COMMISSION
OF THE EUROPEAN COMMUNITIES

# THE RADIOLOGICAL EXPOSURE OF THE POPULATION IN THE RHINE-MEUSE REGION

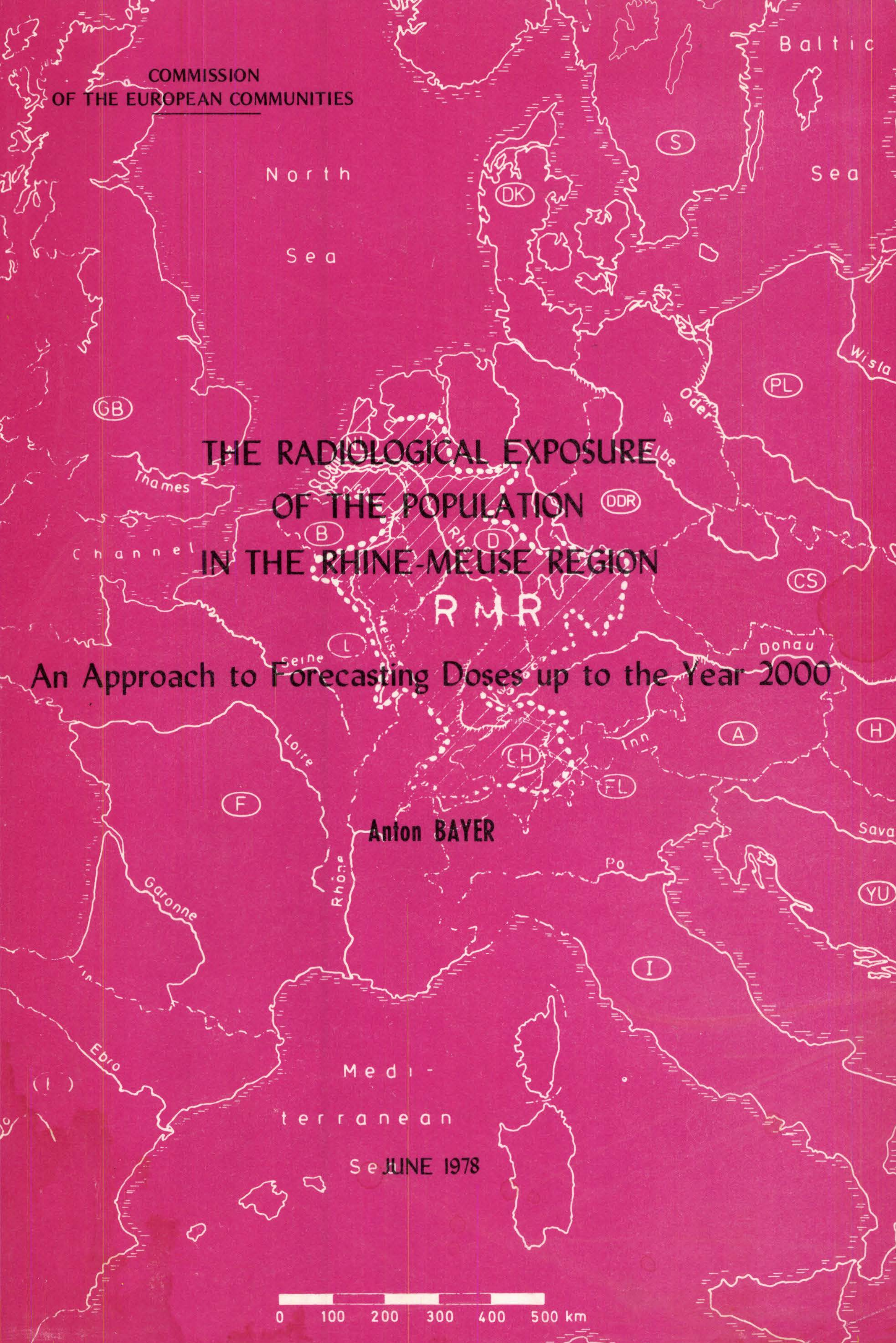
## RMR

## An Approach to Forecasting Doses up to the Year 2000


**Anton BAYER**



JUNE 1978

## NOTE

This report takes into account data
available to the end of 1976

COMMISSION OF THE EUROPEAN COMMUNITIES

# THE RADIOLOGICAL EXPOSURE OF THE POPULATION IN THE RHINE-MEUSE REGION BY NUCLEAR INSTALLATIONS DURING NORMAL OPERATION

## An Approach to Forecasting Doses up to the Year 2000

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A. BAYER

## Two Rivers and Their Names

The "River Rhenus", to give it its Latin name, rises in Switzerland where it is referred to as the "Rhein". This latter form of the name is maintained when the river forms the border firstly between Switzerland and Austria and then between Switzerland and Germany. Turning north at Basle it subsequently forms the border between Germany and France where it adopts a dual personality, that of the French "Rhin" and the German "Rhein". Having left its Gallic phase behind, it reverts entirely to its Germanic identity until it turns eastwards into the Netherlands and is there transformed into the "Rijn". Finally it distributes its waters into the delta where the Lek and the Waal constitute the main channels to the North Sea.

The "River Mosa", as the Romans called it, rises in France to be known as the"Meuse" and retains this name as it crosses the national frontier into Belgium. However, at the Walloon-Flemish linguistic frontier it experiences a change of identity becoming the "Maas" and continues as such into the Netherlands and thence to the North Sea.

In England, which faces the mouths of these two rivers across the North Sea, they are known as the "Rhine" and the "Meuse".

However, in view of the importance of the rivers within the countries which they traverse, the author has chosen a German-Dutch compromise to describe the entire area, namely the

Rhein-Maas Region.

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## List of the most important symbols (simplified)

For the sake of clarification the indices have been omitted. These are explained as they arise in the text.

| Symbol [ Units ]: | Meaning: | Applied firstly in equation: | |
|---|---|---|---|
| A $[Ci]$ | = activity inventory | (5.3-11) | |
| a $\left[\frac{Ci}{m^3, m^2, kg}\right]$ | = specific activity | (5.2-1a) | *) |
| $\dot{B}$ $\left[\frac{m^3}{kg}\right]$ | = bioaccumulation factor | (5.2-4) | *) |
| C $\left[\frac{kg}{s}\right]$ | = animal feed consumption | (5.2-5) | *) |
| D $\left[\frac{rem}{s}\right]$ | = dose rate | (5.2-1) | *) |
| $\int D$ $[rem]$ | = dose after time t | (5.3-20) | |
| DC $\left[\frac{man \cdot rem}{s}\right]$ | = collective dose rate | (5.2-23) | |
| DY $\left[\frac{rem}{s}\right]$ | = dose rate yield | (5.2-22) | |
| d $\left[\frac{rem}{m^3, kg}\right]$ | = specific dose | (5.2-3b) | *) |
| E | exponent - see end of this summary | | |
| F $[m]$ | = deposition factor | (5.2-2) | *) |
| FR $\left[\frac{m^3}{s}\right]$ | = flow rates of rivers | (5.2-6) | |
| f | = depletion factor (atmospheric transport) | (5.2-1) | *) |

*) Further details are given in the summary following equations (5.2-1 to 10)

| | | | |
|---|---|---|---|
| fd | = food (feed) distribution function | (5.2-16)<br>(5.2-17) | |
| G $\left[\frac{kg}{s}\right]$ | = human food consumption | (5.2-4) | *) |
| g $\left[\frac{rem\cdot(m^3,m^2)}{s\cdot Ci}\right]$, $\left[\frac{rem}{Ci}\right]$ | = dose factor | (5.2-1) | *) |
| H $\left[\frac{m^3}{s}\right]$ | = inhalation rate of man | (5.2-3 | *) |
| h $[m]$ | = source height | (5.3-1) | |
| h | = frequency of deposition | (5.3-6) | |
| IR $\left[\frac{m}{s}\right]$ | = irrigation rate | | |
| J $\left[\frac{s}{m^3}\right]$ | = atmospheric dispersion factor | (5.2-1)<br>(5.3-1) | *) |
| K $\left[\frac{m^3}{t}\right]$ | = distribution coefficient | (5.3-12) | |
| k $\left[\frac{m^3,t}{s}\right]$ | = transfer coefficient | (5.3-11) | |
| L $[m]$ | = mixing height | (5.3-2) | |
| l | = land use | (5.2-20)<br>(5.2-21) | |
| p $\left[\frac{man}{m^2}\right]$ | = population density | (5.2-24) | |
| Q $\left[\frac{Ci}{s}\right]$ | = source strength | (5.2-1) | *) |
| R $\left[\frac{kg}{m^2}\right]$ | = area density of soil within root region | (5.3-15) | |

| | | | |
|---|---|---|---|
| r | = location | (5.2-1) | *) |
| S $[m]$ | = sediment deposition factor | (5.2-7) | *) |
| SS $\left[\frac{t}{m^3}\right]$ | = suspended matter content | (5.3-11) | |
| s | = depletion factor (transport in hydrosphere) | (5.2-6) | *) |
| sf | = sejourn frequency | (5.2-15) | |
| T $\left[\frac{s}{kg}\right]$ | = transfer factor | (5.2-5) | *) |
| u $\left[\frac{m}{s}\right]$ | = wind speed | (5.3-1) | |
| u | = use of agricultural products | (5.2-20) (5.2-21) | |
| V $[m^3]$, $[t]$ | = volume of water body, mass of suspended matter or sediment | (5.3-12) | |
| Y $\left[\frac{kg}{m^2 \cdot s}\right]$ | = yield of agricultural products, intended for human consumption | (5.2-19) | |
| y $\left[\frac{kg}{m^2 \cdot s}\right]$, $\left[\frac{kg}{kg, s}\right]$ | = yield of agricultural products | (5.2-20) (5.2-21) | |
| z $[m]$ | = height above ground | (5.3-1) | |
| $\Lambda$ $[s^{-1}]$ | = wash-out constant | (5.3-5) | |
| $\lambda$ $[s^{-1}]$ | = decay constant | (5.3-3) | |
| $\sigma$ $[m]$ | = atmospheric dispersion parameter | (5.3-1) | |

| | | |
|---|---|---|
| $\tau$ [s] | = residence time, relaxation time | (5.3-7) (5.3-12) |
| $\phi$ [man] | = doserate-distribution function | (5.2-24) |

Various forms have been used to express numerical values as appropriate :

for example : $3.5 \cdot 10^{-3}$ = 3.5 (-3) = 3.5 E-3

Summary

The purpose of this study is to assess the future radiological impact of the population in the Rhein-Maas Region attributable to radioactive discharge from nuclear facilities under normal operating conditions. This involves establishing dose rates

- for the period around 1985/90, on the basis of currently available plans for facilities and sites
- for the period around 2000/05 on the basis of the forecasted development of nuclear technology in the coming decades.

Its relatively high population density (approximately 270 inhabitants per $km^2$) and the high level of industrial production, coupled with intensive agriculture, make the Rhein-Maas Region (approx. 222 000 $km^2$, 60.4 million inhabitants) one of the key areas in Europe. Eight Western European countries are situated wholly or partly within this region.

Nuclear electricity generating capacity in the region currently amounts to some 7.5 GWe (total capacity: approx. 60 GWe). According to currently planned facilities and sites, this will rise to about 55 GWe in 1985/90. On the basis of the forecasted development of nuclear technology, this can be expected to double to about 110 GWe, out of a total capacity of approx. 150-300 GWe, by 2000/05. Revised forecasts, however, indicate that growth will be some 25-30% less than this.

Anticipated dose rates are established in the report for the following organs:

bones, gastro-intestinal tract, gonads, liver, lungs, skin, thyroid and whole body.

Account is taken of 17 fission and activation products which contribute the major part of the total dose:

H-3, C-14, Ar-41, Co-58, Co-60, Kr-85, Kr-88, Sr-89, Sr-90, Ru-106, I-129, I-131, Xe-133, Xe-135, Cs-134, Cs-137 and Ce-144.

The calculations are based on their discharge rates from the nuclear facilities i.e. nuclear power stations and the

facilities forming the nuclear infrastructure.

For operational facilities the measured discharge rates have been adopted, while for facilities yet to be commissioned realistic anticipated values are used.

The resulting dose is calculated with regard to the most important exposure pathways:

- for gaseous discharge: exposure from the plume, from the ground, from inhaled activity and from activity ingested with food;
- for liquid effluent: exposure from water bodies, from the ground in inundation areas, and from activity ingested with drinking water and food.

These calculations are backed by data on the regional conditions (meteorology and hydrology) and on the structure of the region (population, agriculture, drinking water supplies and freshwater fisheries).

For the various exposure pathways a list is given of the main formulae used to calculate the individual and collective dose rates. On account of differences in the basic information available for the exposure pathways, the significance of the results obtained varies from case to case.

This is set out and explained in detail.

Investigations show that the maximum individual dose rates for 1985/90, calculated on the basis of conservative assumptions, range from 1 to 2 mrem/yr for most organs. For the thyroid, dose rates of up to some 10 mrem/yr may occur via the gaseous discharge pathway. The average individual dose rates are in the region of 0.015 to 0.035 mrem/yr.

On the assumption that neither the present overall pattern of sites nor the number of facilities per site will change significantly, no appreciable changes are expected by 2000/05 in the maximum individual dose rates. Because of the doubling of nuclear output and capacity, average dose rates will also double. For maximum individual dose rates from liquid effluent, a 100% increase can be expected because concentrations in surface water are expected to double. Because of the added effect of doubling the rate of utilization of river water, the average individual dose rates are expected to increase by a factor of between 2 and 4, depending on the exposure pathway.

An analysis of exposure from gaseous discharges reveals ingestion as the critical pathway for almost all organs. The radionuclides H-3 and C-14 are mainly responsible for this, but additionally, in the case of the thyroid, I-131 emerges as a dominant nuclide. The dose rate to the skin is essentially determined by plume exposure, the most important radioactive noble gas being Kr-85. For exposure attributable to liquid effluent, the most important radioisotopes are those of Co and Cs (ground radiation) and H-3, Sr-90 and I-131 (drinking water pathway, fishmeat pathway etc.).

A comparison with the radiological whole-body dose resulting from global releases of H-3, C-14 and Kr-85 shows that around the year 2000 this will be of the same order of magnitude as that attributable to regional releases.

The conservatively calculated maximum individual dose rates for 1985/90 and 2000/05 are still approximately one order of magnitude below the dose limits of 30 mrem/yr or 90 mrem/yr (thyroid) of the Federal Republic of Germany which were taken as a basis for comparison. The potential risk (cancer), also assessed on the basis of a conservative model, is between 4 and 6 orders of magnitude below the natural risk, depending on the type of damage concerned.

On the basis of these considerations, it is concluded that the anticipated radiological impact from nuclear facilities up to the end of the century gives no cause for concern. Attention is drawn, however, to the fact that if, over a long period, further nuclear facilities continue to be built, measures will have to be taken in due course to reduce the amounts of activity released by each facility.

In addition to a summary of the necessary extension and development of the work involved in further studies on the period under consideration, further questions appropriate to more far-reaching long-term studies are put forward.

## 1. Introduction

The past few years have shown that the growing demand for electrical energy will be met to a greater and greater extent by nuclear power as the primary energy source. Like all energy-producing systems, nuclear technology also affects the environment to a certain extent. In view of the fact that small limits of radiological exposure to man have been set it is necessary to know whether these limits will be reached if nuclear technology is introduced to a large scale.

The radiological impact of nuclear facilities during normal operation derives essentially from the emission of small quantities of radioactivity with gaseous and liquid effluent. These discharged radionuclides ultimately reach man via various geophysical transport and deposition processes and any subsequent processes in the biosphere, and contribute to his radiological impact.

In view of the growing number of nuclear facilities, combined with their concentration in regions having large energy requirements, there has been a growing realization that, in addition to the traditional case-by-case approach that is customarily applied in most safety reports, it is also necessary to give critical attention to the development of nuclear technology and the long-term nuclear construction programmes in prospective regional or global studies. The first regional studies to apply this concept were the 'Mississippi Study' [1], the studies on the Upper Rhein Region [2, 3], and initial considerations for North-East England [4] and the Federal Republic of Germany [5]. An investigation for the 'Tennessee Valley' is under way [6].

The present regional study assesses the expected radiological impact of the population in the Rhein and Maas basins on the basis of the planned and forecasted development of nuclear energy in the coming decades.

The Rhein-Maas Region (RMR) - the position of which in Western Europe can be seen from Figure 1.1. - is part of the central area of Europe in which population and industry are most densely concentrated. About 60 million inhabitants live in an area of approx. 222 000 $km^2$, with an average population density of some 270 inhabitants/$km^2$. Eight Western European countries - Switzerland, Liechtenstein, Austria, Germany, France, Luxembourg, Belgium and the Netherlands - lie wholly or partly within this region. The last five are members of the European Community.

Within the Rhein-Maas Region, which currently has an electricity consumption of approx. 4 500 kWh/year per head of population, there is (late 1974) an installed generating capacity of approx. 60 GWe, including some 7.5 GWe of nuclear capacity (late 1975). Further plans for nuclear facilities published since then cover approximately the period 1985/90. On the basis of these plans, and including facilities already in operation or under construction, the peak-load capacity from nuclear energy in 1985/90 will amount to about 55 GWe. For the year 2000 a peak-load generating capacity of between 150 GWe and 300 GWe can be projected, of which some 110 GWe are expected to be produced from nuclear energy*).

The Rhein-Maas Region is characterized on the one hand by a high level of industrial activity and energy output together with the resulting dense network of roads, railways and power lines, coupled with technologically advanced agriculture. This points to the region's role as one of the economic centres of Europe. On the other hand its interlacing political structure means that questions concerning the discharge of harmful substances into the environment almost always turn into trans-frontier problems. To this extent the question under investigation in the present work is of particular importance for Europe.

The aim of the study is to establish the radiological impact of nuclear facilities. This means trying to calculate:

---

*) Revised projections, see section 4.2.3.

1) local individual dose rates*) and - with reference to the actual population structure - the resulting distributions of individual dose rates.

   This allows comparisons to be made with

   - the statutory dose-rate limits,
   - exposure to natural radiation,
   - exposure from other sources;

2) collective dose rates and thus - as far as possible - average individual dose rates. This provides more or less the same opportunities for comparison as above. In addition, by applying risk factors the potential incidence of harmful effects can also be derived from the collective dose rates. From this it is then possible

   - to make comparisons with the corresponding natural incidence of harmful effects (e.g. as in [2]),
   - and, if the harmful effects are calculated in cash terms, to make a cost-benefit analysis [7,8].

Since local individual dose rates and distributions of individual dose rates provide the greater amount of information, it is preferable to aim at establishing these. In a number of cases, however, there are particular circumstances which mean it is only possible to achieve results of the second, i.e. collective, type.

The accuracy of the obtained results depends on the time span which is considered. For the short term - comprising facilities to be commissioned up to 1985/90 - the sites and the nuclear facilities to be erected thereon are generally known. On the basis of the site map it is generally possible to draw conclusions with reference to particular locations. For the medium term - facilities to be commissioned between 1985/90 and 2000/05 - in general nothing is yet known about firm siting plans. Therefore conclusions depending on locations can not be drawn. National and regional projections, however, provide information on the proportion of generated electricity that is expected to be provided by nuclear power stations, so that for this period -

*) In what follows 'dose' always infers 'equivalent dose'.

mainly with the use of collective dose rates and dose rate - distribution functions - more general conclusions can be drawn. For the long term - the period after 2000/05 - scenarios for energy requirements and energy supply are only meaningful on a global scale. This period is therefore beyond the scope of the present study.

The study takes account - in so far as information is available - of all facilities sited in the region itself. In addition, account is taken as follows of facilities sited in the vicinity of the region:

- in a near distance zone of up to 100 km all nuclear facilities individually;
- in a far distance zone of 100 to 400 km all nuclear facilities, each group of adjacent sites being consolidated into a single point;
- at distances of up to 1000 km the major reprocessing facilities.

Of the full range of radionuclides discharged, account is taken of those fission and activation products known, on the basis of previous studies and assessments, to contribute the major part of the total dose. These are:

H-3, C-14, Ar-41, Co-58, Co-60, Kr-85, Kr-88, Sr-89, Sr-90, Ru-106, I-129, I-131, Xe-133 Xe-135, Cs-134, Cs-137, Ce-144.

No account has been taken of the actinides, as no adequate data are yet available for this group of radionuclides.

Calculations have been made having regard to the various radionuclide transport processes or exposure pathways:

- external exposure from radionuclides in the plume, in liquid effluent and on surfaces,
- internal exposure following incorporation of radionuclides by inhalation (air) or ingestion (drinking water and food).

The geographical structure of the population that forms the basis for the investigation has in general been recorded at district level or the equivalent administrative unit. In-addition, within a radius of some 20 km of nuclear facilities the population has been considered at community level. By means of this further breakdown in the vicinity of facilities, where dose rates are highly dependent on distance, it is possible to gain a more precise picture of maximum exposure levels. The structure of agricultural production is taken into consideration at district level.

Finally, dose rates and dose rate distributions have been calculated for the following organs:

> bones, gastro-intestinal tract, gonads, liver, lungs, skin, thyroid and whole body (= average dose rate for all organs).

By way of qualification it should be noted that in examining the transport processes no account has been taken of the influence on the points under consideration of heat emission from nuclear facilities, since at present only the first steps have been taken towards quantifying any possible effects.

It should be pointed out that the models used here were developed at the "Institut für Neutronenphysik und Reaktortechnik" as part of the "Projekt Nukleare Sicherheit" of the Karlsruhe Nuclear Research Centre.

## 2. Prospective studies - Objectives and limitations

This prospective regional study assesses the expected radiological impact on the population of a region on the basis of planned and forecasted development of nuclear energy.

The objectives of regional studies are intermediate between those of site studies and global studies. Site studies are concerned with the radiological impact in a limited area around a single site; the results are important mainly for the preparation of safety reports. Global studies are aimed at assessing the radiological impact of the emission of long-lived nuclides by nuclear facilities throughout the world. The different approaches can be characterized as follows:

Site studies relate to dispersion via air and water pathways, as determined by local conditions, of radioisotopes of local importance. By restricting investigations to a limited area it is possible to make a comparatively detailed survey of the transport processes, exposure pathways and population groups concerned. This can include giving consideration to the following factors:

- topographic peculiarities of the site and the immediate vicinity;
- particular flow characteristics of the river in the vicinity of the site;
- the position of various residential areas and individual farms;
- the position of arable land, pasture and forest, and the particular use made of them;
- the extraction of small quantities of river water and the use made of it;
- fishing areas used by local fishermen;
- the employment structure (proportion of self-supporting food producers).

