apparent that such diversity of assumptions was warranted. In addition, a common denominator appears to have been the use of overly conservative assumptions in the assessments, which, in several cases, resulted in the adoption of unnecessary countermeasures producing a not insignificant effect on normal living conditions. Some of these factors are discussed in the following section.

5.2. Parameters involved in the Determination of Accident Response

A broad range of parameters are involved in the decision-making process related to the response to accidental releases of radioactive substances. In any given accident situation, parameters influential to the derivation of intervention criteria (i.e., PILs and DILs) and the implementation of countermeasures arise from the particular characteristics of the release scenario, exposure pathways and processes, and response strategy. Controlling parameters arising from the **release scenario** characteristics include the temporal phase sequence, the spatial extent, and the particular contaminants released. **Exposure pathways and processes** give rise to controlling parameters derived from the features of environmental transfer modelling, dosimetric modelling, and characteristics and habits of the population groups involved. Finally, the definition of intervention levels and protective actions is determined, in part, by the particular **response strategy** adopted, that is, the nature of the group to which the response has to be applied, the philosophy of choice and application of primary intervention levels, the particular exposure pathways chosen to apply the DILs, and the other criteria for the selection of countermeasures.

Existing international recommendations on the development of emergency planning principles for the radiological protection of the public [9, 10, 15, 16 and 19] have indicated the usefulness of examining accident response issues in the context of three sequential time phases, respectively defined as: the early phase, the intermediate phase, and the recovery, or late, phase. These recommendations suggest that certain exposure pathways may be specific to each time phase, thus requiring the implementation of different countermeasures at different periods of time. The *early phase* has been considered to encompass that period of time during which there is a threat of a significant release, up to the first few hours after commencement of the release. The *intermediate phase* encompasses the period from the first few hours to a few days following an accident, while the *recovery phase* involves the return to normal living conditions, and may extend over a prolonged period of time.

The effects of the Chernobyl accident on OECD Member countries did not appear until the accident had progressed to the intermediate phase. Nevertheless, the lack of immediate warning or early notice to Member countries at the outset of the release did not provide the countries initially affected with ample time to implement emergency procedures or protective measures in advance of the arrival of the contaminated air masses. As a consequence of the lag in arrival time of the plumes, and especially of the relatively low levels of activity measured, it was not considered necessary to implement such countermeasures typical of the early phase as evacuation or shielding/sheltering, which are primarily addressed at avoiding doses corresponding to the potential rise of non-stochastic health effects. Therefore, virtually all countermeasures adopted in Member countries were aimed at restricting doses to individuals in the range in which only stochastic effects are relevant, and were those typical of the intermediate phase.

It is apparent, however, that the longer-term impact of the Chernobyl accident does not fit completely in the temporal scheme proposed in the current international recommendations, and suggests an extension of the intermediate phase as defined in these recommendations to cover time periods which can span over months or even years. Impacts resulting from, for example, the presence of long-lived radiocaesium in foodstuffs and the environment have necessitated, in fact, the retention of certain restrictive countermeasures related to consumption and marketing of some agricultural products for time durations much longer than a few days or weeks.

The long-range transport of contaminants from Chernobyl also gave rise to problems related to transboundary consequences. For example, the emergency response systems, in particular the monitoring programmes, in many Member countries had been developed on the basis of a well-defined release source characterised by relatively local and short-term impacts. Such was not the case for the Chernobyl accident, and there were, therefore, several resulting implications. One primary consequence was an increase in the level of uncertainty in the extent or degree of countermeasures deemed necessary. Therefore, many

Member countries took additional measures, mostly in the form of precautionary advice, to compensate for this higher level of uncertainty.

The particular contaminants released as a result of the accident at a nuclear facility play an important role in the establishment of intervention criteria and countermeasures. The composition of the release also plays a role in determining the relative importance of the various exposure sources. In the case of the Chernobyl release, the contaminants of greatest concern to Member countries were radioiodine and radiocaesium. In particular, specific intervention criteria for iodine-131, and for caesium-137 and caesium-134 were adopted and applied in many countries to control exposures from ingestion.

The occurrence of accidental releases and deposition of contaminants in relation to the time of the year, or seasonality, may have an important influence on the transfer of radionuclides in foodchains, and thus on the determination of interventions. In northern European countries, the growing season was just beginning at the time of the Chernobyl accident, while in southern Europe many agricultural crops were ready for harvesting and dairy cattle were grazing on new forage. Thus, initially, there were some differences in the extent of grazing and crop-harvesting control implemented by Member countries. Had the accident occurred during the winter season, the need for such control would have been greatly reduced, particularly that relating to radioiodine.

Several parameters influential in the determination of intervention levels arise from the habits and attributes of the individuals exposed to the accidental releases of contaminants. Such parameters include the food source (i.e., local contaminated food, imported contaminated food, imported uncontaminated food), the dietary characteristics, the age of the individuals (i.e., infant, child or adult), the activities of the exposed group (i.e., rural, urban, length of time spent outdoors, etc.), and the particular practices of food-processing (i.e., consumed fresh, preserved/stored, decontamination of food through specific preparation methods). In the case of the Chernobyl accident, the extremely wide range in the characteristics of the affected population groups has made it difficult to generalise and assess actual impacts, even within individual countries.

A critical parameter involved in the assessment of the response to the Chernobyl accident concerns foodstuff processing. Initial countermeasures and intervention levels were aimed at restricting exposures from the consumption of fresh milk and vegetables. However, where amenable, many fresh products were converted into products which could be stored for a period of time, in the anticipation of the radioactive decay process eventually rendering them acceptable for consumption. Such processing and storage is normally carried out to a given extent for some products (e.g., milk to cheese; fresh vegetables to frozen vegetables), but the Chernobyl accident appears to have increased the extent to which such conversion and storage activities have occurred. This has had the effect of delaying potential impacts from longer-lived radionuclides (such as, for example, caesium-137), and has created a need for appropriate intervention levels and countermeasures for preserved and stored foodstuffs. Similarly, harvested animal fodder, which may contain elevated levels of long-lived contaminants such as caesium-137, may create a prolonged situation of potential exposure (for example, through contamination of milk and milk products from domestic animals fed with the fodder), for which suitable countermeasures and intervention levels may need to be developed.

Problems have arisen from public acceptance and understanding of the counter-measures adopted by public health authorities. These problems were based, in part, on the public perception of discrepancies in response amongst the various national and local authorities, but also on a more basic lack of understanding of the complex technical and scientific aspects of radiation and radiological protection. A typical example of this concerns the contrasting ways in which countermeasures were expressed and perceived.

Authorities' instructions were issued in a variety of ways, ranging from providing simple advice up to the adoption of compulsory bans. Often, the public did not appreciate such differences in degree intended by the national authorities, thus leading to confusion over what constituted *safe* protective measures. For example, the use of *prudent advice* measures, not necessarily based on the exceeding of given intervention levels, was often misconstrued by the public to represent actions based on the occurrence of dangerous levels of contamination. In several cases, for example, it was apparent that the issuing of advice to wash leafy vegetables prior to consumption led to the public avoiding the consumption of vegetables altogether. Similarly, for milk, advice or restriction against milk consumption by infants, reasonably justified on the use of very conservative assumptions, often led to the avoidance of milk consumption by all age groups. The resulting repercussions or implications of this situation entailed additional residual impacts on invididuals and society which were not originally intended by the introduction of certain countermeasures.

Finally, the fact that protective actions were often taken largely on the basis of non-radiological criteria rather than on true radiation protection requirements had a very negative influence. The distinction between the two types of criteria was generally not appreciated or understood by the public, or by the politicians for that matter. As a result, any countermeasure, even if it was overly conservative and not justified on objective radiation protection grounds, was considered as necessary as other measures which were far more motivated from the radiation protection viewpoint. This certainly contributed to confuse the public about what was *safe*, what was simply *prudent*, and what was only the result of misinformed fears and psychological reactions to the accident.

6. CONCLUSIONS

On the basis of the information officially made available by Member countries, it can be concluded that, although the radiological consequences of the accident were serious in the area surrounding the Chernobyl site, only in some countries of the OECD area did the levels of radioactive contamination resulting from the release warrant protective actions directly motivated by radiation protection considerations. On the whole, however, these consequences do not raise any major concern for the health of the population in OECD Member countries. In particular, individuals in those countries are not likely to have been subjected to a radiation dose, in terms of effective dose equivalent, significantly greater than that received from one year of exposure to the natural radiation background. As a consequence, the lifetime average risk of radiation-related harm for the individual members of the public has not been changed to any significant extent by the accident. Moreover, the impact on the populations of the OECD Member countries in terms of collective dose appears to be small in comparison with collective doses from natural radiation background or some man-made radiation sources. The number of associated health effects (somatic and hereditary) that can be theoretically calculated from the collective dose will be very small in comparison with the natural incidence of similar effects over the next few decades. The radiation-induced health effects will not constitute a detectable addition to this natural incidence.

As is described in the report, the radiological impact of the Chernobyl accident in OECD Member countries was very uneven, but there was also considerable variation between responses in the different countries, even when they experienced similar levels of contamination. It is believed that such differences arose primarily from four factors:

1. the large emphasis given to non-radiological, non-objective criteria in the decision-making process;
2. differing levels of uncertainty on actual impacts;
3. the use of different methodologies in assessing the potential impact; and
4. the use of different assumptions and values of parameters related to environmental transfer modelling, dosimetry modelling and characteristics of the affected population groups.

There is no doubt that the Chernobyl accident, its development and the way in which its consequences have been managed have offered a number of lessons to be learned. Further improvement of emergency preparedeness and public protection measures will depend on an in-depth reflection on these lessons, a process which is actively being pursued by national authorities and international organisations, including the NEA.

7. EXPLANATION OF TERMS

Some technical terms used in the text are explained in the following:

Activity Quantity of a radionuclide. It describes the rate at which spontaneous nuclear transformations (i.e., radioactive decay) occur in it. It is measured in becquerels (Bq), where 1 Bq equals 1 nuclear transformation per second.

Dose A general term denoting a quantity of radiation. It can be qualified as *absorbed dose, dose equivalent, effective dose equivalent.*

Absorbed Dose Quantity of energy imparted by ionising radiation to a unit mass of matter such as tissue. It is measured in grays (Gy), where 1 Gy equals 1 joule per kilogram. One Gy produces different biological effects on tissue depending on the type of radiation.

Dose Equivalent The quantity obtained by multiplying the *absorbed dose* by a factor representing the different effectiveness of the various types of radiation in causing harm to tissues. It is measured in sieverts (Sv). One Sv produces the same biological effect irrespective of the type of radiation.

Organ Dose Equivalent *Dose equivalent* imparted to a given organ or tissue. It is measured in sieverts (Sv).

Effective Dose Equivalent Weighted sum of the *dose equivalents* to the various organs and tissues. The weighting factor for each organ or tissue expresses the fractional contribution of the risk of death or serious genetic defect from irradiation of that organ or tissue, to the total risk from uniform irradiation of the whole body. It is measured in sieverts (Sv).

Collective Dose Equivalent Total dose over a population group exposed to a given source. It is represented by the product of the average dose equivalent to the individuals in the group by the number of persons comprising the group. It can be expressed as *collective organ dose equivalent* or *collective effective dose equivalent.* It is measured in mansieverts (man Sv).

Critical Group A homogeneous group of population representative of the persons receiving the highest dose among all the population exposed to a given source.

Maximum Individual Dose Average dose to the individuals of the *critical group.*

Committed Dose Total dose (expressed as *organ dose equivalent* or *effective dose equivalent*) gradually delivered to an organism during a given period of time by the decay of a radionuclide fixed within the organism following its intake into the body. The integration time is usually taken as 50 years for workers and 70 years for members of the public.

Intervention Level The value of a quantity (dose, activity concentration) which, if exceeded or predicted to be exceeded in case of an accident, may require the application of a given protective action.

Primary Intervention Level *Intervention level* in terms of dose to individuals projected over a given period of time.

Derived Intervention level The activity concentration in a given environmental medium (air, soil, water) or foodstuff which, under certain assumptions, corresponds to a dose to individuals equal to the *Primary Intervention Level.*

Stochastic Effects Radiation effects, the severity of which is independent of dose and the probability of which is assumed, by the ICRP, to be proportional to the dose without threshold, in the range of low doses of interest in radiation protection.

Non-Stochastic Effects Radiation effects for which a threshold exists, above which the severity of the effect varies with the dose.

Somatic Effects Radiation effects (stochastic and non-stochastic) occurring in the exposed individual.

Hereditary Effects Stochastic effects that occur in the progeny of the exposed individual.

8. QUANTITIES AND UNITS

For many years, special measurement units for quantities of interest in radiation protection were used, which were not coherent with the International System of Units (SI). These old units (röntgen, rad, rem and curie) have been superseded in the last few years by a new set of units which are coherent with the SI system.

These new units, the gray for absorbed dose, the sievert for dose equivalent, and the becquerel for activity of radioactive materials, have been progressively adopted in Member countries, although some residual cases of use of the old units are still being observed. The relationships between the new SI units and those previously used are shown in the following table:

Quantity	SI Unit	New Name and Symbol	Old Unit and Symbol	Conversion Factors
Exposure	kg^{-1}	—	röntgen (R)	$1\ C\ kg^{-1} = 3876\ R$ $1\ R = 2.5 \times 10^{-4}\ C\ kg^{-1}$
Absorbed dose	$J\ kg^{-1}$	gray (Gy)	rad (rad)	$1\ Gy = 100\ rad$ $1\ rad = 10^{-2}\ Gy$
Dose equivalent	$J\ kg^{-1}$	sievert (Sv)	rem (rem)	$1\ Sv = 100\ rem$ $1\ rem = 10^{-2}\ Sv$
Activity	s^{-1}	becquerel (Bq)	curie (Ci)	$1\ Bq = 2.7 \times 10^{-11}\ Ci$ $1\ Ci = 3.7 \times 10^{10}\ Bq$

In addition, multiples and sub-multiples of the above units are frequently used. The most common ones are the following (with correspondence to old units):

Dose Equivalent:

1 sievert (1 Sv)	= 100 rem	
1 millisievert (1 mSv)	= 100 millirem (100 mrem)	
1 microsievert (1mSv)	= 0.1 millirem (0.1 mrem)	

Activity:

1 becquerel (1 Bq)	= 2.7×10^{-11}Ci	= 27 picocuries (pCi)
1 kilobecquerel (1 kBq)	= 2.7×10^{-8} Ci	= 27 nanocuries (nCi)
1 mega becquerel (1 MBq)	= 2.7×10^{-5} Ci	= 27 microcuries (μ Ci)
1 giga becquerel (1 GBq)	= 2.7×10^{-2} Ci	= 27 millicuries (mCi)
1 tera becquerel (1 TBq)	= 27 Ci	

9. OECD MEMBER COUNTRY ACRONYMS

The following acronyms have been used to identify Member countries in the different tables.

AUS	Australia	J	Japan
A	Austria	L	Luxembourg
B	Belgium	NL	Netherlands
CND	Canada	N	Norway
DK	Denmark	P	Portugal
SF	Finland	E	Spain
F	France	S	Sweden
FRG	Federal Republic of Germany	CH	Switzerland
GR	Greece	TR	Turkey
IS	Iceland	UK	United Kingdom
IRL	Ireland	US	United States
I	Italy		

In addition, the following acronyms for the various international organisations have been used in the report.

CEC	Commission of the European Communities
EEC	European Economic Community
IAEA	International Atomic Energy Agency
WHO	World Health Organisation
FAO	Food and Agriculture Organisation
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
ICRP	International Commission on Radiological Protection

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Appendix 1

DOSE ESTIMATES MADE BY OECD MEMBER COUNTRIES

INTRODUCTION

This appendix is in two sections. The first section contains the dose estimates and other information officially transmitted by each Member country, together with technical notes on the calculational procedures adopted. The second section discusses these doses in detail, with particular reference to underlying assumptions and calculational procedures which have given rise to differences in the dose estimates.

Contents

1. DOSE ESTIMATES AND SUPPLEMENTARY INFORMATION

Table A.1 lists the information supplied by each Member country concerning the deposition levels of total caesium (caesium-134 + caesium-137) and iodine-131, as well as the population size and land area of each country. The deposition values refer to the total activity deposited to the ground following the Chernobyl accident, and the maximum concentration of the deposited activity, estimated in each Member country.

The dose estimates are presented for each Member country, in alphabetical order, in the following sub-sections. The data are reported in the same form in which they have been submitted by Member countries.

Table A.1. **Population, land area and total deposition levels**

Country	Population x 10^6	Area (km^2)	Total deposition (TBq)		Peak deposition (kBq/m^2)	
			Iodine-131	Total caesium	Iodine-131	Total caesium
Australia	16	$7.7\ 10^6$	–	–	–	–
Austria	7.4	$8.6\ 10^4$	$1.0\ 10^4$	$2.0\ 10^3$[a]	700	~60
Belgium	10	$3.1\ 10^4$	$1.2\ 10^2$	$4.1\ 10^1$	10	3.0
Canada	25.5	$9.9\ 10^6$	$9.5\ 10^2$	$4.2\ 10^2$	0.24	0.065
Denmark	5.2	$4.3\ 10^4$	$7.3\ 10^1$	$7.2\ 10^1$	4.2	4.6
Finland	4.9	$3.4\ 10^5$	$1.7\ 10^4$	$3.0\ 10^3$	190	~30[a]
France	55	$5.5\ 10^5$	$3.9\ 10^3$	$1.0\ 10^3$	7.6	not given
FRG	61	$2.5\ 10^5$	$4.0\ 10^3$	$1.5\ 10^3$	160	65
Greece	9.8	$1.3\ 10^5$	$3.0\ 10^3$	$7.0\ 10^2$	60	28
Iceland	0.24	$1.0\ 10^5$	$< 1.0\ 10^0$	$< 0.5\ 10^0$	small	0.10
Ireland	3.5	$7.0\ 10^4$	not given	$3.5\ 10^2$	16	22
Italy	56.6	$3.0\ 10^5$	$9.7\ 10^3$	$2.0\ 10^3$	~500	~100
Japan	120	$3.7\ 10^5$	$4.4\ 10^2$	$4.8\ 10^1$	3.8	0.41
Luxembourg	0.37	$2.6\ 10^3$	$5.0\ 10^3$	$1.1\ 10^1$	~40	7.3
Netherlands	14.5	$4.0\ 10^4$	$8.4\ 10^2$	$1.1\ 10^2$	26	~ 9.0[a]
Norway	4.2	$3.2\ 10^5$	$2.5\ 10^4$	$3.6\ 10^3$	not given	>100
Portugal	9.3	$8.9\ 10^4$	$4.4\ 10^{-1}$	$2.7\ 10^{-1}$	0.013	0.012
Spain	37.7	$5.0\ 10^5$	$4.9\ 10^0$	$2.0\ 10^0$	0.089	0.041
Sweden	8.3	$4.5\ 10^5$	$2.0\ 10^4$	$3.7\ 10^3$	950	190
Switzerland	6.5	$4.1\ 10^4$	$1.5\ 10^3$	$3.3\ 10^2$	180	41
Turkey	52	$7.8\ 10^5$	$6.9\ 10^2$	$6.3\ 10^1$	8.0	0.90
United Kingdom	56.6	$2.4\ 10^5$	$> 1.0\ 10^3$	$3.0\ 10^2$	40	20
United States	239	$9.4\ 10^6$	$1.4\ 10^3$	$3.7\ 10^2$	> 1.9	small

a) Caesium-137 only.

1.1 AUSTRALIA

The following statement was received from the Commonwealth Department of Health, Australian Radiation Laboratory, Lower Plenty Road, Yallambie, Victoria, 3085.

Impact on Radiation Doses to the Australian Population Arising from the Chernobyl Accident

1. Continuous measurements of fallout deposit in different parts of Australia, including the food processing areas, have been made since the mid-1950s, and these levels have decreased rapidly since the cessation of atmospheric nuclear tests in the southern Hemisphere in 1974 and in the northern Hemisphere in 1980. There has been no increase in fallout deposit in Australia following the Chernobyl nuclear power accident in April 1986.

2. Measurements of concentrations of radionuclides arising from fallout deposit were made for the major groups of foodstuffs affected by the radioactive contaminants, starting in the 1950s and continuing until such time as the concentrations were so low that further effort in measurement was not warranted, i.e. less than 0.1 Bq/kg or 0.1 Bq/L. Changes in the concentrations of radionuclides in foodstuffs follow the same trends as the fallout deposit levels.

3. Based on the low levels of fallout deposit measured in Australia since the 1950s, and taking into account the extremely low levels during the past decade, it is concluded that the concentrations of radionuclides arising from fallout deposit in foodstuffs grown and processed in Australia are extremely small.

4. Because the concentrations of radioactive contaminants from fallout in Australian-produced foodstuffs are so small, the estimation of dose contribution to the population has not been considered necessary.

5. Following the Chernobyl accident, consideration was given to the levels of radioactive contaminants that might arise in imported foodstuffs from affected countries. Countries have been divided into two lists – List 1 countries, being mainly the northern, southern, central, western and some eastern European countries, are those countries whose governments have given the Australian Government assurances that food exported from them would not exceed contamination limits imposed by them for domestically consumed foodstuffs. List 2 countries, i.e., several eastern European countries, are those countries for which such assurances have not been given. The lists are reviewed from time to time.

6. Food exports from List 2 countries are required to be accompanied by a certificate giving the ^{137}Cs concentration in becquerel/kilogram if the value exceeds 100 Bq/kg, or, otherwise, a statement that the concentration is less then 100 Bq/kg. To minimise delays in importation, those foodstuffs with less than 100 Bq/kg of ^{137}Cs are admitted under standing arrangements with the Commonwealth Department of Health. A permit is required from the Department if the concentration exceeds 100 Bq/kg.

7. A permit is issued for the latter imports if an assessment shows that the dose contribution to a person and to the population from consumption of that foodstuff is insignificant. The assessment takes into account the likely consumption of that foodstuff and the consumption rate of similar Australian-grown foodstuffs.

8. Random sampling of all foodstuffs from List 1 and List 2 countries is undertaken to ensure the veracity of undertakings and certification.

9. Very few imports have exceeded the 100 Bq/kg ^{137}Cs value. Accordingly, determination of the dose contribution to the Australian population for consumption of imported foodstuffs from the Chernobyl-affected areas has not been warranted.

4 December 1986

1.2. AUSTRIA

A map of caesium-137 deposition is given in Figure A.1.

Critical group and collective dose estimates are given in Tables A.2 and A.3, respectively. The estimates of what these doses would have been in the absence of countermeasures are given in Tables A.4 and A.5.

Technical Notes

The foods considered for the ingestion dose calculations are milk, cheese, dairy products, flour, potatoes, vegetables, fruit, beef, pork, veal and chicken. Average consumption rates (as indicated in the proceedings of the National Statistical Bureau of Austria) were assumed for both the collective doses and the critical group doses. However, higher food concentrations were used in the critical group dose calculations. The intake rates for the principal foods are given in Table A.6. Measured food concentrations were used in the calculations for the period May-December 1986; between January and April 1987, the concentration of caesium is assumed to increase slightly in milk and beef. The contribution of imported food to the dose was not explicitly included; it is expected to be a few percent of the doses estimated here.

The age-groups are defined as children aged 5-10 years and infants aged 1 year. The critical group is an identified group of about 200 000 people.

The dose factors used for nuclides taken into the body are those published by the FRG Institut für Strahlenhygiene (ISH-HEFT 63, 78 and 80, 1985), which take into account the higher metabolic rates found in children and infants compared with adults. The doses from external irradiation were estimated using gamma exposure rate measurements from 336 monitoring stations.

A shielding factor of 0.1 is used to account for the reduction of external doses by housing, but no reduction is assumed for inhalation doses. The indoors occupancy factor is taken as 70 per cent.

The doses are considered as best estimates. However, results of wholebody activity measurements carried out on a number of individuals suggest that the doses actually received from inhalation and ingestion are lower than those presented in this report.

Figure A.1. **DEPOSITION OF CESIUM-137 IN AUSTRIA (kBq/m²)**

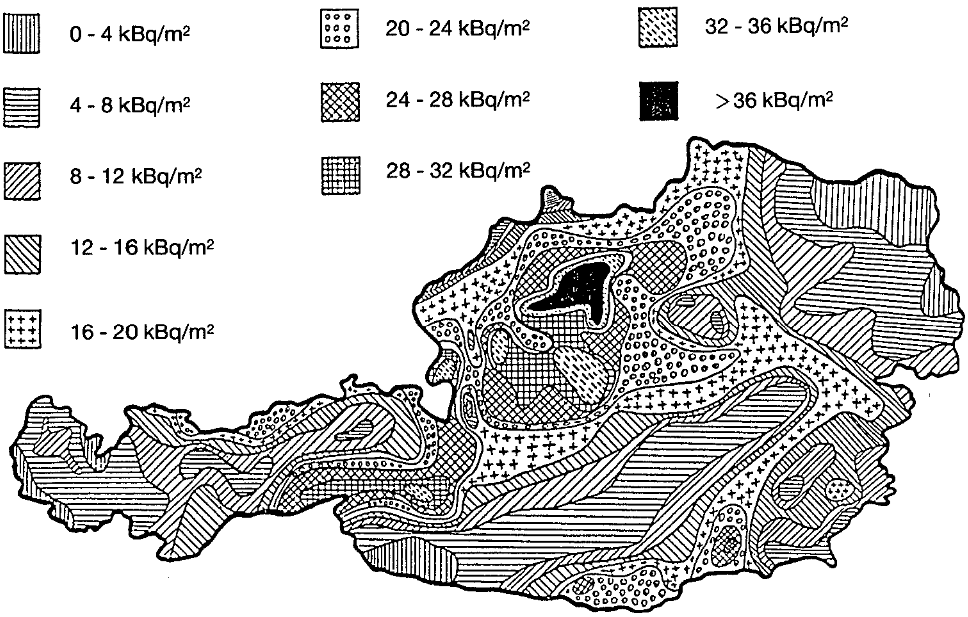


Table A.2. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External Irradiation (deposited activity)		Total: 0.30[a]			Total: 0.33[a]			Total: 0.20	
Inhalation	0.04[a]	0.005[a]	0.05[a]	0.04[b]	0.003[b]	0.05[b]	0.04	0.005	0.05
Milk and Derived Products	0.05[b]	0.28[a]	–	0.15	0.12[a]	–	0-0.23	0.16	–
Vegetables	0.008	0.22[a]	0.04[a]	0.03[a]	0.10[a]	0.04	0-0.05	0.13	–
Meat and Fish	0.005	0.20[a]	0.01[a]	0.01	0.10[a]	0.01	–	–	–
Total	0.10[a]	0.71[a]	0.40[a]	0.23[a]	0.32[a]	0.43[a]	0-0.32	0.295	0.205
Grand Total (I + Cs + others)		1.21[b]			0.98			0.82	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30%.
b = within a factor 3.
c = order of magnitude.

Table A.3. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External irradiation (deposited activity)	832[a]	832[a]	117[a]	117[a]	13[a]	13[a]
Inhalation	1 584[a]	320[a]	891[a]	54[a]	103[a]	6[a]
Milk and Derived products	3 584[a]	1 600[a]	729[a]	162[a]	557[b]	10[b]
Vegetables	4 352[b]	768[b]	882[b]	45[b]	5[b]	5[b]
Meat and Fish	30[b]	832[b]	3[b]	108[b]	–	8[b]
Total	13 982[b]	4 352[b]	2 622[b]	486[b]	678[b]	42[b]

Grand Total Collective Dose Equivalent to the Thyroid: 17 262 manSv
Grand Total Collective Effective Dose Equivalent: 4 880 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30%.
b = within a factor 3.
c = order of magnitude.

Table A.4. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External Irradiation (deposited activity)	Total : 0.3[a]			Total : 0.3[a]			Total : 0.3[a]		
Inhalation	0.04[a]	0.005[a]	0.05[a]	0.1[a]	0.003[a]	0.05[a]	0.04[a]	0.005[a]	0.05
Milk and Derived Products	0.5[b]	0.5[b]	–	1.5[b]	0.3[b]	–	0-2.3[b]	0.3[b]	
Vegetables	0.2[b]	0.3[b]	0.2[b]	0.8[b]	0.15[b]	0.1[b]	0-0.5[b]	0.2[b]	
Meat and Fish	0.07[c]	0.4[b]	0.08[b]	0.07[b]	0.3[b]	0.09[b]			
Total	0.8[b]	2.0[b]	0.6[b]	2.5[b]	0.8[b]	0.2[b]	0-3.2[b]	0.5[b]	0.3
Grand Total (I + Cs + Others)	3.4[b]			3.5[b]			4.0[b]		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 %.
b = within a factor 3.
c = order of magnitude.