The calculated exposure levels can then be given in suitable detail.

Regional Studies relate to the dispersion in air and water within the region of radio-isotopes of local and regional importance discharged by all nuclear facilities in the region. While the same methods can be used to some extent, these studies differ from site studies in that the approach is less detailed, since otherwise the work of collecting data and carrying out calculations would be far greater. The data collected are, therefore used on a statistical basis for comparatively large administrative units (e.g. at district level). Only close to sites, where the highest exposure levels are to be expected, is a fuller analysis (e.g. for villages) required. In general therefore, the expected exposure levels are calculated relatively precisely in the case of higher values, while less precision is required at lower values. The main task of regional studies lies in taking account of the mutual overlapping of exposure patterns from all nuclear facilities in a region. The catchment areas of river systems are particularly suitable subjects for regional study as they provide an area with relatively well-defined limits for investigating transport via the river system of radionuclides discharged with liquid effluent. But with regard to transport through the air as well a watershed, however, also presents a meaningful border for defining a study area in respect of atmospheric transport, since sections of river in adjacent river systems having flow rates sufficient for the majority of nuclear facilities are generally sufficiently distant to give a broad dividing zone.

Global studies are restricted to radioisotopes which can be regarded, on account of their half-life and transport characteristics, as of world-wide importance. It is generally assumed for study purposes that radioactive materials emitted from all nuclear facilities are mixed homogeneously in the transport medium. Exposure pathways and population structures are also simplified on a world scale. Since the transport on the global scale of water or water vapour, carbon dioxide and the noble gases is comparatively well understood, assessments can easily be made of the overall exposure to H-3, C-14 and Kr-85. In the case of Sr-90, I-129, Cs-137 and the actinides, however, global dispersion mechanisms have not yet been adequately clarified so that for these nuclides amongst others it is in general only possible to prepare global inventory data.

These characteristic features of radiological studies - divisions between them are gradual rather than sharply defined - are summarized in Figure 2.1. The various studies complement one another. Thus the findings of global studies can be included in regional studies in respect of the global background radiation level, while in site studies the findings of regional studies can be used for the regional background radiation level and those of global studies for the global background level. This is clearly set out in Figure 2.2.

In contrast to the division of possible subject areas for radiological studies into sites, regions and the World, it is rather more difficult to define suitable periods of time to fit the term "perspective". One possibility is to divide the time scale, on the basis of what is known about plans for commissioning nuclear facilities in the future, into three sections i.e. the short-term, medium-term and long-term.

For the short term, which from the present point of view covers facilities to be commissioned up to about 1985/90, the sites and the nuclear facilities to be constructed there (type, size, year of entry into service, etc.) are in general known.

For the medium term - which covers facilities to be commissioned between about 1985/90 and 2000/05 - with certain exceptions (mainly alternative sites within the framework of national development plans) no details of proposed sites are available. Energy programmes and energy forecasts at regional and national levels, however, provide projections of the increase in electricity production for this period and the proportion of this to be covered by nuclear energy. At the same time, it seems from present projections that, in the initial phase of this period at least, the majority of nuclear power stations in the Rhein-Maas Region will still be equipped with light-water reactors whereas later high-temperature reactors and fast breeders will be introduced.

For the long term - which covers the commissioning of facilities after 2000/05 - it is at present difficult to make forecasts of energy production and the relevant technology. In particular, it is not at the moment possible to make predictions about the successful development of a fusion reactor and the effect it would have on energy supplies.

The varying amount of information available about the different periods also determines the study areas about which corresponding predictions can be made. Since relatively detailed information is available for the short term, this period can be the subject of site, regional and global studies. For the medium term, as far as increased capacity is concerned, we no longer have any specific data but only programmes or projections for larger areas, which means that for this period only general statements can be made in regional and global studies. Finally, for the long term, the lack of detailed information means that it is only possible to work out scenarios for very large regions, i.e. mainly world-wide developments, in global studies. This situation is clearly depicted in Figure 2.3.

# 3. Description of the Rhein-Maas Region

## 3.1. Topography [9 et al.]

The catchment area of the Alpine Rhein (sources to Lake Constance) and the High Rhein (Lake Constance to Basel) is characterized by three topographical zones running from SW to NE. These are respectively part of the Alps, the Central Plateau of Switzerland with its wooded series of folded hills, and the Jura.

The Upper Rhein (Basel to Mainz) flows in a roughly northerly direction through a plain some 40 - 50 km wide, the Upper Rhein Plain. In the southern part, the Vosges on the left and the Schwarzwald (Black Forest) on the right are within its catchment area. To the north the Upper Rhein drains the Pfälzerwald (Palatinate Forest) on the left and the Odenwald on the right. The two major tributaries on the right bank, the Neckar and the Main, extend the catchment area to include the Swabian-Franconian escarpments (Schwäbisch-Fränkische-Stufenland) and the Rhön, Spessart and Vogelsberg ranges of the central highlands.

The Middle Rhein (Mainz to Köln) cuts through the Rheinische Schiefergebirge which are divided on the left bank into the Hunsrück and the Eifel and on the right into the Taunus and the Westerwald with, on the other side of the River Sieg, the adjacent Bergische Land, the Sauerland and the Rothaargebirge. On the left bank the valley of the Moselle extends the catchment area to include the high plateau of Lorraine.

The Lower Rhein (Köln to the sea) begins where the river flows out of the Schiefergebirge into the Köln basin. The catchment area, composed essentially of the old morainal tableland of the geest, has no outstanding relief features and is known as the Lower Rhein Plain.

The Maas, the lower reaches of which form a joint delta with the Rhein, is bounded in its upper reaches by the Argonne Hills on the left and the Lorraine plateau on the right. The middle reaches of the river cut through the Ardennes, a continuation of the Rheinische Schiefergebirge, and the lower part then also flows through the Lower Rhein Plain.

## 3.2. Meteorology [9 et al.]

The catchment area of the Rhein and the Maas is within the zone of westerly winds in the temperate latitudes, and the climate is determined accordingly. The lack of protecting mountain ranges to the west means that flows of moist air from the west can reach far into central Europe without obstruction, exerting a cooling effect in summer and warming the region in the winter. The climate of the region can roughly be divided between the high mountain climate with cold damp winters and the damp temperate climate of the uplands and plains.

Moreover, the topography influences the climate to a considerable extent, particularly where there are marked valley formations. Here the wind has an increased tendency near ground level to blow from certain directions and there is a reduction in wind speed. It follows that in the Lower Rhein Plain, wind conditions are mainly governed by the overall weather situation, with a predominance of relatively high wind speeds. In the central highlands, on the other hand, topographically determined phenomena become more and more frequent. This is reflected by the fact that in the valleys, compared with the adjacent hill regions, there are

- lower wind speeds (by a factor of approximately 2)
- higher temperatures ($\Delta T$ 2 - 4°C)
- less precipitation ( 500 - 800 mm compared with 1000 - 1500 mm).

Figure 3-2 shows a few typical windroses for valley stations (H = 10 m above ground level). These show the increasing wind speeds from south to north. The meteorological data (weather types, wind frequencies, wind speeds, etc.) on which the calculations were based were provided by the national weather services [10 et al.] or the meteorological departments of research centres and nuclear facilities.

## 3.3. Hydrology

In accordance with the extent of the Rhein-Maas Region from the Alps to the North Sea, the hydrology of the region is divided into widely differing zones determined by climate and topography [11, 12 et al.].

The area south of Basel, (area of the Alpine Rhein and High Rhein) is characterized by low precipitation in winter and high precipitation in summer, with a yearly average of 1420 mm, of which the run-off amounts to 300 mm. The run-off pattern is also influenced by the melting of the snow in early summer and the compensatory effect of some 550 glaciers and 1200 lakes. These compensatory factors, however, are not sufficient to eliminate completely the cycle of high run-off rates in summer and low rates in winter.

The catchment area north of Basel, on the other hand, is dominated by tributaries originating in the central highlands of Germany, where there is less precipitation in summer and more in winter, with a yearly average of 800 mm (average precipitation for the whole RMR : 900 mm). Average run-off in this sector is 300 mm. The chronological differences between the run-off patterns in the two parts of the catchment area mean that seasonal variations in flow rates become less and less down the river.

The topographical catchment area of the Rhein is not identical with the topographical precipitation area, since underground streams can form links with other river basins. The largest such transfer of water is that from the upper Danube Basin to Lake Constance, which amounts to an average of 9 $m^3$/second.

In addition to run-off, the suspended-matter content and the speed of flow are also important hydrological data. Figure 3.3 gives average values for these parameters together with the catchment areas and flood plains for a few chosen points on the Rhein and the Maas and for smaller watercourses at their mouths.*)

*) Note: Positions on a river are normally given in river kilometres, which are generally counted upstream from the mouth. On the Rhein, on the other hand, distances are measured downstream from the Rhein bridge at Constance.

Water is drawn from the rivers of the Rhein-Maas Region for the supply of drinking water. This is treated using various processes:

- direct treatment
- indirect treatment

  by bank filtration

  by ground-water enrichment

Fig. 3-4 gives a summary of extraction points, quantities extracted, treatment methods used and the size of the population supplied. The detailed data on which the calculations were based were taken from the relevant literature [14, 15, 16] or were provided by the waterworks concerned. These data are set out in Table 3.1.

Water is also drawn from the rivers of the Rhein-Maas Region for irrigation. However, since documentation on this is still far from complete, this exposure pathway has been investigated only on the basis of simplified assumptions.

## 3.4. Population and administrative structure

The catchment area of the Rhein and the Maas is divided between the following eight States:

| Short name | Official name | Symbol |
|---|---|---|
| Switzerland | Confoederatio Helvetica | CH |
| Liechtenstein | Fürstentum Liechtenstein | FL |
| Austria | Republik Österreich | A |
| Germany | Bundesrepublik Deutschland | D |
| France | République Française | F |
| Luxembourg | Grand-Duché de Luxembourg | L |
| Belgium | Koninkrijk België/Royaume de Belgique | B |
| Netherlands | Koninkrijk der Nederlanden | NL |

Table 3.2 gives the areas and populations of these States together with the areas and populations which belong to the catchment area of the Rhein and the Maas. As the necessary data on which calculations are based are generally only available for administrative units, an 'administrative catchment area' has been devised so that the boundaries of the administrative units at the edge of the catchment area reflect the geophysical boundary as closely as possible (Fig. 3.5). These administrative units are listed in Table 3.3. As defined here, the Rhein-Maas Region covers an area of approximately 222 000 $km^2$ with a population of about 60 million, corresponding to an average population density of about 270 per $km^2$.

As shown in Table 3.2, with an average density of 270 per $km^2$ the Rhein-Maas Region is heavily populated by European standards (the average for the whole of Europe, excluding the USSR, is about 95 per $km^2$). Apart from a few relatively sparsely settled peripheral areas, particularly in the western part of the Rhein-Maas Region (Vosges, upper Maas valley, Ardennes), the following areas can be regarded as marked centres of population:

- the Swiss Central Plateau (Bern Zurich) up to Lake Constance,
- the Upper Rhein Plain (Basel to Mainz/Wiesbaden),
- the conurbation on the Lower Neckar (Stuttgart),
- the Franconian conurbation (Nürnberg),
- the conurbation on the Lower Main (Frankfurt),
- Lower Lorraine (Metz),
- the Saar Region,
- the Rheinland area (Köln, Aachen, Düsseldorf),
- the Ruhr area,
- the conurbation on the Lower Maas (Liège),
- the Rhein-Maas Delta area.

Fig. 3.6 gives an impression of the distribution of population density.

For purposes of calculation the population was recorded on the basis of the administrative units shown in Figure 3.5. The corresponding population data are given in Table 3.3. In addition, so that more careful consideration could be given to the short-range effects, detailed data were collected on the population within a radius of about 20 km from radiation sources. In this way data were collected on some 4 000 communities. Data were taken for the most part from the statistical reports of the countries concerned [18 to 30].

With regard to the age structure of the population, a sufficient approximation for the countries of Central Europe can at present be obtained by assuming a state of equilibrium and an average life expectancy of about 70 years. The proportions of the four age groups - infants, children, adolescents, adults - in the total population can be seen from Table 3.4.

### 3.5. Agriculture and freshwater fisheries

The economy is generally divided into three sectors:

- Agriculture and forestry (primary sector)
- Industry and mining (secondary sector)
- Trade, transport and services (tertiary sector)

Table 3.5 sets out the percentages of persons employed in these sectors of the economy in the eight countries. As there are no data available specifically for the Rhein-Maas catchment area, an estimate was made by applying a weighting based on the proportion of the total population of the country concerned living in the RMR. The resulting estimated distribution - 7.5%: 44%: 48.5% - shows that the region is characterized by a relatively low proportion of workers in agriculture and forestry, which - and this again is a characteristic of the region - is a technologically highly developed sector.

The farming areas can be divided according to climatic conditions and soil types in the region.

The Alpine foreland region to the north of the Alps, a fertile moraine zone traversed by a large number of rivers, is a major centre of stock raising and dairy farming (Swiss Central Plateau, Allgäu). In the river valleys and on the shores of the lakes there is intensive cultivation of special crops, the most important products being wheat, wine, fruit, vegetables, tobacco and hops.

In a north-easterly direction this is followed by a zone of low mountains broken up by many river valleys. The wooded uplands are partly used for forestry, while the middle slopes provide grazing land. In the river valleys and lowlands we find areas of highly mechanized intensive agriculture on good, partly loess-covered soils, as for example in the Upper Rhein Plain and the escarpment areas of Swabia-Franconia and Lorraine. The principal agricultural products of these areas are cereals, primarily wheat, together with potatoes and sugar beet. As for special crops, viticulture takes first place. Fruit and vegetable farming are also of importance, particularly in the vicinity of the main centres of population.

To the north of the Rheinische Schiefergebirge extends a slightly undulating ground moraine area, largely covered with loess loam and thus particularly fertile, with cultivation of cereals, sugar beet and vegetables (Brussels Basin, Köln Basin, Münsterland Basin, Bördenland). To the west and north this is followed by a geest zone of varying structure, with unfertile sandy areas covered in heathland and pine forest alternating with marshes, deciduous forests and fertile farming and grazing land. Between this and the coast there is then the fertile fen and polder area covering the north-eastern part of Belgium, most of the Netherlands and the Ems, Weser and Elbe estuary areas in Germany, where for climatic reasons grazing and dairy farming are predominant. In the Schelde-Rhein delta, along the North Sea coast and in the river valleys, intensively cultivated agricultural and horticultural crops thrive on clay soils.

Figure 3.7 gives a simplified picture of the structure of agricultural land use in the various land use categories. The percentages of the various types of land use within the land use categories, together with the percentages of land under the principal crops by group - calculated in each case from the documents available [31 to 35] - can be seen from Table 3.6. Table 3.7 shows the crop yields and the use made of the principal agricultural products, compiled from the available documents [31 to 38]. These figures and further agricultural data from the literature [39, 40, 41] are the starting data for calculating the radiological exposure via the ingestion pathway, which is carried out for each district.

There is both professional and amateur fishing on the rivers of the Rhein-Maas Region. Catches, especially for amateur fishing, are hard to determine. Using the documents available [16, 42 to 50] the local catch in sections of river downstream of nuclear facilities was established to the extent possible. For the rivers for which no documentation was available, estimates were made on the basis of catches in similar stretches of water. The resulting figures, which were used for calculating the radiological exposure via the ingestion pathway, are set out in Table 3.8.

# 4. Installed electricity generating capacity and nuclear facilities - Present position, plans and projections up to the year 2000.

## 4.1. Installed electricity generating capacity and projections up to the year 2000.

Current total energy consumption and consumption of electricity in the countries of the Rhein-Maas Region is set out in Table 4.1. On the basis of these national data an estimate has been made for the Rhein-Maas Region itself by applying a weighting for the percentage of population living in the region (Table 3.2). For purposes of comparison data for the USA have also been included. The installed electricity generating capacity in these countries is set out in Table 4.2. The installed capacity in the Rhein-Maas Region has been estimated, using the same weighting procedure, at about 60 GWe. At the end of 1975 some 7.5 GWe of this was already being produced from nuclear energy.

Over the past few years the consumption of electricity has been increasing exponentially:

- According to figures compiled by the European Communities [51] on electricity consumption for the countries of the RMR from 1962 to 1972, demand doubles in about 7-11 years.
- According to Schaefer [53] electricity consumption in Germany, which is possibly the single country most representative of the Rhein-Maas Region, doubled within about 11 years.

With regard to projections for the coming decades, it is generally recognized that in future the exponential increase will tail off:

- The UNIPEDE study [54] forecasts a continuing rapid increase in electricity consumption for the countries of the European Community. This will then only begin to level off after the year 2000.
- In a projection for Germany [53] H.Schaefer forecasts a lower rate of increase than the UNIPEDE study. Moreover, according to his figures a levelling off can be expected as early as 1990.

Figure 4.1 gives, on the basis of the installed capacity in the Rhein-Maas Region in 1975, the installed generating capacity expected by the year 2000, assuming doubling times ($t_D$) of 9 and 11 years and having regard to the results of the two studies mentioned above. To simplify matters, it was assumed that the installed capacity will increase in proportion to electricity consumption, for which the projections were made. Accordingly, the peak-load electricity capacity in the Rhein-Maas Region in the year 2000 will be as follows:

| 1975 | 2000 |
|---|---|
| 60 GWe | Extrapolation for $t_D$ = 9 years: 420 GWe<br>Extrapolation for $t_D$ = 11 years: 290 GWe<br>UNIPEDE projection [54]: 250-330 GWe<br>Schaefer projection [53]: 140-185 GWe |

These figures characterize the uncertainty at present surrounding projections of installed electricity generating capacity.

## 4.2. Nuclear facilities and projections up to the year 2000

In the Rhein-Maas Region a number of nuclear facilities are already in operation or under construction; others are at the planning or design stage. For the planned facilities, at least those planned for the period up to 1985/90, the proposed sites are for the most part also known. For the subsequent period up to about 2000/05 the plans, in so far as they have been made public, only give vague indications. For further facilities planned for this period there are no clear site details. We can on the basis of forecasts for the development of nuclear energy in the individual countries, draw general conclusions about the increase in the number of nuclear facilities in the region. For the period after 2000, however, it is very difficult to make any reliable forecasts. Here one generally has to be content with setting out possible 'scenarios' (e.g. [55]). This period is therefore to be excluded from the present study.

4.2.1. Nuclear facilities up to 1985/90

The nuclear facilities in the Rhein-Maas Region which are expected to be in operation by 1985/90 are listed together with the relevant details (type, capacity, year of entry into service, etc) in Table 4.3.*)

The locations of these sites in the region can be seen from Figure 4.2. Detailed site information is given in Figures 4.3.1 to 4.3.38. Details of the corresponding sources of information are given in Table 4.3. Table 4.6 contains a list of the abbreviations used.

According to this list, the following will be installed in the RMR by 1985/90:

| | |
|---|---|
| Nuclear-based electricity capacity | approx 55 GWe |
| Enrichment facilities | approx 2000 t/yr $UF_6$ |
| Fuel element fabrication plants | approx 1400 t/yr |
| Reprocessing plants | approx 40 t/yr |

Since, in addition to the nuclear facilities located within the RMR, those situated in the immediate vicinity also contribute to the exposure via the air pathway, these were also taken into account, in so far as they are already in operation or are expected to be in operation by 1985/90. These facilities are listed in tables 4.4 and 4.5. Their locations can be seen from Figure 4.2 and Figure 4.4.

The boundaries of the peripheral zone were so defined as to take into account

- all nuclear facilities individually in a near distance zone of up to 100 km,
- all nuclear facilities, condensing each group of sites to a single point, in a far distance zone of up to 400 km,
- the major reprocessing plants at distances of up to 1 000 km (far distance zone).

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*) Taking account of plans published up to the end of 1976.

The first two boundaries were drawn on a rather arbitrary basis, since there was no obvious natural division in terms of distribution of facilities in the peripheral zone. For atmospheric transport, ignoring the depletion processes (decay, deposition etc.), the concentration at a distance of 100 km from a discharge source 100 m high decreases to the order of 1% of the maximum value in the immediate vicinity of the facility, and at 400 km has fallen by a further factor of 5. Finally, the third boundary was so chosen as to include all the major reprocessing plants in Western Europe.

4.2.2. Nuclear facilities up to 2000/05.

It is difficult to make any reasonably accurate forecast of the further construction of nuclear facilities for a region in which 8 countries are involved. One way of attempting this is to extract a projection for the Rhein-Maas Region from the individual forecasts for the 8 countries by applying a suitable weighting. Forecasts of installed nuclear power capacity up to the year 2000 for the individual countries are set out in Figures 4.5.1 to 4.5.6.

The projection for the Rhein-Maas Region was drawn up using the data in the OECD/IAEA study [56], as this contains a consistent set of programmes for all the individual states. The projected nuclear power capacities of the individual states were weighted and added together to give a projection for the Rhein-Maas Region. A mixed weighting was applied here, in that the percentage of the population in the countries concerned living within the RMR (demand) and the percentage of the area of these countries coming within the RMR (availability of possible sites) were given equal importance. The resulting curve can be seen in Figure 4.6, which also gives projections for other areas for comparison. According to this, the installed nuclear capacity in the RMR by the year 2000 would be something over 110 GWe (calculated value: 113 GWe). Figure 4.6 also shows the 55 GWe calculated on the basis of site details already published for the period up to 1985/90.

The correlation is remarkably good. The curve thus obtained has also been included in Figure 4.1. It is difficult, however, to make comparisons with the projections shown there because they are based on different assumptions.

Assuming that in a nuclear power station with a capacity of 1 GWe approximately 35 t of fuel are loaded or removed each year, annual fuel consumption rates for the RMR can be calculated, and these can also be seen from Figure 4.6.

Nuclear power stations.

For the year 2000 a nuclear capacity of 113 GWe has been forecast. This means that in addition to the capacity of 55 GWe built up in the preceding period up to 1985/90 a further 58 GWe will have to be created by the year 2000, which corresponds to 50-60 facilities.

In projections of installed nuclear capacity for the period up to the year 2000 forecasts are generally also made of the percentage of total capacity provided by the various types of reactor. Figure 4.7 gives a forecast based essentially on the data in the OECE/IAEA report [56]. The original data have been slightly modified on the assumption that, apart from LWRs, HTRs and FBRs, no other types would be of significance in the RMR. For light-water reactors it was assumed in the above-mentioned study that the ratio of PWRs to BWRs would be 2 : 1.

It is still rather uncertain what proportion of facilities with LWRs will be operated with recycled plutonium. Consideration of this question is still at an early stage [57, 64]. The reason for this uncertainty lies in the close link with the maintenance of stocks of plutonium for fast breeder reactors, the scale of application of which cannot yet be accurately predicted. On the basis of various statements, however, it would appear that it is intended to carry out recycling in LWRs on a relatively large scale starting some time in the 80s. It can then be expected that in the 90s some 20-25% of LWRs will be fuelled with recycled plutonium. Figure 4.7 includes an outline of this situation. The influence of Pu-recycling on the release rates has not been considered in this study.

Fuel element fabrication plants

On the basis of forecast fuel consumption (Figure 4.6), fuel element fabrication plants with a minimum capacity of some 4000 t/year will be needed for the nuclear power stations in operation in the RMR in the year 2000*). In view of the capacity of some 1 5000 t/year, shown in Table 4.3, it will be necessary to extend this by the year 2000 by a further 2 500 t/year. Since fuel element fabrication plants are not subject to any special site requirements compared with other nuclear facilities, it can be assumed by way of approximation that most of them will be sited within the Rhein-Maas Region. Assuming that average-sized facilities will have an output of some 300 t/year, about 8 new plants would have to be built.

Reprocessing facilities

The expected throughput of 4 000 t/year in the year 2000 also reflects the necessary minimum capacity for reprocessing facilities. Within the countries of the RMR the following reprocessing capacities are in operation or planned:

| Site | | Capacity | Proportion available available for nuclear power stations in the RMR +) |
|---|---|---|---|
| Mol | B | 300 t/yr (1982) | - 125 t/yr |
| ("KEWA") | D | 1 500 t/yr (1985) | - 720 t/yr |
| La Hague | F | 800+800 t/yr (1980) | - 125 t/yr |
| Total | | 3 400 t/yr | - 1 000 t/yr |

+) It was assumed that each of the three reprocessing facilities would process only fuel from its own country. The percentage of fuel coming from facilities located in the RMR is as follows: D : 48%, F : 8% and B : 41%.

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*) No account is taken here of different rates of consumption per GWe/year in FBRs and HTRs.

Accordingly, for nuclear power stations in the Rhein-Maas Region alone further capacity of the order of 3000 t/year would have to be made available by the year 2000, corresponding to perhaps two large reprocessing facilities for 1 500 t/year each.

4.2.3. Revised projections (Spring 1977)

The projections set out in the preceding sections are based primarily on plans and forecasts from the years 1974/75. Meanwhile, on account of

- reduced economic growth,
- re-examination of questions of principle with regard to waste from nuclear power stations,
- and delays caused by objectors,

a lower rate of growth is now forecast for nuclear energy. Therefore recent studies forecast an installed nuclear generating capacity for Western Europe in 1985 amounting to between 2/3 and 3/4 of the original projection [66]. For individual countries the OECD [67] has reduced its projections by about the same amount. These reduced projections have been included in Figures 4.5.1 to 4.5.6.

Applying this reduction proportionally to the projection for the Rhein-Maas Region, this means that the installed nuclear capacity forecast for 1985/90 will only be reached three to five years later (see Figure 4.6). Moreover, if these reduction factors are applied to the projections up to the end of the century, it would mean that the installed nuclear capacity forecast for 2000/05 would only be reached seven to twelve years later. In the following sections the conclusions drawn for 1985/90 and 2000/05 should be seen in the light of these likely delays.

## 5. Calculations of radiological exposure

### 5.1. Radiation pathways

The calculation of the radiological exposure (under the conditions of "normal operation of nuclear facilities" assumed here this means the dose rates for the population in the region) is based on the following factors:

- site details of facilities, dates of entry into service and discharge rates; these are average measured rates for operational facilities and assumed rates for planned facilities or those under construction;
- descriptive models for transport in the atmosphere and the hydrosphere, and for the accompanying deposition processes;
- models and assumptions on bio accumulation and transfer processes in the biosphere by means of which the radionuclides can reach man;
- supposed local food production and assumptions as to food supplies to the population;
- data on population structure - population density, age structure, consumer habits;
- coefficients for converting the resulting radiation fields into dose rates for individual organs.

On account of the differences in ways of discharge, transport phenomena and any subsequent processes in the biosphere, a distinction is made between the following exposure pathways by which the radiation of the radionuclides released can come to affect man:

1. for gaseous discharge from the stack

   1.1 external exposure from activity in the plume

   1.2 external exposure from activity deposited on the ground

   1.3 internal exposure from activity incorporated by inhalation

   1.4 internal exposure from activity incorporated with food.

2. for liquid discharge with waste water

   2.1 external exposure from activity in water

   2.2 external exposure from activity deposited on the ground (inundation areas, irrigated areas)

   2.3 internal exposure from activity incorporated with drinking water

   2.4 internal exposure from activity incorporated with food (fish, irrigated crops).

Fig. 5.1 gives a clear picture of the various radiation pathways. They can also be traced in the form of a flow chart in Fig. 5.2. In the flow chart the models and input data discussed in this section are indicated in the rounded boxes, while the rectangular boxes illustrate the interim and final results to be dealt with in the next section.

## 5.2. Calculation of dose rates

The corresponding dose rates are calculated as a function of the nature of the discharge and the subsequent processes in geosphere and biosphere (see e.g. [68 - 73]). Without going into detail, the principal links in the chain leading to the dose rates are presented in simplified form below. More detailed information will be found in the subsequent sections.

The dose rates D at location $\vec{r}$ for the various age groups, organs and nuclides are calculated for the various radiation pathways as follows (the symbols used in equations (5.2-1 to 5.2-10) are listed on pages 31 - 33):

1. for gaseous discharge from the stack of a source at location $\vec{r}_o$

   1.1 external exposure from activity in the plume*)

$$D_{EC}\ (\vec{r}, \vec{r}_o) = g_{EC} \times J\ (\vec{r}, \vec{r}_o) \times f\ (\vec{r}, \vec{r}_o) \times Q_o \qquad (5.2\text{-}1)$$

and in addition

specific activity:

$$a_C\ (\vec{r}, \vec{r}_o) = J\ (\vec{r}, \vec{r}_o) \times f\ (\vec{r}, \vec{r}_o) \times Q_o \qquad (5.2\text{-}1a)$$

*) Sometimes called in short "cloud exposure".

1.2 external exposure from active material deposited on the ground*)

$$D_{EG}(\vec{r},\vec{r}_o) = g_{EG} \times F \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o \qquad (5.2\text{-}2)$$

and in addition

specific activity: $a_G(\vec{r},\vec{r}_o) = F \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o$ (5.2-2a)

1.3 internal exposure from active material incorporated by inhalation

$$D_{IH}(\vec{r},\vec{r}_o) = H \times g_{IH} \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o \qquad (5.2\text{-}3)$$

and in addition

specific dose: $d_H(\vec{r},\vec{r}_o) = g_{IH} \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o$ (5.2-3b)

1.4 internal exposure from active material incorporated with food

a) ingestion of deposited active material via plant products

$$D_{IG,P}(\vec{r},\vec{r}_o) = G_P \times g_{IG} \times B_P \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o \qquad (5.2\text{-}4)$$

and in addition

specific activity: $a_P(\vec{r},\vec{r}_o) = B_P \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o$ (5.2-4a)

specific dose: $d_P(\vec{r},\vec{r}_o) = g_{IG} \times B_P \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o$ (5.2-4b)

b) ingestion of deposited active material via animal products

$$D_{IG,A}(\vec{r},\vec{r}_o) = G_A \times g_{IG} \times T_A \times \sum_P C_P \times B_P \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o \qquad (5.2\text{-}5)$$

and in addition

specific activity: $a_A(\vec{r},\vec{r}_o) = T_A \times \sum_P C_P \times B_P \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o$ (5.2-5a)

specific dose : $d_A(\vec{r},\vec{r}_o) = g_{IG} \times T_A \times \sum_P C_P \times B_P \times J(\vec{r},\vec{r}_o) \times f(\vec{r},\vec{r}_o) \times Q_o$ (5.2-5b)

2. for liquid discharge with waste water from a source at location $\vec{r}_o$ ($\vec{r}$ generally refers to locations downstream of $\vec{r}_o$ on or near the river)

---

*) Sometimes called in short "ground exposure".

2.1 external exposure from activity in water

$$D_{EW}(\vec{r},\vec{r}_o) = g_{EW} \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o \qquad (5.2\text{-}6)$$

$g_{EW}$ $=g_{EWV}$ for exposure from water volume (immersion)

$=g_{EWS}$ for exposure from water surface

and in addition

specific activity: $a_W(\vec{r},\vec{r}_o) = \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o$ (5.2-6a)

2.2 external exposure from active material deposited on the ground during inundation periods

$$D_{ES}(\vec{r},\vec{r}_o) = g_{EG} \times S(\vec{r}) \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o \qquad (5.2\text{-}7)$$

and in addition

specific activity: $a_S(\vec{r},\vec{r}_o) = S(\vec{r}) \times \frac{s(\vec{r},\vec{r}_o)}{FR(\vec{r})} \times Q_o$ (5.2-7a)

2.3 internal exposure from active material ingested with drinking water

$$D_{IW}(\vec{r},\vec{r}_o) = W \times g_{IG} \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o \quad {}^{*)} \qquad (5.2\text{-}8)$$

and in addition

specific dose: $d_W(\vec{r},\vec{r}_o) = g_{IG} \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o$ *) (5.2-8b)

2.4 internal exposure from active material ingested with food

a) ingestion of active material via consumption of fish meat

$$D_{IG,F}(\vec{r},\vec{r}_o) = G_F \times g_{IG} \times B_F \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o \qquad (5.2\text{-}9)$$

and in addition

specific activity: $a_F(\vec{r},\vec{r}_o) = B_F \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o$ (5.2-9a)

specific dose: $d_F(\vec{r},\vec{r}_o) = g_{IG} \times B_F \times \frac{s(\vec{r},\vec{r}_o)}{FR(\vec{r})} \times Q_o$ (5.2-9b)

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*) In the case of mixing with uncontaminated water the proportion must also be taken into account.

b) ingestion of activity via irrigated plant products

$$D_{IG,IP}(\vec{r},\vec{r}_o) = G_p \times g_{IG} \times B_{IP} \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o \qquad (5.2\text{-}10)$$

and in addition

$$\text{specific activity: } a_{IP}(\vec{r},\vec{r}_o) = B_{IP} \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o \qquad (5.2\text{-}10a)$$

$$\text{specific dose: } d_{IP}(\vec{r},\vec{r}_o) = g_{IG} \times B_{IP} \times \frac{s(\vec{r},\vec{r}_o)}{FR(r)} \times Q_o \qquad (5.2\text{-}10b)$$

Summation of the separate dose rates across the spectrum of radionuclides released gives the dose rates for each age group and organ for the various exposure pathways.

$$D_{EP}(\vec{r},\vec{r}_o) = \sum_{\text{radionuclide}} D_{EP}(\vec{r},\vec{r}_o) \qquad (5.2\text{-}11)$$

or, taking account of all sources ($\nu$) in a region,

$$D_{EP}(\vec{r}) = \sum_{\nu} D_{EP}(\vec{r},\vec{r}\ ) \qquad (5.2\text{-}12)$$

EP = exposure pathway

Finally, adding the amounts for the various exposure pathways gives the total dose rates for each age group and organ :

for gaseous discharge

$D^{O}(\vec{r},A) = D_{EC,\gamma}(\vec{r})$ external $\gamma$-exposure from plume (cf. equation 5.2-1)

$+ D_{EC,\beta}(\vec{r})$ external $\beta$-exposure from plume *) (cf. equation 5.2-1)

$+ D_{EG,\gamma}(\vec{r})$ external $\gamma$-exposure from contaminated ground (cf. equation 5.2-2)

$+ D^{O}_{IH}(\vec{r},A)$ internal exposure by inhalation (cf. equation 5.2-3)

$+ \sum_{P,A} D^{O}_{IG,P,A}(\vec{r},A)$ internal exposure from ingestion of plant and animal products (cf. equation 5.2-4,5)

(cf. 5.2-13)

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*) only for the following organs
- skin
- male gonads, if $E_{\beta}^{max} > 36$ KeV [88]
- lungs, from inhaled air [88]

for liquid discharge

$$D^{O}(\vec{r},A) = D_{EW,\gamma}(\vec{r})$$ external exposure from water (cf.equation 5.2-6)

$$+ D_{ES,\gamma}(\vec{r})$$ external exposure from sediment-covered ground (cf.equation 5.2-7)

$$+ D^{O}_{IW}(\vec{r},A)$$ internal exposure from ingestion of drinking water (cf.equation 5.2.8)

$$+\sum_{F,IP} D^{O}_{IG,F,IP}(\vec{r},A)$$ internal exposure from ingestion of fishmeat and irrigated plant products (cf. equations 5.2-9,10)

(5,2-14

(A) = age or age group

O = organ

The dose rates for each age group and organ derived in accordance with equations 5.2-1 to 5.2-14 are initially local dose rates. Strictly speaking, they can only be regarded as individual dose rates - i.e. dose rates to be applied to individuals at location $\vec{r}$ - under the following conditions:

Exposure pathway group A (external exposure - 1.1, 1.2, 2.2- and internal exposure from active material incorporated by inhalation (1.3) and with drinking water (2.3)):

The individuals are living at location $\vec{r}$ and transfer temporarily only to locations $\vec{r'}$ with the same radionuclide concentration in the air and drinking water.

Exposure pathway group B (internal exposure from active material ingested with food - 1.4, 2.4):

The individuals consume only food produced at locations $\vec{r}$ or at locations $\vec{r'}$ with the same radionuclide concentrations in air and water.

(continued page 34)

List of symbols used in equations (5.2 - 1 to 10)

$a \left[\frac{Ci}{m^3, m^2, kg}\right]$ = specific activity of

- $a_A \left[\frac{Ci}{kg}\right]$: animal products
- $a_C \left[\frac{Ci}{m^3}\right]$: air
- $a_F \left[\frac{Ci}{kg}\right]$: fish meat
- $a_G \left[\frac{Ci}{m^2}\right]$: ground surface
- $a_{IP} \left[\frac{Ci}{kg}\right]$: irrigated plant products
- $a_P \left[\frac{Ci}{kg}\right]$: plant products
- $a_S \left[\frac{Ci}{m^2}\right]$: ground surface from sedimentation
- $a_W \left[\frac{Ci}{m^3}\right]$: water

$B \left[\frac{m^3}{kg}\right]$ = bio accumulation factor

- $B_F$ : water → fish meat
- $B_{IP}$ : water → irrigated plant products (dependent on rate of irrigation)
- $B_P$ : air → plant products

$C_P \left[\frac{kg}{s}\right]$ = animal feed consumption

$D \left[\frac{rem}{s}\right]$ = dose rate

- $D_{EC}$ : for external exposure from plume
- $D_{EG}$ : for external exposure from contaminated ground
- $D_{ES}$ : for external exposure from sediment-covered ground
- $D_{EW}$ : for external exposure from water
- $D_{IG,A}$ : for internal exposure from ingestion of animal products

$D_{IG,F}$ : for internal exposure from ingestion of fish

$D_{IG,IP}$: for internal exposure from ingestion of irrigated plant products

$D_{IG,P}$ : for internal exposure from ingestion of plant products

$D_{IH}$ : for internal exposure from inhalation

$D_{IW}$ : for internal exposure from ingestion of drinking water.

$d \left[\frac{rem}{m^3, kg}\right]$ = specific dose

$d_A \left[\frac{rem}{kg}\right]$ : for ingestion of animal products (1 kg)

$d_F \left[\frac{rem}{kg}\right]$ : for ingestion of fish meat (1 kg)

$d_H \left[\frac{kg}{m^3}\right]$ : for inhalation of air (1 $m^3$)

$d_{IP} \left[\frac{rem}{kg}\right]$ : for ingestion of irrigated plant products (1 kg)

$d_P \left[\frac{rem}{kg}\right]$ : for ingestion of plant products (1 kg)

$d_W \left[\frac{rem}{m^3}\right]$ : for ingestion of drinking water (1 $m^3$)

$F\ [m]$ = deposition factor, including dry and wet depostion and depletion effects after deposition

$FR \left[\frac{m^3}{s}\right]$ = flow rate of rivers

$f$ = depletion factor, including fall-out, wash-out and radioactive decay during atmospheric transport

$G \left[\frac{kg}{s}\right]$ = human food consumption; for indices see under "d = specific dose"

$g \left[\frac{\text{rem x}(m^3,m^2)}{\text{s x Ci}}\right], \left[\frac{\text{rem}}{\text{Ci}}\right]$ = dose factor

$g_{EC}\left[\frac{\text{rem x } m^3}{\text{s x Ci}}\right]$: for external exposure from plume

$g_{EG}\left[\frac{\text{rem x } m^2}{\text{s x Ci}}\right]$: for external exposure from contaminated ground

$g_{EW}\left[\frac{\text{rem x } m^3}{\text{s x Ci}}\right]$: for external exposure from water

$g_{IG}\left[\frac{\text{rem}}{\text{Ci}}\right]$ : for internal exposure by ingestion

$g_{IH}\left[\frac{\text{rem}}{\text{Ci}}\right]$ : for internal exposure by inhalation

$H \left[\frac{m^3}{s}\right]$ = inhalation rate of man

$J \left[\frac{s}{m^3}\right]$ = atmospheric dispersion factor

$Q_{\nu} \left[\frac{Ci}{s}\right]$ = source strength

$r$ = location of receiver

$r_{\nu}$ = location of source

$S [m]$ = sediment deposition factor for inundation areas, allowing for deposition and subsequent depletion effects

$s$ = depletion factor for sorption, sedimentation and radioactive decay during transport in hydrosphere

$T_A \left[\frac{s}{kg}\right]$ = plant product/animal product transfer factor

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1 yr = $3.15 \times 10^7$ s , 1 s = $3.17 \times 10^{-8}$ yr

1 $yr^{-1}$ = $3.17 \times 10^{-8} s^{-1}$ , 1 $s^{-1}$ = $3.15 \times 10^7 yr^{-1}$

For the following reasons, however, these conditions are never strictly applicable;

Exposure pathway group A

There is a certain mobility of the population between the place of residence $\vec{r}$ and locations $\vec{r}'$ with different air and water concentrations (e.g. places of work or schooling, local recreation areas, holiday areas, etc). This means that the effective individual dose rate is as follows:

$$D_{eff}(\vec{r}) = \int sf(\vec{r},\vec{r}') \times D(\vec{r}')d\vec{r}' \qquad (5.2\text{-}15)$$

$sf(\vec{r},\vec{r}')$ = sojourn frequency at all locations $\vec{r}'$ of an individual resident at location $\vec{r}$.

Exposure pathway group B

There is an extensive system of food supply - production at locations $\vec{r}$, collection and processing, followed by distribution to locations $\vec{r}'$ - at least for that part of the population which is not self-supporting in food. This similarly leads to an effective individual dose rate:

$$D_{eff}(\vec{r}) = \int fd(\vec{r},D(\vec{r}')\ )d\vec{r}' \qquad (5.2\text{-}16)$$

$fd(\vec{r},D(\vec{r}')\ )$ = food distribution function, which covers the process of localized production and distribution of food and thus also describes the redistribution of dose rates via the ingestion pathway.

A similar consideration also applies to supplies of animal feedstuffs (Equations 5.2-4,5 and 10).

$$a_{p_{eff}}(\vec{r}) = \int fd_{AF}(\vec{r},a_p(\vec{r}')\ )d\vec{r} \qquad (5.2\text{-}17)$$

$fd_{AF}(\vec{r}, a_p(\vec{r}'))$ = Animal feedstuffs distribution function, which covers the process of localized production and distribution of animal feedstuffs and thus also describes the redistribution of the activity in feedstuffs.

Since the necessary conditions for precise calculation of local individual dose rates are not generally met -

the sojourn frequency $sf(\vec{r}, \vec{r}')$ of individuals and the process of food collection and distribution $fd(\vec{r}, D(\vec{r}'))$, which similarly applies to $fd_{AF}(\vec{r}, a_p(\vec{r}'))$, cannot be assessed exactly in most cases -

we have to make do with a series of graduated statements.

The following graduated statements can be made:

1) Local individual dose rates can be given:

a) When the derived local dose rates can be interpreted with a fair degree of approximation as individual dose rates. This applies to the following groups of individuals:

Exposure pathway group A

Places of work and schooling are not very far from the place of residence. The local recreation areas in question (e.g. allotment gardens) are also in the immediate vicinity of the place of residence. These conditions apply to a large portion of the population.

Exposure pathway group B

Food consumed in the household is produced in the immediate vicinity of the place of residence. This condition is met to a certain extent by people employed in agriculture (approx. 7.5% in the Rhein-Maas Region, see Table 3.5), whose degree of self-sufficiency is in most cases in the region of 20 to 30% [35].

b) When, on the basis of at least an established approximation of the sojourn frequencies of individuals or of known redistribution functions for the various foodstuffs, the available local dose rates can be converted to individual dose rates using equations 5.2-15, 16 and 17. However, since $sf(\vec{r},\vec{r'})$, $fd(\vec{r},D(\vec{r'}))$ and $fd_p(\vec{r},a_p(\vec{r'}))$ cannot in general be established on a regional basis and are usually unknown quantities - only in the context of site studies is an attempt made, e.g. by means of questionnaires, to record or reconstruct these functions for a limited area and for certain significant exposure pathways - we try to gain further information by calculating average dose rates and collective dose rates.

2) Average individual dose rates can be given if it is at least possible to allocate the subject to a limited area AR.