Table A.5. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External irradiation (deposited activity)	832[a]	832[a]	117[a]	117[a]	13[a]	13[a]
Inhalation	5 184[a]	320[a]	891[a]	54[a]	103[a]	6[a]
Milk and Derived products	30 000[c]	3 500[c]	6 000[c]	350[c]	4 500[c]	40[c]
Vegetables	8 000[c]	1 000[c]	1 500[c]	60[c]	–	10[c]
Meat and Fish	80[c]	3 000[c]	10[c]	400[c]	–	20[c]
Total	44 096[c]	8 652[c]	8 635[c]	981[c]	4 666[c]	89[c]

Grand Total Collective Dose Equivalent to the Thyroid : 57 397 manSv
Grand Total Collective Effective Dose Equivalent : 9 722 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 %.
b = within a factor 3.
c = order of magnitude.

Table A.6. **Consumption of principal foods**

FOODSTUFF		Adults	Children	Infants
Milk	($L.y^{-1}$)	133	100	175
Vegetables	($kg.y^{-1}$)	68	37	13
Meat	($kg.y^{-1}$)	81	63	11

1.3. BELGIUM

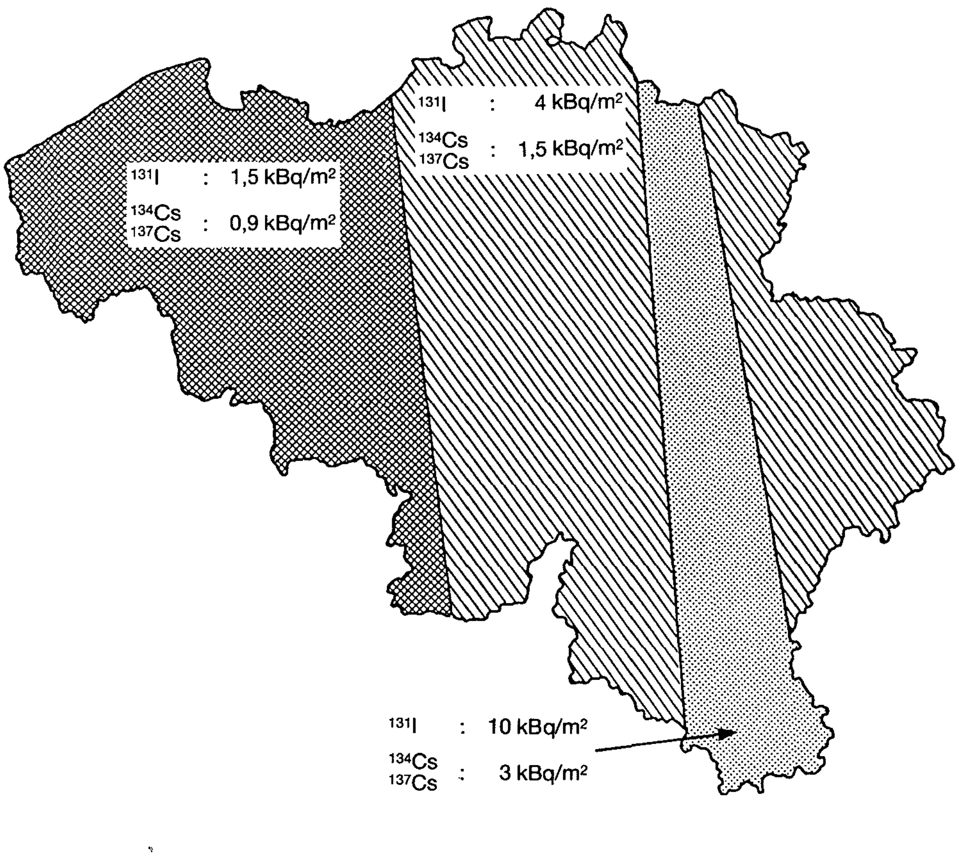
A map of caesium and iodine deposition is given in Figure A.2.

Critical group and collective dose estimates are given in Tables A.7 and A.8, respectively.

Technical Notes

The foods considered for the ingestion dose calculations are milk, meat, green vegetables and water. The intake rates used for the critical group doses are given in Table A.9. The collective doses were calculated using intake rates based on those for the critical group, but modified to reflect consumption of stored, non-contaminated food and

Figure A.2. **DEPOSITION OF IODINE-131 AND CESIUM-137 + 134 IN BELGIUM (kBq/m²)**



preparation losses, as well as differences in quantities consumed. These modifying factors are indicated on Table A.9. In addition, the food concentrations used for calculating the collective doses were taken as 40 per cent of those used for the critical group dose calculations, to reflect the variation of deposition throughout the country. Models were used to predict the variation of concentrations in foods at times beyond the most recent measurements. The procedure adopted to assess the average intake by ingestion, using the factors indicated on Table A.9, led to a relatively high contribution to the total dose from inhalation. The contribution of imported food to the dose was not considered.

The age-groups are defined as adults aged 15 years, children aged 3-14 years and infants aged 0-2 years. The critical group is hypothetical.

The dose factors used for radionuclides taken into the body are those previously recommended by NRPB (NRPB-R162), which were based on ICRP Publication-30. The dose conversion factors used for calculating the doses from external irradiation are those recommended by D.C. Kocher (Health Physics, *38*, 543-621, 1980). A factor of 0.5 is used for shielding from external irradiation from the cloud. A factor of 0.35 is used to account for the shielding from external irradiation from deposited material. No reduction is assumed for inhalation doses.

The collective doses are considered to be conservative estimates. The critical group doses are considered to be upper bounds.

BELGIUM

Table A.7. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium 137 + Caesium 134	Other Nuclides	Iodines	Caesium 137 + Caesium 134	Other Nuclides	Iodines	Caesium 137 + Caesium 134	Other Nuclides
External Irradiation (passing cloud)	$4.3\ 10^{-5}$	$2.3\ 10^{-5}$	$2.9\ 10^{-5}$	$4.3\ 10^{-5}$	$2.3\ 10^{-5}$	$2.9\ 10^{-5}$	$4.3\ 10^{-5}$	$2.3\ 10^{-5}$	$2.9\ 10^{-5}$
External Irradiation (deposited activity)	$2.7\ 10^{-3}$	$3.2\ 10^{-2}$	$9.0\ 10^{-3}$	$2.7\ 10^{-3}$	$3.2\ 10^{-2}$	$9.0\ 10^{-3}$	$2.7\ 10^{-3}$	$3.2\ 10^{-2}$	$9.0\ 10^{-3}$
Inhalation	$5.5\ 10^{-3}$	$1.6\ 10^{-3}$	$6.0\ 10^{-3}$	$9.5\ 10^{-3}$	$2.0\ 10^{-3}$	$8.7\ 10^{-3}$	$7.6\ 10^{-3}$	$1.3\ 10^{-3}$	$6.8\ 10^{-3}$
Milk and Derived products	$1.5\ 10^{-2}$	$2.2\ 10^{-2}$	–	$4.2\ 10^{-2}$	$4.3\ 10^{-2}$	–	$1.1\ 10^{-1}$	$9.0\ 10^{-2}$	–
Vegetables	$6.8\ 10^{-3}$	$4.3\ 10^{-3}$	$1.7\ 10^{-4}$	$1.9\ 10^{-2}$	$9.4\ 10^{-3}$	$3.6\ 10^{-4}$	–	–	–
Meat and Fish	$1.3\ 10^{-3}$	$1.0\ 10^{-2}$	–	$3.6\ 10^{-3}$	$2.0\ 10^{-2}$	–	–	–	–
Total	$3.1\ 10^{-2}$	$7.0\ 10^{-2}$	$1.5\ 10^{-2}$	$7.7\ 10^{-2}$	$1.1\ 10^{-1}$	$1.8\ 10^{-2}$	$1.2\ 10^{-1}$	$1.2\ 10^{-1}$	$1.6\ 10^{-2}$
Grand Total (I + Cs + Others)		$1.2\ 10^{-1}$			$2.0\ 10^{-1}$			$2.6\ 10^{-1}$	

Table A.8. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	0.4	0.4	0.08	0.08	0.02	0.02
External Irradiation (deposited activity)	134	134	29	29	6.8	6.8
Inhalation	1 648	103	629	34	116	6.4
Milk and Derived products	182	40	110	17	65	8.8
Vegetables	77	10	46	4.6	–	–
Meat and Fish	17	3.6	9.5	1.6	–	–
Total	2 060	291	824	85	188	22

Grand Total Collective Dose Equivalent to the Thyroid : 3100 man Sv
Grand Total Collective Effective Dose Equivalent : 400 man Sv

Table A.9. **Intake rates of critical individuals**

AIR, FOODSTUFF		Adults	Children	Infants
Inhalation	($m^3.d^{-1}$)	23	15	3.8
Milk	($L.y^{-1}$)	300	300	260
Green vegetables	($kg.y^{-1}$)	55	55	0
Water	($L.d^{-1}$)	1.65	0.95	0.7
Meat (muscle)	($kg.y^{-1}$)	40	40	0

Note :

The intake rates of average individuals are taken as equal to those for critical individuals multiplied by the following factors:

Inhalation = 1
Milk and vegetables = × 0.1 for iodine
= × 0.5 for other radionuclides
Meat = × 0.1 for all radionuclides

These reduction factors account for differences of intakes rates, consumption of stored non-contamined food and food preparation losses.

1.4. CANADA

Maps of iodine and caesium deposition are given in Figures A.3 and A.4.

Critical group and collective dose estimates are given in Tables A.10 and A.11, respectively.

Technical Notes

The Canadian submission of dose estimates to NEA was accompanied by the following notes.

Assumptions used in the Dose Calculations

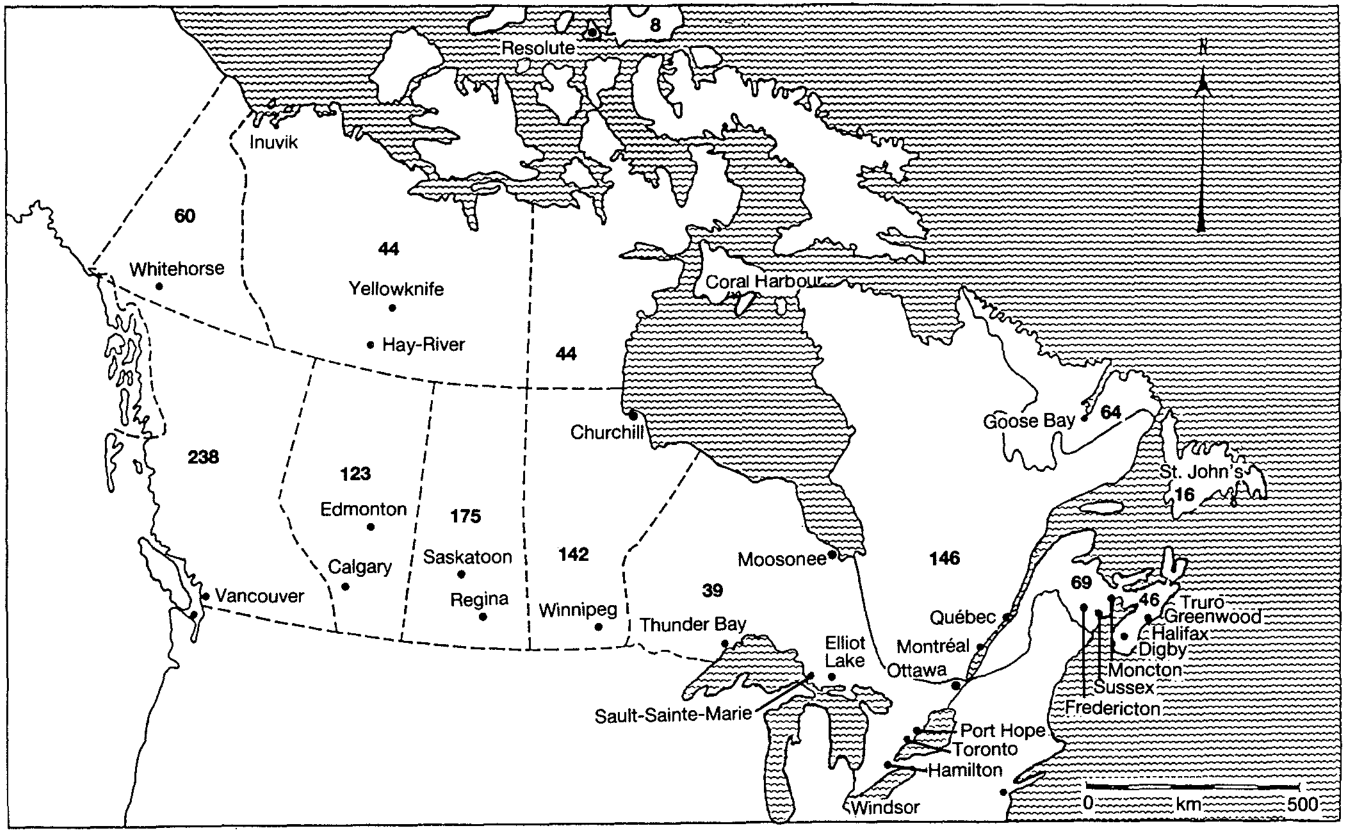
The input data were time-integrated concentrations of each radionuclide in air, on the ground, and in milk. For the calculation of total depositions and collective doses, simple arithmetic averages were carried out over 28 monitoring stations. It was found that population-weighted averages changed the final results by only a few per cent.

External irradiation doses from the passing cloud and from deposited activity were calculated using the factors derived by D.C. Kocher (Health Physics *38*, 543-621, 1980). No credit was given for shielding by buildings or other structures. Doses for children and adults from these pathways were assumed to be the same as for adults.

Doses from inhalation and ingestion were calculated from the factors given in ICRP Publication-30. Isotopes of caesium only were assumed to affect the vegetable and meat pathways. Twenty per cent of deposited caesium was assumed to be retained on the surfaces of green leafy vegetables for a period of twenty days, and on fodder until it was consumed by livestock. The retention half-time in meat was taken to be 110 days. The following metabolic parameters were used:

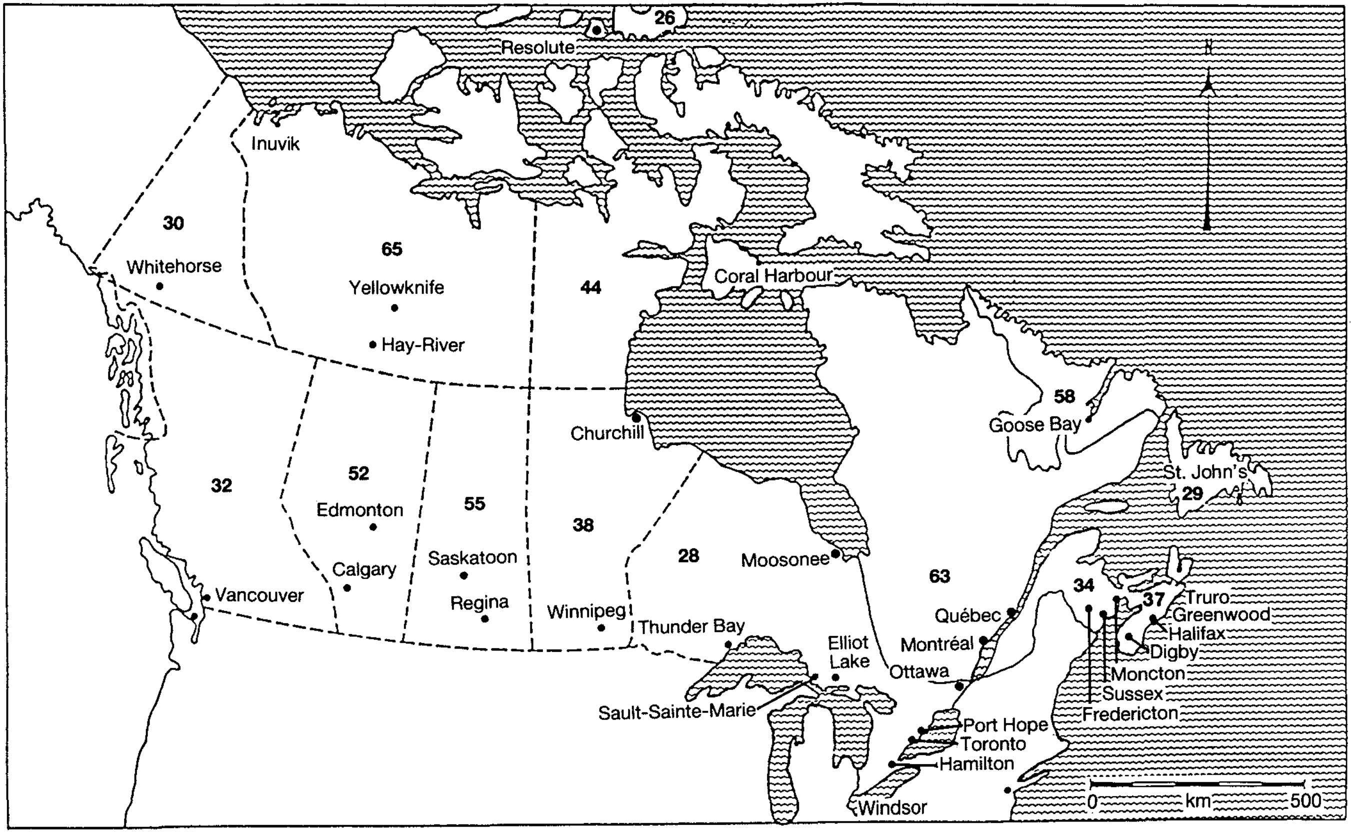
	Units	Adults	Children	Infants
Breathing rate	$m^3.d^{-1}$	23	15	3.8
Thyroid Mass	grams	17.5	4.6	1.8
Milk Consumption	$L.d^{-1}$	0.47	0.66	0.54
Meat Consumption	$kg.d^{-1}$	0.188	0.106	–
Green Leafy Vegetable Consumption	$kg.d^{-1}$	0.175	0.071	–

Figure A.3. **DEPOSITION OF IODINE-131 BY PROVINCE OR DISTRICT IN CANADA (MBq/km²)**



● Monitoring Station

Figure A.4. **DEPOSITION OF CESIUM-137 + 134 BY PROVINCE OR DISTRICT IN CANADA (MBq/km²)**



● Monitoring Station

CANADA

Table A.10. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	0.0002	0.0004	0.0001	0.0002	0.0004	0.0001	0.0002	0.0004	0.0001
External Irradiation (deposited activity)	0.16	2.05	0.20	0.16	2.05	0.20	0.16	2.05	0.20
Inhalation	0.02	0.02	0.004	0.06	0.02	0.002	0.03	0.004	0.002
Milk and Derived products	0.12	0.41	–	0.73	0.65	–	1.24	0.54	–
Vegetables	–	0.59	–	–	0.22	–	–	–	–
Meat and Fish	–	2.99	–	–	1.22	–	–	–	–
Total	0.30	6.06	0.20	0.95	4.16	0.20	1.43	2.59	0.20
Grand Total (I + Cs + Others)		6.56			5.31			4.22	

Table A.11. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	0.01	–	0.005	–	0.0002
External Irradiation (deposited activity)	–	20.75	–	4.04	–	0.38
Inhalation	7.19	0.70	3.48	0.34	0.17	0.02
Milk and Derived products	35.32	3.70	41.76	1.15	6.67	0.09
Vegetables	–	9.47	–	0.75	–	–
Meat and Fish	–	19.69	–	2.14	–	–
Total	42.51	54.32	45.24	8.42	6.84	0.49

Grand Total Collective Dose Equivalent to the Thyroid: 94.59 man Sv
Grand Total Collective Effective Dose Equivalent: 63.23 man Sv

1.5. DENMARK

A map of iodine and caesium deposition is given in Figure A.5.

Critical group and collective dose estimates are given in Tables A.12 and A.13, respectively.

Technical Notes

The foods considered for the ingestion dose calculations are milk, cheese, grain, vegetables and potatoes, fruits, meat, fish and eggs. The intake rates used are given in Table A.14. Measurements of concentration in foods from May to October 1986 are used to calculate the doses; from October 1986 to April 1987, the concentrations are assumed to remain constant. The October 1986 measurements include the new harvest. The contribution of imported food to the dose is considered to be a very small fraction of the total.

The age-groups are defined as adults aged over 10 years, children aged 1-10 years, and infants aged less than 1 year. No critical group has been identified; therefore, the dose estimates given in Table A.12 are for the whole population of Denmark.

The dose factors used for radionuclides taken into the body are those previously recommended by NRPB (NRPB-R162), which were based on ICRP-30. The model used for the calculation of doses from external irradiation is not known. A reduction factor of 12 is used for shielding from external irradiation; this includes an allowance for the time spent outdoors. No reduction factor is assumed for inhalation doses.

The doses are considered to be best estimates.

Figure A.5 **DEPOSITION OF IODINE-131 AND CESIUM-137 AND CESIUM-134 AT STATE EXPERIMENTAL FARMS IN DENMARK (Bq/m²)**

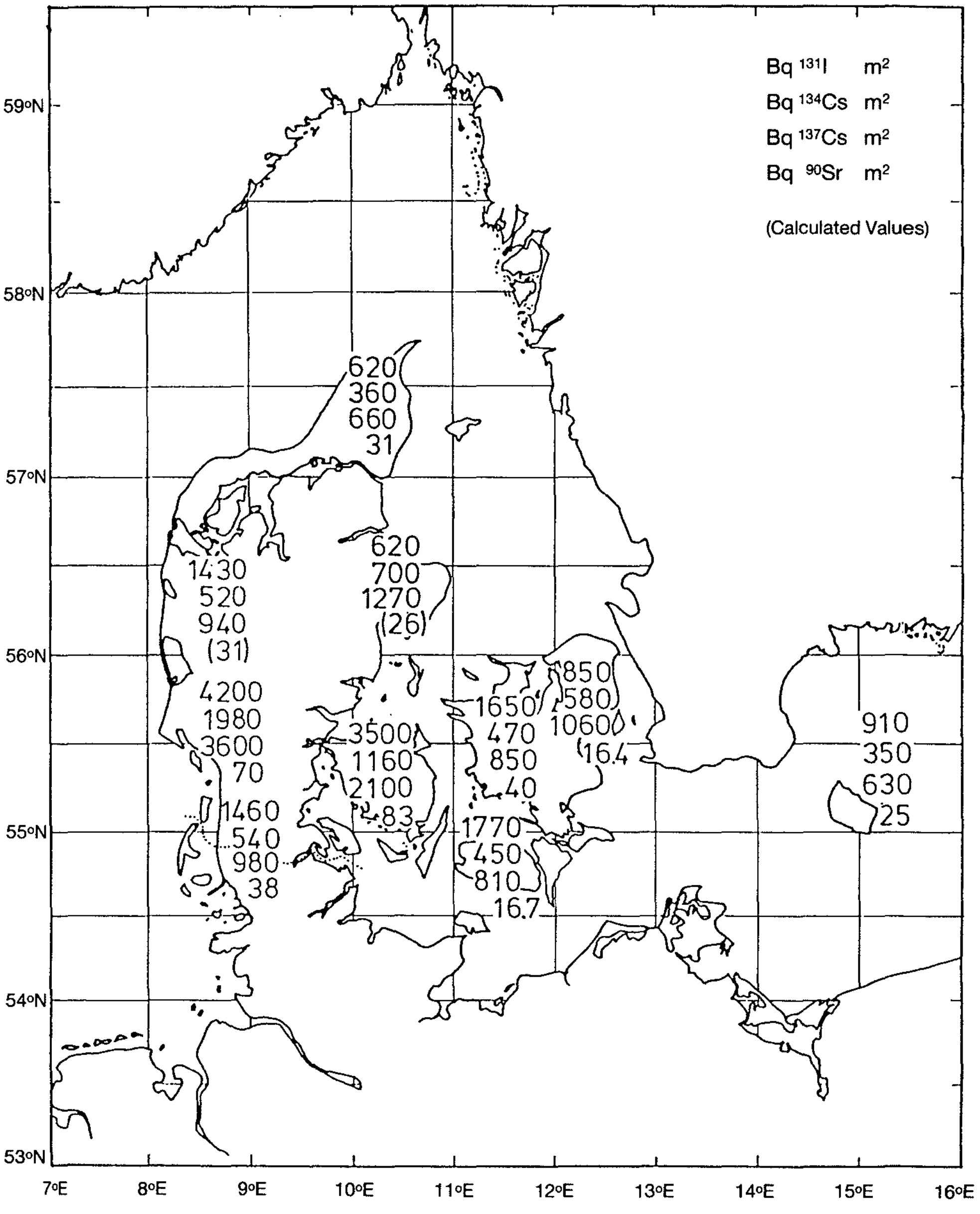


Table A.12. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External Irradiation (deposited activity)	*see "other nuclides"*	0.0013	0.0002	–	0.0013	0.0002	–	0.0013	0.0002
Inhalation	0.0005	0.0002	–	0.0009	0.00024	–	0.00073	0.0001	–
Milk and Derived Products	0.0004	0.008	0.00007	0.0019	0.024	0.00016	0.0062	0.056	0.0004
Vegetables	–	0.008	0.00008	–	0.014	0.00012	–	0.016	0.0001
Meat and Fish	–	0.004	0.00003	–	0.007	0.000004	–	–	–
Total	0.0009	0.022	0.001	0.0028	0.47	0.00048	0.007	0.073	0.0007
Grand Total (I + Cs + Others)		0.023			0.050			0.081	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within ± 30%.

Table A.13. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External Irradiation (passing cloud)	–	–	–	–	–	–
External Irradiation (deposited activity)	6.9	6.9	0.84	0.84	0.09	0.09
Inhalation	78	3.2	16	0.62	1.5	0.05
Milk and Derived products	98	39	47	14	15.8	3.8
Vegetables	38	38	7.6	7.6	0.97	0.97
Meat and Fish	19	19	3.8	3.8	–	–
Total	240	106	75	27	18	4.9

Grand Total Collective Dose Equivalent to the Thyroid: 333 man Sv
Grand Total Collective Effective Dose Equivalent: 138 man Sv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within ± 30%.

Table A.14. **Consumption of foodstuffs**

Grams/day/person

FOODSTUFF	Adults	Children	Infants
Milk	456	750	800
Cheese	25.3	15	–
Grain	223	200	–
Vegetables & Potatoes	408	230	300
Fruits	142	150	175
Meat	152	150	–
Fish	30.3	30	–
Eggs	30.3	30	–

1.6. FINLAND

A map of iodine and caesium deposition is given in Figure A.6.

Critical group and collective dose estimates are given in Tables A.15 and A.16, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.17 and A.18.

Technical Notes

The foods considered for the ingestion dose calculations are milk and milk products, grain, potatoes, root vegetables, leafy vegetables, berries and fruits, beef, pork, other meats, eggs and freshwater and saltwater fish. The intake rates used are given in

Figure A.6 **REGIONAL DISTRIBUTION OF THE TOTAL DEPOSITION OF IODINE-131 AND CESIUM-137, IN 1986, IN FINLAND (kBq/m²)**

(The uncertainties of the data are within a factor of three)

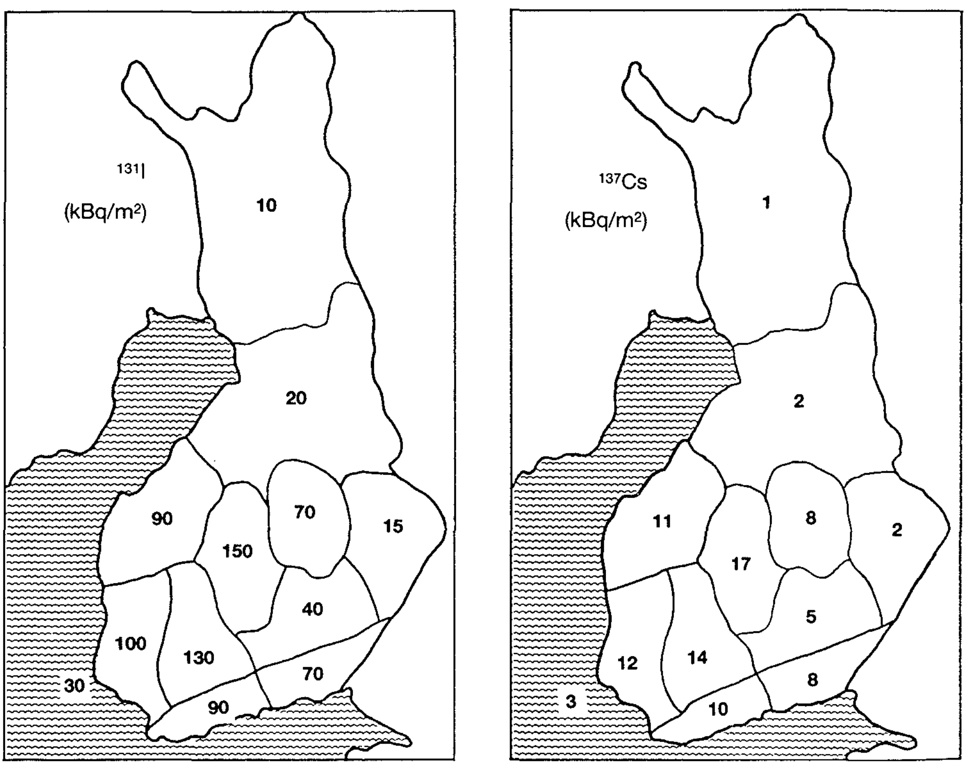


Table A.19. Critical group intakes are assumed to be the same as those used for the collective dose calculations, except that the freshwater fish intake rates are higher. The food concentrations used in the calculation of both collective and critical-group doses are the same; only the exposure to external irradiation is assumed to vary. Models are used to supplement measurements of the time variation of food concentrations. The contribution of imported food to the dose is considered to be about 1 per cent.