Exposure pathway group A

Places of residence and work or schooling, local recreation areas, etc., are within a definable area AR: in this case the average dose is calculated as follows:

$$\overline{D_{AR}} = \frac{\int_{AR} D(\vec{r})d\vec{r}}{S_{AR}} \qquad (5.2\text{-}13)$$

$S_{AR}$ $[m^2]$ = size of area AR

For the major part of the population the size of this area AR is likely to be approximately equal to that of a district.

Exposure pathway group B

Foodstuffs are collected as a function of various economic mechanisms within a catchment area AR and redistributed to consumers within this catchment area. Assuming by way of approximation that the catchment area is self-sufficient, the resulting average dose can be calculated as follows:

$$\overline{D_{AR}} = G \times \frac{\int_{AR} d(\vec{r}) \times Y(\vec{r})\, d\vec{r}}{\int_{AR} Y(\vec{r}) d\vec{r}} \qquad (5.2\text{-}19)$$

$Y \left[ \frac{kg}{m^2 \times s} \right]$ = yield intended for human consumption.

$Y(\vec{r})$ for plant products being as follows

$$Y_P(\vec{r}) = u_{P,HF} \times y_P \times 1_P^{AG}(\vec{r}) \times 1_{AG}(\vec{r}) \qquad (5.2.\text{-}20)$$

(For explanations of symbols and figures see Tables 3.6 and 3.7).

and $Y(\vec{r})$ for animal products it is

$$Y_A(\vec{r}) = u_A \times Y_A^{AF} \times u_{P,AF} \times y_P \times 1_P^{AG}(\vec{r}) \times 1_{AG}(\vec{r}) \qquad (5.2\text{-}21)$$

(For explanations of symbols and figures see Tables 3.6 and 3.7).

It is difficult, on account of the diffuse structure of the free economy, to define meaningful areas AR. By analogy with exposure pathway group A, the approximate size of a district was also adopted here as a first approximation. In fact, however, the area may, depending on the product concerned, be much larger. In that case it may be more reasonable to aim at establishing the collective dose rate.

3) Collective dose rates are given when the conditions for calculating average dose rates

- definition of an area AR for production and consumption
- statistically reliable rates of consumption rates G

can no longer be met. This applies when food is distributed over a wide area, and for special products.

The dose rate yield gained via the agricultural yield within an area AR is obtained as follows

$$DY_{AR} = \int_{AR} d(\vec{r}) \times Y(\vec{r}) d\vec{r} \qquad (5.2\text{-}22)$$

$$DY \left[\frac{rem}{s}\right] = \text{dose rate yield}$$

This dose rate yield is at the same time the sum of all individual dose rates applicable in respect of the foodstuffs produced in area AR, and its numerical value is thus equal to that of the collective dose rate.

$$DC_{AR} = DY_{AR} \qquad (5.2\text{-}23)$$

$$DC \left[\frac{man \times rem}{s}\right] = \text{collective dose rate}^{*)}$$

cf.also equation (5.2-26)

These ideas are set out clearly in Figure 5.3.

From the calculated local individual dose rates for various age groups and organs - equations 5.2-1-16 - dose rate distribution functions**) can be derived on the basis of the population density by age group.

$$\phi(D^{O}(A)) = \int_{R} p'(\vec{r},A) d\vec{r} \qquad (5.2\text{-}24)$$

$$= 0 \text{ for values of } \vec{r} \text{ where } D^{O}(\vec{r},A) < D$$

where $p'(\vec{r},A)$

$$= p(\vec{r},A) \text{ for values of } \vec{r} \text{ where } D^{O}(\vec{r},A) \geq D$$

---

*) [man] is not a dimension; it is merely meant to indicate that the dose rate concerned applies collectively to a number of individuals.

**) In the present context distribution function always means the complementary distribution function.

$\phi$ $\left[ man \right]$ = dose rate distribution function

p $\left[ \frac{man}{m^2} \right]$ = population density (cf.Figure 3.6)

R = section of region

For each dose rate D, the distribution function gives the number of individuals subject to this or a higher dose rate.

In addition the following can be calculated:

the average dose rate

$$\overline{D^O(A)} = \frac{\int_R D^O(\vec{r},A) \times p(\vec{r},A)d\vec{r}}{\int_R p(\vec{r},A)d\vec{r}} \qquad (5.2\text{-}25)$$

$\overline{D}$ $\left[ \frac{rem}{s} \right]$ = average dose rate

and the collective dose rate

$$DC^O(A) = \int_R D^O(\vec{r},A) \times p(\vec{r},A)d\vec{r} \qquad (5.2\text{-}26)$$

DC $\left[ \frac{man \times rem}{s} \right]$ = collective dose rate (cf also equation 5.2-23)

If it is desired to convert from the age group approach to the 'average individual', the corresponding dose rate can be calculated having regard to the age structure as follows:

$$D^O(\vec{r}) = \sum_A f_A \times D^O(\vec{r},A) \qquad (5.2\text{-}27)$$

$$\overline{D^O} = \sum_A f_A \times \overline{D^O(A)} \qquad (5.2\text{-}28)$$

$$DC^O = \sum_A DC^O(A) \qquad (5.2\text{-}29)$$

$f_A$ = fraction of age group A in total population (of Table 3.4)

## 5.3. Models and input data

### 5.3.1 Sources and source strengths

During normal operation nuclear facilities discharge small quantities of radionuclides which depend on the type and design of the facility concerned and are subject to certain annual variations. It is on these data that the calculation of radiological exposure is based.

For facilities already in operation for some time, data on source strengths are compiled by referring to the discharge rates recorded in previous years (documented in e.g. [74 to 77]) and deriving average values, for which so-called 'runaway' values are also taken into account. The resulting discharge rates for facilities in the Rhein-Maas Region are listed in Table 5.1. The following changes from the current position were assumed:

| | |
|---|---|
| Würenlingen (No 6): | shutdown of the 'Diorit' research reactor |
| Karlsruhe (No 17): | shutdown of the 'FR2' research reactor and the 'MZFR' PHWR |
| | annual throughput of 40 t of 30 000 MWd/t fuel in the 'WAK' reprocessing plant DF (plume) H-3: 10; C-14: 1; Kr-85: 10; I-129: $3x10^2$ |
| | emission of 1/50th of the values given in Table 5.2 (1 000 MWe LMFBR) from the 'KNK' LMFR (20 MWe) |
| Kahl (No 27): | shutdown of the 'VAK' 15 MWe BWR. |

For facilities recently commissioned or still to be commissioned, on the other hand, it is reasonable to adopt realistic anticipated values on the basis of previous experience with similar facilities already in operation, taking account of the advanced design of the facilities.

Anticipated values for 1000 MWe nuclear power stations, as collected and applied in various studies, are set out in Table 5.2. The first two columns give data on source strengths used in the Mississippi [1] and Tennessee [6] studies initiated by the USAEC and USNRC. These data were calculated from information on radionuclide inventories with the help of discharge models for each type of nuclear power station. The next two columns contain data compiled in Germany [78-82, 5]. These take more account of the measured discharge rates of modern facilities. Finally, there are certain other discharge rates compiled in the course of a study initiated by the European Community in the United Kingdom [83]. The range of variations between these data can be clearly seen by comparing the figures. The last column then gives figures adopted for the present study. They were compiled on the basis of the various studies and should be seen in the light of the ranges of variation mentioned above.

The compilation of realistic anticipated values for the reprocessing plants which will be put into operation in the future is a difficult undertaking. The discharge rates depend on a series of parameters to which it is not yet possible to attach definitive values; the most important of these are the cooling time and the decontamination factors. Figure 5.4 gives the throughput, as a function of cooling time (=time between unloading and beginning of reprocessing operations), of a number of major nuclides in a 1500 t/yr reprocessing plant for 30 000 MWd/t LWR fuel.

Assuming, for future reprocessing plants, that

1. they are on inland sites with no discharge of liquid waste into the environment;
2. cooling time is one year (= 365 days);

3. for gaseous discharge it is possible to achieve the following decontamination factors, which are regarded as realistic by experts:

| | | | |
|---|---|---|---|
| Tritium | $D_T$ | = | 10 |
| Carbon | $D_C$ | = | 1 |
| Noble gases | $D_{NG}$ | = | 100 |
| Iodine | $D_I$ | = | 300 |
| Caesium | $D_{Cs}$ | = | $3 \times 10^8$ |

we arrive at the discharge rates set out in Table 5.3.

Since no discharge data are available for the operational reprocessing plants at Windscale (GB) and La Hague (F), plausible data were compiled, and these are set out in Table 5.4.

Discharge from fuel element fabrication plants concerns only uranium and plutonium and their decay products. Since no data based on adequate statistical evidence are yet available for these isotopes, these plants have not been considered.

For enrichment plants no discharge data have been published.

5.3.2. Atmospheric dispersion and deposition processes [88]

Long-term atmospheric dispersion of radionuclides released during normal operation was described for an inner zone using a dispersion function calculated as an average over the whole angle $\phi = 2\pi$ with a Gaussian distribution in direction z [84, 85, 86, 87].

$$J(r,z) = \frac{1}{(2\pi)^{3/2} \times \sigma_z(r) \times u \times r} \times \left\{ \exp\left[ -\frac{(z-h)^2}{2\sigma_z^2(r)} \right] + \exp\left[ -\frac{(z+h)^2}{2\sigma_z^2(r)} \right] \right\} \quad (5.3\text{-}1)$$

For an outer zone, where the activity discharged is distributed almost homogeneously throughout the mixing layer, the following dispersion formula, similarly averaged over $\phi = 2\pi$, was used:

$$J(r,z) = \frac{1}{2\pi \times L \times u \times r} \quad (5.3\text{-}2)$$

For the intermediate zone appropriate interpolations were made [88].

$J\left[\frac{s}{m^3}\right]$ = atmospheric dispersion factor

$r\,[m]$ = distance from source

$z\,[m]$ = height above ground

$h\,[m]$ = stack height

$u\,[\frac{m}{s}]$ = wind speed

$\sigma_z\,[m]$ = atmospheric dispersion parameter

$L\,[m]$ = mixing layer height

Wind roses for individual sites were taken into account in terms of

- wind speeds for each particular wind direction: $u(\phi)$
- wind frequencies for each particular wind direction: $f(\phi)$.

For most sites these data are available in the form of average values for an eight-point wind rose. A breakdown of weather situations according to the stability categories A to F as defined by Pasquill is not possible in most cases, and therefore the few available frequency calculations (see Table 5.5) were used.

The dispersion parameters $\sigma_z$ for each weather category also depend on the unevenness of the land surface. Of the four unevenness categories given by Nester [90]

| | |
|---|---|
| I | short grass |
| II | fields under cultivation, hedges |
| III | low woodland and buildings |
| IV | tall woodland, towns |

the $\sigma_z$ values for category III were used. The dispersion factor as a function of weather categories and the various degrees of ground unevenness is depicted in Figure 5.5.

The values adopted for mixing layer heights, which are also dependent on weather categories, were estimates for conditions in Central Europe [94]. These too are given in Table 5.5.

The depletion factor for airborne activity f depends essentially on the following processes:

- radioactive decay

$$f_r(r) = \exp(- \frac{\lambda \times r}{u}) \qquad (5.3\text{-}3)$$

$\lambda \left[s^{-1}\right]$ = decay constant

- dry deposition

  for the inner zone

$$f_d(r) = \exp\left\{ -\sqrt{\frac{2}{\pi}} \times \frac{v_d}{u} \int_0^r \frac{\exp\left(-\frac{h^2}{2\sigma_z(r)}\right)}{\sigma_z(r)} dr \right\} \qquad (5.3\text{-}4)$$

$v_d$ /m/s/ = deposition velocity

for the other zones see /88/;

- wet deposition

$$f_w(r) = \exp\left(-\frac{\Lambda \times r}{u}\right) \qquad (5.3\text{-}5)$$

$\Lambda\,[s^{-1}]$ = washout coefficient.

The depletion factor f can thus be derived as follows:

$$f(r) = h_d \times f_r(r) \times f_d(r) + h_w \times f_r(r) \times f_w(r) \qquad (5.3\text{-}6)$$

$h_d$ = rate for dry deposition

$h_w$ = rate for wet deposition

The following values were adopted /88/:

$v_d$ = 0.01 m/s for iodine isotopes

$v_d$ = 0.003 m/s for all radioisotopes except those of iodine and noble gases+)

$\Lambda = 2.8 \times 10^{-5} s^{-1}$, derived from /86/ and /95/

$h_d$ = 0.87
$h_w$ = 0.13 } /95/

The deposition factor F is determined by the deposition process and the depletion processes (radioactive decay, seepage etc.) after deposition.

It is calculated as follows:

- for dry deposition

$$F_d = v_d \times \tau_{s_{eff}} \left(1 - e^{-\frac{\Delta t}{\tau_{s_{eff}}}}\right) \qquad (5.3\text{-}7)$$

---

+) This is the geometric mean value of deposition velocities from:

1) "Berechnungsgrundlagen - Abluft" /72/ : $v_d$ = 0.001 m/s

2) "Reactor Safety Study" - WASH 1400 (1975) : $v_d$ = 0.01 m/s

- for wet deposition

$$F_w = \Lambda \times h_{cl} \times \tau_{s_{eff}} \times (1 - e^{-\frac{\Delta t}{\tau_{s_{eff}}}}) \quad (5.3\text{-}8)$$

$F$ [ m ] = deposition factor

$h_{cl}$[ m ]= layer thickness of plume

$\tau_{s_{eff}}$[ s ]= effective retention time in upper soil layer (for values see Table 5-6)

$\Delta t$ [ s ]= total time since commissioning of facility

The product F x f of equation 5.2-2 can thus be expressed as follows:

$$F \times f = F_d \times f_r \times f_d \times h_d + F_w \times f_r \times f_w \times h_w \quad (5.3\text{-}9)$$

5.3.3. Hydrospheric dispersion and sorption processes [ 101 ]

The assumption that there is a simple hydrospheric dispersion function - by analogy with the atmospheric dispersion function for r downstream of $r_o$

$$J(\vec{r},\vec{r_o}) = \frac{1}{FR(\vec{r})} \quad (5.3\text{-}10)$$

as applied in equations (5.2-6 to 10) - is only valid in the case of relatively undisturbed dispersion (limited influence of sorption and desorption processes). In contrast to atmospheric dispersion, in which the deposition processes depend only on the concentrations of radionuclides in the transport medium, for hydrospheric dispersion the processes of

- adsorption and absorption
- ion exchange
- precipitation reactions

also depend on the concentrations of radionuclides in the other substances involved, so that it is usually necessary to take these interactions into account [100]. The exchange processes between the water body, suspended matter and sediments in a reach of river are depicted in Figure 5.6. Since the calculations are carried out section by section in a downstream direction [101], the various reaches must be linked together, as shown in Figure 5.7.

Since most of the activity is transported via water [102-104], the transport and sorption processes*) can be described using a system of coupled linear differential equations with constant coefficients [101]:

For the l-th reach of a river (from upstream to downstream) this system can be expressed, using the symbols

w = water body
ss = suspended matter
s = sediment

as follows

$$\frac{d}{dt}A_w^l = Q^l + FR^{l-1} \times a_w^{l-1} + k^l_{ss,w} \times a^l_{ss} + k^l_{s,w} \times a^l_s - FR^l \times a^l_w - k^l_{w,ss} \times a^l_w - k^l_{w,s} \times a^l_w - \lambda \times A^l_w \qquad (5.3\text{-}11a)$$

$$\frac{d}{dt}A_{ss}^l = SS^{l-1} \times FR^{l-1} \times a^{l-1}_{ss} + k^l_{w,ss} \times a^l_w + k^l_{s,ss} \times a^l_s - SS^l \times FR^l \times a^l_{ss} - k^l_{ss,w} \times a^l_{ss} - k^l_{ss,s} \times a^l_{ss} - \lambda \times A^l_{ss} \qquad (5.3\text{-}11b)$$

$$\frac{d}{dt}A_s^l = k^l_{w,s} \times a^l_w + k^l_{ss,s} \times a^l_{ss} - k^l_{s,w} \times a^l_s - k^l_{s,ss} \times a^l_s - \lambda \times A^l_s \qquad (5.3\text{-}11c)$$

---

*) Sum of all processes resulting in a bond between dissolved nuclides and solid components.

| | | |
|---|---|---|
| A | [ Ci ] | = activity inventory |
| a | $\left[\frac{Ci}{m^3, t}\right]$ | = specific activity |
| $k_{m,n}$ | $\left[\frac{m^3, t}{s}\right]$ | = transfer coefficient for transfer from 'm' to 'n' |
| SS | $\left[\frac{t}{m^3}\right]$ | = average suspended-matter content |
| FR | $\left[\frac{m^3}{s}\right]$ | = average flow rate |
| $\lambda$ | $\left[s^{-1}\right]$ | = radiological decay constant |

Transport of activity by means of bed load transport was ignored, since estimates have shown [ 101 ] that this is negligible in comparison with transport via suspended matter.

Under stable conditions a state of equilibrium is reached for the inventories ($\frac{d}{dt} \times A = 0$) in all rivers. Discounting seasonal variations, this equilibrium is established relatively quickly compared with the periods of time for which doses are calculated [ 105,106 ] (see also relaxation times $\tau$ below). The system of differential equations is then replaced by a system of algebraic equations. The transfer factors $k_{m,n}$ can be determined from the measurable parameters as follows:

$$k_{w,ss} = \frac{V_w \times V_{ss} \times K_d}{\tau_{w,ss}(V_w + K_d \times V_{ss})} \qquad k_{ss,w} = \frac{k_{w,ss}}{K_d} \qquad (5.3\text{-}12)$$

$$k_{w,s} = \frac{V_w \times V_s \times K_d}{\tau_{w,s}(V_w + K_d \times V_s)} \qquad k_{s,w} = \frac{k_{w,s}}{K_d} \qquad (5.3\text{-}13)$$

$$k_{ss,s} = \max(0, FR^{l} \times (SS^{l-1} - ss^{l})$$

$$k_{s,ss} = \max(0, FR^{l} \times (SS^{l} - ss^{l-1})) \qquad (5.3\text{-}14)$$

$K_d$ $\left[\frac{m^3}{t}\right]$ = distribution coefficient for suspended matter/water

$$K_d = \frac{a_{ss}}{a_w}$$

$V_w$ $[m^3]$ = volume of water body

$$V_w = FR \times \frac{l}{u}$$

l [m] = length of river section

u $\left[\frac{m}{s}\right]$ = flow velocity

$V_{ss}$ [t] = suspended matter content

$$V_{ss} = V_w \times SS$$

$V_s$ [t] = sediments involved in sorption processes

$$V_s = l \times w \times d_{eff} \times \rho$$

w [m] = width of river

$d_{eff}$ [m] = effective depth of sediments involved in sorption processes

$d_{eff} \approx 3$ cm [107, 108]

$\rho$ $\left[\frac{t}{m^3}\right]$ = density of sediments

$\rho \approx 1.1$ t/m³ [109]

$\tau$ [s] = relaxation time before establishment of equilibrium

$\tau_{w,ss}$ = 1 d, $\tau_{w,s}$ = 20-50d [103, 105, 107]

The necessary hydrological parameters for these calculations were taken from [110 to 117] and other sources. A number of selected values are set out in Figure 3.3. The values of distribution coefficients are listed in Table 5.7.

### 5.3.4. Bioaccumulation and transfer factors

Section 5.2 introduced the following concepts for the calculation of dose rates:

bioaccumulation factors

$$B_P \left[\frac{m^3}{kg}\right] , \quad B_{IP} \left[\frac{m^3}{kg}\right] , \quad B_F \left[\frac{m^3}{kg}\right]$$

and the transfer factor

$$T_A \left[\frac{s}{kg}\right]$$

Except for H-3 and C-14, these were calculated as follows:

air plant products bioaccumulation factor $B_P$

$$B_P = (h_d \times v_d + h_w \times \Lambda \times h_{cl}) \times (\tau_{P_{eff}} \times \frac{1}{Y_P} + s \times \tau_{s_{eff}} \times \frac{B_{SP}}{R}) \tag{5.3-15}$$

$\tau_{P_{eff}}$ [s] = effective residence time of deposited material on leaves of plants (applies if leaves are edible: green vegetables, grass)

$$\tau_{P_{eff}} = \frac{\tau_r \times \tau_{wea}}{\tau_r + \tau_{wea}}$$

$\tau_r$ = residence time due to radioactive decay

$\tau_{wea}$ = residence time against due to weathering on plant

= 20.20d [71]

$\tau_{P_{eff}}$ = 7.34 d for I-131

= 20.20 d for other radionuclides

$Y_P \left[\frac{kg}{m^2\ yr}\right]$ = leafy vegetable yield: $Y_V = 2\ \frac{kg}{m^2\ yr}$

(see Table 3.7)

grass yield (for animal product calculations):

$Y_G = 2.5\ \frac{kg}{m^2\ yr}$

(see Table 3.7)

s = proportion of deposited material transferred from plant to ground by action of weather

$s = 0.17$ for I-131

$s = 1$ for other radionuclides

(derived using values of $\tau_{p_{eff}}$)

These figures are based on the conservative assumption that the action of weather causes no resuspension in the air.

$\tau_{s_{eff}}$ [s] = effective residence time of deposited material in the root region of soil (for values see Table 5.6)

$P_{SP} \left[\frac{kg}{kg}\right]$ = soil → plant bioaccumulation factor soil: dry weight; plants: weight when fresh (for figures see Table 5.8.1)

$R \left[\frac{kg}{m^2}\right]$ = area density of soil within root region soil: dry weight

$R = 240\ \frac{kg}{m^2}$ [71]

The figures thus calculated for green vegetables and other plant products are set out in Table 5.8.2.

For the radio-isotopes H-3 and C-14 it is assumed that in the plant the same H-3/$H_{nat}$ and C-14/$C_{nat}$ ratios are established as obtain in the surrounding atmosphere.

Therefore

for H-3 $$B_p = \frac{0.75 \text{ kg/kg}}{9 \times 10^{-3} \text{kg/m}^3} = 83.3 \frac{m^3}{kg} \qquad (5.3\text{-}16)$$

assuming:

0.75 kg $H_2O$ per 1 kg plant (fresh weight) [ 71 ]

$9 \times 10^{-3}$ kg $H_2O$ per 1 $m^3$ air [ 72 ]

for C-14*) $$B_p = \frac{0.11 \text{ kg/kg}}{0.16 \times 10^{-3} \text{kg/m}^3} = 687.5 \frac{m^3}{kg} \qquad (5.3.17)$$

assuming:

0.11 kg C per 1 kg plant (fresh weight) [ 71 ]

$0.16 \times 10^{-3}$ kg C per 1 $m^3$ air [ 71 ]

These two figures are also included in Table 5-8.2.

Water → irrigated plant product bioaccumulation factor $B_{IP}$

$$B_{IP} = IR \times (i \times \zeta_{P_{eff}} \times \frac{1}{Y_p} + s_i \times \zeta_{s_{eff}} \times \frac{B_{SP}}{R}) \qquad (5.3\text{-}18)$$

IR $\left[\frac{m}{s}\right]$ = irrigation rate

$$IR = \frac{100 \text{ mm water}}{60 \text{ d (growth period)}}$$

This figure has been ascertained on the basis of surveys.

i = proportion of total material deposited on leaves during irrigation
$i = 0.25$ [ 71 ]

*) This model assumes that C-14 is emitted in the form of $CO_2$ from nuclear facilities. New measurements indicate however that C-14 is also partially emitted in the form of CO or of alkanes (cf: H.Schüttelkopf, Report KFK-2421 (1977)). Thus the model is a conservative assessment within the inner zone, where the latter compound have not yet been oxidized to $CO_2$.

$s_i$ = proportion of total material deposited on soil directly during irrigation and indirectly by the action of weather on plants

$s_i$ = 0.79 for I-131

= 1 for other radionuclides

(derived using values of i)

The figures thus calculated for green vegetables and other plant products are set out in Table 5.8.2.

For the radionuclide H-3 a balance is once again assumed for calculation purposes between the $H\text{-}3/H_{nat}$ ratios in plants and water.

Therefore

for H-3: $$B_{IP} = 0.75 \times 10^{-3} \frac{m^3}{kg} \qquad (5.3\text{-}19)$$

(see equation 5.3-16)

This figure is also included in Table 5.8.2.

The figures for

- the water → fish bioaccumulation factor $B_F$,
- the food intake → meat transfer factor $T_{A,meat}$,
- the food intake → milk transfer factor $T_{A,milk}$

have been taken from [71] and are included in Table 5.8.1.

5.3.5. ~~Dose factors~~

The values of the dose factors for external exposure

$$g_{EC}\left[\frac{\text{rem x m}^3}{\text{s x Ci}}\right],\ g_{EG}\left[\frac{\text{rem x m}^2}{\text{s x Ci}}\right],\ g_{EW}\left[\frac{\text{rem x m}^3}{\text{s x Ci}}\right]$$

gives the dose rates in rem/s received by an individual in a medium with a concentration by volume of 1 $Ci/m^3$ or on a surface with a surface concentration of 1 $Ci/m^2$. The values of the dose factors for external exposure used in this study are listed in Table 5.9. It should be noted that for the inner zone around discharge sources in which the concentration has not yet reached a homogenous distribution the whole-body dose from gamma radiation has been calculated using a fully numerical integration across the concentration profile of the plume. The procedure is described in detail in /88/.

The values of the dose factors for internal exposure

$$g_{IH}\left[\frac{\text{rem}}{\text{Ci}}\right],\ g_{IG}\left[\frac{\text{rem}}{\text{Ci}}\right]$$

give the dose $\int D$ in rem received by an individual over a defined period after inhaling from the air or ingesting with food 1 Ci of activity at time t=0. The period chosen for $\tau$ - which is generally indicated in defining the dose factor $g(\tau)$ - is not usually more than 50 years. The following relationship then applies:

$$\int D(\tau) = g(\tau) \times A_0 \qquad (5.3\text{-}20)$$

$\int D(\tau)$ /rem/ = dose after time t= $\tau$

$g(\tau)\left[\frac{rem}{Ci}\right]$ = dose factor for period $\tau$

$A_o$ [Ci] = quantity of activity inhaled or ingested at time t=0.

Since one of the objects of the present study is to know the dose rate at time t=0 resulting from activity incorporated since the commissioning of a facility at time $t = -\tau$, the following relationship applies

$$D(t=0) = \int_{-\tau}^{0} g'(t) \times a(t)\, dt \qquad (5.3\text{-}21)$$

$D(t=0)\left[\frac{rem}{s}\right]$ = dose rate at time t=0

$g'(t)\left[\frac{rem}{Ci.s}\right]$ = derivation of dose factor as a function of time

$a(t)\left[\frac{Ci}{s}\right]$ = activity inhalation or ingestion rate

Assuming a nearly constant incorporation rate $a_o$, we thus obtain

$$D(t=0) = \int_{-\tau}^{0} g'(t)\, dt \times a_o$$

$$= g(\tau) \times a_o \qquad (5.3\text{-}22)$$

It can be seen that this line of investigation similarly leads to $g(\tau)$, $\tau$ here being the operating life of a nuclear facility up to the moment under consideration.

In view of the fact that

- Sr-90 in the organ 'bones' is the only one of the radionuclides under consideration here to produce a $g(\tau)$ that still shows any appreciable increase after $\tau > 1$ year,
- these considerations are based on a state of virtual equilibrium,

the dose factors g($\tau$ = 50 years) used were those published by the USNRC [71]. In view of the criticisms made of these sets of data, the dose factors for the organs 'whole body' and 'thyroid' of soldat [123] were adopted for the isotopes I-129 and I-131. These are set out in tables 5.10 and 5.11.

5.3.6. Consumption data

On account of varying agricultural use in an area, different professional activities and individual tastes among consumers, the nutritional habits of the population - as to quantity and composition - exhibit both regional and personal variations. Average consumption data and the variation limits have been compiled [124]. Data from this source for the four age groups in this study are set out in Table 5.12.

The last column of this table gives the factor by which the average consumption of a particular food group can be exceeded by certain sections of the population - i.e. not just by any one individual. This applies in particular to agricultural households, since on the one hand (for adults) the heavy manual work leads to an increased calorie requirement, and on the other hand the opportunity of simply taking certain foods from within the farm leads to increased consumption of these foods. For this section of the population the consumption of other foods can then be below the calculated average values.

## 6. Radiological impact from nuclear facilities in the Rhein-Maas Region and the adjacent zone

As already indicated in the Introduction, the aim of this study is to establish the expected dose rates for the following organs:

bones, gastro-intestinal tract, gonads, liver, lungs, skin, thyroid and whole body ( = average for all organs).

The results are to be presented in the form of

a) local individual dose rates,

b) distributions of individual dose rates, together with average and maximum individual dose rates,

c) collective dose rates,

d) a breakdown of dose rates by radionuclide and exposure pathway.

The criteria governing the assessment of these various forms of dose rate were set out in Section 5.2. The basic formulae for calculating the individual contributions from the various exposure pathways and for ascertaining total exposure were also set out in that section.

In the following sections below the results obtained on the basis of the data set out in Section 5.3, are presented in the following order:

Impact via the gaseous effluent pathway

Projections for 1985/90

Extrapolations for 2000/05

Impact via the liquid effluent pathway

Projections for 1985/90

Extrapolations for 2000/05.

At this point it is worth drawing attention once again to the problems raised by projections for these periods, as discussed in Section 4.2.3.

## 6.1 Impact via the gaseous effluent pathway

### 6.1.1. Projection for 1985/90

For the purposes of calculating radiological exposure for 1985/90 it was assumed that

a) the nuclear facilities listed in Section 4.2.1 would be in operation,

b) these facilities would have average discharge rates broadly in line with those given in Section 5.3.1,

c) the models used for calculating radiological exposure (Sections 5.3.2 to 5.3.6) give a sufficiently accurate picture of the processes as they actually operate.

The most important aspects of the multitude of results obtained - reflecting the wide range of parameters: radionuclides, exposure pathways, organs and age groups - are presented and discussed below.

a) Local individual dose rates $D(\vec{r})$

aa) External $\gamma$-exposure from activity in the plume (cf equation 5.2.-1)

The major part of radiation received via this pathway is contributed by radioactive noble gases. The $\gamma$-radiation penetrates the whole body more or less homogeneously, so that any organ-related features can be disregarded. For similar reasons there is no need to take account of age. This radiation is included in the overall assessment as a contribution to the whole-body dose rate and to each of the organ dose rates. The local individual dose rates via this exposure pathway are given in Fig. 6-1.1.

In this and the following figures the gradation of the isodose lines is 1-2-5-10. The plotting programme was based on a grid of 6.55 x 6.55 km, which corresponds to a grid of 1.8 x 1.8 mm in the figures. If these figures are to be interpreted correctly, it should be pointed out that because of

- the relatively coarse grid compared with the gradient of the atmospheric dispersion factor, and
- the gradation of the isodose lines

it is not always possible to record the maximum values in the vicinity of nuclear facilites. At worst, the isogram for the highest dose rate can be below the actual maximum value by a factor of approximately 5. The two reasons given above are more or less equally responsible for this situation.

The maximum value of the whole-body dose rates calculated for some 7 500 grid points is 2.69 mrem/yr.

ab) External $\gamma$-exposure from active material deposited on the ground (see equation 5.2-2)

The $\gamma$-radiation from active material deposited on the ground penetrates the whole body more or less homogeneously, so that here too, as in aa), both organ- and age-related factors can be disregarded. This dose is included in the overall assessment as a contribution to the whole-body dose rate and to each of the organ dose rates.

With regard to ground radiation, there is no need to take the $\beta$-radiation into account, as the deposited material passes relatively quickly into the upper soil layer, where the $\beta$ radiation is then absorbed.

It follows from equations 5.3-7 and 5.3-8 that the surface concentration and thus the dose rate is proportional to

$$D_{EG} \propto \tau_{s_{eff}} \times \left(1 - e^{-\frac{\Delta t}{\tau_{s_{eff}}}}\right)$$

$\tau_{s_{eff}}$ = effective residence time in upper soil layer

$\Delta t$ = total time since commissioning of facility.

The equilibrium surface concentration and hence the equilibrium dose rate that will be reached after a sufficiently long period is then proportional to

$$D_{EG}^{\infty} \propto \tau_{s_{eff}}.$$

As indicated in Table 5-6, the equilibrium concentration is reached for most radioisotopes in a relatively short time compared with the expected life of a nuclear facility (approx. 30 years), whereas in the case of Cs-137 only about 50% of the equilibrium value is reached.

Figure 6-1.2a shows the expected local individual dose rates via this exposure pathway for 1985/90. The maximum value of the whole-body dose rates calculated for the various grid points is 0.065 mrem/yr.*)

For comparison, Fig. 6-1.2b gives the expected local individual dose rates for a state of equilibrium. The maximum value of the whole-body dose rates calculated for the various grid points is 0.17 mrem/yr.*)

A comparison of the two figures shows that for most locations in the region the dose rates for a state of equilibrium are greater than those for 1985/90 by a factor of between 2 and 5. The main reason for this is the slow build-up of the Cs-137 concentration. In the immediate vicinity of facilities which will have had a relative short operational life by 1985/90 there could be even higher factors, since it is possible that there the 'shorter-lived' radionuclides will not have reached a state of equilibrium either.

ac) External $\beta$-exposure from activity in the plume (see equation 5.2-1)

For this exposure pathway too, the major contribution derives almost exclusively from the radioactive noble gases. The $\beta$ radiation affects in particular the surfaces of the body (skin) and those of the respiratory organs (lungs). Exposure of the skin is due to the plume surrounding the body, while the lungs are affected by the inhaled gases. In addition, the exposure of the male gonads was included in the calculations for values of $E_\beta > 36$ keV, allowing for the attenuation due to the protecting skin.

The local individual dose rates for the organ 'skin' via this exposure pathway are given in Fig.6-1.3. The maximum value of

*) In Fig.6-1.2a and b the maximum isodose lines for 0.05 mrem/yr and 0.1 mrem/yr could not be identified.

the skin dose rates calculated for the various grid points is 1.53 mrem/yr.

ad) Internal exposure from active material incorporated by inhalation (see equation 5.2-3)

In accordance with their metabolic behaviour, the radionuclides incorporated by inhalation are distributed in varying proportions in the various organs. The resulting exposure level is therefore organ-related. Furthermore, on account of variations in breathing rate and metabolism with age it is also dependent on the age group.

As an example for this exposure pathway, Figs. 6-2.1 to 3 show the local individual dose rates for the organs:

whole body, bones and thyroid.

The local dose rates for the other organs closely approximate to those for the whole body. The dose rates shown in these figures are an average for all age groups (cf equation 5.2-27), i.e. they apply to the "average individual".

The maximum values of the dose rates calculated for the various grid points are:

| | |
|---|---|
| whole body: | 0.007 mrem/yr |
| bones : | 0.023 mrem/yr |
| thyroid : | 0.053 mrem/yr. |

ae) Internal exposure from active material incorporated with food (see equations 5.2-4 and 5.2-5)

Except for the lungs, the radionuclides incorporated by ingestion are distributed to the individual organs in the same way as those incorporated by inhalation. Here too, therefore, the resulting exposure level is organ-related. Furthermore, on account of variations in food intake and metabolism with age it also depends on the age group.

As an example for this exposure pathway, Figs. 6-3.1 to 3 show the local individual dose rates for the organs:

whole body, bones and thyroid.

Here too, the dose rates for the other organs closely approximate to those for the whole body. Similarly, the dose rates given in the figures are averages for all age groups (see equation 5.2-27), i.e. they apply to the "average individual".

The maximum values of the dose rates calculated for the various grid points are:

| | |
|---|---|
| whole body | 0.39 mrem/yr |
| bones | 1.05 mrem/yr |
| thyroid | 1.86 mrem/yr. |

By was of qualification it should be noted that the local dose rates given in Figs. 6-3.1 to 3 were calculated on the assumption that the food consumed at location $\vec{r}$ was also produced there, which implies that the area concerned is under cultivation. This assumption, however, is only valid for the population employed in agriculture (7.5%, see Table 3.5), and then only to a certain extent, since even here as a result of specialization the degree of self-sufficiency is only between 20 and 30% [35]. The figures are to be interpreted in the light of these reservations.

As has already been indicated in the previous sections, it is practically impossible, on account of the freedom of trade within and between the states of the Rhein-Maas Region, to define specific catchment and distribution areas or to reconstruct the food distribution functions fd (equation 5.2-16), with which it would be possible to calculate the actual local dose rates. However, in order to allow at least approximately, for the levelling effect of these distribution processes, average individual dose rates were calculated (equation 5.2-18) for

- the administrative units listed in Table 3.3 and
- countries or regions.

These average dose rates, calculated assuming autarchy within each administrative unit, are set out together with collective dose rates (see Part c of this section) in Table 6.1. The maximum values of the dose rates calculated for administrative units are:

| | |
|---|---|
| whole body | 0.026 mrem/yr |
| bones | 0.066 mrem/yr |
| thyroid | 0.441 mrem/yr. |

b) Distribution functions $\phi$ (D) for individual dose rates, average and maximum individual dose rates $\bar{D}$ and $D_{max}$

In order to present a clear picture of the varying doses to which the population is exposed, use is made of the distribution function or, to be more precise, the complementary distribution function (see equation 5.2-24). This gives, for each dose rate D, the number of individuals subjected to this or a higher dose rate.

The distribution functions calculated for the eight organs allowing for all exposure pathways*) - these calculations were based not on grid points but on the coordinate positions of local authority areas - are set out in Figures 6-4.1 to 6-4.8**). Both the distribution functions for the four age groups and the overall function for the whole population are given. The average individual dose rates (see equation 5.2-25) are also included; these are also to be found, together with maximum individual dose rates and collective dose rates (see Part c of this section) in Table 6.2.

In order to assess the effects of varying assumptions about the ingestion pathway on the form of the distribution function, these functions were derived with reference to two models:

- food consumed at location $\vec{r}$ was also produced there (CV-model, CV means community values)
- food consumed within ministrative unit AR (district) was also produced within this administrative unit (see equation 5.2-19) (DV model, DV means district value)

*) For the exposure pathway "ground radiation" the state of equilibrium $D^{\infty}_{EG}$ was assumed.

**) $x$ -axis: log scale; y-axis: $\sqrt[4]{\ }$-scale

A comparison shows that higher maximum dose rates occur with the CV model than with the DV model, since in the latter case locally occurring peaks are eliminated by the process of averaging over an administrative unit. Moreover, the maximum values derived using the CV model depend on the organ and age group. They are set out in Table 6.2.

With the DV model, on the other hand, the maximum values do not appear to be organ-related, with the exception of the skin and thyroid dose rates, or age-related, with the exception of that for the thyroid. This is because of the fact that with this model the maximum dose rates occur in the vicinity of the Mühleberg nuclear power station, as a result of relatively high discharge levels for noble gases from this facility (see Table 5.1). Since, according to [75], apart from noble gases this power station discharges only the I-131 isotope, which makes a significant contribution via the ingestion pathway only to the thyroid dose rate, it is only for this organ that the expected correlation with the ingestion pathway models is apparent.

The effect of the ingestion pathway models on the average individual dose rates included in Table 6.2 is negligible. As shown in this table, the average individual dose rates, taking all age groups together, are of the order of 0.01 mrem/yr for the whole body, GI-tract, gonads, liver and lungs, while for the bones (about 0.015 mrem/yr), skin (about 0.032 mrem/yr) and thyroid (about 0.026 mrem/yr) higher values are found because of the influence of "critical" isotopes (C-14, $\beta$-radiation from noble gases, iodine isotopes). The age-related average individual dose rates for most organs range from about 0.009 mrem/yr (adults) to about 0.02 mrem/yr (infants). For the skin and thyroid the dose rates range from 0.03 mrem/yr to 0.04 mrem/yr and from 0.02 mrem/yr to 0.1 mrem/yr.

c) Collective dose rates DC

The collective dose rates can be calculated by adding together the individual dose rates for the whole population (equations 5.2-26 and 5.2-29).

The resulting collective dose rates for the eight organs, derived from the individual dose rates calculated as described above, are set out in Table 6.2. As this table shows, for the whole body, digestive tract, gonads, liver and lungs they are of the order of 600-640 man-rem/yr, while - as with the average individual dose rates - the figures are higher for the bones (about 930 man-rem/yr), skin (about 1 920 man-rem/yr) and thyroid (about 1 590 man-rem/yr).

The collective dose rates set out in Table 6.2, being derived from the individual dose rates, calculated as described above, are applicable assuming agricultural autarchy. In order to check to what extent this can be assumed for the Rhein-Maas Region as a whole,

- total production was assessed using the data on land use (Fig. 3.7 and Table 3.6) and on crop yields and crop utilization (Table 3.7),
- total consumption was calculated using data on consumption (table 5.12) and the population of the region (Table 3.2).

The resulting figures are summarized in tabular form below.

It can be seen from this that for most agricultural products the degree of autarchy is less than 100% *). Calculating exposure via the ingestion pathway on the assumption of self-sufficiency thus leads to an over-estimate of the figures for this exposure pathway.

In order to take account of this factor, the integral dose rate for all agricultural products was calculated in accordance with equation 5.2-22.

For this, use was made of

- data on the proportionate utilization of land for arable farming and grazing; these data were taken for each administrative unit from the available statistics [39, 40 and 41];

*) The degree of self-sufficiency estimated on the basis of national data has been added for comparison.

Production and consumption of agricultural products in the Rhein-Maas Region.

| | Production [$10^6$ t/yr] | Consumption [$10^6$ t/yr] | Autarchy = production / consumption % | Autarchy*) estimated from [32] % |
|---|---|---|---|---|
| Cereals | 2.97 | 4.23 | 70.2 | 80 |
| Potatoes | 3.35 | 4.41 | 76.0 | 102 |
| Vegetables | 3.01 | 3.14 | 95.9 | 89 |
| Fruit | 2.90 | 5.44 | 53.3 | 63 |
| Meat | 3.70 | 4.11 | 90.0 | 111 |
| Milk | 4.54 | 4.35 | 104.4 | 101 |

*) Estimates made on the basis of national data disregarding Switzerland.

- data on the percentages of the arable and grazing land used for various agricultural products (Table 3.6);
- crop yields and crop utilization (Table 3.7).

The resulting integral dose rates are given in Table 6.1.

The sum of the integral dose rates for the whole Rhein-Maas Region is identical with the collective dose rate for the population (equation 5.2-23), provided that all foodstuffs produced within the region are consumed there and that imported foodstuffs are not contaminated with radionuclides. In the course of the free exchange of goods, however, products from the Rhein-Maas Region are also taken for consumption in the adjacent regions and vice-versa. Since basic foodstuffs are generally consumed close to the producting area, however, this exchange is not likely to have any great effect on the overall result.

The collective dose rates revised in line with these considerations are set out in Table 6.3. These figures are less than the collective dose rates calculated assuming autarchy, the factors concerned being as follows:

| | | |
|---|---|---|
| Whole body | : | 0.80 |
| Bones | : | 0.76 |
| Skin | : | 0.94 |
| Thyroid | : | 0.73 |

There is thus also a corresponding reduction in the actual values of average individual dose rates for all age groups together, which are also included in Table 6.3.

d) Contributions of the various radionuclides and exposure pathways to dose rates

An assessment of the contributions made by the various radionuclides and exposure pathways to the level of radiological exposure can be made by breaking down the dose rate in accordance with these two parameters.

This breakdown was made for the following organs:

whole body, bones, skin, thyroid

on the basis of the average individual dose rates for the Rhein-Maas Region[x)]. The results are set out in Tables 6-4.1 to 6-4.4. The most important radionuclides and exposure pathways for the various organs are as follows:

| | |
|---|---|
| Whole body : | C-14[xx)], H-3<br>ingestion pathway |
| Bones : | C-14[xx)]<br>ingestion pathway |
| Skin : | Kr-85<br>radiation from plume |
| Thyroid : | I-131<br>ingestion pathway |

For the other organs, the distribution closely resembles that for the whole body.

x) For the exposure pathway "ground radiation" a state of equilibrium $D^{\infty}_{EG}$ was assumed.

xx) See footnote of section "5.3.4 Bioaccumulation and transfer factors".

According to this analysis the radioisotopes

H-3, C-14, Kr-85, I-131 and Cs-137

contribute most to exposure via the gaseous effluent pathway. Of the individual exposure pathways, the ingestion pathway is by far the most important. Radiation from the plume and the ground radiation each play a more or less equally important part. The inhalation pathway is of less importance.