The age-groups are defined as adults aged 10 years and over, children aged 2-9 years, and infants aged up to 1 year. The critical group has been identified as the population of the most affected province; this is about 670 000 people.

The dose factors used for radionuclides taken into the body are those previously recommended by NRPB (NRPB-R162), which were based on ICRP Publication-30. The doses from external irradiation are calculated from the values given in NRPB-DL10. A factor of 0.3 is used for shielding from external irradiation; this includes an allowance for the time spent outdoors. No reduction is assumed for inhalation doses.

The doses are considered to be best estimates.

FINLAND

Table A.15. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External irradiation (deposited activity)	0.02[b]	0.25[b]	0.03[b]	0.02[b]	0.25[b]	0.03[b]	0.02[b]	0.25[b]	0.03[b]
Inhalation	0.02[b]	–	–	0.04[b]	–	–	0.03[b]	–	–
Milk and Derived products	0.01[b]	0.15[b]	0.02[b]	0.02[b]	0.30[b]	0.02[b]	0.05[b]	0.45[b]	0.04[b]
Vegetables	–	0.05[b]	–	–	0.05[b]	–	–	0.01[b]	–
Meat and Fish	–	0.40[b]	–	–	0.20[b]	–	–	0.04[b]	–
Total	0.05[b]	0.85[b]	0.05[b]	0.08[b]	0.80[b]	0.05[b]	0.10[b]	0.75[b]	0.07[b]
Grand Total (I + Cs + Others)		0.95[b]			0.93[b]			0.92[b]	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 per cent
b = within a factor 3
c = order of magnitude

Table A.16. Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External irradiation (deposited activity)	–	520	–	70	–	10
Inhalation	2 300	70	600	20	50	2
Milk and Derived products	1 100	630	300	160	80	30
Vegetables	–	170	–	20	–	1
Meat and Fish	–	700	–	50	–	1
Total	3 400	2 090	900	320	130	40

Grand Total Collective Dose Equivalent to the Thyroid: 4 500 manSv
Grand Total Collective Effective Dose Equivalent: 2 450 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor 3.

Table A.17. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External Irradiation (deposited activity)	0.02[b]	0.25[b]	0.03[b]	0.02[b]	0.25[b]	0.03[b]	0.02[b]	0.25[b]	0.03[b]
Inhalation	0.02[b]	–	–	0.04[b]	–	–	0.03[b]	–	–
Milk and Derived Products	0.05[b]	0.15[b]	0.02[b]	0.10[b]	0.30[b]	0.02[b]	0.25[b]	0.45[b]	0.04[b]
Vegetables	–	0.05[b]	–	–	0.05[b]	–	–	0.01[b]	–
Meat and Fish	–	0.40[b]	–	–	0.02[b]	–	–	0.04[b]	–
Total	0.09[b]	0.85[b]	0.05[b]	0.16[b]	0.8[b]	0.05[b]	0.30[b]	0.75[b]	0.07[b]
Grand Total (I + Cs + Others)		1.0[b]			0.95[b]			1.1[b]	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 per cent
b = within a factor 3
c = order of magnitude

FINLAND

Table A.18. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External Irradiation (deposited activity)	–	520	–	70	–	10
Inhalation	2 300	70	600	20	50	2
Milk and Derived products	5 800	770	1 500	200	400	40
Vegetables	–	170	–	20	–	1
Meat and Fish	–	700	–	50	–	1
Total	8 100	2 230	2 100	360	450	50

Grand Total Collective Dose Equivalent to the Thyroid: 10 700 manSv
Grand Total Collective Effective Dose Equivalent: 2 640 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3.

Table A.19. **Intake rates**

FOODSTUFF	Daily consumption (kg/day)	Concentration of caesium-137 (Bq/kg)	Daily intake (Bq)
Milk and Milk Products	0.9	20	18
Grain	0.2	10	2
Potato	0.2	< 5	< 1
Root vegetables	0.04	< 5	< 0.2
Leafy vegetables	0.07	< 10	< 0.7
Berries and fruits	0.2	30	6
Meat			
Beef	0.06	100	6
Pork	0.08	10	0.8
Other	0.04	50	2
Eggs	0.03	< 5	< 0.2
Fish (cleaned)			
Baltic herring	0.02	30	0.6
Other seawater fish	0.01	50	0.5
Freshwater fish	0.01	300-3 000	3-30
Cultured fish	0.003	30	0.09
Imported fish	0.01	5	0.05

Total Daily Intake: 40-60 Bq
Total Annual Intake: 14 600-25 000 Bq

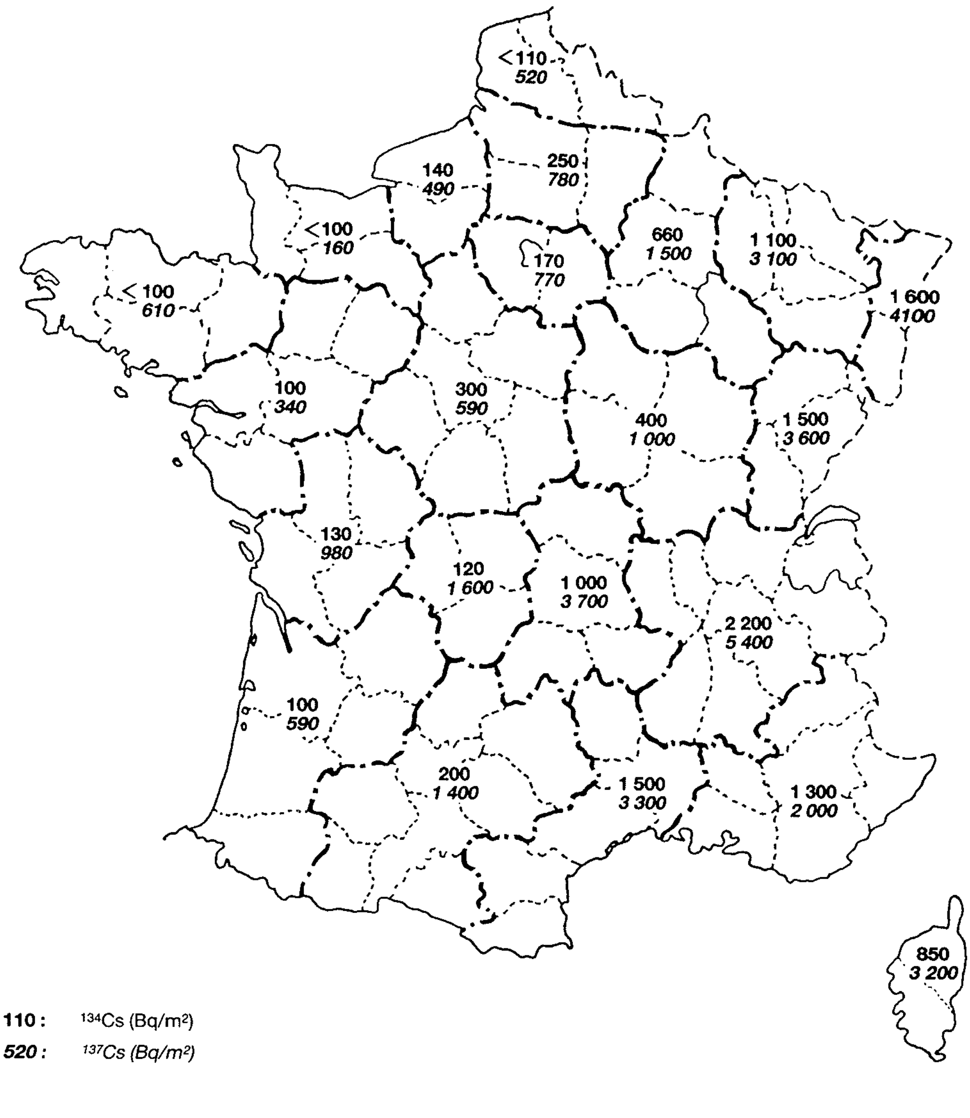
1.7. FRANCE

A map of caesium deposition is given in Figure A.7.

Critical group and collective dose estimates are given in Tables A.20 and A.21, respectively.

Figure A.7. **DEPOSITION OF CESIUM-137 AND CESIUM-134 IN FRANCE (Bq/m²)**

(based on measurements made in June-July 1986)



Technical Notes

The age-groups are defined as adults aged 10 years and over, children aged 2-9 years and infants aged up to 1 year. The critical group has been identified as those people living in East France.

FRANCE

Table A.20. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud) External Irradiation (deposited activity)	Total : $15\text{-}10^{-3}$			Total : $15\text{-}10^{-3}$			Total : $15\text{-}10^{-3}$		
Inhalation Milk and Derived Products Vegetables Meat and Fish	$7.0\ 10^{-3}$	$25\ 10^{-3}$	$2.0\ 10^{-3}$	$20\ 10^{-3}$	$50\ 10^{-3}$	$2.0\ 10^{-3}$	$62\ 10^{-3}$	$130\ 10^{-3}$	$2.0\ 10^{-3}$
Total									
Grand Total (I + Cs + Others)	$49\ 10^{-3}$			$87\ 10^{-3}$			$209\ 10^{-3}$		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES : Within ± 30 %.

Table A.21. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud); External Irradiation (deposited activity)	–	277	–	48	–	5
Inhalation; Milk and Derived Products; Vegetables; Meat and Fish	4 620	647	2 130	232	670	62
Total	4 620	924	2 130	280	670	67

Grand total Collective Dose Equivalent to the Thyroid: 7 420 manSv
Grand Total Collective Effective Dose Equivalent: 1 271 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within ±30 %.

1.8. FEDERAL REPUBLIC OF GERMANY

Maps of caesium-134 and caesium-137 deposition are given in Figures A.8 and A.9.

Average individual and critical group dose estimates are given in Tables A.22 and A.23. Collective dose estimates are given in Tables A.24 and A.25.

Technical Notes

Two sets of doses are presented. The first set is based on environmental concentrations and radioecological models; these are the doses which are given in the main report. For the second set of estimates, the doses from inhalation and ingestion are based on wholebody measurements. These measurements show that caesium concentrations in males, females and children were fairly constant from July to December 1986; it is assumed that they continue to remain constant until April 1987. The results of the wholebody measurement programme suggest that in general the doses actually received in West Germany are similar to, or lower than, the theoretical estimates. The contribution from imported foods is considered to be less than 5 per cent.

The age-groups are defined as adults aged 10 years and over, children aged 2-9 years and infants aged up to 1 year. The critical group has been identified as a group of about 200 000 people living close to the Alps.

The dose factors used for radionuclides taken into the body are based on ICRP Publication-30. The model used for calculating the doses from external irradiation is not known. A reduction factor is used for shielding from external irradiation, and individuals are assumed to spend 50 per cent of their time outdoors.

Figure A.8. **DEPOSITION OF CESIUM-134 IN THE FEDERAL REPUBLIC OF GERMANY (Bq/m²)**

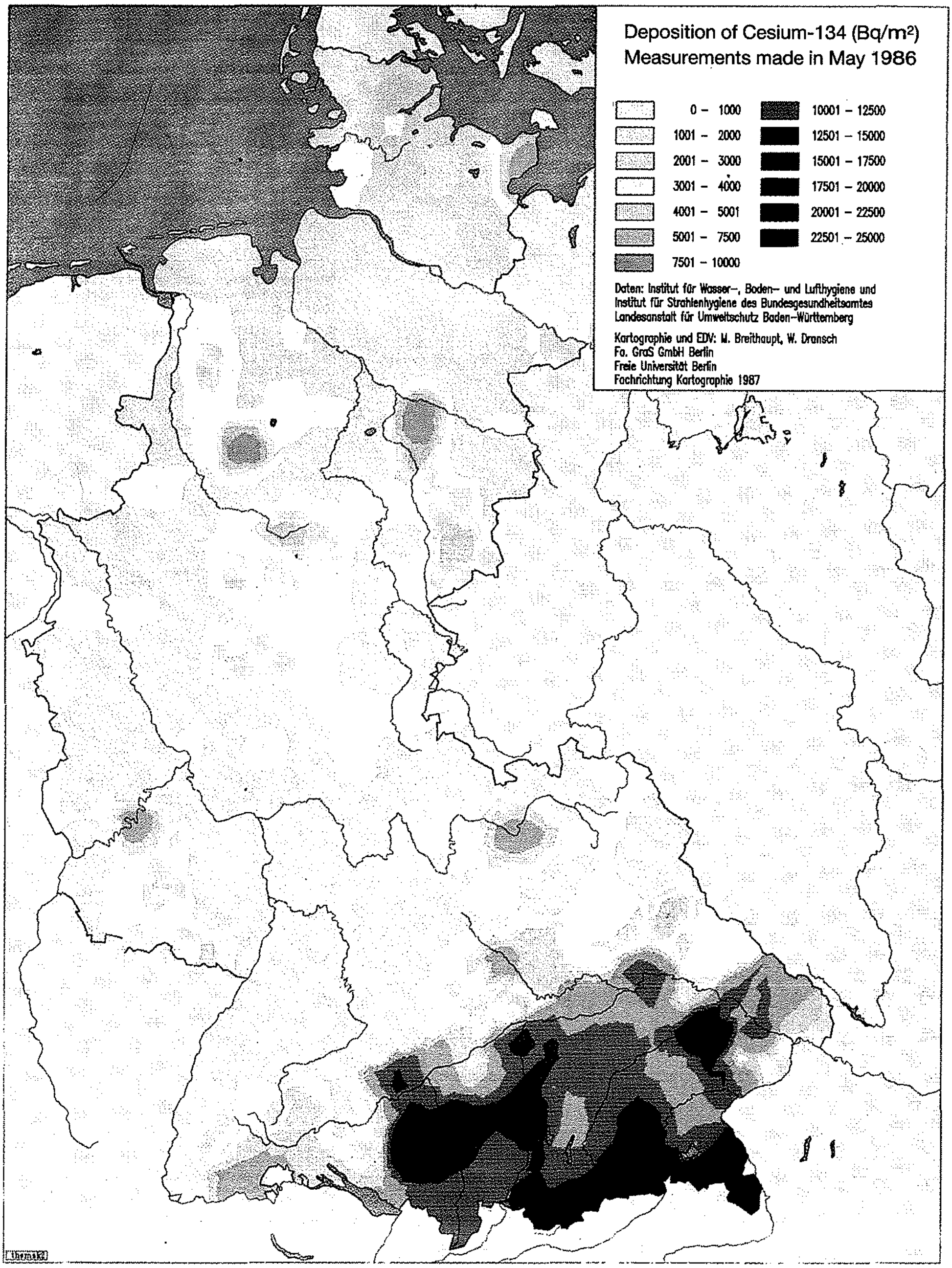


Figure A.9. **DEPOSITION OF CESIUM-137 IN THE FEDERAL REPUBLIC OF GERMANY (Bq/m²)**

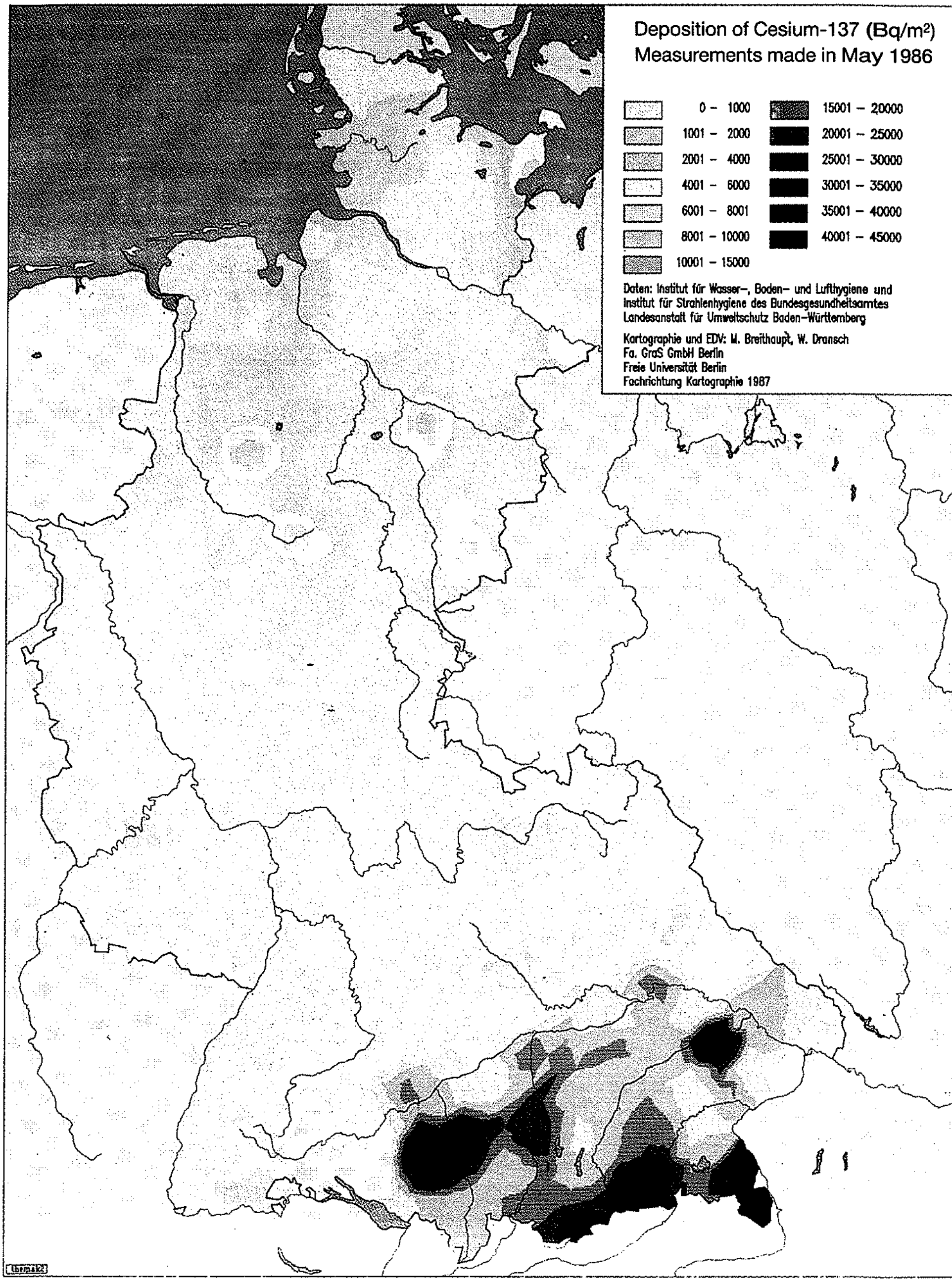


Table A.22. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures, from environmental concentrations and radioecological models

PATHWAY	AVERAGE DOSES *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)									
External irradiation (deposited activity)	Total : 0.1-0.6			Total : 0.1-0.6			Total : 0.14		
Inhalation	0.016	0.004	–	–	0.04	–	0.034	0.07	–
Milk and Derived Products		0.01-0.04	–		0.02-0.06	–		0.02-0.06	–
Vegetables	0.1	0.03	–	0.1-0.34	0.02	–	0.034	0.01	–
Meat and Fish		0.03	–		0.02	–		0.01	–
Total									
Grand Total (I + Cs + Others)	0.2			0.2			0.29		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3

Note:
The data refer to the average individual; they have to be multiplied by a factor of 4 to obtain the individual doses to the critical group (South-East Bavaria).

Table A.23. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures, from wholebody measurements

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud); External Irradiation (deposited activity)	Total : 0.6			Total : 0.6			–	–	–
Inhalation; Milk and Derived Products; Vegetables; Meat and Fish	0.15	0.3	N.E.	0.2	0.2	N.E.	0.03	<0.002	N.E.
Total									
Grand Total (I + Cs + Others)	0.9			0.8			0.03		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3

Note:

N.E. = not examinined.

Table A.24. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures, from environmental concentrations and radioecological models

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*			
	Adults		Children and Infants	
	Thyroïd D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	0.2 %	1 %	–	–
External irradiation (deposited activity)	9 %	47 %	–	–
Inhalation	40 %	12 %	–	–
Milk and Derived products Vegetables Meat and Fish	51 %	40 %	–	–
Total	58 000	14 000	33 000	4 000

Grand Total Collective Dose Equivalent to the Thyroid: 91 000 manSv
Grand Total Collective Effective Dose Equivalent: 18 000 manSv

Table A.25. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures, from wholebody measurements

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)						
External Irradiation (deposited activity)						
Inhalation						
Milk and Derived products						
Vegetables						
Meat and Fish						
Total	44 000	15 000	25 000	4 000		

Grand Total Collective Dose Equivalent to the Thyroid: 69 000 manSv
Grand Total Collective Effective Dose Equivalent: 19 000 manSv

1.9. GREECE

Maps of iodine and caesium deposition are given in Figures A.10 and A.11.

Average individual and collective dose estimates are given in Tables A.26 and A.27, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.28 and A.29.

Technical Notes

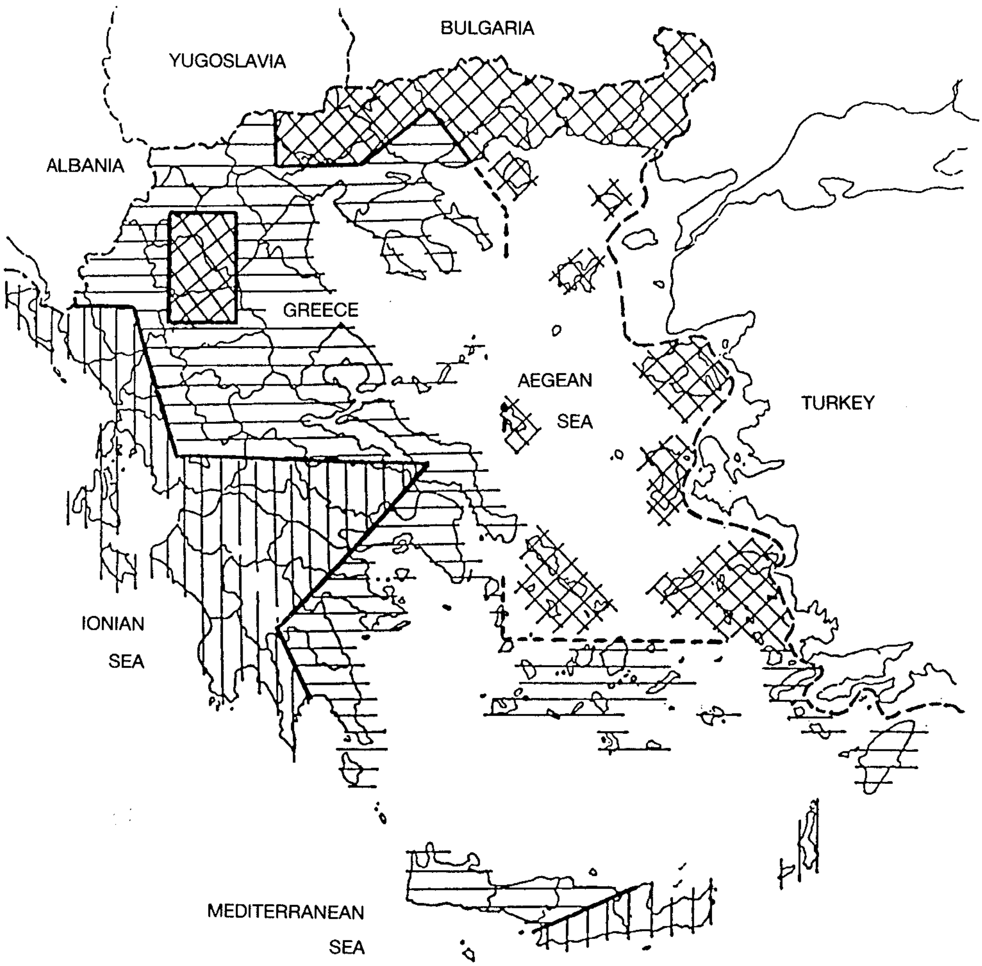
The foods considered for the ingestion dose calculations are meat, fish, milk, cheese, eggs, potatoes, leafy and root vegetables, and fruits. The intake rates used are given in Table A.30. The contribution of imported food to the dose is not considered.

The age-groups are defined as adults aged 10 years and over, children aged 2-9 years and infants aged up to 1 year. No critical group has been identified.

The dose factors used for radionuclides taken into the body are those published by the FRG Institut für Strahlenhygiene (ISH-HEFT 63, 78 and 80, 1985), which takes into account the higher metabolic rates found in children and infants compared with adults. The model used for calculating the doses from external irradiation is not known. A shielding factor of 0.1 has been used to take account of the reduction of the external dose by buildings.

The doses are considered to be best estimates.

Figure A.10. **DEPOSITION OF IODINE-131 IN GREECE (kBq/m²)**



Average deposition, kBq/m²

(cross-hatched)	>25
(horizontal lines)	15-25
(vertical lines)	< 15

Figure A.11. **DEPOSITION OF CESIUM-137 + 134 IN GREECE (kBq/m²)**

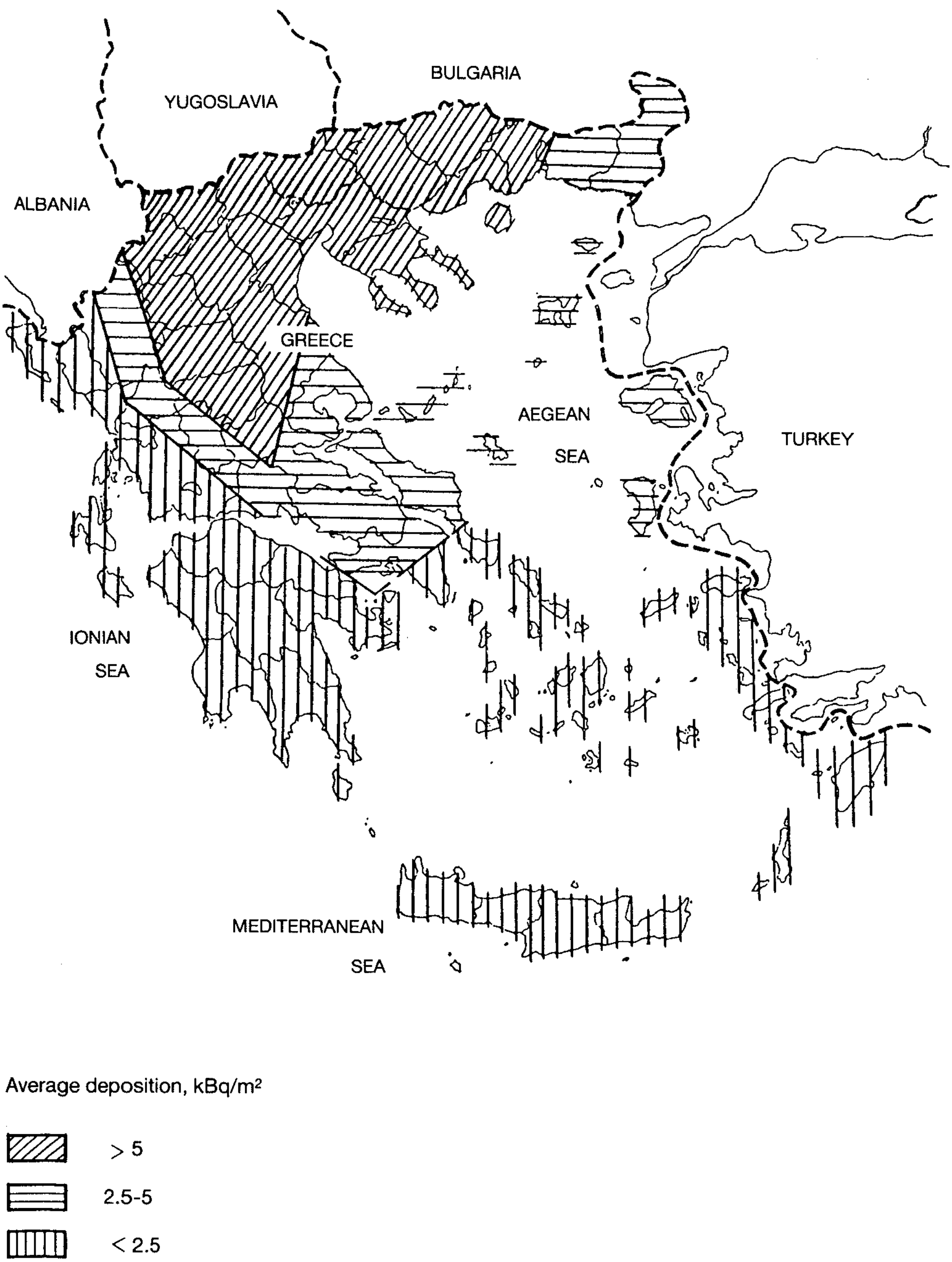


Table A.26. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated with countermeasures

PATHWAY	AVERAGE DOSES *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External Irradiation (deposited activity)	0.0008	0.0175	0.0063	0.0008	0.0175	0.0063	0.0008	0.0175	0.0063
Inhalation	0.0074	0.0040	0.0436	0.0102	0.0018	0.0588	0.0100	0.0004	0.0531
Milk and Derived Products	0.0220	0.0658	–	0.1180	0.0932	–	0	0	–
Vegetables	0.0259	0.0892	0.0234	0.0424	0.0485	0.0124	0.1098	0.0420	0.0107
Meat and Fish	0.0078	0.0473	–	0.0096	0.0220	–	0.0120	0.0095	–
Total	0.0639	0.2238	0.0733	0.1810	0.1830	0.0775	0.1326	0.0694	0.0701
Grand Total (I + Cs + Others)	0.36			0.44			0.27		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within ± 30 %.