6.1.2. Extrapolation for 2000/05

For the period from 1985/90 to 2000/05, no details are available of proposed sites for nuclear facilities - present planning covers only the period up to 1985/90 - but only projections on a national scale (see Section 4.2). It is therefore impossible to give local individual dose rates for 2000/05.

For the purpose of working out extrapolations for the individual dose rate distribution function, the following assumptions were made:

- the nuclear industry will develop in accordance with the forecasts discussed in Section 4.2. This means that installed nuclear capacity in the Rhein-Maas Region will approximately double between 1985/90 and 2000/05;
- the discharge rates (Table 5.1) adopted in the previous sections for the period up to 1985/90 are also applicable for the period up to 2000/05;
- the site distribution (proportion of sites in the vicinity of major cities, in conurbations and in rural areas) and the average number of facilities per site will not alter significantly between 1985/90 and 2000/05.

On the basis of these assumptions, the two extremes of the individual dose rate distribution functions for 2000/05 can be extrapolated from those for 1985/90 as follows:

- the maximum individual dose rates for 1985/90 will not change significantly by 2000/05 on the above assumptions;

instead, the number of individuals subject to these dose rates will roughly double.

- the segment of the population subject to the lowest dose rate in 1985/90 - this generally means the population living at some distance from rivers and thus from nuclear sites - will, broadly speaking, also be receiving the lowest dose rate in 2000/05. This lowest rate, however, will have approximately doubled by 2000/05.

The corresponding distribution functions for 2000/05 - the pattern between the two extremes has been approximately aligned with that for 1985/90 - are shown in Figures 6-4.1 to 6-4.8.

On these assumptions the collective dose rates calculated for 1985/90 will be doubled by 2000/05, as will the average individual dose rates. The expected dose rates for this period can be obtained by doubling the figures set out in Table 6.4.

The contributions of various radionuclides and exposure pathways to the dose rates will remain unchanged on the above assumptions.

## 6.2. Impact via the liquid effluent pathway

### 6.2.1. Projection for 1985/90

The assumptions on which the projections for 1985/90 are based are set out in Section 6.1.1.

a) Local individual dose rates $D(\vec{r})$

aa) External $\gamma$-radiation (see equations 5.2-6 and 5.2-7)

The external radiation comprises that from activity in water (equation 5.2-6) and that from activity associated with sediments (equation 5.2-7). The latter factor is of importance at locations which are temporarily covered by changing water levels or floods. Since both types of radiation are of importance in the river bank zone, these two exposure pathways are dealt with together in this section. Radiation from sediments generally accounts for more than 99% of the total dose.

Figures 6-5.1 to 3 and 6-6.1 to 5 give the dose rates for the bank zones of the following rivers:

Rhein, Aare, Neckar, Main, Moselle and Maas.

It was assumed here that the concentration of activity in the upper soil layer of the flood plain was equal to the concentration of activity in the sediments on the river bed at the same point, decreasing with depth over a relaxation distance of 3 cm /101/. This is a conservative estimate. Since the $\beta$-radiation can be disregarded on account of the absorption processes in the water and the soil, the dose rates given apply equally to all organs and age groups.

The maximum value of these dose rates - expressed for the sake of convenience in mrem/h - is around 1.2 (-3) mrem/h. On the basis of 200 h/yr (assumed average sojourn time for keen amateur fishermen) this corresponds to an individual dose rate of 0.24 mrem/yr and, on the basis of 8 760 h/yr, to a local dose rate of 10.5 mrem/yr.

ab) Internal exposure from active material ingested with drinking water (see equation 5.2-8)

In accordance with their metabolic behaviour, the radionuclides ingested with drinking water are distributed in varying proportions to the various organs. The resulting dose rates are therefore organ- and age-related. Figures 6-5.1 to 3 show the local individual dose rates on the Rhein for the whole body, bones and thyroid. These were calculated on the assumption that all drinking water consumed is drawn from the river. The local dose rates for the other organs closely approximate to those for the whole body. The dose rates shown in the figures are an average for all age groups (equation 5.2-27), i.e. they apply to the 'average individual'. The maximum values of these dose rates are as follows:

whole body : 0.08 mrem/yr

bones : 0.17 mrem/yr

thyroid : 0.19 mrem/yr

Figures 6-6.1 to 5 show the local whole-body dose rates for the other rivers. The maximum value is of the order of 0.1 mrem/yr. The ratio between the dose rates for the bones and thyroid and those for the whole body is roughly the same as the ratio for the Rhein, since the conditions are similar.

A realistic calculation of the individual dose rates can be made on the basis of the data set out in Table 3-1 on the waterworks treating surface water in the region. The individual dose rates for the 'average individual' calculated on the basis of these data are set out in Table 6-5 together with collective dose rates (see Part c of this section). The maximum values for the dose rates calculated for the supply areas of particular waterworks are:

whole body : 0.06 mrem/yr

bones : 0.07 mrem/yr

thyroid : 0.09 mrem/yr

ac) Internal exposure from active material ingested with food (see equations 5.2-9 and 5.2-10)

The radionuclides discharged with liquid effluent contribute to the total dose via the consumption of freshwater fishmeat (equation 5.2-9) and irrigated plant products (equation 5.2-10). As for all ingestion pathways, the dose rates are organ- and age-related. Figures 6-5. 1 to 3 show the local individual dose rates on the Rhein for the organs whole body, bones and thyroid. These were calculated on the following assumptions:

- non-migratory fish account for all freshwater fishmeat consumed;
- all food plants are irrigated with river water.

The local dose rates for the other organs closely approximate to those for the whole body. The dose rates given in the figures are averages for all age groups together (equation

5.2-27), i.e. they apply to the 'average individual'. The maximum values of these dose rates are as follows:

Consumption of fishmeat — Amateur fishermen (see Table 5-12)

| | | |
|---|---|---|
| Whole body | 0.013 mrem/yr | x 65 = 0.85 mrem/yr |
| Bones | 0.017 mrem/yr | x 65 = 1.11 mrem/yr |
| Thyroid | 0.0015 mrem/yr | x 65 = 0.10 mrem/yr |

Consumption of irrigated plant products

| | |
|---|---|
| Whole body | 0.06 mrem/yr |
| Bones | 0.15 mrem/yr |
| Thyroid | 0.06 mrem/yr |

Figures 6-6. 1 to 5 show the local whole-body dose rates for the other rivers. The maximum values are 0.09 mrem/yr (x 65 = 5.9 mrem/yr for amateur fishermen) for the fishmeat pathway and 0.08 mrem/yr for the exposure pathway "irrigated plant products". The ratio of the dose rates for the bones and thyroid to those for the whole body is roughly the same as that for the Rhein, since conditions are similar.

b) Distribution function $\phi$ (D) for individual dose rates, average and maximum individual dose rates $\bar{D}$ and Dmax

The pre-condition for calculating the dose rate distribution functions, i.e. a correlation between the local dose rates and the population distribution, cannot be satisfied to the same extent for exposure via the liquid effluent pathway as for the gaseous discharge pathway. The reason for this is that there is as yet insufficient information on the proportion of the population exposed to radiation as a result of using rivers. Exposure via drinking-water, as already noted in the previous part of this section, forms an exception, owing to the availability of waterworks' supply data.

For the eight standard organs, calculated distribution functions for the drinking-water pathway are shown in Figures

6-7. 1 to 8. Both the distribution functions for the four age groups and the overall function for the whole population are given. The average individual dose rates (see equation 5.2-25) are also included; these are also to be found, together with maximum individual dose rates and collective dose rates (see Part c of this section) in Table 6-6.

As can be seen from this Table, the average individual dose rates for the GI-tract, liver and lungs for the section of the population supplied with surface water, taking all age groups together, are in the region of 0.013 to 0.014 mrem/yr, while for the thyroid (approx. 0.016 mrem/yr), whole body, gonads, skin (approx. 0.019 mrem/yr) and bones (approx. 0.024 mrem/yr) higher values are found; in the case of bones this is essentially on account of the isotope Sr-90. The age-related variations in the average individual dose rates are greatest in the case of bone dose rates. Here the dose varies between about 0.020 mrem/yr (adults) and 0.036 mrem/yr (children). For the other organs there is less variation. The average values for the whole population of the Rhein-Maas Region are lower by a factor of approximately 5.

c) Collective dose rates DC

The collective dose rates can be calculated by adding together the individual dose rates for the whole population (equations 5.2-26 and 5.2-29), in so far as these are known. As was noted above, this is only possible for the drinking-water pathway. The collective dose rates for the catchment areas of waterworks calculated from the individual dose rates on the basis of the size of population supplied are set out for the whole body, bones and thyroid in Table 6-5. The collective dose rates for the whole Rhein-Maas Region are set out for all eight organs in Table 6-6. As can be seen from this table, these rates are of the order of 160 to 180 manrem/yr for the GI-tract, liver and lungs, while - as with the average individual dose rates - for the thyroid (205 manrem/yr), whole body, gonads, skin (235 manrem/yr) and bones (approx. 300 manrem/yr) higher values are found. Some of the collective dose rates are also included in Table 6.7.

For exposure via the fishmeat pathway, since date are available on the quantities caught (see Table 3.8), but not on individual consumption, it is initially only possible to calculate integral dose rates (equation 5.2-22). As the total catch (2 507 t/yr, see Table 3.8) is small in comparison with total consumption of freshwater fish (19 338 t/yr, see Tables 5.12 and 3.2) it can be assumed that the entirety of this catch is consumed in the region. Accordingly, the integral dose rates can be regarded as collective dose rates (equation 5.2-23). These are set out in Table 6.7.

Currently published data on the extraction of river water for irrigation purposes are regarded as very incomplete. As a first step, in order to estimate the order of magnitude of the collective dose rates, integral dose rates were calculated on the following assumptions:

- water is extracted at a rate of 1 $m^3/s$,
- the radionuclide concentration is as at Rhein kilometre 500 (see list below),
- the irrigation rate amounts to 100 mm per growth period (see equation 5.3-18),
- for economic reasons, only high-value crops (vegetables) are irrigated.

These assumptions hold for an irrigated area of 51.8 $km^2$, which can yield vegetables for some 2 million inhabitants. The integral dose rates calculated on this basis are set out in Table 6-7.

For the dose from external exposure during time spent at the riverside, on account of the lack of data on average sojourn frequencies and times for the various population groups it is most difficult to calculate collective dose rates. On the assumption that amateur fishermen make by far the greatest contribution to the collective dose rate, an upper estimate was made, following a direct survey among amateur fishermen, on the basis of the following data:

- keen fishermen: 10 per km of river bank = 20 per river kilometre,
- average sojourn time : 200 h/yr,
- average local dose rate: 3(-4) mrem/h (see Figures 6.5 and 6.6),
- length of radionuclide-bearing watercourses : 2 700 km.

This resulted in a collective dose rate of about 3 manrem/yr. Time spent in the inundation area by other population groups, such as walkers, canoeists, campers etc. can be allowed for by applying a factor of 2, so that a collective dose rate of 6 manrem/yr can be regarded as an upper estimate for this exposure pathway. This figure is included in Table 6-7.

In order to provide an estimate of the collective dose rates for all water pathways, Table 6.7 also includes the totals of the individual amounts. These totals should be seen in the light of the assumptions and reservations on the basis of which the individual amounts were calculated. This is equally true for the average individual dose rates included in the same table; these rates were obtained by simply averaging out the collective dose rates over the 60.4 million inhabitants of the region.

d) Contributions of the various radionuclides to dose rates

Since an overall assessment of exposure via the liquid effluent pathway could only be made with a number of reservations, a breakdown of the radionuclide components for each single exposure pathway was drawn up for the following organs:

whole body, bones, thyroid.

This was based on the percentages of radionuclides obtaining at Rhein kilometre 500, which can be regarded as representative of the whole region (see above). The results are set out in Tables 6-8.1 to 3. The principal radionuclides for the two main exposure pathways 'drinking water' and 'irrigated vegetables' are H-3,Sr-90 and I-131. For the fishmeat pathway, Cs-134 and Cs-137 are also of importance. External exposure comes mainly from the Co and Cs isotopes.

Radionuclide concentrations and pro rata composition at Rhein kilometre 500

| Nuclide | Concentration [Ci/m$^3$] | Percentage [%] | excluding H-3 [%] |
|---|---|---|---|
| H-3 | 6.40 (-7) | 99.858 | - |
| Co-58 | 1.87 (-10) | 0.029 | 20.64 |
| Co-60 | 1.93 (-10) | 0.030 | 21.31 |
| Sr-89 | 6.97 (-11) | 0.011 | 7.69 |
| Sr-90 | 3.63 (-11) | 0.006 | 4.01 |
| Ru-106 | 7.20 (-13) | 0.0001 | 0.08 |
| I-131 | 1.42 (-10) | 0.022 | 15.68 |
| Cs-134 | 8.26 (-11) | 0.013 | 9.12 |
| Cs-137 | 1.58 (-10) | 0.025 | 17.44 |
| Ce-144 | 3.65 (-11) | 0.006 | 4.03 |
| Total | 6.41 (-7) | 100 | 100 |

6.2.2. Extrapolation for 2000/05

The assumptions on which the extrapolations of the projected figures for the period 2000/05 are based are set out in Section 6.1.2. For the liquid effluent pathway, however, since the resulting activity concentrations are essentially proportional to the installed capacity upstream, the conclusions to be drawn are in some respects different.

The local individual dose rates shown in Figures 6-5.1 to 3 and 6-6.1 to 5 are expected to double for points on the middle and lower reaches of the rivers concerned. For points on the upper reaches of these rivers it is difficult to make an extrapolation since here the dose rates depend on the exact location of the new sites.

There are two aspects affecting an extrapolation of the individual dose-rate distribution function for the drinking-water pathway:

- the activity concentration in surface water will approximately double (see above);
- the extraction of surface water for drinking-water supplies is also expected (see Section 7) to increase by a factor of approximately 2.

The increased use of surface water will result from

- an increase in the amounts of surface water passing through waterworks which already treat surface water;
- an extension of the use of surface water to waterworks which previously treated only ground water.

The doubling of the activity concentration will lead, on the basis of the supply system considered, to a doubling of all dose rates.

The effects of a 100% increase in surface water extraction must be examined in the light of two supply models:

- Model A: the increase in extraction is the result of doubling the amounts of surface water passing through those waterworks which already treat surface water;
- Model B: the increase can be ascribed entirely to waterworks which did not previously treat surface water. It is assumed here that the technical characteristics (method of treatment, mixing ratio etc.) of the newly included waterworks correspond to those of the waterworks in Table 3-1.

Model A results in an increase in the proportion of surface water in drinking water:

$$P_{2000/05} = \frac{2P_{1985/90}}{100+P_{1985/90}} \times 100$$

$P$ [%] = proportion of surface water in drinking water (see Table 3.1).

Where the proportion of surface water was previously small, the increase means that concentrations will be doubled, while in cases where the proportion is already very high a smaller rise can be expected. Since the maximum values of the distribution functions set out in Fig.6-7 are derived from drinking water which already consists exclusively of treated surface water (see Tables 3.1 and 6.5), no increase is expected in the maximum individual dose rates. The average individual dose rates will be subject to an increase of less than factor 2.

Model B results in a doubling of the population receiving supplies of treated surface water. Maximum and average individual dose rates for the distribution functions thus remain unchanged.

The distribution functions derived on the basis of a 100% increase in concentration and these two supply models for 2000/05 have been included in Figures 6-7.1 to 3. They are to be regarded as limit curves for the actual pattern of events.

On the basis of the projections and supply models, the collective dose rates for the exposure pathways 'external exposure' and 'internal exposure via consumption of fishmeat' will be twice as high by 2000/05 as those calculated for 1985/90. For the drinking-water pathway the maximum increase would be approximately a quadrupling of the 1985/90 values. Assuming that amounts of water extracted for irrigation purposes will double, a fourfold increase can also be expected for the exposure pathway 'irrigated vegetables'.

The contributions of the individual radionuclides to the dose rates for the various exposure pathways will remain unchanged on these assumptions.

## 6.3 Comparison of gaseous and liquid effluent pathways

In the preceding sections the radiological exposure resulting from releases of radionuclides was calculated in the form of various dose rates. Depending on how much is known about the various exposure pathways and on the assumptions which had to be made, the findings are of varying significance, as indicated in the various sub-sections. These findings - the most important figures for the whole body, bones, skin and thyroid are set out for comparison in Table 6-9 - are to be seen in the light of these reservations.

The maximum individual dose rates resulting from gaseous discharge were calculated, for the ingestion pathway, assuming agricultural autarchy (which is approximatively true for farmers). For most organs these are in the region of 1 mrem/yr. Only for the thyroid is the rate as high as 10 mrem/yr. The maximum dose rates apply essentially to infants. The maximum individual dose rates resulting from liquid discharge have been set out separately for each exposure pathway since, as already pointed out in Section 6.2, the basic criteria differ so widely that it scarcely appears worthwhile to calculate a total. The highest dose rates here are associated with the fishmeat pathway (fishermen) and amount, for most organs, to something of the order of 1 mrem/yr. For the thyroid the maximum is in the region of 0.1 mrem/yr. A purely arithmetical summation of these maximum values gives dose rates of up to about 1.6 mrem/yr (bones).

On the basis of the assumptions made, extrapolating these figures for 2000/05 does not indicate any significant changes in the maximum dose rates from gaseous discharge. The maximum dose rates from liquid discharge can be expected more or less to double.

The average individual dose rates set out in Table 6-9 relate to the region's total population of 60.4 million. The dose rates resulting from gaseous discharge are between about 0.8(-2) mrem/yr (whole body) and 3(-2) mrem/yr (skin). The corresponding dose rates arising from liquid discharge - here there is no objection to adding together the individual pathways - are somewhat lower, being between about 0.5(-2) mrem/yr (thyroid) and 1(-2) mrem/yr (bones). The average total dose rate varies from about 1.4(-2) mrem/yr (whole body) to 3.5(-2) mrem/yr (skin).

Extrapolation of these figures for 2000/05 results in a doubling of the average dose rates for the gaseous effluent exposure pathways, while for the liquid effluent pathways the dose rates can be expected to be between two and four times higher, depending on the particular pathway. Because of this uneven increase the average dose rates from liquid effluent pathways for the whole body and bones will then be higher than those from gaseous effluent pathways. The average total dose rate will vary from about 3.3(-2) mrem/yr (whole body) to about 8.1(-2) mrem/yr (skin).

## 6.4. Comparison with certain findings of the "Mississipi Study"

Of the previous forward studies [1 to 6], the findings of the "Mississipi Study" [1] are most closely comparable with the results obtained here, since the two studies have very similar aims. A concise comparison of the starting data and objectives of the studies is given below:

Basic data on the regions concerned

RMR (= Rhein-Maas Region):

| | | |
|---|---|---|
| area | : | 222 342 km$^2$ |
| run-off | : | 2 710 m$^3$/s |
| population | : | 60 432 400 inhab. |
| population density | : | 270 inhab. per km$^2$ |

UMRB (= Upper Mississippi River Basin):

| | | |
|---|---|---|
| area | : | 785 026 km$^2$ |

| | | |
|---|---|---|
| run-off | : | 4 757 $m^3/s$ |
| | | 3 907 $m^3/s$ (net) |
| population | : | 17 870 942 inhab. (1970) |
| | | 29 091 800 inhab. (2000) |
| population density | : | 23 inhab.per $km^2$ (1970) |
| | | 37 inhab.per $km^2$ (2000) |

Installed nuclear capacity

RMR :

| | | |
|---|---|---|
| Output | : | 55 Gwe (1985/90) |
| | | 110 GWe (2000/05) |
| Reprocessing capacity | : | 40 t/yr (1985/90) |
| | | 80 t/yr (2000/05) |

UMRB :

| | | |
|---|---|---|
| Output | : | 356 GWe (2000) |
| Reprocessing capacity | : | 12 300 t/yr (2000) |

Aim of study

RMR :

Assessment of dose rates on the basis of known facility and site plans for the period 1985/90. Extrapolation of results on the basis of energy forecasts for the period 2000/05.

UMRB :

Assessment of dose rates for the year 2000 on the basis of computer data on facilities and sites compiles with reference to forecast demand and statutory requirements.

Out of the large number of findings, a first comparison can be made for the whole body dose rate. The average dose rates over all age groups in the year 2000 will be as follows:

RMR : 0.038 mrem/yr, including
gaseous effluent pathway: 0.016 mrem/yr (= 41%)

liquid effluent pathway : 0.022 mrem/yr (= 59%)
(see Table 6-9)

UMRB :0.169 mrem/yr, including

gaseous effluent pathway : approx. 0.161 mrem/yr
(= approx. 95%)

liquid effluent pathway : approx. 0.008 mrem/yr
(= approx. 5%)

(estimated from [1, Fig. II-3])

The higher overall dose rate obtained for the "Mississippi study" area is thus the result of a dose rate via the gaseous effluent pathway some 10 times higher than that for the Rhein-Maas Region, and this is discussed in detail below. The dose rates for the liquid effluent pathway are roughly of the same order of magnitude.

A breakdown of exposure via the gaseous effluent pathway into the contributions from each individual exposure pathway reveals the following picture:

| | RMR: | UMRB: |
|---|---|---|
| Plume exposure | 23.7% | 2.4% |
| Ground exposure | 19.4% | 10.2% |
| Exposure from inhalation | 5.5% | 82.5% |
| Exposure from ingestion | 51.4% | 4.9% |

The relatively low proportion of plume exposure in the total external dose in the Mississippi study is due essentially to the centroid concept adopted. Under this system the population of 479 counties is assigned, for ease of calculation, to 300 centroids (average area about 2 600 $km^2$), in each of which the population is then concentrated at a single geographical point. This mathematical depopulation of the inner zones around nuclear facilities means that radioactive noble gases with a relatively short half-life (e.g. Ar-41 ($T_{1/2}$=1.8h) and Kr-88 ($T_{1/2}$= 2.8h) but high dose factors (see Table 5-9) are in effect eliminated prematurely and thus make no further contribution to exposure via this pathway.

The comparison brings out one striking aspect of the "Mississippi study" findings, namely the high proportion of the total dose contributed by the inhalation pathway, due almost exclusively to the inhalation of tritium [1, Fig. II-3].

The total tritium component of the whole-body dose rate amounts to about 82% [1, Fig.II-5], compared with about 26% (Table 6-4) in the present study.