Table A.27. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated with countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External Irradiation (deposited activity)	149.88	201.48	25.94	34.87	3.25	4.37
Inhalation	2 048.42	450.47	470.06	100.36	59.23	11.27
Milk and Derived products	6 445.86	719.12	5 206.97	299.39	0	0
Vegetables	7 684.25	1 134.37	1 891.73	146.43	627.00	28.85
Meat and Fish	2 466.95	451.29	443.55	44.79	69.31	3.82
Total	18 796	2 957	8 038	626	759	48

Grand Total Collective Dose Equivalent to the Thyroid: 27 593 manSv
Grand Total Collective Effective Dose Equivalent: 3 631 manSv

Table A.28. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	AVERAGE DOSES *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External Irradiation (deposited activity)	0.0008	0.0175	0.0063	0.0008	0.0175	0.0063	0.0008	0.0175	0.0063
Inhalation	0.0074	0.0040	0.0436	0.0102	0.0018	0.0588	0.0100	0.0004	0.0531
Milk and Derived Products	0.0220	0.0760	–	0.1180	0.1096	–	0	0	–
Vegetables	0.0691	0.1082	0.0379	0.0917	0.0549	0.0181	0.1960	0.0420	0.0107
Meat and Fish	0.0098	0.0716	–	0.0120	0.0319	–	0.0120	0.0095	–
Total	0.1091	0.2773	0.0878	0.2327	0.2157	0.0832	0.2188	0.0694	0.0701
Grand Total (I + Cs + Others)	0.47			0.53			0.36		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within ± 30 %.

Table A.29. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External Irradiation (deposited activity)	149.88	201.48	25.94	34.87	3.25	4.37
Inhalation	2 048.42	405.47	469.92	100.36	59.23	11.27
Milk and Derived products	6 526.94	802.66	5 228.66	322.63	0	0
Vegetables	19 525.17	1 762.58	4 021.33	233.47	1 113.65	44.15
Meat and Fish	3 190.17	666.70	560.50	62.23	70.27	3.82
Total	31 440	3 884	10 306	753	1 246	64

Grand Total Collective Dose Equivalent to the Thyroid: 42 992 manSv
Grand Total Collective Effective Dose Equivalent: 4 701 manSv

Table A.30. **Average daily consumption of essential foodstuffs**

Grams/day

FOODSTUFF	Adults	Children	Infants
Meat			
Veal	53	40	28
PorK	45	18	
Lamb	28	18	
Chicken	32	18	15
Fish	34	23	7
Milk	180	450	500
Cheese	41	27	
Eggs	24	45	50
Potatoes	168	160	50
Vegetables			
Leafy	85	45	20
Others	270	180	80
Fruits	258	225	200
Grain	275	135	
Other Foodstuffs*	161	134	

* = Not Contamined.

1.10. ICELAND

Owing to the very low levels of deposition recorded in Iceland, the only dose assessment that could realistically be performed was to estimate the average individual effective dose equivalent. This was estimated to be not higher than 1 microsievert.

1.11. IRELAND

Critical group and collective dose estimates are given in Tables A.31 and A.32, respectively.

Technical Notes

The foods considered for the ingestion dose calculations are milk and milk products, vegetables and meat. The intake rates used are similar to those used for the United Kingdom (see Section 1.22).

The critical group is hypothetical.

The dose factors used for radionuclides taken into the body are those recommended by NRPB*, which take into account the higher metabolic rates found in children and infants compared with adults. The doses from external irradiation are calculated using the dose conversion factors recommended in NRPB-DL10.

* Kendall, G.M., Kennedy, B.W., Greenhalgh, J.R., Adams, N., and Fell, T.P., *Permitted Dose Equivalents to Selected Organs and Effective Dose Equivalents from Intake of Radionuclides*, NRPB-GS7, H.M.S.O., 1987.

Table A.31. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other nuclides	Iodines	Caesium-137 + Caesium-134	Other nuclides	Iodines	Caesium-137 + Caesium-134	Other nuclides
External irradiation (passing cloud)	Total: $< 1.0\ 10^{-2}$			Total: $< 1.0\ 10^{-2}$			Total: $< 1.0\ 10^{-2}$		
External irradiation (deposited activity)	Total: $1.3\ 10^{-2}$			Total: $1.3\ 10^{-2}$			Total: $1.3\ 10^{-2}$		
Inhalation	Total: $5.0\ 10^{-3}$			Total: $8.0\ 10^{-3}$			Total: $5.0\ 10^{-3}$		
Milk and Derived products Vegetables Meat and Fish	Total: $2.9\ 10^{-1}$			Total: $2.9\ 10^{-1}$			Total: $3.4\ 10^{-1}$		
Total									
Grand Total ($I + C_s$ + Others)	$31.8\ 10^{-2}$			$21.1\ 10^{-2}$			$36.8\ 10^{-2}$		

Table A.32. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	< 2.8	–	< 0.35	–	< 0.35
External irradiation (deposited activity)	–	44.8	–	5.6	–	5.6
Inhalation	31	1.4	5	0.3	5	0.2
Milk and Derived products Vegetables Meat and Fish	756	226.5	242	30.5	805	48.8
Total	787	277	247	37	810	55

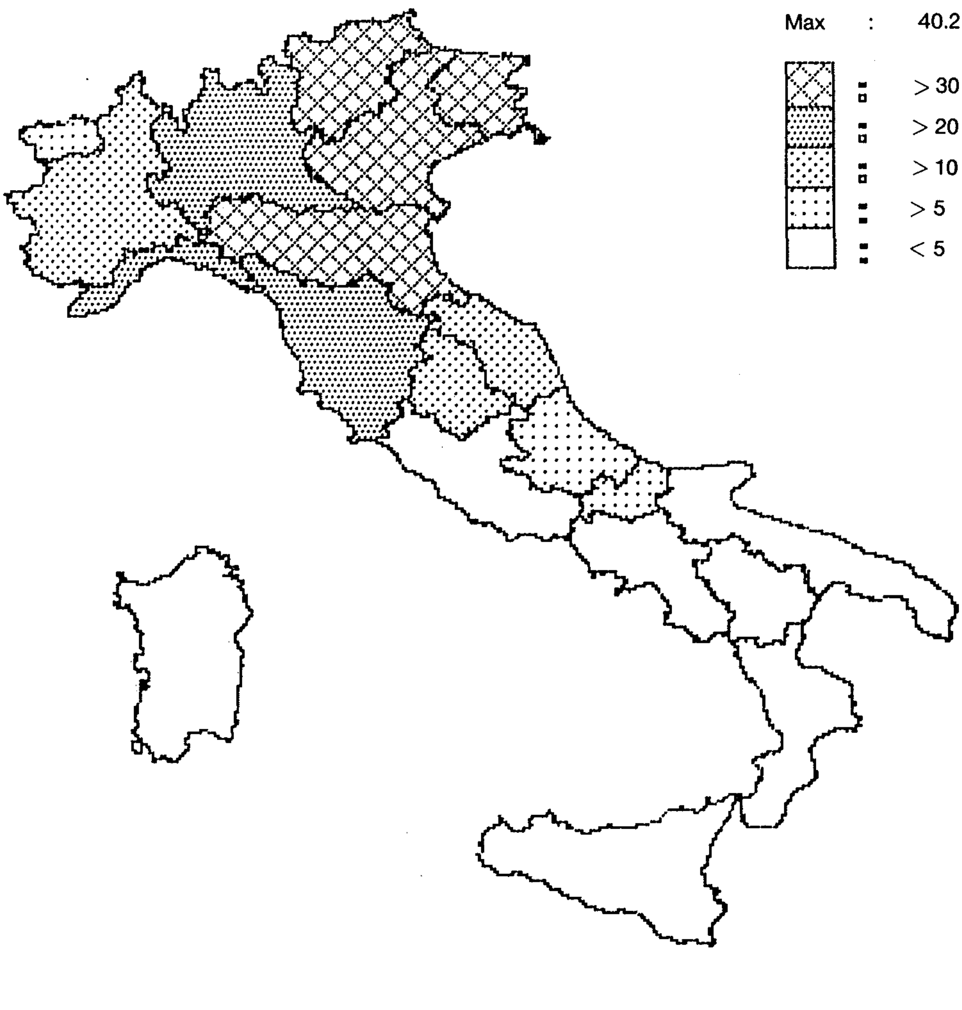
Grand Total Collective Dose Equivalent to the Thyroid: 1 844 manSv
Grand Total Collective Effective Dose Equivalent: 369 manSv

1.12. ITALY

Maps of iodine-131 and caesium-137 deposition are given in Figures A.12 and A.13 for dry deposition, and in Figures A.14 and A.15 for deposition owing to rainfall.

Critical group and collective dose estimates are given in Tables A.33 and A.34, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.35 and A.36.

Figure A.12. **DRY DEPOSITION OF IODINE-131 IN ITALY (kBq/m²)**

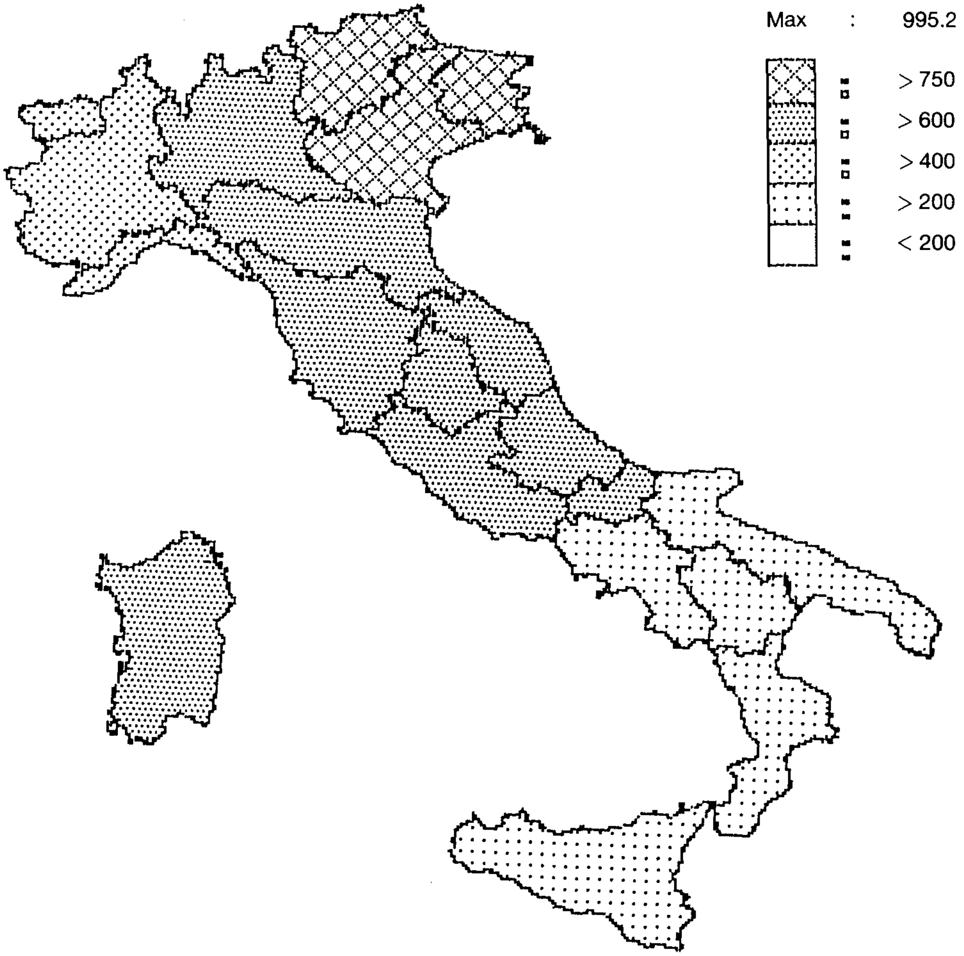


Technical Notes

Collective dose estimates have been made independently by two national bodies; both sets of doses are presented in Tables A.34 and A.36.

The foods considered for the ingestion dose calculations are bread, pasta, beef, pork, poultry, lamb, milk, fish, leafy vegetables, other vegetables, dairy products, eggs, fresh fruit, oil, and wine. The intake rates used for the principal foods are given in Table A.37. Models are used to predict the future variation of food concentrations with time. Higher food concentrations are used for calculating the critical group doses than for calculating the collective doses.

Figure A.13. **DRY DEPOSITION OF CESIUM-137 IN ITALY (kBq/m²)**



The critical group is hypothetical.

The dose factors used for radionuclides taken into the body are taken from ICRP Publication-30, NRPB-R162 and ISH-HEFT 63, 78 and 80. The doses from external irradiation are calculated using the dose conversion factors recommended in NRPB-DL10. Shielding factors of 0.3 or 0.4 (one value used by each national body) are used to take account of the reduction of the external dose by buildings; these factors include an allowance for time spent outdoors. No reduction of the inhalation dose is assumed whilst an individual is indoors.

Figure A.14. **WET DEPOSITION OF IODINE-131 IN ITALY (kBq/m²)**

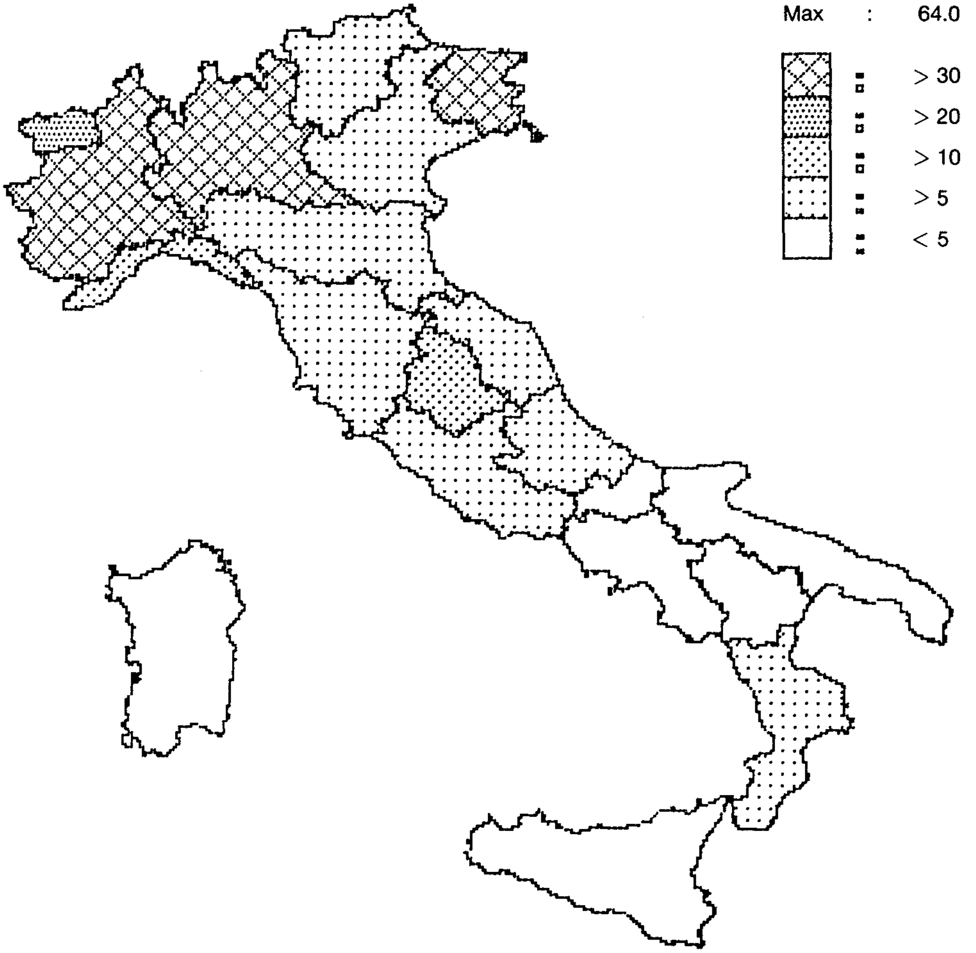


Figure A.15. **WET DEPOSITION OF CESIUM-137 IN ITALY**
(kBq/m²)

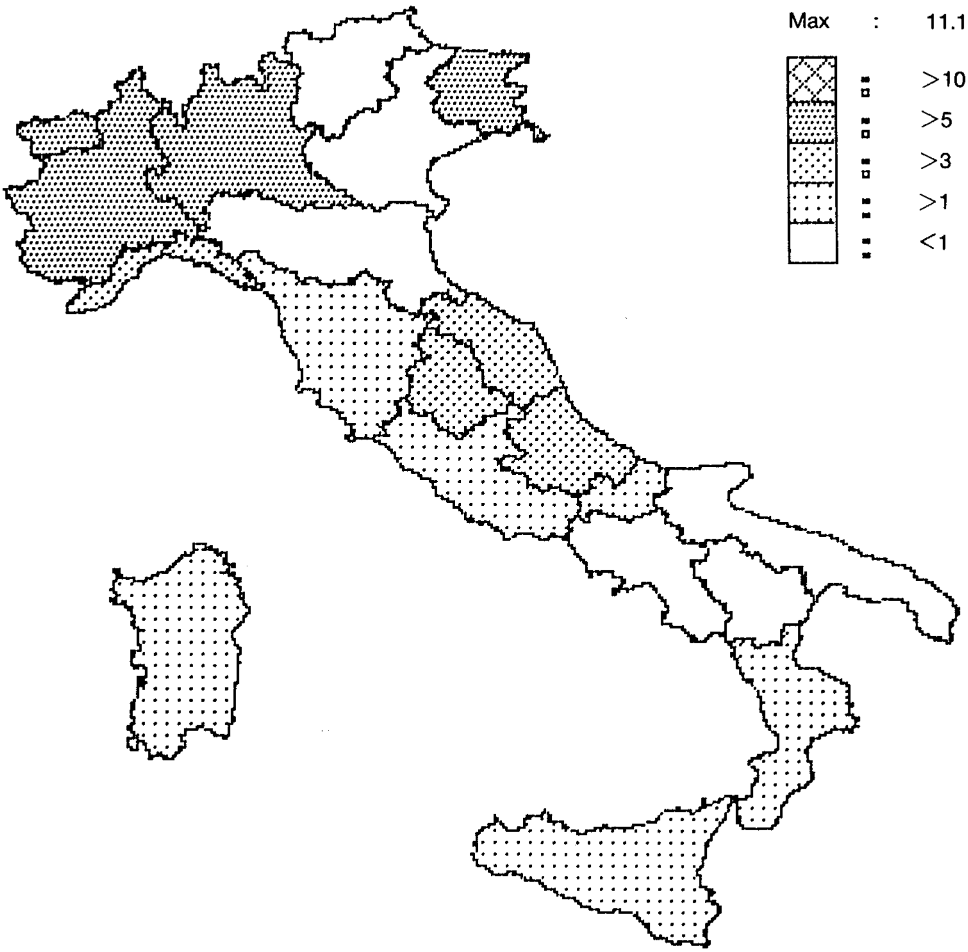


Table A.33. **Individual effective dose equivalent committed from the first year of exposure/intake May 1986-April 1987**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*		
	Adults	Children	Infants
External irradiation (passing cloud)	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
External irradiation (deposited activity)	0.8	0.8	0.8
Inhalation	0.025	0.043	0.034
Milk and Derived products / Vegetables / Meat and Fish	1.8	2.4	2.4
Total			
Grand Total (I + C_s + others)	2.6	3.2	3.2

Table A.34. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
External irradiation (deposited activity)	3 760*	3 760/3 940	504*	504/375	44*	44/30
Inhalation	19 369/10 530	791/2 600	5 267/3 500	173/500	371/180	12/40
Milk and Derived products / Vegetables / Meat and Fish	61 779/74 750	15 671/19 420	22 438/25 300	3 217/3 425	1 990/2 540	248/270
Total	84 908/85 280	20 222/25 960	28 209/28 800	3 895/4 300	2 405/2 720	304/340

Grand Total Collective Dose Equivalent to the Thyroid: 115 522/116 800 manSv
Grand Total Collective Effective Dose Equivalent: 24 420/30 600 manSv

Notes:
Collective dose estimates have been made independently by two national bodies; both sets of doses are given.
* In one of the two evaluations performed, only iodine-131 has been taken into account for thyroid dose equivalent.

Table A.35. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*		
	Adults	Children	Infants
External irradiation (passing cloud)	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
External irradiation (deposited activity)	0.8	0.8	0.8
Inhalation	0.025	0.043	0.034
Milk and Derived products / Vegetables / Meat and Fish	2.1	3.6	4.2
Total			
Grand Total (I + C_s + others)	2.9	4.4	5.0

Table A.36. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
External irradiation (deposited activity)	3 760*	3 760/3 940	504*	504/375	44*	44/30
Inhalation	19 369/10 530	791/2 600	5 267/3 500	173/500	371/180	12/40
Milk and Derived products / Vegetables / Meat and Fish	117 287/178 000	18 437/24 520	72 207/85 550	4 997/5 525	12 193/13 040	577/670
Total	140 416/188 530	22 988/31 060	77 978/89 050	5 674/6 400	12 608/13 220	633/740

Grand Total Collective Dose Equivalent to the Thyroid: 231 002/290 800 manSv
Grand Total Collective Effective Dose Equivalent: 29 295/38 200 manSv

Notes:
Collective dose estimates have been made independently by two national bodies; both sets of doses are given.

* In one of the two evaluations performed, only iodine-131 has been taken into account for thyroid dose equivalent.

Table A.37. **Intake rates**

FOODSTUFF	INTAKE RATES (kg.y^{-1})		
	Adults	Children	Infants
Milk & Milk Products	90/95	120/120	255/250
Green Leafy Vegetables	33/72	26/45	12/13
Meat	47/68	30/40	14/14
Bread & Pasta	110/110	85/85	7/20
Fish	7/11	7/11	5/7
Fruit	77/110	77/110	13/18

Note:
Collective dose estimates have been made independently by two national bodies; the two sets of intake rates used are listed here.

1.13. JAPAN

Maps of iodine and caesium deposition are given in Figures A.16 and A.17.

Critical group and collective dose estimates are given in Tables A.38 and A.39, respectively.

Technical Notes

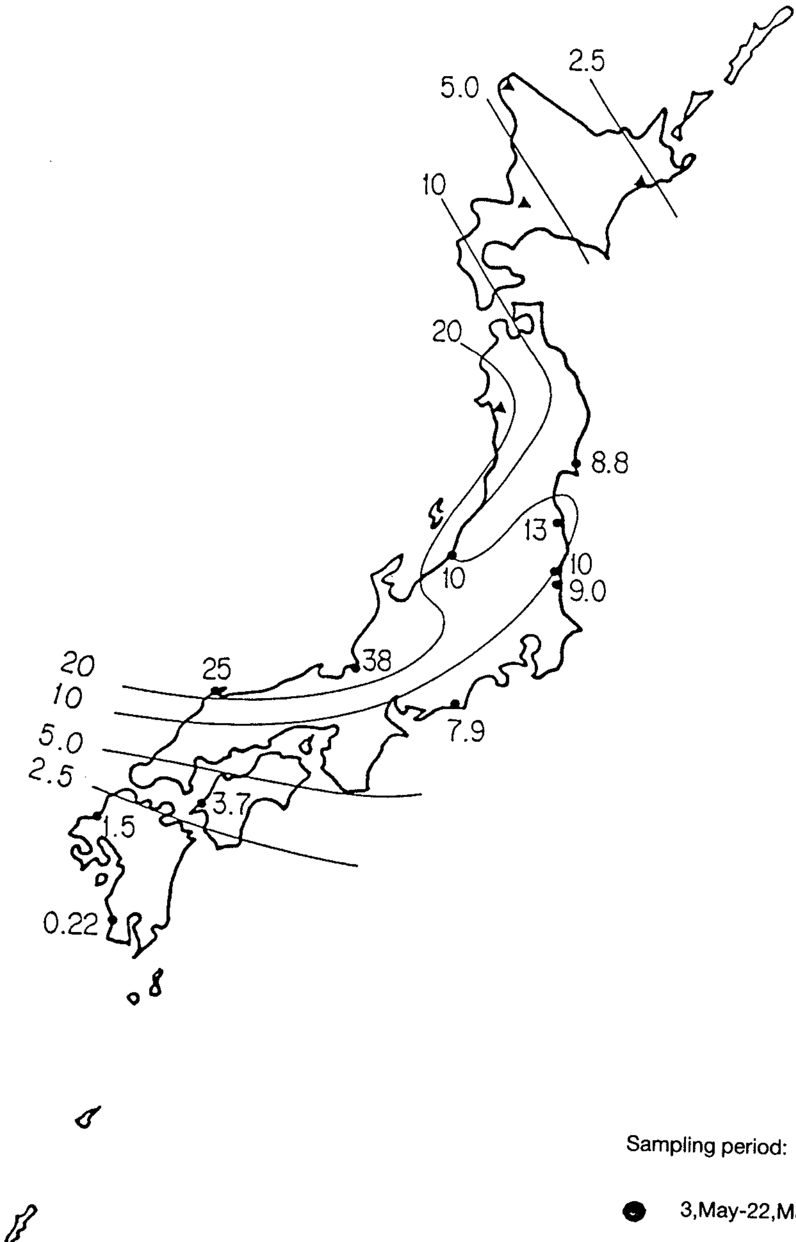
The foods considered for the ingestion dose calculations are milk (not including milk products) and leafy vegetables. The intake rates used are given in Table A.40. These intake rates are used for both the critical group and the collective dose calculations; they are considered to be conservative for average individuals. Measured food and soil concentrations are extrapolated to later times using an exponential function. Higher food concentrations are used for the calculation of the critical group doses than for the collective doses. None of the foods considered in this assessment are imported into Japan.

The age-groups are defined as adults aged 10 years and over, children aged 2-9 years and infants aged up to 1 year. The critical group is hypothetical; the individuals are assumed to eat all their food from the most contaminated sources.

The dose factors used for radionuclides taken into the body are based on ICRP Publication-30. The dose conversion factors used for calculating the doses from external irradiation are those recommended by D.C. Kocher (Health Physics, *38*, 543-621, 1980). No account is taken of the shielding of houses for the calculation of external irradiation.

The doses are considered to be upper bounds.

Figure A.16. **DEPOSITION OF IODINE-131 IN JAPAN**
(10^2 MBq/km^2)



Sampling period:

● 3,May-22,May 1986

▲ 1,May-8,May 1986

Figure A.17. **DEPOSITION OF CESIUM-137 +134 IN JAPAN**
(10^1 MBq/km^2)

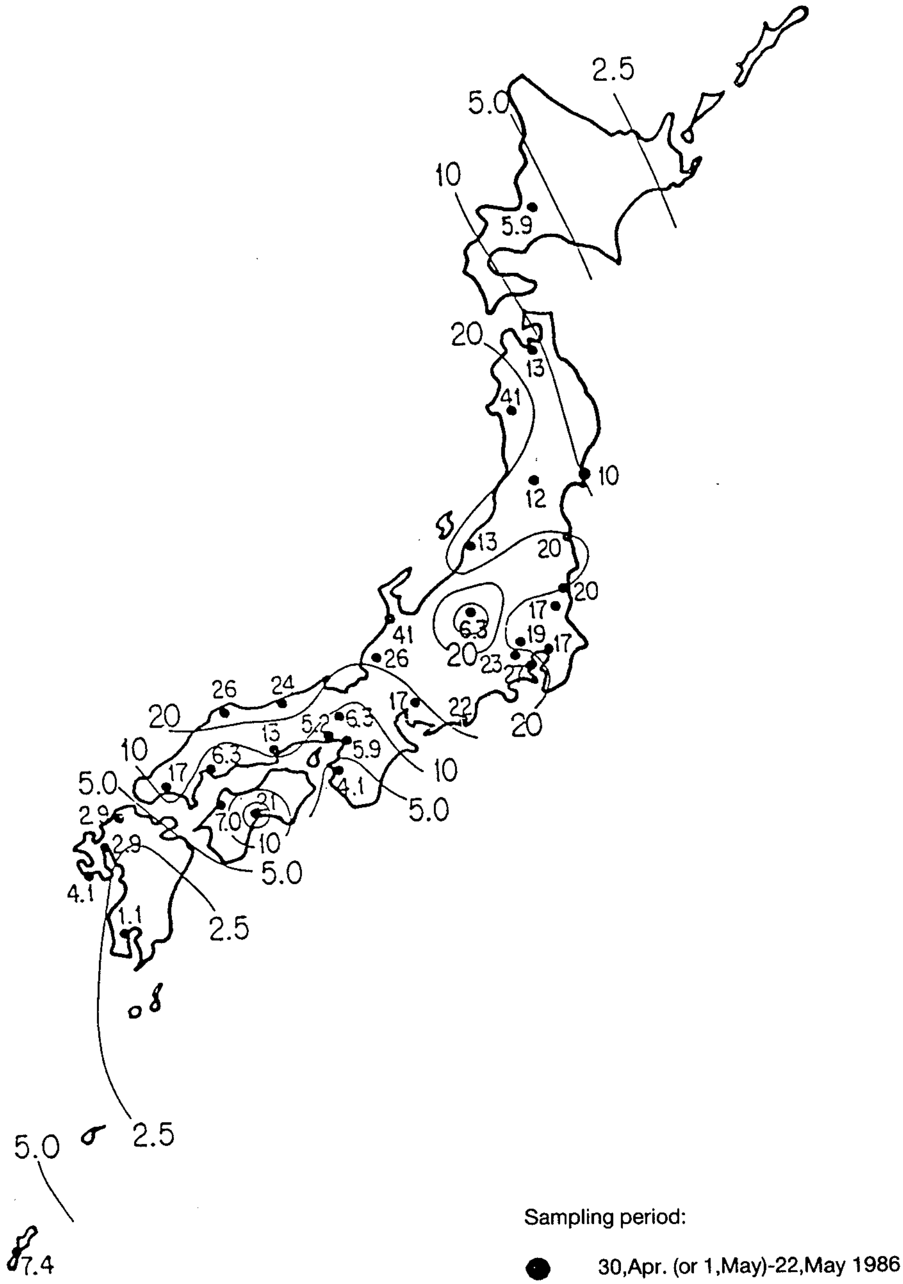


Table A. 38. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides*	Iodines	Caesium-137 + Caesium-134	Other Nuclides*	Iodines	Caesium-137 + Caesium-134	Other Nuclides*
External irradiation (passing cloud)	7.7 10^{-6}	2.4 10^{-6}	1.5 10^{-6}	7.7 10^{-6}	2.4 10^{-6}	1.5 10^{-6}	7.7 10^{-6}	2.4 10^{-6}	1.5 10^{-6}
External irradiation (deposited activity)	1.5 10^{-3}	9.9 10^{-3}	1.8 10^{-3}	1.5 10^{-3}	9.9 10^{-3}	1.8 10^{-3}	1.5 10^{-3}	9.9 10^{-3}	1.8 10^{-3}
Inhalation	8.0 10^{-4}	1.3 10^{-4}	5.9 10^{-4}	1.6 10^{-3}	2.0 10^{-4}	9.2 10^{-4}	1.2 10^{-3}	1.8 10^{-4}	8.2 10^{-4}
Milk and Derived Products	5.0 10^{-4}	5.5 10^{-4}	1.2 10^{-4}	6.3 10^{-3}	5.3 10^{-3}	1.1 10^{-3}	1.5 10^{-2}	1.5 10^{-2}	3.3 10^{-3}
Vegetables	3.7 10^{-3}	2.4 10^{-4}	5.1 10^{-5}	9.2 10^{-3}	4.6 10^{-4}	9.9 10^{-5}	7.4 10^{-3}	4.4 10^{-4}	9.5 10^{-5}
Total	6.4 10^{-3}	1.1 10^{-2}	2.6 10^{-3}	1.9 10^{-2}	1.6 10^{-2}	4.0 10^{-1}	2.5 10^{-2}	2.6 10^{-2}	6.1 10^{-3}
Grand Total (I + C_s + Others)	2.0 10^{-2}			3.8 10^{-2}			5.7 10^{-3}		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3

* Ruthenium-103 and 106 only are evaluated.

Table A. 39. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in man Sv**					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	$6.7\ 10^{-1}$	$8.1\ 10^{-1}$	$1.2\ 10^{-1}$	$1.4\ 10^{-1}$	$1.0\ 10^{-2}$	$1.2\ 10^{-2}$
External irradiation (deposited activity)	$3.2\ 10^{2}$	$4.1\ 10^{2}$	$5.7\ 10^{1}$	$7.1\ 10^{1}$	4.8	6.9
Inhalation	$2.3\ 10^{3}$	$7.7\ 10^{1}$	$8.0\ 10^{2}$	$2.6\ 10^{1}$	$5.2\ 10^{1}$	1.7
Milk and Derived products	$1.6\ 10^{2}$	$1.2\ 10^{1}$	$3.4\ 10^{2}$	$2.2\ 10^{1}$	$7.2\ 10^{1}$	5.2
Vegetables	$2.8\ 10^{3}$	$1.0\ 10^{2}$	$1.2\ 10^{3}$	$4.3\ 10^{1}$	$8.4\ 10^{1}$	3.0
Total	5 600	600	2 400	160	210	17

Grand Total Collective Dose Equivalent to the Thyroid: 8 200 manSv
Grand Total Collective Effective Dose Equivalent: 780 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3

* Iodine-131 and cesium-137 + 134 only are considered.

Table A. 40. **Intake rates**

PATHWAY		Adults	Children	Infants
Inhalation	$(m^3.d^{-1})$	20	8	3
Milk	$(L.d^{-1})$	0.2	0.5	0.6
Leafy Vegetables	$(g.d^{-1})$	100	50	20

1.14. LUXEMBOURG

Average individual and collective dose estimates are given in Tables A.41 and A.42, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.43 and A.44.

Technical Notes

The main foods considered for the ingestion dose calculations are milk and milk products, meat (beef, pork, veal, poultry, fish), vegetables (salads, potatoes, etc.), fruits (apples, pears, strawberries, etc.) and cereals. In addition, less commonly eaten foods, such as game, mutton, mushrooms, chocolate and honey, are also taken into account, but they do not contribute significantly to the doses. The intake rates used are given in Table A.45. Models are used to predict the future variation of food concentrations with time. The contribution of imported food is considered to have little influence on the doses estimated.

The age-groups are defined as adults aged 10 years and over, children aged 2-9 years and infants aged up to 1 year. No critical group has been identified.

The dose factors used for radionuclides taken into the body are those published by the Institut für Strahlenhygiene (ISH-HEFT 63, 78 and 80, 1985), which take into account the higher metabolic rate found in children and infants compared with adults. The model used for calculating the doses from external irradiation is not known. Adults and children are assumed to spend 80 per cent of their time indoors, during which time they receive no external irradiation; infants are assumed to spend 90 per cent of their time indoors, with complete shielding. No reduction in inhalation is assumed whilst individuals are indoors.

The doses are considered to be best estimates.

Table A. 41. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	AVERAGE DOSES *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation (passing cloud) External Irradiation (deposited activity)	Total: $3.6\ 10^{-2}$			Total: $3.6\ 10^{-2}$			Total: $1.8\ 10^{-2}$		
Inhalation	$3.4\ 10^{-3}$	$2.4\ 10^{-3}$	$3.9\ 10^{-3}$	$6.8\ 10^{-3}$	$1.2\ 10^{-3}$	$5.0\ 10^{-3}$	$1.0\ 10^{-2}$	$4.0\ 10^{-4}$	$1.3\ 10^{-3}$
Milk and Derived Products	$4.4\ 10^{-3}$	$3.1\ 10^{-2}$		$1.6\ 10^{-2}$	$2.9\ 10^{-2}$		$1.7\ 10^{-2}$	$3.9\ 10^{-2}$	
Vegetables and Fruits	$2.1\ 10^{-3}$	$6.4\ 10^{-3}$	$8.6\ 10^{-3}$	$4.6\ 10^{-3}$	$3.7\ 10^{-3}$	$1.1\ 10^{-2}$	$3.2\ 10^{-3}$	$5.8\ 10^{-4}$	$2.7\ 10^{-2}$
Meat and Fish	–	$2.3\ 10^{-2}$		–	$9.3\ 10^{-3}$		–	–	
Total									
Grand Total ($I + C_s$ + Others)	0.121			0.123			0.117		

Table A. 42. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	11.6	–	1.4	–	0.08
External irradiation (deposited activity)	–		–		–	
Inhalation	35.7	3.1	5.5	0.5	0.9	0.05
Milk and Derived products	57.2	12.8	13.8	2.0	2.4	0.34
Vegetables and Fruits	25.0	3.5	5.4	0.35	0.43	0.02
Meat and Fish	6.8	8.5	0.35	0.44	–	–
Total	124.7	39.5	31.0	4.7	3.7	0.5

Grand Total Collective Dose Equivalent to the Thyroid: 159.4 manSv
Grand Total Collective Effective Dose Equivalent: 44.7 manSv

LUXEMBOURG

Table A. 43. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	AVERAGE DOSES *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation (passing cloud) External Irradiation (deposited activity)	Total: 3.6 10^{-2}			Total: 3.6 10^{-2}			Total: 1.8 10^{-2}		
Inhalation	3.4 10^{-3}	2.4 10^{-3}	3.9 10^{-3}	6.8 10^{-3}	1.2 10^{-3}	5.0 10^{-3}	1.0 10^{-2}	4.0 10^{-4}	1.3 10^{-3}
Milk and Derived Products	7.7 10^{-3}	3.2 10^{-2}		2.8 10^{-2}	3.0 10^{-2}		2.8 10^{-2}	4.0 10^{-2}	
Vegetables and Fruits	5.7 10^{-3}	7.3 10^{-3}	8.6 10^{-3}	9.7 10^{-3}	4.0 10^{-3}	1.1 10^{-2}	8.2 10^{-3}	6.5 10^{-4}	2.7 10^{-2}
Meat and Fish	–	2.3 10^{-2}		–	9.3 10^{-3}		–	–	
Total									
Grand Total (I + C_s + Others)	0.130			0.141			0.133		

Table A. 44. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	11.6	–	1.4	–	0.08
External irradiation (deposited activity)	–		–		–	
Inhalation	35.7	3.1	5.5	0.5	0.9	0.05
Milk and Derived products	93.6	14.2	33.8	2.5	4.0	0.40
Vegetables and Fruits	63.5	4.9	11.3	0.55	1.2	0.04
Meat and Fish	6.8	8.5	0.35	0.44	–	–
Total	199.6	42.3	51	5.4	6.1	0.6

Grand Total Collective Dose Equivalent to the Thyroid: 256.7 manSv
Grand Total Collective Effective Dose Equivalent: 48.3 manSv

LUXEMBOURG

Table A. 45. **Intake rates for average individuals**

FOODSTUFF	INTAKE RATES ($g.d^{-1}$)		
	Adults	Children	Infants
Milk & Milk Products	300	500	700
Meat	240	150	–
Vegetables	300	200	100
Fruits	200	200	–
Cereals	260	160	–

1.15. NETHERLANDS

A map of caesium-137 deposition is given in Figure A.18.

Average individual and collective dose estimates are given in Tables A.46 and A.47, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.48 and A.49.

Technical Notes

The foods considered for the ingestion dose calculations are grain, potatoes, sugar, vegetables and fruit, milk and milk products, beef, pork, chicken and eggs, saltwater and freshwater fish and water. The intake rates used are given in Table A.50. Models are used to predict the future variation of food concentrations with time. The contribution of imported food to the doses is not considered, but is thought to be small.

The average age used for children is 10 years, and for infants, 1 year. No critical group has been identified.

The dose factors used for radionuclides taken into the body are those published by the Institut für Strahlenhygiene (ISH-HEFT 63, 78 and 80, 1985), which take into account the higher metabolic rates found in children and infants compared with adults. The model used for calculating the doses from external irradiation is not known. A shielding factor of 0.3 is used to take account of the reduction of the external dose by buildings; this factor includes an allowance for time spent outdoors. No reduction of the inhalation dose is assumed whilst an individual is indoors.

The doses are considered to be best estimates.

Figure A.18. **DEPOSITION OF CESIUM-137 IN THE NETHERLANDS (kBq/m²)**

Table A. 46. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	AVERAGE DOSES *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other nuclides	Iodines	Caesium-137 + Caesium-134	Other nuclides	Iodines	Caesium-137 + Caesium-134	Other nuclides
External irradiation (passing cloud)	9.5 10^{-5}	1.3 10^{-5}	1.5 10^{-5}	9.5 10^{-5}	1.3 10^{-5}	1.5 10^{-5}	9.5 10^{-5}	1.3 10^{-5}	1.5 10^{-5}
External irradiation (deposited activity)	4.2 10^{-3}	1.8 10^{-2}	5.8 10^{-3}	4.2 10^{-3}	1.8 10^{-2}	5.8 10^{-3}	4.2 10^{-3}	1.8 10^{-2}	5.8 10^{-3}
Inhalation	4.0 10^{-3}	7.0 10^{-4}	3.1 10^{-3}	6.6 10^{-3}	2.5 10^{-4}	2.8 10^{-3}	5.3 10^{-3}	5.4 10^{-4}	2.2 10^{-3}
Milk and Derived Products	1.8 10^{-3}	7.5 10^{-3}	–	5.9 10^{-3}	2.3 10^{-2}	–	2.8 10^{-2}	6.4 10^{-2}	–
Vegetables	7.6 10^{-3}	2.5 10^{-3}	–	1.6 10^{-2}	4.0 10^{-3}	–	2.1 10^{-2}	4.2 10^{-3}	–
Meat and Fish	4.0 10^{-3}	1.5 10^{-3}	–	6.0 10^{-4}	1.7 10^{-3}	–	4. 10^{-4}	1.0 10^{-3}	–
Total	2.2 10^{-2}	3.0 10^{-2}	8.0 10^{-3}	4.0 10^{-2}	4.8 10^{-2}	8.7 10^{-3}	5.6 10^{-2}	9.0 10^{-2}	8.0 10^{-3}
Grand Total (I + C_s + Others)	0.06			0.10			0.19		

Table A. 47. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	2	2	0.3	0.3	0.03	0.03
External irradiation (deposited activity)	400	400	70	70	10	10
Inhalation	1 100	50	300	15	30	1.5
Milk and Derived products	650	150	350	30	200	25
Vegetables	1 800	100	550	25	100	5
Meat and Fish	150	50	50	10	3	1
Total	4 100	750	1 320	150	350	40

Grand Total Collective Dose Equivalent to the Thyroid: 5 800 manSv
Grand Total Collective Effective Dose Equivalent: 950 manSv

Table A. 48. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	AVERAGE DOSES *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation (passing cloud)	$9.5\ 10^{-5}$	$1.3\ 10^{-5}$	$1.5\ 10^{-5}$	$9.5\ 10^{-5}$	$1.3\ 10^{-5}$	$1.5\ 10^{-5}$	$9.5\ 10^{-5}$	$1.3\ 10^{-5}$	$1.5\ 10^{-5}$
External irradiation (deposited activity)	$4.2\ 10^{-3}$	$1.8\ 10^{-2}$	$5.8\ 10^{-3}$	$4.2\ 10^{-3}$	$1.8\ 10^{-2}$	$5.8\ 10^{-3}$	$4.2\ 10^{-3}$	$1.8\ 10^{-2}$	$5.8\ 10^{-3}$
Inhalation	$4.0\ 10^{-3}$	$7.0\ 10^{-4}$	$3.1\ 10^{-3}$	$6.6\ 10^{-3}$	$8.5\ 10^{-4}$	$2.8\ 10^{-3}$	$5.3\ 10^{-3}$	$5.4\ 10^{-4}$	$2.2\ 10^{-3}$
Milk and Derived Products	$2.7\ 10^{-3}$	$1.1\ 10^{-2}$	–	$9.0\ 10^{-3}$	$2.5\ 10^{-2}$	–	$4.0\ 10^{-2}$	$9.0\ 10^{-2}$	–
Vegetables	$1.1\ 10^{-2}$	$4.0\ 10^{-3}$	–	$2.4\ 10^{-2}$	$6.0\ 10^{-3}$	–	$3.1\ 10^{-2}$	$6.3\ 10^{-3}$	–
Meat and Fish	$4.0\ 10^{-3}$	$1.5\ 10^{-3}$	–	$6.0\ 10^{-4}$	$1.7\ 10^{-3}$	–	$4.0\ 10^{-4}$	$1.0\ 10^{-3}$	–
Total	$2.7\ 10^{-2}$	$3.6\ 10^{-2}$	$8.0\ 10^{-3}$	$4.5\ 10^{-2}$	$6.3\ 10^{-2}$	$8.7\ 10^{-3}$	$8.1\ 10^{-2}$	$1.3\ 10^{-1}$	$8.1\ 10^{-3}$
Grand Total (I + C_s + Others)	0.07			0.13			0.25		

Table A. 49. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	2	2	0.3	0.3	0.03	0.03
External irradiation (deposited activity)	400	400	70	70	10	10
Inhalation	1 100	50	300	15	30	1.5
Milk and Derived products	1 000	220	500	50	300	50
Vegetables	2 700	150	800	50	150	10
Meat and Fish	150	50	50	10	3	1
Total	5 350	850	1 720	195	500	70

Grand Total Collective Dose Equivalent to the Thyroid: 7 600 manSv
Grand Total Collective Effective Dose Equivalent: 1 120 manSv

Table A.50. **Average consumption**

FOODSTUFF	CONSUMPTION ($kg.y^{-1}$)			
	Average[a]	Adults	Children	Infants
Grain (products)[a]	54	65	45	20
Potatoes	60	70	50	20
Sugar(s)	37	40	30	10
Vegetables and Fruit[b]	116	130	100	40
Milk (products)	162	145	200	230
Cowmeat	17	20	15	5
Pigmeat	27	30	20	5
Chicken and Eggs	18	20	15	5
Seafish	6	10	5	2
Other fish	0.2	0.2	0.1	–
Water	–	600	350	200

a) Only 40 per cent of the grains (the locally produced part) has been considered in the calculations.

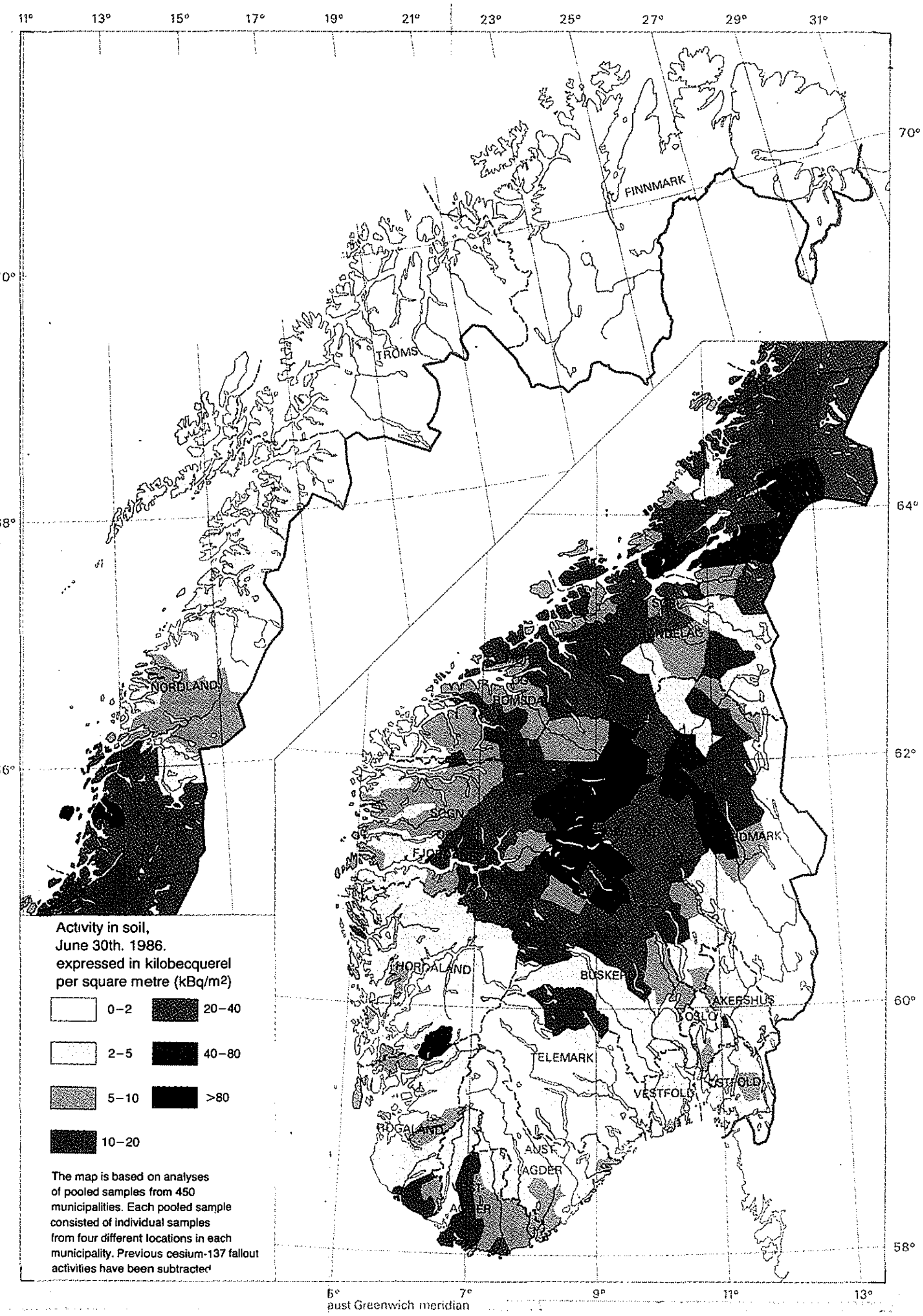
b) Of this product group, 50 per cent is vegetables, and 50 per cent is fruit.

1.16. NORWAY

A map of caesium-137 + 134 deposition is given in Figure A.19.

Critical group and collective dose estimates are given in Tables A.51 and A.52, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.53 and A.54.

Figure A.19. **DEPOSITION PATTERN OF Cs (134 + 137) IN NORWEGIAN MUNICIPALITIES (Mean Values)**



NORWAY

Table A.51. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in microsieverts*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation[c] (passing cloud)	0.07	0.01	0.06	0.07	0.01	0.06	0.07	0.01	0.06
External irradiation[b] (deposited activity)	100	1 300	200	100	1 300	200	100	1 100	200
Inhalation[b]	14	2	4	36	5	7	130	16	30
Milk and Derived[b] products	30	70	–	220	60	–	680	30	–
Vegetables[b]	–	70	–	–	60	–	–	30	–
Meat and Fish[b]	–	310	–	–	260	–	–	130	–
Total	144	1 752	204	356	1 685	207	910	1 306	230
Grand Total (I + C_s + Others)		2 100			2 250			2 450	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 per cent

b = within a factor 3

c = order of magnitude

Table A.52. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)						
External irradiation (deposited activity)						
Inhalation						
Milk and Derived products						
Vegetables						
Meat and Fish						
Total	1 560	500	160	130	78	72

Grand Total Collective Dose Equivalent to the Thyroid: 1 798 manSv

Grand Total Collective Effective Dose Equivalent: 702 manSv

Table A.53. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in microsieverts*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation[c] (passing cloud)	0.07	0.01	0.06	0.07	0.01	0.06	0.07	0.01	0.06
External irradiation[b] (deposited activity)	100	1 300	200	100	1 300	200	100	1 100	200
Inhalation[b]	14	2	4	36	5	7	130	16	30
Milk and Derived[b] products	30	70	–	220	60	–	680	30	–
Vegetables[b]	–	70	–	–	60	–	–	30	–
Meat and Fish[b]	–	800	–	–	660	–	–	320	–
Total	144	2 242	204	356	2 085	207	910	1 496	230
Grand Total (I + C_s + Others)		2 600			2 660			2 636	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 per cent

b = within a factor 3

c = order of magnitude

Table A.54. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)						
External irradiation (deposited activity)						
Inhalation						
Milk and Derived products						
Vegetables						
Meat and Fish						
Total	1 810	750	300	180	108	102

Grand Total Collective Dose Equivalent to the Thyroid: 2 218 manSv
Grand Total Collective Effective Dose Equivalent: 1 032 manSv

1.17. PORTUGAL

Owing to the very low levels of deposition observed, which were quite uniformly distributed over the country, no maps of caesium and iodine deposition are presented.

Critical group and collective dose estimates are given in Tables A.55 and A.56.

Technical Notes

Only doses due to ingestion of contaminated foods were considered, but these did not take into account imported food.

The estimated doses to the critical group were derived assuming a maximum intake of food by a hypothetical group.

PORTUGAL

Table A.55. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation[c] (passing cloud)	–	–	–	–	–	–	–	–	–
External irradiation[b] (deposited activity)	–	–	–	–	–	–	–	–	–
Inhalation[b]	–	–	–	–	–	–	–	–	–
Milk and Derived products	$2\ 10^{-4}$	$2\ 10^{-3}$	–	$5\ 10^{-4}$	$4\ 10^{-3}$	–	$1\ 10^{-3}$	$8\ 10^{-3}$	–
Vegetables	$7\ 10^{-4}$	$6\ 10^{-3}$	–	$1\ 10^{-3}$	$8\ 10^{-3}$	–	$2\ 10^{-3}$	$1\ 10^{-2}$	–
Meat	–	$2\ 10^{-3}$	–	–	$3\ 10^{-3}$	–	–	$4\ 10^{-3}$	–
Total	$9\ 10^{-4}$	$1\ 10^{-2}$	–	$2\ 10^{-3}$	$1.5\ 10^{-2}$	–	$3\ 10^{-3}$	$2.2\ 10^{-2}$	–
Grand Total (I + C_s + Others)		$1\ 10^{-2}$			$2\ 10^{-2}$			$3\ 10^{-2}$	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3.

Table A.56. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External irradiation (deposited activity)	–	–	–	–	–	–
Inhalation	–	–	–	–	–	–
Milk and Derived products	16	3.9	13	2.7	3.3	$5.8\ 10^{-1}$
Vegetables	86	24	30	5.9	5.5	$9.2\ 10^{-1}$
Meat and Fish	–	16	–	3.2	–	$5.0\ 10^{-1}$
Total	102	44	43	12	9	2

Grand Total Collective Dose Equivalent to the Thyroid: 154 manSv
Grand Total Collective Effective Dose Equivalent: 58 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3.

1.18. SPAIN

Owing to the very low levels of deposition observed, no maps of iodine and caesium deposition are presented.

Critical group dose estimates are given in Table A.57. Owing to the low deposition levels observed, it was not considered useful to calculate collective doses for Spain.

Technical Notes

The foods considered for the ingestion dose calculations are milk and leafy vegetables. The intake rates used are given in Table A.58. The contribution of imported food to the dose is not considered.

The average age for children is taken as 10 years; that for infants is taken as 1 year. The critical group is hypothetical.

The dose factors used for radionuclides taken into the body are those previously recommended by NRPB (NRPB-R162), and are based on ICRP Publication-30. The doses from external irradiation are also calculated using the dose conversion factors recommended by NRPB in NRPB-DL10. No account is taken of the shielding of houses for the calculation of doses from external irradiation and inhalation.