The quantities of tritium released in the regions concerned are as follows:

| | RMR | UMRB |
|---|---|---|
| Region: | 3 200 Ci/yr | 7 090 000 Ci/yr [1, Table C-9] |
| Inner Zone: | 70 000 Ci/yr (FRP "KEWA", N 02)*) | |
| | 14 000 Ci/yr (FRP Mol, N 12)*) | |

Allowing for the fact that approximately half of the tritium discharged from the reprocessing plant at Mol and one quarter of that discharged from the "KEWA" reprocessing plant contribute to the regional inventory

$$3200 \text{ Ci/yr} + 0.5 \times 14\,000 \text{ Ci/yr} + 0.25 \times 70000 \text{ Ci/yr} = 28000 \text{ Ci/yr}$$

and taking into account the area ratio of 1:3.5 between RMR and UMRB, the tritium concentration ratio between the two regions turns out at 1:70. A 70-fold increase in the tritium concentration in the Rhein-Maas Region would result in a whole-body dose rate approximately 16 times higher, which would then correspond to the dose rate given in the "Mississippi Study". The **difference** in the proportions of C-14 in the whole-body dose rate can also be put down to varying discharge rates. These discharge rates are as follows:

| | RMR: | UMRB: |
|---|---|---|
| Region: | 580 Ci/yr | 2.28 (-3) Ci/yr [1, Table C-9] |
| Inner zone: | 600 Ci/yr (NO2) | |
| | 120 Ci/yr (N12) | |

*) See Table 4-4 and Fig.4-4

These varying assumptions on discharge rates mean that in the present study C-14 contributes 28% of the whole-body dose rate, while in the "Mississippi Study", on account of the negligible contribution from C-14, no data are to be found.

The ratios between organ dose rates and whole-body dose rates that can be calculated from these two studies show certain variations. Essentially, these can be put down to the variations in discharge rates for those radionuclides which have a predominant influence on the dose rates. This is illustrated below for the following organs: bones, skin and thyroid.

**Bones**

RMR : 0.059 mrem/yr, including

gaseous effluent pathway : 0.022 mrem/yr (= 37%) (See Table 6 - 9)

ratio bones/whole body*):

$$\frac{0.022 \text{ mrem/yr}}{0.016 \text{ mrem/yr}} = 1.4$$

UMRB : 0.034 mrem/yr, including

gaseous discharge pathway via air : approx.0.027 mrem/yr (= approx. 80%)

(estimated from [1, Fig. II-3]

ratio bones/ whole body :

$$\frac{0.027 \text{ mrem/yr}}{0.161 \text{ mrem/yr}} = 0.17$$

The difference between the two ratios results from the fact that in the findings of the "Mississippi Study" (tritium contribution to whole-body dose rate: 82%) the elimination of the tritium dose is of greater significance than in the present study (tritium contribution to whole-body dose rate: 26%). The fact that the present study furthermore arrives at a ratio greater than 1 is due to the age-dependent ratios between the organ dose factors for C-14. These are as follows (see Table 5-11):

for infants, children and adolescents -bones/whole body = 1
for adults - bones/whole body = 5,

and on account of the higher discharge rates for C-14 assumed

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*) ratio of the organ dose rates actually

in the present study, it is only here that they are of significance.

Skin

RMR : 0.081 mrem/yr, including
gaseous effluent pathway : 0.058 mrem/yr (=72%) (see Table 6-9)

ratio skin/whole body :

$$\frac{0.058 \text{ mrem/yr}}{0.016 \text{ mrem/yr}} = 3.6$$

or (skin-whole body)/whole body = 2.6

UMBR : 0.179 mrem/yr inc'uding
gaseous discharge pathway : approx.0.174 mrem/yr (=97%)
(estimated from [1, Fig.II-3]

ratio skin/whole body :

$$\frac{0.174 \text{ mrem/yr}}{0.161 \text{ mrem/yr}} = 1.08$$

or (skin-whole body)/whole body = 0.08

The difference between the two dose rate ratios '(skin-whole body)/whole body' is essentially due to the ratio between Kr-85 and H-3 discharge rates.

The amounts of Kr-85 discharged in the regions concerned are as follows:

| | RMR: | UMRB: |
|---|---|---|
| Region: | 105 000 Ci/yr | 958 000 Ci/yr |
| Near distance zone : | 190 000 Ci/yr (NO2) | |
| | 38 000 Ci/yr (N12) | |

Weighting the discharge rates as for tritium

105 000 Ci/yr + 0.5 x 38 000 Ci/yr + 0.25 x 190 000 Ci/yr = 171 500 Ci/yr

gives the following Kr-85/H-3 discharge ratios.

RMR:
$$\frac{171\ 500 \text{ Ci/yr}}{28\ 000 \text{ Ci/yr}} = 6.13$$

UMRB:
$$\frac{958\ 000 \text{ Ci/yr}}{7\ 090\ 000 \text{ Ci/yr}} = 0.135$$

These ratios for discharge rates bear roughly the same relationship to one another as those calculated above for the (skin-whole body)/whole body dose rates, which confirms the above observation.

Thyroid

RMR : 0.054 mrem/yr, including
gaseous effluent pathway : 0.036 mrem/yr (= 66.7%) (see Table 6-9).

ratio thyroid/whole body

$$\frac{0.036\ \text{mrem/yr}}{0.016\ \text{mrem/yr}} = 2.3$$

UMRB : 0.753 mrem/yr, including
gaseous discharge pathway : approx 0.546 mrem/yr (= approx. 72.5%)
(estimated from [1,Fig.II-3])

ratio thyroid/whole body

$$\frac{0.546\ \text{mrem/yr}}{0.161\ \text{mrem/yr}} = 3.4$$

The difference between the two dose rate ratios is essentially due to the ratio between I-131 and H-3 discharge.

The amounts of I-131 discharged in the regions concerned are as follows:

RMR: 6.5 Ci/yr UMRB: 2 150 Ci/yr

This gives the following I-131/H-3 discharge ratios

RMR:

$$\frac{6.5\ \text{Ci/yr}}{28\ 000\ \text{Ci/yr}} = 2.3(-4)$$

UMRB:

$$\frac{2\ 150\ \text{Ci/yr}}{7\ 090\ 000\ \text{Ci/yr}} = 3.0\ (-4)$$

These ratios for discharge rates bear roughly the same relationship to one another as those calculated above for thyroid/whole body dose rates, which confirms the above observation.

For the other organs, there are no appreciable differences, as the dose rates for the organs concerned approximate very closely to the whole body dose rate in both studies.

This short comparison shows that differences in the obtained result of both studies can be explained by the different data anticipated and the different characteristics of the two regions. Greater discrepancies could not be detected.

## 7. On the question of accuracy

As already mentioned in the introduction, the need for an assessment of radiological exposure on a regional basis, as opposed to calculation of the exposure of the population in the vicinity of nuclear facilities, long regarded as an important part of safety reports, has only recently been generally recognized.

One reason for the introduction of this aspect was the fact that nuclear engineering was emerging from the experimental and demonstration stages and developing into an energy technology with an increasingly dense network of facilities. A further and equally important reason was the almost simultaneous realization that in addition to the exposure pathways which had received most attention -'direct irradiation' and 'irradiation through inhalation', irradiation via the so-called ecological pathway - i.e. 'irradiation from ingestion of foodstuffs' also made a significant contribution to total exposure (see for example [126], [125] and [127]). Since to some extent the production, distribution and consumption of these foodstuffs take place over an extensive area it seemed appropriate to deal with the question on a regional basis.

The regional studies carried out to date, cited in the introduction [1 to 6], and the data and parameters on which they drew [e.g. 68 to 73, 128 and 129] indicate that they are a relatively new departure. The results still contain comparatively significant inaccuracies, inherent to a certain extent in the nature of forward studies, as emerges from previous sections.

The inaccuracies involved are pointed out below by way of example on the basis of observations on the steps described in previous sections. This will give an idea -albeit incomplete - of the order of magnitude of the inaccuracy and may provide an impetus for investigation in the future.

Population structure (see Section 3.4)

The population statistics for the years 1970 to 1975 were used as a basis for these reflections and for the calculations for 1985/90 and 2000/05. The birthrate has recently shown a noticeable decline in all central European countries, however. This not only reduces the total population, but also produces a shift in the age structure towards a higher average age. This shift generally has the effect, until some new equilibrium is reached, of lowering the dose rate for the 'average person' (see equa- 5.2-27 and 28), so far as this depends on age, while the reduction in the population reduces the collective dose rate (see equations (5.2-26 and 29)).

Assuming a reduction in the birth rate stabilizing at 75% of the previous rate[x)], the resulting changes based on the data in Table 3-4 are given in simplified form in the following table.

Change in the average age and total population due to a fall in the birth-rate to 75% of the previous rate.

| Time since fall in birth-rate commenced [yr] | Increase in average age [yr] | Total population (=100% for t=0) [%] |
|---|---|---|
| 0 | 0 | 100 |
| 10 | +1 | 96 |
| 20 | +2 | 93 |
| 30 | +2.5 | 89 |
| 40 | +2.5 | 86 |
| 50 | +2 | 82 |
| 60 | +1 | 79 |
| 70 | 0 | 75 |

[x)] This assumption (75%) has been made on the basis of trends observed in the West and Central European countries.

Since, however, the changes outlined yield dose rates lower than those calculated in this study, the results may be regarded as an upper estimate. There are no surveys or forecasts relating to possible geographical shifts in the population within the Rhein-Maas Region as a whole or population movements into or out of the area over the next few decades. In view of the economic attractiveness of the region the number of people moving in should exceed the number moving out and thus losses due to the fall in the birthrate will be at least partially made up.

Agriculture and freshwater fishing (see Section 3.5)

It is difficult to forecast how the land will be used in the coming decades since this is subject to changes due to cyclical fluctuations and trends in consumer taste for which long-term predictions cannot be made. In general it is assumed that the number of people with farming as their main occupation will decrease in favour of the number farming as a secondary means of livelihood which, together with changing tastes, could produce a swing from so-called basic foodstuffs to special products. In view of this uncertain situation the present circumstances must for practical reasons be applied to the whole of the period in question.

It is even more difficult to compile a fisheries forecast for the rivers in the Rhein-Maas Region. There has been a reduction in fishing, since the rivers have become increasingly polluted over the past few years. Further deterioration can perhaps be excluded in view of various agreements designed to prevent further degradation of the quality of the river water, and the present situation may be regarded as representative for some time to come.

Drinking water supplies (see Section 3.3)

It is possible to formulate only an approximate idea of the future use of surface water as drinking water within the Rhein-Maas Region, since only general data are available. Forecasts for developments in the future use of water are set out in the following table.

Forecasts for the use of surface water as drinking water

| Forecast | Use of water | Increase [1] $X(t)=X_0 x (1 + \alpha x t)$ |
|---|---|---|
| For Germany [95] | Drinking water: 1965: 1 $\frac{mm}{yr}$ [2]<br>2000: 3 " | $\alpha = 5.7(-2)yr^{-1}$ |
| For the Netherlands [130] | Water: 1972: 0.52 $\frac{10^9 m^3}{yr}$<br>2000: 3 " | $\alpha = 1.7(-1)yr^{-1}$ |
| For the Rhein Region [131] | Drinking water: 1972/73: 0.62 $\frac{10^9 m^3}{yr}$<br>1980: 0.79 " | $\alpha = 3.6(-2)yr^{-1}$ |

1) a linear increase is assumed.

2) on the basis of an area of 250 000 $km^2$, this corresponds to 0.25 $10^9 m^3/yr$ (1965) and 0.75 $10^9 m^3/yr$ (2000)

Taking as a basis a rounded off value of $\alpha = 5 \times 10^{-2} yr^{-1}$ for the increase in use of water for the provision of drinking water within the whole Rhein-Maas Region, an increase by a factor of 1.5 may be expected for 1975 to 1978 and an increase by a factor of 2.25 by the year 2000.

As can be seen, the few forecast values taken from the literature and set out in the above table show considerable differences. This is partly due to various regional factors. For the whole Rhein-Maas Region the uncertainty of the rate of increase assumed should be a factor of approximately 2 or 3.

Development of nuclear technology (see Section 4.2)

Reference was previously made in Section '4.2.3 - Revised projections' to the influences which within two or three years have reduced the original projections for nuclear output up to 1985 to two-thirds or three-quarters of the nuclear capacity originally predicted. The medium term forecasts up to the year 2000 should also be seen in the light of these probable short-term changes.

Effluent rates (see Section 5.3.1)

For plants which have already been in operation for some time the average value for the annual effluent rates is derived (Table 5-1) and used in the calculations. Fluctuations in these annual release rates may be identified by means of the variation/average value ratio.

Average value: $\bar{x} = \frac{\sum_{\nu=1}^{n} x_\nu}{n}$ Variation: $s = \sqrt{\frac{\sum_{\nu=1}^{n} (x_\nu - \bar{x})^2}{n-1}}$

n = number of years in operation

For the Obrigheim (No 20) plant, which will be considered here as a typical example of a nuclear power plant, the $s/\bar{x}$ ratios set out in the following table are obtained for the annual emission rates over the period 1969-1975 [76, 77].

'Variation/average value' ratio of the annual emission rates of the Obrigheim nuclear power plant - operating period 1969-75.

| Emission | | $s/\bar{x}$ |
|---|---|---|
| Gaseous releases: | noble gases | 0.68 |
| | I-131 | 2.02 |
| Liquid releases : | H-3 | 0.30 |
| | remaining mix | 0.77 |

The table shows that the variations lie within the order of magnitude of the average values.

Assuming that several facilities (m) with statistically similar emission properties are in operation at one location, then the following apply:

$$\bar{X} = m \times \bar{x} \qquad S = \sqrt{m} \times s \qquad S/\bar{X} = \frac{1}{\sqrt{m}} \times s/\bar{x}$$

As can be seen, the variation/average value ratio for the total emission at the location is smaller than for the individual facilities.

In the same way the variation/average value ratio may be compiled with regard to exposure via the water pathway. In this case 'm' is the number of facilities situated upstream of the observation point in question.

In the case of facilities not yet commissioned the question arises as to how realistic the anticipated values applied are. Here a comparison of the anticipated values shown in Table 5-2 and derived from various projections indicates the range of the emission rates regarded as realistic. As is apparent, this range is for the most part within the order of magnitude of the anticipated values.

Atmospheric dispersion (see Section 5.3.2)

Ground roughness category III 'Low trees and buildings' (see Section 5.3.2), which generally gives a slightly higher estimate of the predominant roughness in the area around nuclear facilities, was taken as a basis for the dispersion calculations made in this study. Factors are given in the table below which indicate the extent to which the atmospheric dispersion factor, at various distances from a source 100 m high and for various ground roughness categories differ from the reference case.

Ratio of the atmospheric dispersion factors $J_x/J_{III}$ near to ground level for various ground roughness categories x (height of the plume source: 100 m)

| Distance [km] | Roughness [93] | | | |
|---|---|---|---|---|
| | I low grass | II fields under cultivation, hedges | III low trees, buildings | IV high trees towns |
| 1km | 0.37 | 0.64 | 1 | 0.73 |
| 10km | 1.43 | 1.18 | 1 | 1.14 |
| 100km | 1 | 1 | 1 | 1 |

It is clear that in the reference case the highest specific activity is at a distance of 1 km, while at a distance of 10 km the specific activity is lower than the values for other ground roughness categories by a factor of 1.4 at the maximum.

Cooling towers were not taken into consideration for atmospheric dispersion. Cooling towers may affect dispersion as follows:

1) by their structural volume, increasing turbulence;
2) by their heat and steam emissions, which may alter turbulence and humidity factors.

The first steps are currently being taken to quantify these possible effects [132, 133].

Hydrospheric dispersion (see Section 5.3.3)

As regards hydrospheric dispersion, it is clear from what is already known that a great deal of detailed knowledge will be required for a precise understanding of some phenomena. The latter include the effect of:

1) the chemical form of radioactive emissions,

2) the chemical state of the river,

3) the concentration of natural components of the river, and

4) heat transfer to the river

on the transport and interaction processes. As previously shown in Section 5.3.3, most of the activity emitted is transported with the water [102 to 104]: thus the sorption and sedimentation processes depend in particular upon the parameters mentioned above.

Accumulation and transfer factor (see Section 5.3.4)

The accumulation and transfer factors of USNRC [71] formed the chief basis of this study. The range of factors published in the literature on the basis of various measurements or evaluations will be characterized by way of an example on the basis of two sets of data for Isotope I-131 (transfer from air to milk) and for Cs-137 (bioaccumulation freshwater to fish).

Air-to-milk transfer factors for I-131

| Reference | | Air-to-milk transfer factor $T_{A\ milk} \times C_p \times B_p$ $\left[\frac{m^3}{l}\right]$ 1) |
|---|---|---|
| A. Bayer | [127] | 1000 |
| F.O. Hoffman | [134] | 1600 |
| EPA-520 | [135] | 920 |
| WASH-1258 | [136] | 540 |
| WASH-1535 | [137] | 1200 for $v_d$ = 1 cm/s |
| F.O. Hoffman | [138] | 4800 |
| WASH-1400 | [139] | 860 for $v_d$ = 1 cm/s |
| USNRC-1.109 | [71] | 2540 for $v_d$ = 1 cm/s |

1) see equation (5.2-5)

Freshwater-to-fish bioaccumulation factors for Cs-137

| Reference | Freshwater-to-fish bioaccumulation factor $B_F$ $\left[\frac{1}{kg}\right]$ |
|---|---|
| D.E. Reichle et al. [140] | 640 - 9500 |
| J.F. Fletcher et al. [ 68] | 1000 |
| S.E. Thompson et al. [141] | 400 |
| St.M. Jinks et al. [142] | 3680 |
| C.M. Micholet et al. [143] | 350 |
| J.K. Soldat et al. [ 69] | 2000 |
| H. Hermann et al. [144] | 170 |
| BMI (D) [ 73] | 3000 $\frac{mg}{kg}$ /K 1) |
| USNRC-1.109 [ 71] | 2000 |

1) K = concentration of stable potassium in the water [mg/l]

Rhein: Kilometre 28: 1.25 mg/l
Kilometre 571: 8.52 mg/l [145]

As can be seen from these two tables, most of the values from the literature are spread within limits roughly corresponding to an order of magnitude. This is due partly to differing conditions for measurements and also to different degrees of conservatism in the evaluation of measurements for the establishment of recommended data.

Dose factors (see Section 5.3.5)

Since dose factors, like transfer factors, are compiled from a series of individual factors which may be measured or evaluated in various ways, there may be discrepancies here also between the sets of data put forward. This may be demonstrated, again by way of example, by means of the thyroid-ingestion dose factors for the isotopes I-129 and I-131.

Thyroid-ingestion dose factors for I-129 and I-131

| Nuclide | Age group | $q_{IG}$ [rem/Ci] "Mississippi Study" [1] | USNRC [71] | Soldat [123] |
|---|---|---|---|---|
| I-129 | Infant | - | 6.8 (+7) | 1.4 (+7) |
| | Child | 4.6 (+6) | 2.8 )+7) | 5.6 (+6) |
| | Young person | 1.3 (+6) | 9.6 (+6) | 4.3 (+6) |
| | Adult | 7.4 (+6) | 7.2 (+6) | 7.2 (+6) |
| I-131 | Infant | - | 1.3 (+7) | 1.4 (+7) |
| | Child | 7.8 (+6) | 5.4 (+6) | 5.7 (+6) |
| | Young person | 2.1 (+6) | 2.3 (+6) | 2.4 (+6) |
| | Adult | 1.9 (+6) | 1.9 (+6) | 1.9 (+6) |

As can be seen from this comparison, the dose factors for I-131 in the 3 sets of data show good agreement, whereas those for I-129 differ, sometimes considerably. This discrepancy is due mainly to different assumptions with regard to the length of time the iodine remains in the thyroid gland. Whereas the effect of this is not apparent in the case of I-131 which has a relatively short half-life, the effect on dose factors for the long-lived I-129 is fully reflected.

The following example illustrates that the sets of data also differ to some extent with regard to the main assumptions made:

Whereas the tritium inhalation factor was dealt with as follows in the "Mississippi Study" [1]:

Inhalation = Inhalation through lungs + inhalation through skin

$\approx$ 2 x inhalation through lungs

there was no special mention of tritium inhalation through the skin in the USNRC Regulatory Guide [71] the latter used in this study. These examples may give some idea of the inaccuracies which can be involved in dose factors.

Consumption data (see Section 5.3.6)

Variations in the eating habits of the population due to differences in the agricultural use of an area, occupation and individual trends in consumer taste were discussed earlier in Section 5.3.6. Table 5-12 shows for the main foodstuff groups the factors by which the average consumption figures may be exceeded by certain population groups. These factors are approximately two for basic foodstuffs. They may be much higher for special foodstuffs. Thus the average consumption of fresh water fish by inland fishermen is higher by a factor of approximately 65 than the average consumption obtained for the total population. These two factors of 2 and 65 may be taken as an indication of the range of deviations in the eating habits of certain population groups from the statistically determined consumption data. A detailed consideration of the special conditions is possible only within the context of individual site studies.

Summary

The uncertainties and inaccuracies pointed out in the above section fall into three groups:

1. Uncertainty of forecasts

   for example nuclear engineering

   population trends

   provision of foodstuffs and drinking water.

   These uncertainties are inherent in forecasting and characteristic of prospective studies.

2. Fluctuation of parameters

   2.1 fluctuations in time

   e.g. rate of release from nuclear facilities

   agricultural yields

   2.2 regional differences

   e.g. ground roughness

   chemical state of water

   condition of ground

2.3 individual differences

e.g. consumption of foodstuffs

Within the context of regional studies only temporal and regional average values are generally applied. It is usually possible to consider local and individual factors only within the context of site studies.

3. Inaccuracy of parameters

e.g. inaccuracies inherent in measurement results

inaccuracies - or rather uncertainties - due to widely differing measurement results.

Within this context further investigations should be performed especially in the field of transfer, bio-accumulation and dose factors to reduce these uncertainties.

Widely differing measurement results due largely to different temporal and regional environmental conditions belong to group 2 'fluctuation of parameters'.

It is not at present possible to work out a total inaccuracy. It seems more sensible to estimate the inaccuracies of the individual parameter fields; for this the above observations on accuracy may be regarded as a starting point.