The doses are considered to be upper bounds

Table A.57. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides*	Iodines	Caesium-137 + Caesium-134	Other Nuclides*	Iodines	Caesium-137 + Caesium-134	Other Nuclides*
External irradiation (deposited activity)	$2.01\ 10^{-5}$	$4.06\ 10^{-4}$	–	$2.01\ 10^{-5}$	$4.06\ 10^{-4}$	–	$2.01\ 10^{-5}$	$4.06\ 10^{-4}$	–
Inhalation	$1.68\ 10^{-4}$	$3.20\ 10^{-4}$	$5.32\ 10^{-5}$	$2.14\ 10^{-4}$	$5.04\ 10^{-4}$	$5.39\ 10^{-5}$	$2.50\ 10^{-4}$	$5.25\ 10^{-4}$	$5.76\ 10^{-5}$
Milk	$1.43\ 10^{-3}$	$6.58\ 10^{-3}$	–	$6.14\ 10^{-3}$	$2.27\ 10^{-2}$	–	$1.88\ 10^{-2}$	$6.12\ 10^{-2}$	–
Vegetables	$3.83\ 10^{-3}$	$2.14\ 10^{-2}$	$6.74\ 10^{-5}$	$4.51\ 10^{-3}$	$1.86\ 10^{-2}$	$6.20\ 10^{-5}$	–	–	–
Meat and Fish	–	–	–	–	–	–	–	–	–
Total	$5.45\ 10^{-3}$	$2.87\ 10^{-2}$	$1.21\ 10^{-4}$	$1.09\ 10^{-2}$	$4.22\ 10^{-2}$	$1.16\ 10^{-4}$	$1.91\ 10^{-2}$	$6.21\ 10^{-2}$	$5.76\ 10^{-5}$
Grand Total ($I + C_s$ + Others)		$3.43\ 10^{-2}$			$5.32\ 10^{-2}$			$7.13\ 10^{-2}$	

* Only the dose from ruthemium-103 was calculated in addition to the doses from iodine-131 and caesium-137 + 134.

Table A.58. **Critical group intake rates**

PATHWAY		Adults	Children	Infants
Inhalation	($m^3.month^{-1}$)	666.67	308.33	116.67
Milk Ingestion	($L.month^{-1}$)[a]	8.83	13.7	13.7
Leafy Vegetables Ingestion	($kg.month^{-1}$)[a]	13.73	5.83	–

a) National data for maximum individual.

1.19. SWEDEN

A map of caesium-137 deposition is given in Figure A.20.

Critical group and collective dose estimates are given in Tables A.59 and A.60, respectively. The doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.61 and A.62.

Technical Notes

The foods considered for the ingestion dose calculations are milk, milk products, meat (cattle, pigs, sheep, moose, reindeer), fish (inland lakes, Baltic), green vegetables, cereals, fruits, berries and potatoes. The intake rates used are those given in Table 10.1 1 in the Yearbook of Agricultural Statistics 1986 (Official Statistics of Sweden, Stockholm, 1986). The doses are calculated from the sum of monthly averages of measured food concentrations until October 1986; between October 1986 and April 1987 it is assumed that the levels remain constant at the October 1986 values. Higher values of food concentration are used in the critical group calculations than in the collective dose calculations. Imported food is considered to contribute, at most, a few percent to the doses given in the Tables.

The age-groups are defined as adults aged over 10 years, children aged 2-10 years and infants aged 0-2 years. The critical group is an identified group of 2000-4000 people. The dose estimates for this group take into account wholebody measurements. Individuals in this group are estimated to receive an internal dose about 5 times the national average.

The dose factors used for radionuclides taken into the body are those published by the Institut für Strahlenhygiene (ISH-HEFT 63, 78 and 80, 1985), which take into account the higher metabolic rates found in children and infants compared with adults. The doses from external irradiation are based on the dose conversion factors recommended by D.C. Kocher (Health Physics, *38*, 543-621, 1980). A shielding factor of 0.33 is assumed for external irradiation (including an allowance for time spent outdoors). No account is taken of the filtering effect of houses for the calculation of doses from inhalation.

The doses are considered to be best estimates, but are likely to be revised when the results of a planned wholebody measurement programme have been analysed.

Figure A.20. **DEPOSITION OF CESIUM-137 IN SWEDEN (kBq/m²)**

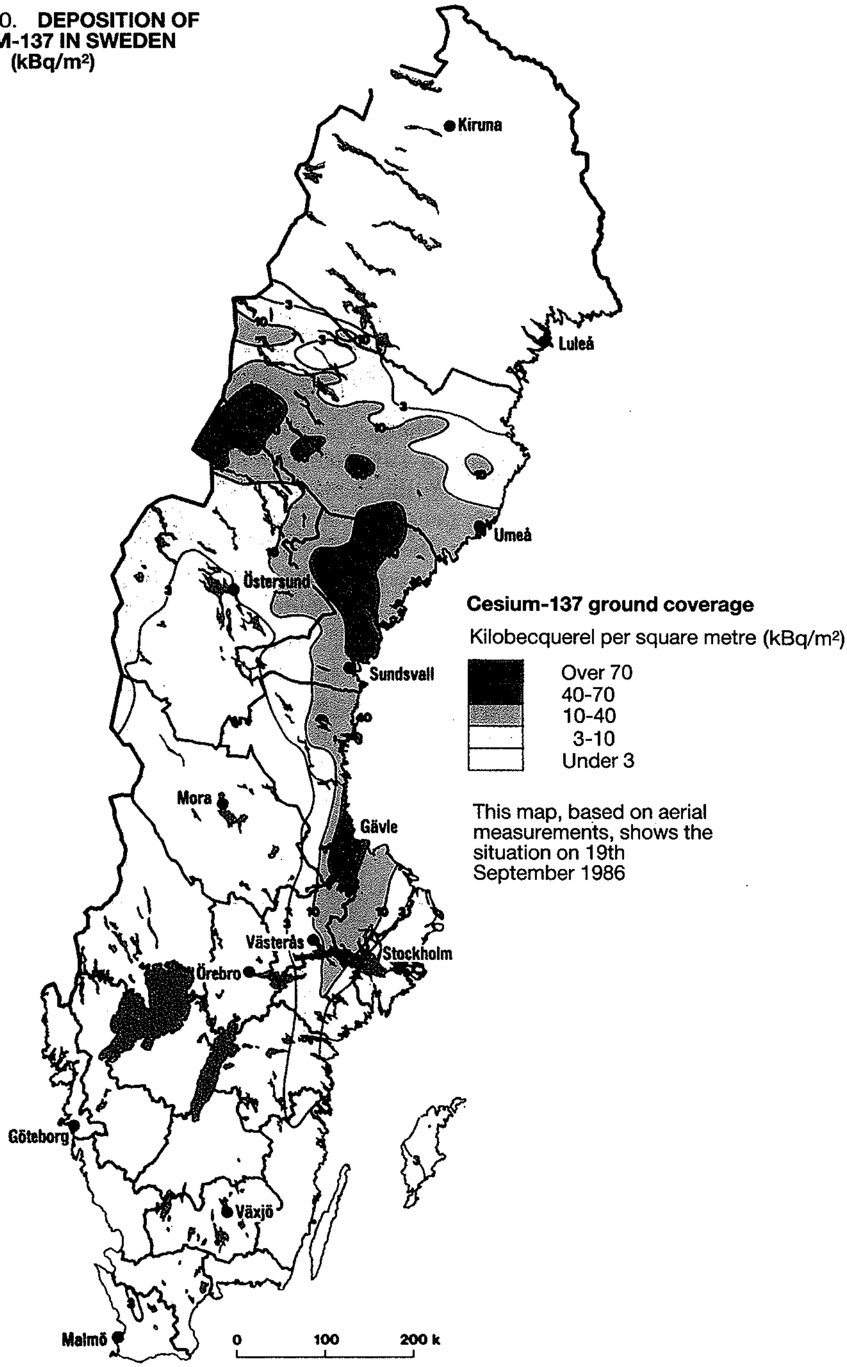


Table A.59. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in microsieverts*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation[b] (passing cloud)	0.15	0.015	0.05	0.15	0.015	0.05	0.15	0.015	0.05
External irradiation[b] (deposited activity)	300	1 500	200	300	1 500	200	300	1 500	200
Inhalation[b]	10	1	5	17	1	7	14	1	5
Milk and Derived[b] products	0.3	150	0	1	300	0	3	150	0
Vegetables[c]	0	150	0	0	150	0	0	50	0
Meat and Fish[c]	0	200	0	0	100	0	0	50	0
Total	310	2 000	205	318	2 050	207	317	1 750	205
Grand Total (I + C_s + Others)		2 515			2 575			2 272	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 per cent
b = within a factor 3
c = order of magnitude

Table A.60. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation[b] (passing cloud)	1	1	0.1	0.1	0.01	0.01
External irradiation[b] (deposited activity)	700	700	70	70	7	7
Inhalation[b]	1 600	80	250	8	25	1
Milk and Derived[b] products	250	250	40	40	10	10
Vegetables[c]	250	250	25	25	10	10
Meat and Fish[c]	200	200	20	20	5	5
Total	3 000	1 480	405	163	57	33

Grand Total Collective Dose Equivalent to the Thyroid: 3 462 manSv
Grand Total Collective Effective Dose Equivalent: 1 676 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 %
b = within a factor 3
c = order of magnitude.

Table A.61. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in microsieverts*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation[b] (passing cloud)	0.15	0.015	0.05	0.15	0.015	0.05	0.15	0.015	0.05
External irradiation[b] (deposited activity)	300	1 500	200	300	1 500	200	300	1 500	200
Inhalation[b]	10	1	5	17	1	7	14	1	5
Milk and Derived[b] products	0.3	150	0	1	300	0	3	150	0
Vegetables[c]	0	150	0	0	150	0	0	50	0
Meat and Fish[c]	0	270	0	0	150	0	0	50	0
Total	310	2 070	205	318	2 100	207	317	1 750	205
Grand Total (I + C_s + Others)		2 585			2 625			2 272	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 per cent
b = within a factor 3
c = order of magnitude

Table A.62. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation[b] (passing cloud)	1	1	0.1	0.1	0.01	0.01
External irradiation[b] (deposited activity)	700	700	70	70	7	7
Inhalation[b]	1 600	80	250	40	25	1
Milk and Derived[b] products	250	250	40	40	10	10
Vegetables[c]	250	250	25	25	10	10
Meat and Fish[c]	500	500	25	25	5	5
Total	3 300	1 780	410	168	57	33

Grand Total Collective Dose Equivalent to the Thyroid: 3 767 manSv
Grand Total Collective Effective Dose Equivalent: 1 981 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 %
b = within a factor 3
c = order of magnitude.

1.20. SWITZERLAND

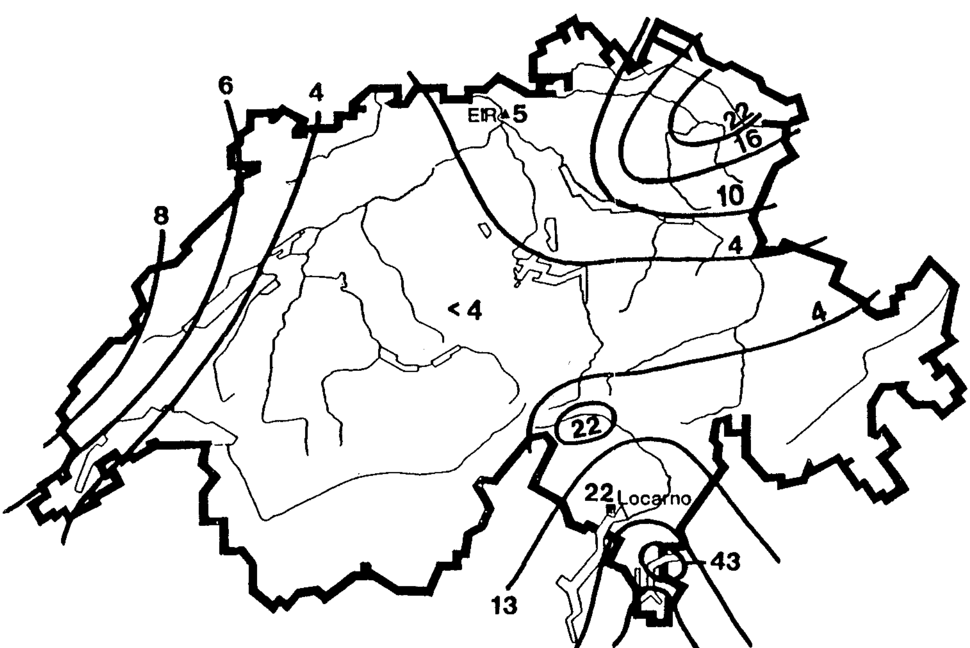
A map of caesium-137 deposition is given in Figure A.21.

Critical group and collective dose estimates are given in Tables A.63 and A.64, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.65 and A.66.

Technical Notes

The foods considered for the ingestion dose calculations are milk, vegetables and meat. The intake rates used are given in Table A.67. The consumption rates of milk for adults and children are thought to be conservative. The dose from iodine-131 in meat is not considered. In calculating the doses account is taken of wholebody measurements.

Figure A.21. **DEPOSITION OF CESIUM-137 IN SWITZERLAND (kBq/m²)**



Cs-134 value ≃ Cs-137 value × 0.5

The dose factors used for radionuclides taken into the body are those published by the Institut für Strahlenhygiene (ISH-HEFT 63, 78 and 80, 1985), which take into account the higher metabolic rates found in children and infants compared with adults. The dose factors used are those for adults, 10 year-old children and 1 year-old infants, respectively. A shielding factor of 0.25 is used to take account of the reduction of the external dose by buildings.

The critical group doses are considered to be upper bounds. Wholebody measurements indicate that the real total caesium content of the average Swiss inhabitant is only 50 per cent of what was calculated by assumed consumption rates and measured food contamination. This suggests that the average dose of Swiss inhabitants is only half the value given in this report. However, there were almost no thyroid-measurements performed to confirm the results of the caesium measurements.

SWITZERLAND

Table A.63. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External irradiation (deposited activity)	0.02	0.33	0.15	0.02	0.33	0.15	0.02	0.33	0.15
Inhalation	Total: 0.02			Total: 0.02			Total: 0.02		
Milk and Derived products	0.08	0.62	0.01	0.18	0.39	0.02	0.20	0.53	0.10
Vegetables	0.07	0.04	0.01	0.14	0.03	0.03	0.02	–	–
Meat and Fish	–	0.67	–	–	0.42	–	–	0.06	–
Total	0.19	1.66	0.17	0.36	1.17	0.20	0.26	0.92	0.25
Grand Total (I + C_s + Others)	2.02			1.73			1.43		

Table A.64. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External irradiation (deposited activity)	290	290	30	30	4	4
Inhalation	950	30	100	3	12	0.4
Milk and Derived products	3 060	450	710	50	95	8
Vegetables	2 670	110	560	20	10	0.3
Meat and Fish	–	380	–	30	–	0.4
Total	6 970	1 260	1 400	133	121	13

Grand Total Collective Dose Equivalent to the Thyroid: 8 500 manSv
Grand Total Collective Effective Dose Equivalent: 1 400 manSv

Table A.65. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Ptojected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation (passing cloud)	–	–	–	–	–	–	–	–	–
External irradiation (deposited activity)	0.02	0.33	0.15	0.02	0.33	0.15	0.02	0.33	0.15
Inhalation	Total: 0.02			Total: 0.02			Total: 0.02		
Milk and Derived products	0.08	0.62	0.01	0.18	0.39	0.02	0.97	0.55	0.10
Vegetables	0.07	0.04	0.01	0.14	0.03	0.03	0.08	–	0.02
Meat and Fish	–	0.67	–	–	0.42	–	–	0.06	–
Total	0.19	1.66	0.17	0.36	1.17	0.20	1.09	0.94	0.27
Grand Total (I + C_s + Others)	2.02			1.73			2.30		

Table A.66. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	–	–	–	–	–	–
External irradiation (deposited activity)	290	290	30	30	4	4
Inhalation	950	30	100	3	12	0.4
Milk and Derived products	3 060	450	710	50	460	20
Vegetables	2 670	110	560	20	40	1.4
Meat and Fish	–	380	–	30	–	0.4
Total	6 970	1 260	1 400	133	516	26

Grand Total Collective Dose Equivalent to the Thyroid: 8 900 manSv
Grand Total Collective Effective Dose Equivalent: 1 400 manSv

Table A.67. **Food consumption**

FOODSTUFF	CONSUMPTION ($kg \cdot d^{-1}$)		
	Adults	Children	Infants
Milk	0.5	0.5	0.7
Vegetables	0.2	0.2	0.03
Meat	0.15	0.15	0.02

1.21. TURKEY

Critical group and collective dose estimates are given in Tables A.68 and A.69, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.70 and A.71.

Technical Notes

The foods considered for the ingestion dose calculations are milk and milk products, vegetables and fruits, meat and fish. The intake rates used are given in Table A.72. Ingestion doses from caesium radionuclides are calculated assuming food concentrations to remain constant throughout the year. The food concentrations used for the critical group calculations are higher than those used for the collective dose calculations. The contribution of imported food to the dose is considered to be less than 5 per cent.

The age-groups are defined as children aged 1-10 years and infants aged less than 1 year. The critical group is an identified group of about 40 000 people.

The dose factors used for radionuclides taken into the body are those recommended by ICRP Publication-30. The model used for the calculation of doses from external irradiation is not known. No shielding factors are used to reduce the doses from external irradiation and inhalation.

The doses are considered to be upper bounds.

TURKEY

Table A.68. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation (passing cloud)	$9.6\ 10^{-4}$	$7.8\ 10^{-4}$	$1.2\ 10^{-4}$	$8.0\ 10^{-4}$	$2.6\ 10^{-4}$	$1.0\ 10^{-4}$	$5.0\ 10^{-4}$	$1.3\ 10^{-4}$	$5.0\ 10^{-4}$
External irradiation (deposited activity)	$2.8\ 10^{-3}$	$1.8\ 10^{-2}$	$7.0\ 10^{-3}$	$3.0\ 10^{-3}$	$1.6\ 10^{-2}$	$6.0\ 10^{-3}$	$1.0\ 10^{-4}$	$1.0\ 10^{-3}$	$4.0\ 10^{-4}$
Inhalation	$1.3\ 10^{-3}$	$3.1\ 10^{-4}$	$2.4\ 10^{-4}$	$1.4\ 10^{-2}$	$1.6\ 10^{-3}$	$3.1\ 10^{-3}$	$2.4\ 10^{-2}$	$3.7\ 10^{-3}$	$8.2\ 10^{-3}$
Milk and Derived Products	$2.5\ 10^{-3}$	$1.2\ 10^{-3}$	$1.5\ 10^{-3}$	$2.0\ 10^{-2}$	$1.1\ 10^{-3}$	$1.2\ 10^{-2}$	$7.0\ 10^{-2}$	$4.0\ 10^{-2}$	$4.5\ 10^{-2}$
Vegetables	$5.6\ 10^{-3}$	$5.9\ 10^{-3}$	$5.2\ 10^{-3}$	$1.7\ 10^{-2}$	$2.6\ 10^{-2}$	$1.7\ 10^{-2}$	–	–	–
Meat and Fish	$5.2\ 10^{-4}$	$2.2\ 10^{-2}$	$5.0\ 10^{-3}$	$1.4\ 10^{-3}$	$8.0\ 10^{-3}$	$3.8\ 10^{-3}$	–	–	–
Total	$1.4\ 10^{-2}$	$4.8\ 10^{-2}$	$1.9\ 10^{-2}$	$5.6\ 10^{-2}$	$6.3\ 10^{-2}$	$4.2\ 10^{-3}$	$9.5\ 10^{-2}$	$4.5\ 10^{-2}$	$5.4\ 10^{-2}$
Grand Total (I + C_s + Others)	$8.1\ 10^{-2}$			$1.2\ 10^{-1}$			$1.9\ 10^{-1}$		

Table A.69. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	17	17	1	1	0.1	0.1
External irradiation (deposited activity)	194	194	25	25	0.2	0.2
Inhalation	403	18	467	19	80	4
Milk and Derived products	778	18	667	43	233	16
Vegetables	1 706	153	567	59	–	–
Meat and Fish	156	257	47	6	–	–
Total	3 254	657	1 774	153	313	20

Grand Total Collective Dose Equivalent to the Thyroid: 5 341 manSv

Grand Total Collective Effective Dose Equivalent: 830 manSv

Table A. 70. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External irradiation (passing cloud)	$9.6\ 10^{-4}$	$7.8\ 10^{-4}$	$1.2\ 10^{-4}$	$8.0\ 10^{-4}$	$2.6\ 10^{-4}$	$1.0\ 10^{-4}$	$5.0\ 10^{-4}$	$1.3\ 10^{-4}$	$5.0\ 10^{-4}$
External irradiation (deposited activity)	$2.8\ 10^{-3}$	$1.8\ 10^{-2}$	$7.0\ 10^{-3}$	$3.0\ 10^{-3}$	$1.6\ 10^{-2}$	$6.0\ 10^{-3}$	$1.0\ 10^{-4}$	$1.0\ 10^{-3}$	$4.0\ 10^{-4}$
Inhalation	$1.3\ 10^{-3}$	$3.1\ 10^{-4}$	$2.4\ 10^{-4}$	$1.4\ 10^{-2}$	$1.6\ 10^{-3}$	$3.1\ 10^{-3}$	$2.4\ 10^{-2}$	$3.7\ 10^{-3}$	$8.2\ 10^{-3}$
Milk and Derived Products	$2.5\ 10^{-3}$	$1.2\ 10^{-3}$	$1.5\ 10^{-3}$	$2.0\ 10^{-2}$	$1.1\ 10^{-2}$	$1.2\ 10^{-2}$	$7.0\ 10^{-2}$	$4.0\ 10^{-2}$	$4.5\ 10^{-2}$
Vegetables	$8.4\ 10^{-3}$	$8.8\ 10^{-3}$	$7.5\ 10^{-3}$	$2.7\ 10^{-2}$	$3.9\ 10^{-2}$	$2.7\ 10^{-2}$	–	–	–
Meat and Fish	$5.2\ 10^{-4}$	$2.2\ 10^{-2}$	$5.0\ 10^{-3}$	$1.4\ 10^{-3}$	$8.0\ 10^{-3}$	$3.8\ 10^{-3}$	–	–	–
Total	$1.7\ 10^{-2}$	$5.1\ 10^{-2}$	$2.1\ 10^{-2}$	$6.6\ 10^{-2}$	$7.6\ 10^{-2}$	$5.2\ 10^{-2}$	$9.6\ 10^{-2}$	$4.5\ 10^{-2}$	$5.4\ 10^{-2}$
Grand Total (I + C_s + Others)	$8.9\ 10^{-2}$			$1.9\ 10^{-1}$			$1.9\ 10^{-1}$		

Table A. 71. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)	17	17	1	1	0.1	0.1
External irradiation (deposited activity)	194	194	25	25	0.2	0.2
Inhalation	403	18	467	19	80	4
Milk and Derived products	778	18	667	43	233	16
Vegetables	2 637	233	900	93	–	–
Meat and Fish	156	257	47	6	–	–
Total	4 185	737	2 107	187	313	20

Grand Total Collective Dose Equivalent to the Thyroid: 6 605 manSv
Grand Total Collective Effective Dose Equivalent: 944 manSv

Table A. 72. **Intake rates**

FOODSTUFF		Adults	Children	Infants
Milk and Milk products	($L.d^{-1}$)	0.2	0.5	1
Vegetables and fruits	($kg.y^{-1}$)	300	250	–
Meat and Fish	($kg.y^{-1}$)	40	20	–

1.22. UNITED KINGDOM

A map of caesium-137 deposition is given in Figure A.22.

Critical group and collective dose estimates are given in Tables A.73 and A.74, respectively. The corresponding doses which it is estimated would have been received in the absence of countermeasures are given in Tables A.75 and A.76.

Technical Notes

The foods considered for the ingestion dose calculations are milk, milk products, green vegetables and fruit, meat (beef, lamb, game), fish, grain, root vegetables and water. The intake rates used are given in Table A.77. Models are used to predict the future variation of food concentrations with time. Higher food concentrations are used for calculating the critical group doses than for calculating the collective doses. The collective doses received from food are calculated from the geographical distribution of agriculture, assuming that all food produced in the United Kingdom is eaten in the country. This avoids the need to make assumptions concerning where an individual obtains his food from. The contribution of imported food to the dose is not considered, but is thought to be small.

The age-groups are defined differently for the calculation of critical group doses and collective doses. For collective doses, the dose factors for a one-year old child are used for the fraction of the population under 5 years in age, those for a ten-year-old child are used for the population aged between 5 years and 18 years, and those for an adult are used for all people of 18 years and over. The doses have then been re-distributed according to the following age group definitions; infants aged 0-2 years, children aged 2-15 years and adults aged over 15 years. This is clearly a compromise and will overestimate the doses assigned to *infants* and, to a lesser extent, to *children* (since the dose factors used for iodine-131 are highest for infants). The total collective doses given assume the population to consist entirely of adults; these doses will be slightly underestimated. Owing to the different methods used to calculate the total collective doses and their breakdown by age, the sums of the collective doses calculated for the three age-groups are not equal to the totals given. For the critical group calculations, infants are taken to be one-year-olds and children to be aged 10 years. The critical group is hypothetical and very extreme.

The dose factors used for radionuclides taken into the body are those recommended by NRPB*, which take into account the higher metabolic rates found in children and infants compared with adults. The doses from external irradiation are calculated from measured dose-rates during May 1986 and using the dose conversion factors recommended in NRPB-DL10 thereafter. Two sets of shielding factors are used to take account of the reduction of the external and inhalation doses owing to buildings, the first set for the critical group calculations, the second set for the collective dose calculations. These shielding factors are given in Table A.78.

The critical group doses are considered to be overestimated and are calculated for individuals living in parts of North Wales, Cumbria and South-West Scotland; the collective doses are best estimates.

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* Kendall, G.M., Kennedy, B.W., Greenhalgh, J.R., Adams, N. and Fell, T.P., *Permitted Dose Equivalents to Selected Organs and Effective Dose Equivalents from Intake of Radionuclides*, NRPB-GS7, H.M.S.O., 1987.

Figure A.22. **DEPOSITION OF CESIUM-137 IN THE UNITED KINGDOM (Bq/m^2)**

(Based on Analyses by the Institute for Terrestrial Ecology)

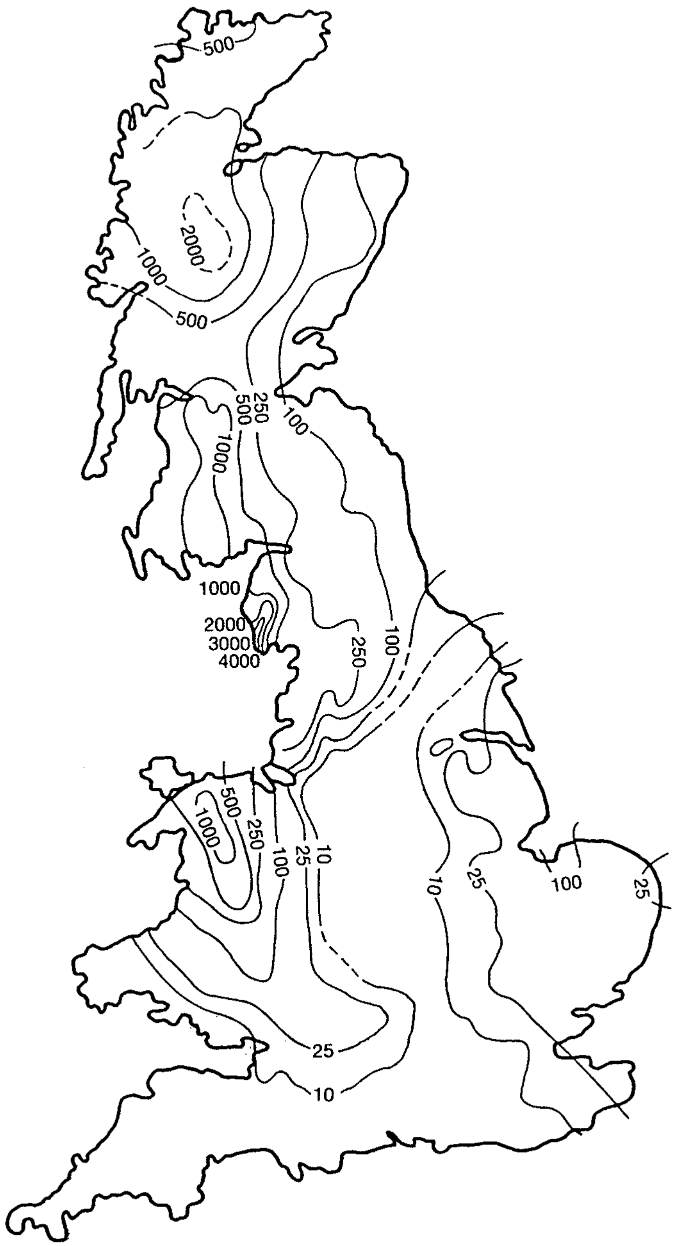


Table A. 73. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Gamma Irradiation (passing cloud)	$3.3\ 10^{-4}$	Total: $3.7\ 10^{-5}$		$3.3\ 10^{-4}$	Total: $3.7\ 10^{-5}$		$3.3\ 10^{-4}$	Total: $3.7\ 10^{-5}$	
External Gamma Irradiation (deposited activity)	Total: $1.0\ 10^{-1}$			Total: $1.0\ 10^{-1}$			Total: $1.0\ 10^{-1}$		
Inhalation	$3.1\ 10^{-3}$	Total: $9.2\ 10^{-3}$		$5.7\ 10^{-3}$	Total: $1.2\ 10^{-2}$		$4.5\ 10^{-3}$	Total: $9.2\ 10^{-3}$	
Milk and Derived Products	$4.6\ 10^{-2}$	$4.3\ 10^{-1}$	–	$1.2\ 10^{-1}$	$4.2\ 10^{-1}$	–	$2.9\ 10^{-1}$	$3.7\ 10^{-1}$	–
Vegetables	$5.7\ 10^{-3}$	$1.8\ 10^{-2}$	–	$1.1\ 10^{-2}$	$1.3\ 10^{-2}$	–	$1.7\ 10^{-2}$	$6.7\ 10^{-3}$	–
Meat and Fish	$3.4\ 10^{-2}$	$2.5\ 10^{-1}$	–	$6.4\ 10^{-2}$	$1.7\ 10^{-1}$	–	$2.9\ 10^{-2}$	$2.8\ 10^{-2}$	–
Water	$8.6\ 10^{-2}$	$1.7\ 10^{-2}$	–	$1.4\ 10^{-1}$	$9.9\ 10^{-3}$	–	$3.2\ 10^{-1}$	$7.8\ 10^{-3}$	–
Grain	$2.7\ 10^{-8}$	$1.7\ 10^{-2}$	–	$5.1\ 10^{-8}$	$1.2\ 10^{-2}$	–	$8.7\ 10^{-8}$	$6.9\ 10^{-3}$	–
Total	$1.8\ 10^{-1}$	$8.4\ 10^{-1}$	–	$3.4\ 10^{-1}$	$7.4\ 10^{-1}$	–	$6.6\ 10^{-1}$	$5.3\ 10^{-1}$	–
Grand Total (I + C_s + Others)		1.0			1.0			1.2	

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Deliberately pessimistic

Table A. 74. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Estimated **with** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External Gamma Irradiation (passing cloud)	1	1	0.3	0.3	0.05	0.05
External Gamma Irradiation (deposited activity)	250	250	60	60	10	10
Inhalation	710	60	270	15	35	2
Milk and Derived products	6 500	1 000	4 400	360	1 700	100
Vegetables and Fruit	650	30	290	9	80	2
Meat and Fish	1 300	360	370	60	35	4
Grain	45	50	6	7	0.5	0.5
Total	9 400	1 800	5 300	510	1 900	120

Grand Total Collective Dose Equivalent to the Thyroid: 11 000 manSv
Grand Total Collective Effective Dose Equivalent: 2 100 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3

Note:

These collective doses are based on the distribution of food production in the United Kingdom and assume that all food produced is eaten in the country. The total doses assume an entirely adult population and slightly underestimate the doses received. The doses to each age-group use only three different conversion factors to represent the variation of received dose with age at intake. This means that the doses given for each age-group are slightly overestimated.

Table A. 75. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Gamma Irradiation (passing cloud)	$3.3\ 10^{-4}$	Total: $3.7\ 10^{-5}$		$3.3\ 10^{-4}$	Total: $3.7\ 10^{-5}$		$3.3\ 10^{-4}$	Total: $3.7\ 10^{-5}$	
External Gamma Irradiation (deposited activity)	Total: $1.0\ 10^{-1}$			Total: $1.0\ 10^{-1}$			Total: $1.0\ 10^{-1}$		
Inhalation	$3.1\ 10^{-3}$	Total: $9.2\ 10^{-3}$		$5.7\ 10^{-3}$	Total: $1.2\ 10^{-2}$		$4.5\ 10^{-3}$	Total: $9.2\ 10^{-3}$	
Milk and Derived Products	$4.6\ 10^{-2}$	$4.3\ 10^{-1}$	–	$1.2\ 10^{-1}$	$4.2\ 10^{-1}$	–	$2.9\ 10^{-1}$	$3.7\ 10^{-1}$	–
Vegetables	$5.7\ 10^{-3}$	$1.8\ 10^{-2}$	–	$1.1\ 10^{-2}$	$1.3\ 10^{-2}$	–	$1.7\ 10^{-2}$	$6.7\ 10^{-3}$	–
Meat and Fish	$3.4\ 10^{-2}$	$5.0\ 10^{-1}$	–	$6.4\ 10^{-2}$	$3.4\ 10^{-1}$	–	$2.9\ 10^{-2}$	$5.4\ 10^{-2}$	–
Water	$1.3\ 10^{-1}$	$2.6\ 10^{-2}$	–	$2.1\ 10^{-1}$	$1.5\ 10^{-2}$	–	$4.7\ 10^{-1}$	$1.2\ 10^{-2}$	–
Grain	$2.7\ 10^{-8}$	$1.7\ 10^{-2}$	–	$5.1\ 10^{-8}$	$1.2\ 10^{-2}$	–	$8.7\ 10^{-8}$	$6.9\ 10^{-3}$	–
Total	$2.2\ 10^{-1}$	1.1	–	$4.1\ 10^{-1}$	$9.2\ 10^{-1}$	–	$8.2\ 10^{-1}$	$5.6\ 10^{-1}$	–
Grand Total (I + C_s + Others)	1.3			1.3			1.4		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Deliberately pessimistic

Table A. 76. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in manSv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External Gamma Irradiation (passing cloud)	1	1	0.3	0.3	0.05	0.05
External Gamma Irradiation (deposited activity)	250	250	60	60	10	10
Inhalation	710	60	270	15	35	2
Milk and Derived products	6 500	1 000	4 400	360	1 700	100
Vegetables and Fruit	650	30	290	9	80	2
Meat and Fish	1 300	370	380	65	40	4
Grain	45	50	6	7	0.5	0.5
Total	9 400	1 800	5 300	510	1 900	120

Grand Total Collective Dose Equivalent to the Thyroid: 11 000 manSv
Grand Total Collective Effective Dose Equivalent: 2 100 manSv

ORDER OF MAGNITUDE OF THE UNCERTAINTIES: Within a factor of 3

Note :

These collective doses are based on the distribution of food production in the United Kingdom and assume that all food produced is eaten in the country. The total doses assume an entirely adult population and slightly underestimate the doses received. The doses to each age-group use only three different conversion factors to represent the variation of received dose with age at intake. This means that the doses given for each age-group are slightly overestimated.

Table A. 77. **Intake rates**

CRITICAL-GROUP INHALATION RATES			CRITICAL-GROUP WATER INTAKE RATES		
Age Group	Inhalation Rate		Age Group	Water Intake Rate	
	$L.d^{-1}$	$L.y^{-1}$		$L.d^{-1}$	$L.y^{-1}$
1 Year	$0.38\ 10^4$	$1.4\ 10^6$	1 Year	0.7	260
10 Years	$1.5\ 10^4$	$5.5\ 10^6$	10 Years	0.95	350
Adult Male	$2.3\ 10^4$	$8.4\ 10^6$	Adult Male	1.65	600

FOOD INTAKE RATES FOR ADULTS			FOOD INTAKE RATES FOR CHILDREN AGED 10 YEARS		FOOD INTAKE RATES FOR CHILDREN AGED 1 YEAR	
FOODSTUFF	Intake Rate ($kg.y^{-1}$)		Intake Rate ($kg.y^{-1}$)		Intake Rate ($kg.y^{-1}$)	
	Per Caput	Critical Group	Per Caput	Critical Group	Per Caput	Critical Group
Milk (litres)	150	300	150	300	170	260
Milk products	13	40	9	30	5	16
Beef and Veal	18	60	12	40	2	7
Mutton and Lamb	7	30	5	20	1	3
Game	–	60	–	40	–	7
Offals	2	20	1.3	15	0.2	2
Green Vegetables	40	80	27	60	15	30
Fruits	19	60	13	40	8	20
Grain Products	67	130	45	90	25	50
Oat Products	1	15	1	10	0.4	6

Table A. 78. **Occupancy and shielding factors used for inhalation and external irradiation pathways**

Group	Reduction Factor	Inhalation	External Gamma Irradiation	
			From the cloud	From deposited activity
Critical group	Occupancy*	0	0	0.6
	Shielding	–	–	0.5
Average individual	Occupancy*	0.9	0.9	0.9
	Shielding	0.3	0.1	0.1

* Fraction of time spent indoors.

1.23. UNITED STATES

A map of iodine deposition is given in Figure A.23.

Critical group and collective dose estimates are given in Tables A.79 and A.80, respectively.

Technical Notes

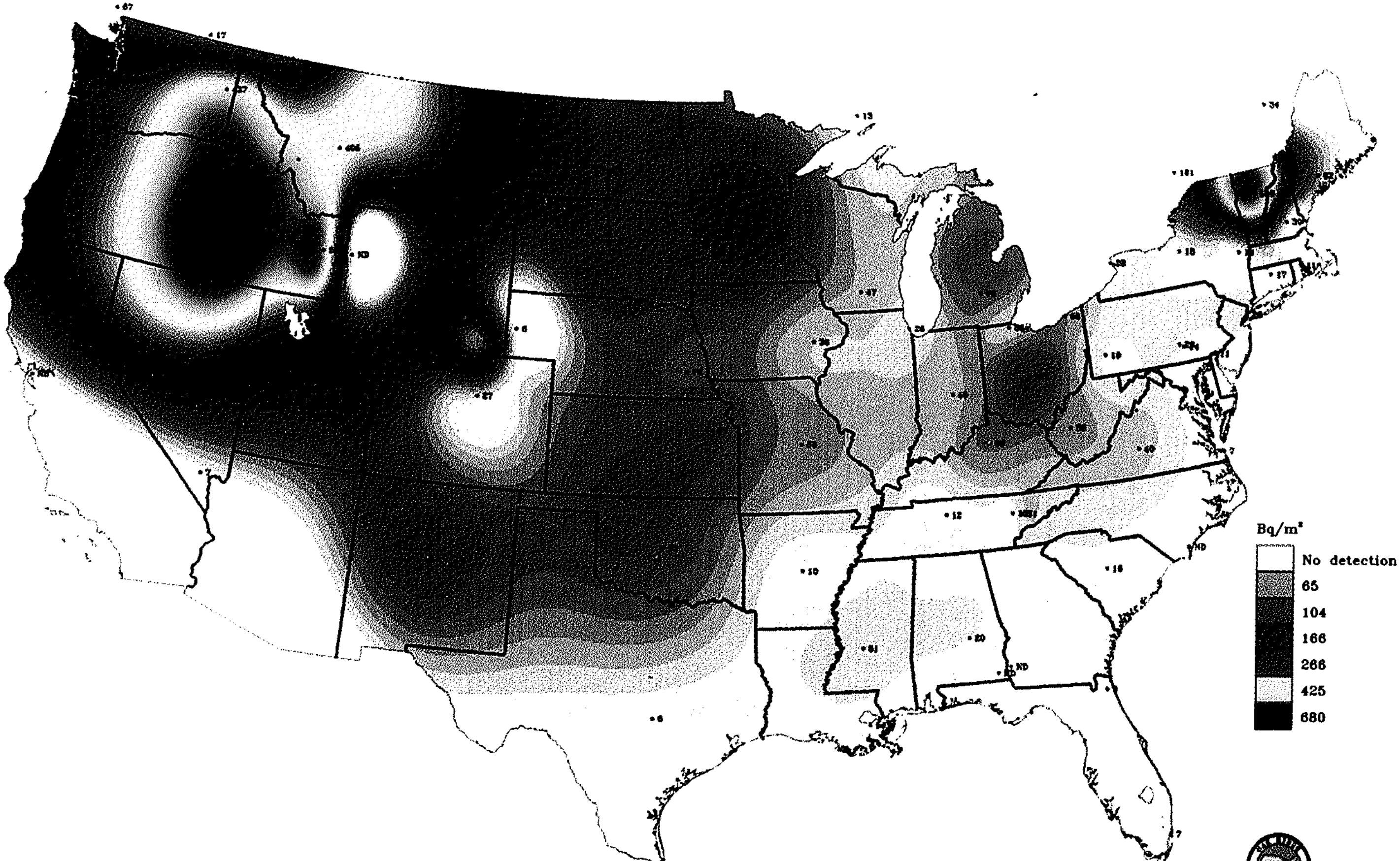
The foods considered for the ingestion dose calculations are milk and milk products. Doses are based on measurements. The contribution of imported food to the dose is not considered.

The critical group is an identified group within the State of Washington.

The doses are considered to be preliminary best estimates.

Figure A.23. **CUMULATIVE IODINE-131 IN PRECIPITATION IN THE UNITED STATES**

ORNL-DWG 87-5592



Source: Oak Ridge National Laboratory.

Table A. 79. **Individual effective dose equivalent committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	DOSES TO CRITICAL GROUPS *in mSv*								
	Adults			Children			Infants		
	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides	Iodines	Caesium-137 + Caesium-134	Other Nuclides
External Irradiation (passing cloud)	$1.6\ 10^{-8}$	$2\ 10^{-9}$	$2\ 10^{-8}$	N.A.	–	–	–	–	–
External Irradiation[c] (deposited activity)	N.A.	$4.4\ 10^{-3}$	–	–	$4.4\ 10^{-3}$	–	–	$4.4\ 10^{-3}$	–
Inhalation[c]	$0.8\ 10^{-6}$	$1\ 10^{-7}$	$1\ 10^{-6}$	N.A.	–	–	–	–	–
Milk and Derived[b] Products	$2.7\ 10^{-4}$	$3.0\ 10^{-7}$	–	$9.0\ 10^{-4}$	$2.7\ 10^{-6}$	–	$1.6\ 10^{-2}$	$1.2\ 10^{-5}$	–
Vegetables	N.A.	–	–	–	–	–	–	–	–
Meat and Fish	N.A.	–	–	–	–	–	–	–	–
Total	$3\ 10^{-4}$	$4.4\ 10^{-3}$	–	$9\ 10^{-4}$	$4.4\ 10^{-3}$	–	$1.6\ 10^{-2}$	$4.4\ 10^{-3}$	–
Grand Total (I + C_s + Others)	$5\ 10^{-3}$			$5\ 10^{-3}$			$2\ 10^{-2}$		

ORDER OF MAGNITUDE OF THE UNCERTAINTIES

a = within ± 30 per cent
b = within a factor 3
c = order of magnitude

Note:
N.A. = not assessed.

Table A. 80. **Collective thyroid and effective dose equivalents committed from the first year of exposure/intake (May 1986-April 1987)**

Projected **without** countermeasures

PATHWAY	COLLECTIVE DOSE EQUIVALENTS *in man Sv*					
	Adults		Children		Infants	
	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.	Thyroid D.E.	Effective D.E.
External irradiation (passing cloud)						
External irradiation (deposited activity)						
Inhalation						
Milk and Derived products	$3\ 10^{3}$ [a] $3.5\ 10^{2}$ [b]					
Vegetables	N.A.					
Meat and Fish	N.A.					
Total						

Grand Total Collective Dose Equivalent to the Thyroid: 3 000 manSv
Grand Total Collective Effective Dose Equivalent: N.A.

a) Total U.S. collective dose equivalent.
b) Collective dose equivalent in State of California (max.).

N.A. = Not Assessed.

2. DISCUSSION OF DOSE ESTIMATES

The doses calculated by Member countries will differ both as a result of variations in deposition levels and food concentrations experienced, and also because of different assumptions used in the calculations. In this section, the dose estimates are examined in order to investigate which differences can be ascribed to genuine variations in the radiological impact of the Chernobyl accident in Member countries. There are a number of factors, all of which contribute in different proportions to the observed diversity of doses. It is, therefore, not possible to isolate a particular factor and examine its specific influence on the dose values. However, by examining the ranges of assumptions that underly the calculations, some insight can be gained of the relative influence of different assumptions.

The range of assumptions and values assigned to different parameters by each Member country is summarised in Table A.81. Given on this Table are the references for the dose conversion factors, the reduction factors assumed to take account of the shielding and filtering effects of buildings, and the procedures adopted for calculating future doses from ingestion and external irradiation from deposited activity.

With only one exception, no Member country has taken account of a reduction in inhalation dose owing to the filtering effect of buildings. However, a range of reduction factors for external irradiation have been used, from about 0.1 to unity. At first sight this would suggest that any comparison of cloud-gamma and deposited-gamma doses would be difficult, but this is not necessarily the case. Generally, it is only those Member countries least affected by the Chernobyl accident which have assumed that there is no reduction in external dose (Canada, Japan, Spain), whereas most of the European countries with high levels of deposition have used a reduction factor of about 0.3. There are exceptions to this: Turkey, Luxembourg and, for critical group doses only, the United Kingdom have assumed little or no shielding, whilst Denmark and Greece have assumed shielding factors of about 0.1. However, if these exceptions are taken into account, the Member countries can be considered in two groups, for which the shielding factors used are generally similar. These groups are those countries within Europe with high levels of deposition and those outside of Europe, together with Spain and Portugal.

The doses calculated from external irradiation from deposited activity are also dependent upon the dose conversion factors used. At least two sets of dose conversion factors have been used here: those recommended by NRPB and those recommended by D.C. Kocher (Health Physics, *38*, 543-621, 1980). Generally, these sets of factors are similar, differing by factors of two or three at most for most radionuclides. However, the differences for a few radionuclides are more significant. The gamma dose from tellurium-132 is likely to have made a significant contribution to the total external dose from deposited activity in the first year, and the dose conversion factors recommended by NRPB and Kocher

Table A. 81. **Summary of modelling assumptions**

Country	Dose conversion factors used		Overall shielding factors (including occupancy)		Modelling of future concentrations
	Intake	External	Inhalation	External	
Austria	ISH 63, etc.[a]	Measurements	1	0.37	assumed small rise
Belgium	NRPB-R162	NI	1	0.35	full modelling
Canada	ICRP-30	Kocher	1	1	simple modelling
Denmark	NRPB-R162	NI	1	0.83	assumed constant
Finland	NRPB-R162	NRPB-DL10	1	0.3	full modelling
France	NI	NI	NI	NI	NI
FRG	ISH 63, etc.[a]	NI	1	0.5	full modelling
Greece	ISH 63, etc.[a]	NI	1	0.1	simple modelling
Ireland	New[b]	NRPB-DL10	NI	NI	NI
Italy	ISH 63, etc.[a]	NRPB-DL10	1	0.3/0.4[c]	simple modelling
Japan	ICRP-30	Kocher	1	1	simple modelling
Luxembourg	ISH 63, etc.[a]	NI	1	0.8/0.9[d]	simple modelling
Netherlands	ISH 63, etc.[a]	NI	1	0.3	full modelling
Norway	NI	NI	NI	NI	NI
Portugal	NI	NI	NI	NI	NI
Spain	NRPB-R162	NRPB-DL10	1	1	NI
Sweden	ISH 63, etc.[a]	Kocher	1	0.33	assumed constant
Switzerland	ISH 63, etc.[a]	NI	NI	NI	NI
Turkey	ICRP-30	NI	1	1	assumed constant
UK	New[b]	NRPB-DL10	0.37/1[e]	0.19/0.7[e]	full modelling
USA	NI	NI	NI	NI	NI

NI No Information

a) ISH 63, 78 and 80 refers to the use of dose factors recommended by ICRP Publication-30, but with account taken of those recommended in ISH-HEFT 63, 78 and 80 (1985), where these differ from ICRP-30.

b) The dose factors used by Ireland and the UK are based on those recommended by ICRP Publication-30, but with account taken of the higher metabolic rate found in children and infants in a similar way to the recommendations in ISH-HEFT 63, 78 and 80. They have been published as an NRPB report in 1987 (see reference in Section 1.22).

c) Two different shielding factors have been used in the dose estimates for Italy: one each by the two organisations which performed the calculations.

d) Two different occupancy factors were used by Luxembourg; the lower shielding factor applies for adults and children, the higher factor applies for infants.

e) More reduction in dose is assumed for average individuals than for critical individuals.

for this radionuclide are over a factor of 7 apart, (NRPB uses the lower figure). Where countries have calculated the dose from this radionuclide, a significant difference could, therefore, result. However, it is not known which countries have explicitly calculated the dose from tellurium-132 and, therefore, it is not possible to examine the implications of this any further.

Table A.82 gives the range of foods considered by each Member country. Generally, the foods which are likely to contribute most to the ingestion dose from iodine-131 are milk and leafy vegetables, although in countries where vegetables are grown under cover or cows were still fed on stored feed during May 1986, other foods such as free-range eggs, lamb and game are potentially important. In the United Kingdom, the consumption of undiluted rain water has also been considered for the critical group, and this contributes significantly to

Table A.82. **Foods considered for dose calculations**

Country	Foods considered
Austria	Milk, cheese, dairy products, flour, potatoes, vegetables, fruit, beef, pork, veal, chicken
Belgium	Milk, meat, green vegetables
Canada	Milk, meat, green vegetables
Denmark	Milk, cheese, grain, vegetables and potatoes, fruit, meat, fish, eggs
Finland	Milk and milk products, grain, potatoes, root vegetables, leafy vegetables, fruit, beef, pork, other meat, eggs, fish
France	No Information
FRG	No Information
Greece	Meat, fish, milk, cheese, eggs, potatoes, vegetables, fruit
Ireland	Milk and milk products, vegetables, meat
Italy	Bread, pasta, beef, pork, poultry, lamb, milk, fish, leafy vegetables, other vegetables, dairy products, egg, fresh fruit, oil, wine
Japan	Milk, leafy vegetables
Luxembourg	Milk and milk products, vegetables, meat
Netherlands	Grain, potatoes, sugar, vegetables and fruit, milk and milk products, water, beef, pork, chicken and eggs, salt water fish, fresh water fish
Norway	Milk and milk products, vegetables, meat
Portugal	Milk, vegetables, meat
Spain	Milk, leafy vegetables
Sweden	Milk, milk products, beef, pork, lamb, moose, reindeer, fish, green vegetables, grain, fruit, potatoes
Switzerland	Milk, vegetables, meat
Turkey	Milk and milk products, vegetables and fruit, meat and fish
UK	Milk, milk products, green vegetables and fruit, beef, lamb, game, water, fish, grain, root vegetables
USA	Milk

the dose from iodine-131. For the dose from caesium radionuclides, the range of important foods is much wider, encompassing milk and milk products, beef, lamb and game, vegetables and fruit. Some Member countries have also found grain to be important. Although the stated ranges of foods considered by each country show a wide variation, the implications this has for the doses calculated are not so significant. Nearly all Member countries have considered the three most important groups of foods, namely, milk and milk products, leafy vegetables and meat. The likely contributions from foods not considered are unlikely to be more than about 10 per cent of the collective doses calculated; the implications for critical-group individual doses are much broader, because of the almost unlimited scope for defining the habits of a critical group.

Much more significant in influencing the doses calculated are the intake rates assumed for each food and each age-group. Table A.83 lists these for the three most important groups of foods. It is clear that these assumptions and parameter values differ over a wide range; using the same environmental measurements, the dose estimates made by different countries could vary by factors of an order of magnitude. However, these differences should not necessarily be assumed to be artificial; where Member countries have used intakes obtained from surveys within their own territory, the resulting differences in doses are real differences stemming from different national dietary habits. But some

Table A. 83. **Assumed intake rates**

Country	Milk (L.y[-1])			Green vegetables (kg.y[-1])			Meat (kg.y[-1])		
	Adults	Children	Infants	Adults	Children	Infants	Adults	Children	Infants
AVERAGE INDIVIDUALS									
Austria	133	100	175	68	37	13	81	63	11
Belgium[a]	30-150	30-150	26-130	6-28	6-28	0	4	4	0
Canada	172	241	197	64	26	0	69	39	0
Denmark	167	274	292	149[b]	84[b]	110[b]	56	55	0
Finland	329[c]	NI	NI	26	NI	NI	66	NI	NI
France	NI	NI	NI	NI	NI	NI	NI	NI	NI
FRG	NI	NI	NI	NI	NI	NI	NI	NI	NI
Greece	66	164	183	31	16	7	94	34	16
Ireland	150	150	170	40	27	15	55	38	6
Italy[d]	90/95[c]	120[c]	255/250[c]	33/72	26/45	12/13	47/68	30/40	14
Japan	73	183	219	37	18	7	—— Not Considered ——		
Luxembourg	110[c]	183[c]	256[c]	183[e]	146[e]	37[e]	88	55	0
Netherlands	145[c]	200[c]	230[c]	65	50	20	70	50	15
Norway	NI	NI	NI	NI	NI	NI	NI	NI	NI
Portugal	NI	NI	NI	NI	NI	NI	NI	NI	NI
Spain	NI	NI	NI	NI	NI	NI	NI	NI	NI
Sweden	NI	NI	NI	NI	NI	NI	NI	NI	NI
Switzerland	183	183	256	73	73	11	55	55	7
Turkey	73[c]	183[c]	365[c]	300[e]	250[e]	0	40[e]	20[f]	0
UK	150	150	170	40	27	15	55	38	6
USA	NI	NI	NI	NI	NI	NI	NI	NI	NI
CRITICAL GROUP									
Belgium	300	300	260	55	55	0	40	40	0
Ireland	300	300	260	80	60	30	200	135	22
Spain	106	164	164	165	70	0	NI	NI	NI
UK	300	300	260	80	60	30	200	135	22

NI No Information.

a) The intake rates for Belgium include factors to allow for preparation losses, consumption of stored food, etc.

b) These include the consumption of potatoes.

c) These include the consumption of milk products.

d) Where two intake rates are given for Italy, these are the different values used in the dose calculations performed by two different organisations.

e) These include the consumption of all vegetables and fruit.

f) These include the consumption of fish.

g) Intake rates are only given for countries which used different values for critical group dose estimates compared with those used for the collective dose estimates.

differences cannot be ascribed to this source. In particular, there are two clear examples of this. The first arises from the varying definitions of the infant age-group. Some infants are assumed to be almost entirely on a milk diet, whilst others are assumed to be eating a more varied diet, including meat. The doses for these two differently defined groups of infants should, therefore, not be directly compared; those infants on the varied diet are likely to have higher doses estimated for them than those on an all-milk diet. Secondly, there are the differences in assumptions concerning the assumed diets of the critical group. For most countries, the critical group dose estimates have been calculated using the same intake rates as used for calculating the collective dose estimates. However, three countries, Belgium, Ireland and the United Kingdom, have assumed intake rates for the critical group which are generally higher, by a factor of two or more, than the average intake rates assumed. This will give rise to relative increases in the critical group doses which are directly related to the assumption that the critical group diet is enhanced compared with the national diet. Since, for these three countries, the critical group for which the doses are estimated is hypothetical, it is unlikely that the resulting differences in estimated doses are reflections of real differences of the radiological impact of the Chernobyl accident.

The dietary habits assumed have implications beyond influencing the magnitude of the total dose estimate. Since the ingestion dose pathway is generally estimated to contribute a substantial fraction of the total dose, the dietary habits assumed in the dose calculations have a significant influence on the relative contributions of other dose pathways (i.e., inhalation and deposited gamma). This is clearly shown in the dose estimates for Belgium. Table A.83 shows that, generally, the intake rates assumed for the average individual in Belgium are significantly lower than those adopted by other countries. This is principally because the Belgian intake rates have been chosen to take into account factors in the average diet which resulted in a lower intake of radionuclides from Chernobyl fallout. In particular, the intake rates used include an allowance for the consumption of stored, uncontaminated food. This is a factor which other countries have not, generally, taken into account. Consequently, the contribution of ingestion to the total collective dose is relatively low. This, together with a relatively low estimate for deposited-gamma dose has produced a percentage contribution of 35 per cent to the collective effective dose from inhalation. For the collective thyroid dose (for which deposited-gamma is a less significant pathway than for effective dose), the contribution from inhalation is estimated to be 80 per cent.

With regard to the dose conversion factors used for radionuclides taken into the body, the values used can be divided into two sets. One set is based on the values recommended in ICRP Publication-30, and the other set is based on the new values recommended by the Institut für Strahlenhygiene (Federal Republic of Germany), which take account of the higher metabolism of caesium and iodine nuclides in young children. The differences in the dose factors are significant; for inhalation, the *new* values are about half the ICRP Publication-30 figures for children and about five times lower for infants, whilst for ingestion the *new* values are about four times lower for children and between five and eight times lower for infants. These differences will be carried directly through to the calculated doses. However, owing to the imposition of countermeasures in some countries and different assumed intake rates of foods, it is not possible clearly to identify these differences in the calculated doses.

The percentage contribution of the three main food groups to the total critical-group effective dose from ingestion is shown in Table A.84 for adults. The doses to adults from each type of food show little consistency between Member countries; the percentage contributions from milk and milk products range from 13 per cent for Canada to 50-60 per

Table A. 84. **Percentage contribution by individual foods to the critical group effective dose from food (adults)**

Country	Milk and milk products (%)	Vegetables and fruit (%)	Meat and fish (%)
Austria	40	33	27
Belgium	62	19	19
Canada	13	14	73
Denmark	41	39	20
Finland	29	8	63
France	NI	NI	NI
FRG	NI	NI	NI
Greece	31	49	20
Ireland	NI	NI	NI
Italy	NI	NI	NI
Japan	23	77	–
Luxembourg	46-58	11-23	31-42
Netherlands	37	41	22
Norway	21	15	65
Portugal	46	43	11
Spain	24	76	–
Sweden	30	30	40
Switzerland	35	6	33
Turkey	11	34	56
UK	53	3	31
USA	100	–	–

NI No Information

cent for Belgium, Luxembourg and the United Kingdom (and, of course, 100 per cent for the United States; but they considered only this food pathway). It may be noted that both Belgium and the United Kingdom assumed a relatively high intake rate of milk (300 L/y) for their critical group calculations for adults. Even more marked is the spread of contributions to the dose from the consumption of green vegetables and meat. As well as from all the factors mentioned above (differences in intake rates, deposition levels and countermeasures taken), differences in the percentage contributions of these foods to the total dose will also arise from agricultural practices (whether or not vegetables are habitually grown under cover or in the open during May, what foodstuffs are normally fed to livestock) and will depend on which types of meat and vegetables are most commonly eaten. One example of this is the consumption of lamb. Generally, throughout Europe, lamb has been contaminated to a higher level than most other meats (with the exception of some game). This is partly because the diet of sheep is rarely supplemented with other feedstuffs. However, only in the United Kingdom has this higher contamination contributed significantly to the average dose (about 40 per cent of the collective effective dose from meat consumption comes from lamb), because the consumption of lamb within Europe (excluding the United Kingdom) is generally small.

Although the absolute doses calculated by different countries are likely to show wide differences for a number of reasons, the proportions of the dose contributed by external

Table A. 85. **Percentage contribution of ingestion and deposited-gamma to the adult collective effective dose**

Country	Dose (adults) saved by countermeasures	Contribution to total dose	
		Ingestion (%)	Deposited gamma (%)
Austria	50	74	19
Norway	33	Not Given	
FRG	30*	40	47
Greece	24	78	7
Sweden	17	47	47
Italy	15	77	17
Netherlands	12	40	53
Turkey	11	65	30
Luxembourg	6.6	63	29
Finland	6.3	72	25
UK	1	82	14
Belgium	–	18	46
Canada	–	60	38
Denmark	–	91	7
Ireland	–	84	14
Japan	–	19	68
Switzerland	0	74	23

* Estimate of dose-saving to whole population.

irradiation and ingestion might be expected to be more uniform, since the same levels of deposition are responsible for both. In Figure A.24, the percentage contributions to the adult collective effective dose by the three main dose pathways, ingestion, deposited-gamma and inhalation, are shown for each country. Clearly, there is little uniformity between Member countries, although some groups of neighbouring states with similar predictions of relative contributions can be identified (e.g. Austria and Italy, or Ireland and the United Kingdom). Some variation would be expected owing to the imposition of food restrictions in some countries. Table A.85 lists the percentage contribution of the two pathways, ingestion and deposited-gamma, to the adult collective effective dose in order of estimated percentage dose saved by countermeasures. Since, generally, countermeasures were taken to reduce the dose from ingestion, the relative contribution from deposited-gamma would be expected to be greatest in those countries which implemented very strict countermeasures and least where no countermeasures were taken. To some extent, Table A.85 shows this trend. However, there are some notable exceptions, particularly Austria, Greece, Italy and Belgium.

For completeness, the relative contributions of inhalation, deposited-gamma and ingestion to the collective thyroid doses estimated by each country are shown in Figure A.25. Again, there is little uniformity between countries, although generally the contribution from inhalation has been enhanced and that from deposited-gamma reduced, relative to the contributions to effective dose. Table A.86 lists the contributions of inhalation and ingestion to the adult collective thyroid dose for each country, together with estimates of the dose-saving achieved by food restrictions. To some extent, the relative contribution of

Figure A.24. **PERCENTAGE CONTRIBUTION BY PATHWAY TO COLLECTIVE EFFECTIVE DOSE**

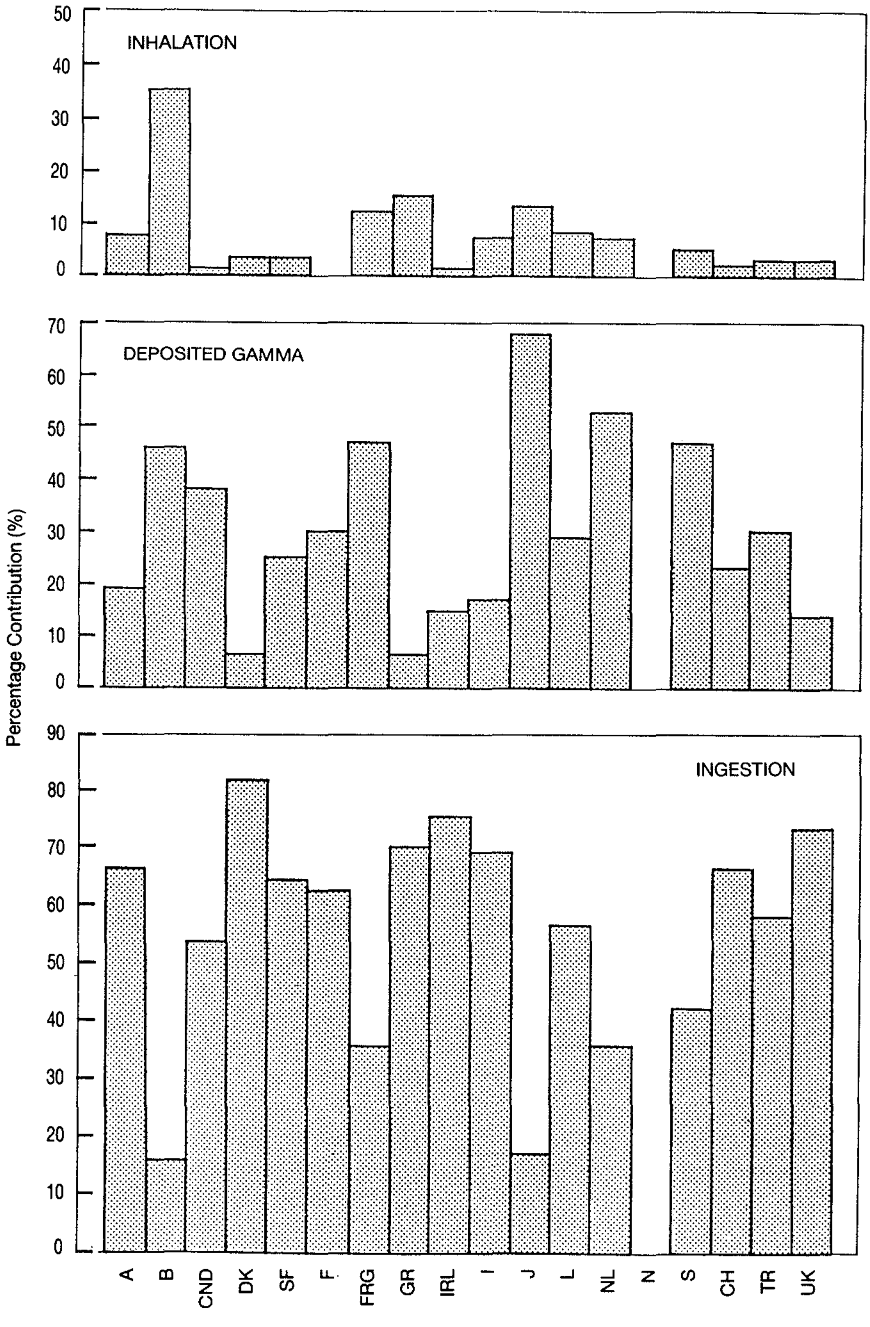


Figure A.25. **PERCENTAGE CONTRIBUTION BY PATHWAY TO COLLECTIVE THYROID DOSE**

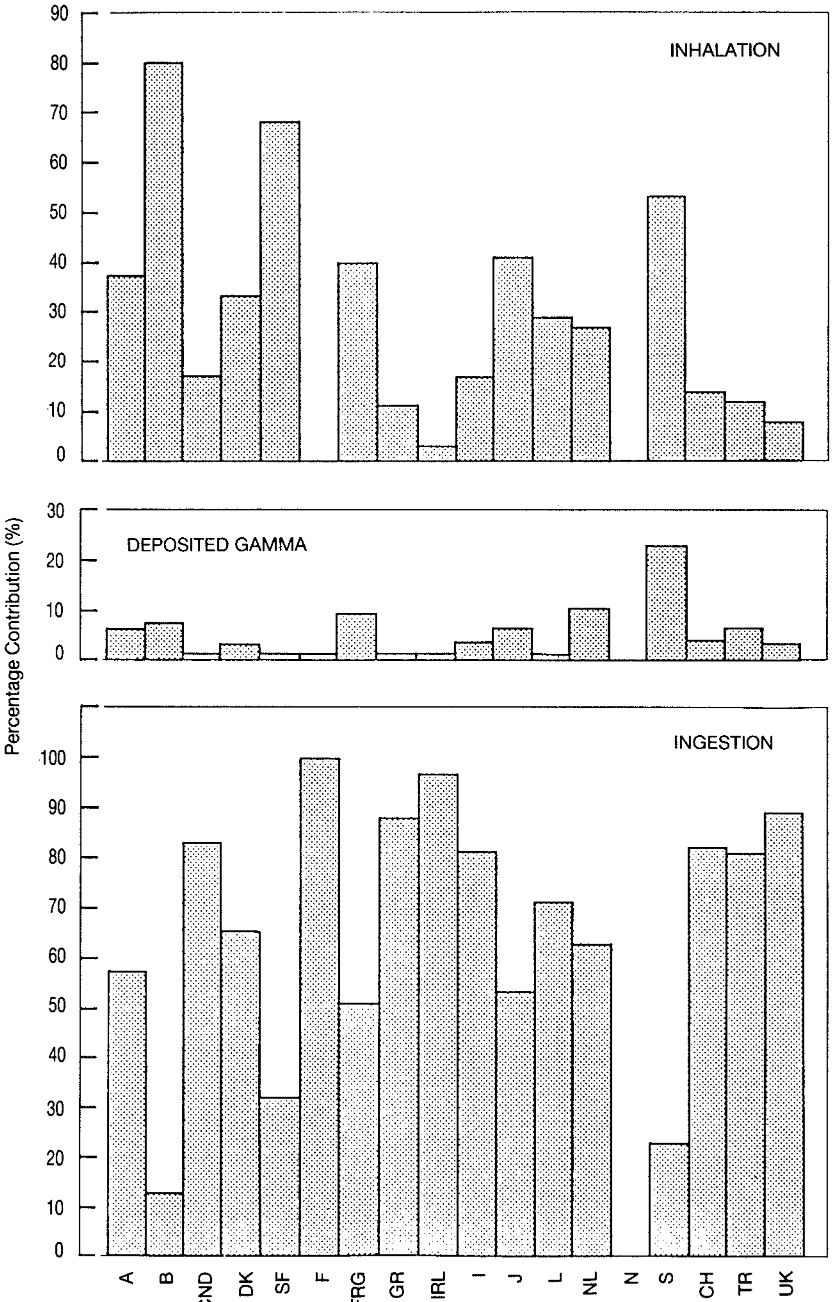


Table A. 86. **Percentage contribution of ingestion and inhalation to the adult collective thyroid dose**

Country	Dose (adults) saved by countermeasures	Contribution to total dose	
		Ingestion (%)	Inhalation (%)
Austria	68	57	37
FRG	60*	51	40
Finland	58	32	68
Italy	47	81	17
Greece	40	88	11
Luxembourg	38	71	29
Netherlands	23	63	27
Turkey	22	81	12
Norway	14	Not Given	
Sweden	9.1	53	23
UK	< 1	89	8
France	Very Small	Not Given	
Belgium	–	13	80
Canada	–	83	17
Denmark	–	65	33
Ireland	–	97	3
Japan	–	53	41
Switzerland	0	82	14

* Estimate of dose-saving to whole population.

inhalation should increase with increasing dose-saving. Although there is some indication that the relative contribution from inhalation is linked to the dose-saving from the countermeasures taken, other factors in the dose assessment are clearly dominating the results. To some extent this is expected, because the doses from inhalation and ingestion are not so closely linked as those from deposited-gamma and ingestion. The contamination in food is related to the pattern of ground contamination, which was dominated by the pattern of rainfall, whilst variations in air concentration resulted from complex dispersion processes, with rain being only one contributory factor.

3. CONCLUSION

Dose estimates, both of collective doses and critical group doses have been officially submitted to NEA by each OECD Member country. These provide a good basis for assessing the radiological impact of the accident at Chernobyl on Member countries. However, differences in the assumptions underlying the dose estimates have resulted in differences between the doses which are not necessarily representative of a true diversity of the doses received in each country. The way in which these different assumptions have influenced the calculated doses is complex, and it is not easy to see which doses have been influenced by which parameters, or to identify trends in the doses which have resulted from a single factor or group of factors. Detailed intercomparison of the doses should therefore be undertaken with caution.

Appendix 2

RESPONSE TO THE CHERNOBYL NUCLEAR ACCIDENT IN OECD MEMBER COUNTRIES[a]

RESPONSE	COUNTRY[b]	NOTES
A. Environmental Monitoring:		
1. *Intensify/ expand* monitoring activities	All Countries *Duration:* Ongoing in some countries to a very limited extent	Initial monitoring was exploratory, followed by intensive monitoring where determined to be necessary. In general, monitoring activities have shifted to programs designed to assess longer term impacts and accumulation of contaminants. Current focus is on ^{137}Cs in foodchains.
B. Public Information:		
1. *Establish* means for issuance of information to the public	All Countries	News releases, tourist advisories, telephone *hotlines*. Problems with overloading of telephone service and public understanding of technical issues/facts.
C. Outdoor Public Activities:		
1. *Advice* to stay indoors or avoid specific outdoor activities	A, SF, FRG (some States), TR *Duration:* A few days to 2 weeks *Extent:* Regional	Advice to stay out of rain, to keep children from playing in rainwater puddles, and to keep children from playing in sand and from engaging in dust-generating activities. *CND, CH:* Gave explicit *advice against* the need for such measures.
2. *Advice* to take sanitary precautions when entering from outside	A, TR *Duration:* A few days *Extent*: Regional	Advice to wash hands and to clean shoes.

a) Information provided by the competent authorities in the Member countries, and updated until May 1987.

b) See Chapter 9 for key to Member Country acronyms.

RESPONSE	COUNTRY[b]	NOTES
3. *Monitoring* of people and land vehicles travelling from potentially contaminated areas	A, DK, SF, F, FRG, GR, IRL, L, NL, P, E, S, TR, UK, US *Duration:* A few days to 2 weeks *Extent:* Points of entry	*Basis*: Avoid inadvertent spread of contamination; Assess exposures to nationals returning from the Chernobyl region. Generally, was compulsory cleaning of vehicles found contaminated. *SF*: Monitoring of people travelling to or from the Kiev region still conducted *on request*.
4. *Advice* to clean transport vehicles at border points of entry/exit.	A, DK, SF, FRG, NL, TR *Duration:* 1-4 weeks *Extent:* TR: Bulgarian border	*Basis*: Avoid spread of contaminants collected from roads. *FRG*: Used a criteria of 100 kBq/m^2 for vehicles.
5. *Advice* to nationals not to travel to potentially contaminated foreign areas	A, SF, FRG, IRL, L, NL, N, E, S, UK, US *Duration*: 1-3 weeks	*Basis*: Avoid unnecessary exposure until contamination levels in affected areas were better understood. *N*: Press statement advising against travel to an area within 500 km of Chernobyl.
6. *Monitoring* of fishing boats.	DK, NL, TR *Duration:* DK: 4-12 May; TR: May *Extent:* DK (Baltic Sea); TR (Black Sea); NL (cargo boats)	*Basis*: Surveillance of potential deposition on boats and consequent contamination of crew/fish catches.
D. Water:		
1. *Advice* not to drink rainwater or to use for house-hold purposes	A, CND, SF, FRG, GR, I, J, L, NL, N, S, CH, TR, UK, US (1 State) *Duration:* 2-4 weeks *Extent:* Limited to remote geographical areas, with exception of A	*Basis*: Minimise ^{131}I doses in remote areas where rainwater was primary source of drinking water. *NL*: Not to use rainwater for greenhouses.

RESPONSE	COUNTRY[b]	NOTES
2. *Advice* not to use rain-water for watering livestock	A, SF, TR *Duration:* TR: May *Extent:* Regional; TR (Trace region)	
3. *Advice* not to use rain-water in the sauna	SF	
4. *Advice* to filter rain-water through charcoal filters before drinking	J	
E. Milk and Dairy Products:		
1. *Prohibition* on allowing dairy cattle to graze outdoors	A, DK, I, L, NL, TR *Duration:* Generally 1-2 weeks; TR: 1-4 weeks *Extent:* Regional; TR (Trace region)	*Basis*: Deposition levels excessive with regard to potential for milk contamination. *TR*: Prohibition progressively phased-out; Followed by advice.
2. *Advice* to keep dairy cattle from grazing outdoors	B, SF, FRG, GR, S, TR *Duration*: 1-8 weeks; GR: 3 months *Extent*: Regional; TR (Trace region)	
3. *Restrictions* on marketing and consumption of cow milk and dairy products	A, SF, FRG, GR, I, NL, N, S, TR *Duration:* 1-4 weeks *Extent:* Regional; N: One dairy closed for one month	*I*: Prohibition on consumption of fresh milk by children (< 10 years) and pregnant women; Based on precautionary reasons, considering emergency levels for food contamination had been exceeded in Northern Italy. *TR*: Limited to a few villages on the Bulgarian border. *FRG*: No milk to infants (1-14 May).

RESPONSE	COUNTRY[b]	NOTES
4. *Advice* to avoid consumption of cow milk and dairy products	A, NL, CH *Duration:* 2 weeks *Extent:* Regional	*A, NL*: Advice not to drink fresh milk directly from farms.
5. *Advice* to avoid consumption of milk from sheep and goats	A, GR, N, CH, TR *Duration:* A few weeks *Extent:* Regional	*Basis*: Precautionary measure; Higher levels in sheep/goat milk than in cow milk were observed. *N*: In some areas, goat milk used as fodder instead of in cheese production.
6. *Restrictions* on marketing and consumption of milk from sheep and goats	A, I, NL *Duration:* A few weeks *Extent:* Regional	
7. *Advice* not to market fresh goat cheese	CH, TR *Duration:* CH: 3 weeks; TR: 8 weeks *Extent:* Regional	*Basis*: Elevated ^{131}I levels in goat milk.
8. *Restrictions* on marketing and consumption of fresh sheep/goat cheese	N, S *Duration*: A few weeks *Extent*: Regional	
9. *Prohibition* on marketing and consumption of sheep/goat cheese	A, GR, I, NL, TR *Duration:* GR: 3 months; TR: 1 week; NL: 5 weeks *Extent:* Regional	*Basis*: Elevated ^{131}I levels in sheep/goat dairy products.
10. *Restrictions* on imports of milk and dairy products	Practically All Countries *Duration:* Most Action Levels still valid, although surveillance of imports is minimal or terminated	*Basis*: Controls on contaminated foodstuffs not subject to domestic production and marketing controls.

RESPONSE	COUNTRY[b]	NOTES
11. *Prohibition* on imports of milk/dairy products from Eastern European countries	TR, CEC Member Countries *Duration:* TR: 12-18 May; CEC: 1-12 May	*Basis*: Uncertainty on levels of contamination.
F. Vegetables, Fruit and Grains:		
1. *Advice* not to consume fresh leafy vegetables	A, FRG (some States) GR, I, NL, S, CH, TR *Duration:* Generally a few days to 3 weeks; GR: 3 months *Extent:* Regional	*CH*: For children (< 2 years), pregnant women and nursing mothers.
2. *Advice* to wash fresh vegetables prior to consumption	A, B, DK, FRG, GR, IRL, I, J, L, NL, S, CH, TR *Duration*: 1-2 weeks *Extent*: National	
3. *Advice* to delay planting of early vegetables	SF *Duration:* Early May *Extent:* Regional	Delay by 2 weeks. To minimize uptake of radioactivity.
4. *Advice* on consumption of non-cultivated plants and mushrooms	A, SF, FRG, NL, S *Duration:* SF: 7-16 May; FRG: May-September *Extent:* Regional	*SF*: Such plants/mushrooms should be boiled, and only eaten 1-2 times per week.
5. *Restrictions* on domestic marketing of fresh leafy vegetables	FRG, NL, S *Duration*: FRG: 3 weeks *Extent*: Regional	

RESPONSE	COUNTRY[b]	NOTES
6. *Prohibition* on domestic marketing of fresh leafy vegetables	A, F, I, L, NL, N *Duration:* 1-3 weeks *Extent:* Regional	*NL*: Destroyed spinach (4-10 May). *I*: Precautionary measure; Lifted 13 May in Central and Southern regions, 18 May in Northern Italy. *F*: Spinach in Alsace region. *N*: Lettuce and parsley in Trondelag.
7. *Restrictions* on imports of vegetables, fruit and grains	Practically All Countries *Duration:* Most Action Levels still valid, although surveillance of imports is minimal or terminated	*Basis*: Controls on contaminated foodstuffs not subject to domestic production and marketing controls.
8. *Prohibition* on imports of vegetables, fruit and grains from Eastern European countries	S, TR, CEC Member Countries *Duration:* S: 30 April-5 May; TR: 12-18 May; CEC: 1-12 May	*Basis*: Uncertainty on actual levels of contamination.
9. *Development* of special harvesting methods for crops	S *Duration:* At least first year *Extent:* Regional; in areas of highest deposition	Leave a higher than normal stubble, to avoid or minimize contamination resulting from contact with active soil.
G. Meat:		
1. *Restrictions* on domestic marketing of lamb/sheep	A, GR, NL, N, S, CH, UK *Duration:* GR: 3 months; UK: Ongoing; N: Ongoing *Extent:* Regional	Initiated in late June, with concern on levels of ^{137}Cs. *UK*: Based on levels rising above the Action Level of 1000 Bq/kg recommended by the CEC Group of Experts on Article 31 of the Euratom Treaty. *N*: Meat classified as unfit for human consumption may be disposed of at selected sites, or may be used as animal fodder by fur producers.

RESPONSE	COUNTRY[b]	NOTES
2. *Prohibitions* on domestic marketing of animal thyroids	GR, I, L, NL *Duration:* A few months *Extent:* National	Meat packers advised to destroy thyroid glands.
3. *Restrictions* on domestic marketing of beef/horse meat	A, N *Duration:* Ongoing *Extent:* Regional	*N:* Only meat from animals that had been grazing in cultivated fields for at least 4 weeks, or that had been fed indoors for at least 4 weeks, approved for slaughter (8 September 1986).
4. *Advice* on domestic marketing of reindeer meat	SF *Duration:* Ongoing *Extent:* National	
5. *Restrictions* on domestic marketing of reindeer meat	N, S *Duration:* Ongoing; Initiated in June *Extent:* Regional	Concern on accumulation of ^{137}Cs, and on future harvests.
6. *Advice* on consumption of freshwater fish	SF, NL, S *Duration:* Ongoing *Extent:* Regional	Advice to limit consumption to 1-2 times per week in areas of highest deposition. Concern on accumulation of ^{137}Cs.
7. *Prohibition* on marketing of freshwater fish	N, CH *Duration:* Ongoing *Extent:* Regional	*N*: 29 municipalities (4/7/86); 8 additional municipalities (4/8/86). *CH*: Concerned only Lake Lugano.
8. *Advice* not to hunt certain game	IRL, NL, E, S *Duration:* Ongoing; Initiated in June *Extent:* Regional	Concern over elevated ^{137}Cs levels in woodcock. *E*: Advice not to hunt migratory birds.
9. *Advice* on domestic marketing of game	NL, SF *Duration:* Ongoing; Initiated in June *Extent:* National	
10. *Restrictions* on domestic marketing of game	S *Duration:* Ongoing *Extent:* National	Precautionary measure.

RESPONSE	COUNTRY[b]	NOTES
11. *Restrictions* on imports of meat	Practically All Countries *Duration:* Most Action Levels still valid, although frequency of inspection and surveillance greatly reduced	*Basis*: Controls on contaminated foodstuffs not subject to domestic production and marketing controls. Current concern on longer-term accumulation of ^{137}Cs.
12. *Prohibition* on imports of meat from Eastern European countries	S, TR, CEC Member Countries *Duration:* S: 30 April-5 May; TR: 12-18 May; CEC: 1-12 May	*Basis*: Uncertainty on actual levels of contamination.
H. Others:		
1. Provision of government compensation for agricultural losses	A, SF, FRG, GR, I, NL, N, S, TR, UK	*A*: Compensation to farmers allocated from Federal Disaster Fund. *GR:* Compensation for lost sheep/goat cheese production. *NL*: Compensation to spinach producers. *N*: Compensation to sheep, beef, dairy and reindeer farmers. *S*: Compensation to dairy farmers for milk losses and costs of stored feed, and potentially to reindeer owners. *TR*: Dairy farmers supplied with uncontaminated forage. *UK*: Compensation to sheep farmers.
2. *Advice* to take protective measures and special procedures in changing industrial air conditioning/ventilation filters	A, B, SF, FRG, GR, I, L, NL, S, CH *Duration:* 2-4 weeks	*SF*: Replace filters earlier than usual. *I, CH*: Delay cleaning/replacement of filters to let ^{131}I decay. *All*: Provide protective clothing to workers.

RESPONSE	COUNTRY[b]	NOTES
3. *Restrictions/Prohibitions* in the use of sewage sludge for soil amendment	A, SF, L, S, CH *Duration:* 1-3 weeks; A: May-July *Extent:* Regional	*A*: Prohibition on spreading sludge on agricultural lands. *SF*: Avoid application to cropland until August. *S*: Enacted activity limits. *CH*: Limit on quantities applied to cropland.
4. *Advice not* to administer stable iodine	A, CND, SF, F, FRG, GR, L, NL, E, S, CH, TR, US *Extent:* National	*Basis*: Avoid unnecessary risk of iodine poisoning. Deemed not necessary for radiological protection purposes.
5. *Advice* to administer stable iodine	SF *Duration:* 2 weeks (2-16 May)	Single dose of 200 mg of potassium iodide only if travelling to within 50 km of Chernobyl.

Appendix 3

MEMBERSHIP OF THE COMMITTEE ON RADIATION PROTECTION AND PUBLIC HEALTH

This report has been prepared under the authority of the Committee on Radiation Protection and Public Health. The Committee reviewed a preliminary summary report, and the information provided by Member countries for the preparation of the final report, during its Special Session on the Chernobyl accident on 1st-2nd September, 1986. The Committee then approved the final report at its meeting of 9th-10th March, 1987.

The following lists include the regular members of the Committee and the additional experts who attended these two meetings.

SPECIAL SESSION ON THE CHERNOBYL ACCIDENT (1st-2nd September, 1986)

Australia

COOK, J.E., Acting Director, Australian Atomic Energy Commission, Regulatory Bureau
WRIGHT, W., Chief, Technical and Commercial Services Division, Australian Atomic Energy Commission

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MUECK, K., Austrian Research Centre Seibersdorf

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DESCHOUWER, P, Secrétaire Général, Ministère de la Santé Publique et de la Famille
COTTENS, E., Inspecteur-Chef, Service de Protection contre les radiations ionisantes, Ministère de la Santé Publique et de la Famille
STALLAERT, P., Inspecteur général, Service de Protection contre les radiations ionisantes, Ministère de la Santé Publique et de la Famille
GOVAERTS, P., Chef de Section Météorologie et Etudes, Centre d'Etude de l'Energie Nucléaire
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European countries of the OECD have been affected by the widespread dissemination of radioactive material released from the Chernobyl reactor accident in the URSS, in April 1986. This report provides an assessment of radiation doses received by the population of these countries and a critical analysis of the countermeasures applied. One of the main lessons learned is the need for improved preparedness to cope effectively with a nuclear emergency having transnational consequences.

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