## 8. Radiological impact from worldwide nuclear technology

In Chapter 6 of this study the radiological impact on the population of the Rhein-Maas Region originating from emissions from nuclear facilities in this region and the adjacent area was calculated. The exposure from the 'first pass' of the radionuclides emitted was obtained.

Moreover, radionuclides with 'global significance' (i.e. radionuclides with a sufficiently long half-life and appropriate transport behaviour) which are emitted from nuclear installations throughout the world also constitute a further contribution to the total exposure from nuclear technology. These include radionuclides emitted from installations in the Rhein-Maas Region which have left the region by reason of geophysical circulation processes and have then re-entered the region.

For simplicity, radionuclides with 'global significance' may be divided into the following three groups:

1. H-3, C-14, Kr-85
2. Sr-90, I-129, Cs-137
3. Actinides (e.g. Pu-239, Pu-240, etc.)

For the first group global dispersion occurs relatively quickly after release (which is in the form of $H_2O$, $CO_2$ or noble gases). The second and third groups contain radionuclides with sufficiently long half-lives, but dispersion occurs very slowly during the alternating processes of fallout and resuspension. This is particularly true of the third group. Since, moreover, suitable models for transport behaviour have not yet been elaborated, survey results will have to suffice for the time being for these groups.

On the basis of projections for the development of worldwide nuclear engineering up to the year 2000, the expected dose rates for this period resulting from the emission of inter alia H-3, C-14 and Kr-85 were calculated in a study for the European Community carried out by UK-NRPB [83]. The applied projections for nuclear capacity are shown in Fig. 8-1 and the dose rates derived from these projections in Fig. 8-2.

What was said in Section '4.2.3 Revised Projections' about the projections for the Rhein-Maas Region is also largely true of the applied projections: it now seems likely that the forecasts originally made for 1985 will probably apply only three or five years later and the forecasts for 2000 only seven or twelve years later. This should be remembered when considering the dose rates calculated in Fig. 8-2.

Values were compiled and applied in [83] as the sums of the discharge rates for the entire circuit: these values are given in Table 8-1 and were based on the last complete release (DF = 1) of these three radionuclides. These discharge rates were compared with the total discharge rates derived from numerical values compiles in 5.3.1 of this report - also assuming complete release - for an LWR nuclear engineering plant (2/3 PWR + 1/3 BWR). As can be seen the numerical values for H-3 and Kr-85 correspond sufficiently well, given the degree of accuracy obtainable in such investigations. In the case of the C-14 the discrepancy is greater due to different C-14 release rates of the total nuclear cycle. These are:

| | | | |
|---|---|---|---|
| UK-NRPB [83] | : | PWR | 2.5 Ci/(1000 MWt/yr) |
| | | BWR | 5.8 " |
| | | HTR | 21.9 " |
| | | LMFBR | - |
| This study [82] | : | LWR | 8 Ci/(1000 MWt/yr) |
| | | HTR | 30 " |
| | | LMFBR | 1.5 " |

Due to the weight applied in [83] for the year 2000

LWR : HTR : LMFBR = 0.70: 0.06: 0.24

an overall release rate is obtained of

UK-NRPB [83] : 4 Ci/(1000MWt/yr)

This study : 8 Ci/(1000MWt/yr)

A 4-section model was used in [83] to calculate the concentration of H-3 : surface water and deep see water from the northern and southern hemispheres respectively. For the calculation of the concentration of C-14, four further sections were added to the model : humus covering and troposphere, again from the northern and southern hemispheres respectively. Finally, a 4-section model was adopted for the calculation of the concentration of Kr-85. The troposphere was divided into two bands each for the northern and southern hemispheres.

The results obtained in [83] for the 35°-60° north latitude band may be found in Fig.8-2. The gonad dose rate (equal to the whole-body dose rate) was calculated for H-3, C-14 and Kr-85 and the skin dose rates for Kr-85. The dose rates expected from the emission rates in this report are also given. As this shows, C-14 produces the highest partial dose within the gonad dose rate; for the discharge rates taken as a basis for this report, the gonad dose rate for the year 2000 is just under 0.1 mrem/yr. The skin dose rate from Kr-85, however, assuming as above 'complete worldwide discharge' is already approximately 3 mrem/yr for the year 2000. The dose rates for the years 1985 and 2000 from Fig. 8-2 taking account of the time lag which will presumably apply (see Section 4.2.3) are also set out in Table 8-2.

The observation made in Chapter 7 is valid for the dose rate for C-14: this dose is calculated from the current $CO_2$ concentration in the air. There is likely to be an increase in the use of fossil fuels which will in turn increase the atmospheric $CO_2$ content. Consequently the actual resultant dose rate for C-14, which is proportional to the C-14/$C_{stable}$ content, will probably be below the rate calculated.

Dose rates lower than those calculated here are expected once decontamination plants, mainly in reconditioning plants, are built to retain these nuclides. It is not yet possible to make a realistic estimate of the effects of the reduced output on the total exposure up to the year 2000, since there is still insufficient information on the construction of reconditioning plants in all countries engaged in nuclear engineering. The release rate is unlikely to be reduced by an international worldwide agreement on the limitation of overall release rates, and will probably come about as a result of national laws limiting the maximum doses in the vicinity of reconditioning plants. Target decontamination factors, which are though to be realistic for large-scale reconditioning plants in Western Europe may be found in Table 5-3. If applied throughout the world, these would in the long term, reduce the expected concentration of H-3 by a factor of 10 and of Kr-85 by a factor of 100, which would considerably reduce the skin dose rate in particular. Only applied in Western Europe this potential reduction of the global impact can only be reached to a degree of 22% *). The separation of C-14 has not yet received the same attention as the separation of Kr-85. In view of its significance for the gonad dose rate, however, efforts will also have to be made to reduce the discharge rates in the long term.

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*) Installed nuclear capacity in the year 2000 :

| | | |
|---|---|---|
| Western Europe: | 700 GWe | [83] |
| World: | 3160 GWe | [83] |

# 9. Radiological impact from natural radiation, nuclear weapon tests and medical diagnosis and treatment

## 9.1. Natural radiation exposure

Natural radiation exposure includes external and internal irradiation caused by cosmic radiation, terrestrial radiation and ingestion or inhalation of the naturally occurring radionuclides.

### External exposure from cosmic radiation

Cosmic radiation is produced when elementary particles and high-energy light nuclei impinge on the earth's atmosphere (primary radiation). Reactions with nitrogen and oxygen nuclei in the air produce secondary cosmic radiation. The intensity of this radiation is to a considerable extent dependent on the height above sea level, since part of the radiation is absorbed by the atmosphere. It is practically constant in time. Typical values for the resultant exposure rate in our latitudes will be seen in Table 9-1. The general rule applies that with effect from 30 mrem/yr for NN = Om up to a height of several kilometres the dose rate doubles approximately every 1 500 m [146].

### External exposure from terrestrial radiation

Terrestrial radiation comes from the natural radioactive substances, in particular K-40, Rb-87, Th-232, U-235 and U-238, and their decay products which occur in various concentrations throughout the world. The dose rate produced by this terrestrial radiation is dependent upon the geological formations of the substrata and varies from place to place.

The total external radiation exposure (cosmic radiation plus terrestrial radiation) was compiled by evaluating references [146 to 151] for the Rhein-Maas Region In Fig. 9-1. As this

Figure shows the annual dose rate within the region is between approximately 55 mrem/yr and 200 mrem/yr. The lowest values - 55 to 80 mrem/yr - occur in the low-lying areas of the lower Rhein. In the lower mountainous areas, with the exception of the Black Forest and the Vosges, the dose rate varies between approximately 70 and 135 mrem/yr. The values for the high mountain areas of Switzerland are between 110 and 160 mrem/yr. The highest external radiation exposure occurs in the Black Forest and the Vosges, reaching 150 to 200 mrem/yr due to the very high proportion of terrestrial radiation (granite in the southern Black Forest and the southern Vosges).

Internal exposure from radionuclides ingested or inhaled

In addition to the radionuclides K-40, Rb-87, Th-232, U-235 and U-238 and their decay products, radioactive nuclides such as H-3 and C-14 are produced by cosmic radiation. A proportion of these naturally occurring radionuclides pass by means of the food chain into the human body where they increase the radiological impact Radon and its decay products are also inhaled into the respiratory organs and increase the impact on these organs. The partial doses from the most important radionuclides are set out in simplified form in Table 9-2.

Total natural radiation exposure

Since the gonad dose rate (equal to the whole body dose rate) from internal irradiation varies scarcely at all from place to place in our latitudes, the total whole body dose rate from natural radiation effects is the sum of the locally determined values for the external exposure plus approximately 20 mrem/yr from internal exposure. This is also shown in Fig. 9-1.

A further source of radiation, which is generally included under the natural external exposure from terrestrial radiation, is the radionuclides contained in building materials.

The following apply in Switzerland for the proportion of time spent inside dwellings [146]:

a) a reduction in cosmic radiation of 19%

b) an increase in terrestrial radiation of 19%.

The two factors together produce an increase in external irradiation of 7 mrem/yr.

For Germany [153] lengthy periods spent inside dwellings produce an average increase in the exposure from terrestrial radiation of 14 mrem/yr (minimum -32 mrem/yr; maximum +200 mrem/yr). If the average time spent inside dwellings is applied these values may be halved.

9.2. Radiation exposure from nuclear weapon tests

The long-lived fission products from nuclear weapon tests carried out principally in 1961 and 1962 also add to the dose exposure. The following dose rates were obtain in various countries of the Rhein-Maas Region for the year 1975 from measurements and estimates:

Switzerland [75]:

Whole body dose rate

| | | |
|---|---|---|
| a) | from external exposure from the air and inhalation | 0.1 mrem/yr |
| b) | from external exposure from the ground (Cs-137) | 2 mrem/yr |
| c) | from internal exposure from radionuclides ingested or inhaled (Sr-90) | 3 mrem/yr |
| | Total approximately | 5 mrem/yr |

Germany [153] :

Genetically significant dose rate

| | | |
|---|---|---|
| a) | from external irradiation from the ground | < 8 mrem/yr |
| b) | from internal irradiation from radionuclides ingested or inhaled | < 1 mrem/yr |
| | Total: | < 8 mrem/yr |

Netherlands [154]:

Gonad dose rate

| | |
|---|---|
| a) from external irradiation from the ground | 0.7 mrem/yr |
| b) from internal irradiation from radionuclides ingested or inhaled (Cs-137) | 0.2 mrem/yr |
| Total: | 0.9 mrem/yr |

Bone marrow dose rate

| | |
|---|---|
| from internal irradiation from radionuclides ingested or inhaled (Sr-90) | 1.2 mrem/yr |

These dose rates, which were calculated by national research institutes, lie between 2 and $<8$ mrem/yr. This large difference may be due to actual site differences or to the different methods of investigation used in the various countries. The second cause indicates the urgency to harmonise the different methods of measurement in the various countries.

## 9.3. Radiation exposure from the use of ionizing radiations and radionuclides in medicine

X-ray diagnosis gives rise to the greatest partial dose within the average applied dose. The application of radionuclides in nuclear medicine gives rise to a relatively small proportion of the average dose.

The average dose rates for the whole population for the year 1975 were :

Switzerland [75] :

X-ray diagnosis

| | |
|---|---|
| Whole body dose rate | 80 mrem/yr |
| Genetically significant dose rate | 43 mrem/yr |

Germany [153]:

| | Genetically significant dose rate | |
|---|---|---|
| **X-ray** diagnosis | approx. | 50 mrem/yr |
| Radiation therapy | $<$ | 1 mrem/yr |
| Nuclear medicine | approx. | 2 mrem/yr |

The situation is probably similar in the other countries of the Rhein-Maas Region. This short summary shows that the radiological impact of the population due to non nuclear sources is many times higher than the impact due to nuclear facilities.

## 10. Review and conclusions

The aim of this prospective regional study was to estimate the future radiological impact of the population in the Rhein-Maas Region attributable to nuclear facilities under normal operating conditions. This was to be followed up by the calculation of dose rates

- for the period 1985/90 on the basis of projected installations and sites
- for the period 2000/05 on the basis of the forecasted development of nuclear technology in the decades to come.

Its relatively high population density (approx. 270 inhabitants/km$^2$) coupled with a high level of industrial and energy production and highly developed agriculture makes the Rhein-Maas Region (approximately 222 000 km$^2$, approximately 60.4 million inhabitants) one of the key regions in Europe. It comprises, wholly or in part, eight western European countries.

The electricity generating capacity currently installed in the region totals approximately 60 GWe. Various electricity consumption forecasts suggest that by 2000/05 installed capacity will rise to approx. 150-300 GWe.

### Nuclear installations

Nuclear energy accounts for approximately 7.5 GWe of current electricity production in the Rhein-Maas Region. Plans for future nuclear installations and sites suggest that this capacity will rise to approx. 55 GWe by around 1985/90, and on the basis of predicted developments in nuclear technology it will have doubled to total approx. 110 GWe by 2000/05. The latest forecasts show that nuclear technology will develop at only two thirds to three quarters of the growth rate originally assumed. This means that the nuclear capacity planned originally for 1985/90 will not be installed until three to five years later and the capacity forecast for 2000/05 about seven to twelve years later. This rescheduling applies also to the dose rates calculated in the present investigation.

The projected installations which form part of the nuclear infrastructure will have the following installed capacity by 1985/90 :

- enrichment plants: approx. 2 000 t/yr $UF_6$
- fuel element fabrication plants: approx. 1 400 t/yr
- fuel reprocessing plants: approx. 40 t/yr.

As no specific forecasts are available for these installations it was assumed that their capacity would double in the period 1985/90 - 2000/05, in line with the doubling of the nuclear generating capacity.

In order to take into account the radiological exposure of the population of the region attributable to nuclear installations situated outside it the latter were grouped into those within a near distance zone of 100 km and those situated in a far distance zone between 100 and 400 km (in the case of large reprocessing plants, 1 000 km) from the region. The first category, which is the more important one, will, on the basis of plans for installations and sites, have the following generating and processing capacities by 1985/90:

- nuclear power stations: approx. 18 GWe
- enrichment plants: -
- fuel element fabrication plants: approx. 800 t/yr
- reprocessing plants: approx 1800 t/yr

Assuming that for every GWe of electricity produced a fuel supply and reprocessing capacity of approx. 35 t/yr is required, the ratio of nuclear capacites for the Rhein-Maas Region and the near distance zone is as follows:

fuel fabrication : fuel consumption : fuel reprocessing
= 0.86: 1: 0.72

It was assumed as for the Rhein-Maas Region that in the near distance zone and far distance zone nuclear generating and processing capacity would double in the period 1985/90 to 2000/05.

Calculation of radiological exposure attributable to nuclear installations in the Rhein-Maas Region and surrounding zones

The aim of this investigation was to calculate for the organs given below the probable dose rates attributable to radioactive releases from nuclear installations:

Bones, gastro-intestinal tract, gonads, liver, lungs, skin and thyroid gland and for the whole body.

The results were to be presented in the following form

- local individual dose rates
- individual dose rate distributions and average and maximum individual dose rates
- collective dose rates
- a classification of dose rate according to the type of radionuclide and the exposure pathway concerned.

As a first step the main stages in computing the individual radiological contributions via the various pathways and the total organ-related exposure were then established. As selection of the mode of presentation of the dose rates for a given pathway was determined by the basic data available, the value of the results varied from case to case and these were presented and annotated in detail.

The calculations of the dose rates was based on the release rates for 17 fission and activation products. Investigations and assessments conducted so far have shown that the following radionuclides are responsible for the greater part of the total radiological exposure:

H-3, C-14, Ar-41, Co-58, Co-60, Kr-85, Kr-88, Sr-89, Sr-90, Ru-106, I-129, I-131, Xe-133, Xe-135, Cs-134, Cs-137 and Ce-144.

The actinides were not taken into account since they are a radionuclide group about which too little is known.

Where installations had been operating for any length of time average values were established on the basis of release rates measured in the preceding years and these were then used as a basis for the calculations.

In the case of installations which had been operating for a short period only or which are still to be comissioned, values were used which appeared to be realistic probable values.

Exposure was calculated via the main exposure pathways: i.e.

in the case of gaseous releases with the exhaust air

- external radiation attributable to activity in the stack plum
- external radiation attributable to activity deposited on the ground
- internal radiation attributable to activity inhaled
- internal radiation attributable to activity ingested with food

in the case of liquid releases with the waste water

- external radiation attributable to activity in the water
- external radiation attributable to activity deposited on the ground (in flood plains)
- internal radiation attributable to activity ingested with drinking water
- internal radiation attributable to activity ingested with food (fish, irrigated agricultural produce).

Finally, the following criteria were also taken into account for the investigations

- the meteorological characteristics of the region (frequency of weather categories, wind direction, wind velocity, precipitation, etc.)
- the hydrological characteristics of the Rhein-Maas catchment area (flow rates, flow velocity, suspended matter content, etc)
- the regional structure of the population (recorded at district level or in the case of immediate proximity of nuclear installations at community level)

- the regional structure of agricultural production (proportion of total area represented by arable land and pasture, proportion of total agricultural production represented by the various agricultural products, yields etc.)
- regional structure of drinking water supply, in so far as the surface water is involved (quantities drawn off, treatment processes, proportion of ground water added, etc.)
- the regional structure of yields from freshwater fishing
- quantities consumed by average population according to age.

A section added later was better able to illustrate the uncertain factors and inaccuracies in the models and basic data used. The aim was to give some idea of the inaccuracies, which in the case of several individual parameters can be of an order of magnitude.

The calculations were performed on the basis of parameters which are summarized again here:

- basic data on the nuclear installations and their releases, and on the population affected, including its structure and supply sources;
- models of the transport processes of the radionuclides emitted and the exposure via the various exposure pathways;
- objectives with regard to the results to be obtained.

The assumptions which had to be made for simplification and their effect on the results were clearly shown. The main ones were that:

- the model of a population remaining at its place of residence leads to overestimation of the external radiation and of exposure via the inhalation pathway in the case of population near the site and to underestimation of the exposure of the population living further away

- ignoring the screening effect of house walls, and in the case of beta radiation, also of clothing, leads to overestimation of external exposure
- the model of self-sufficient agriculture in a small area also leads to overestimation of exposure via the ingestion pathway in the vicinity of the site and to underestimation at locations further away from the site
- ignoring the decay period of the radionuclides in food between harvest and consumption and possibly also the attenuation of the radionuclides deposited on surfaces due to the food being cleaned leads to overestimation of exposure via the ingestion pathway
- the frequency of periods spent on river banks in inundation areas is based on data for keen anglers as no other data were available. The frequency of visits by this group to river banks was used as a basis for calculating maximum external exposure
- ignoring decontamination the decay period of the radionuclides in the pipework of the water authority between intake and draw-off for consumption leads to overestimation of the exposure via the drinking water pathway
- the model in which fish are assumed to remain in one location overestimates the maximum dose rates and underestimates the minimum dose rates via this exposure pathway
- fresh water fish consumption is based on data from professional fishing families for the calculation of the maximum exposure via this pathway
- quantities of water taken from rivers for irrigation purposes were merely estimated in terms of order of magnitude as there were no statistical data available. The assumption that vegetables derive all their water from irrigation represents a conservative estimate. As mentioned earlier, if the reduction in activity due to cleaning the food is ignored, the exposure via this pathway is overestimated.

Main results

The following is a selection of conclusions for the main dose rates for the organs, bones, skin, thyroid gland and whole body, resulting from the "first pass" of discharges from facilities within the Rhein-Maas Region and the two surrounding zones.

Maximum individual dose rates (within the Rhein-Maas Region)

| Organs | Gaseous releases [mrem/yr] | | Liquid releases [mrem/yr] | |
|---|---|---|---|---|
| | 1985/90 | 2000/05 | 1985/90 | 2000/05 |
| Whole body | 1.02 | No major changes anticipated | 1.22 | Expected to double approximately |
| Bones | 1.08 | | 1.62 | |
| Skin | 1.26 | | 1.22 | |
| Thyroid gland | 10.8 | | 0.57 | |

Average individual dose rates (related to the whole population of the Rhein-Maas Region)

| Organs | Gaseous releases [mrem/yr] | | Liquid releases [mrem/yr] | |
|---|---|---|---|---|
| | 1985/90 | 2000/05 | 1985/90 | 2000/05 |
| Whole body | 7.81 (-3) | 1.56 (-2) | 6.21 (-3) | 2.22 (-2) |
| Bones | 1.09 (-2) | 2.18 (-2) | 1.01 (-2) | 3.67 (-2) |
| Skin | 2.92 (-2) | 5.84 (-2) | 6.21 (-3) | 2.22 (-2) |
| Thyroid gland | 1.79 (-2) | 3.58 (-2) | 4.69 (-3) | 1.83 (-2) |

The maximum individual dose rates which can be expected in 1985/90 - they were mainly calculated for infants and children - are, with the exception of the thyroid gland, in the range of 1 to 2 mrem/yr. Dose rates of approx. 10 mrem/yr via the gaseous discharge pathway can occur in the thyroid gland. The maximum dose rates calculated for exposure via the gaseous discharge pathway were arrived at by adding together the individual exposure pathways at the same location, while the maximum dose rates shown for the liquid effluent pathway were calculated on the basis of the maximum values occurring at various locations for the individual exposure pathways. The individual dose rates so calculated for liquid effluent are thus the sums of the maximum individual contributions, which are higher than the maximum dose rates actually occurring. Summation of the maximum dose rates for both forms of discharge should be seen in the same light.

The average individual dose rates which can be expected to occur in 1985/90 fall within the range of approx. 0.5 (-2) to 3 (-2) mrem/yr. As the dose rates are to be understood as average values distributed over the whole population, it is possible to calculate the sums of the dose rates attributable to the two forms of discharge. These rates fall within the range of approx. 1.5 (-2) to 3.5 (-2) mrem/yr.

The determining factor in the extrapolation of these values into the period 2000/05 is a doubling of the nuclear generating and processing capacity and consequently doubling of the integral release rates and doubling of the use of surface water for drinking water supply and irrigation purposes.

If it is assumed that current site distribution and the number of installations on each site are not going to change radically, there will be little or no effect on maximum dose rates attributable to gaseous releases. Average dose rates will double.

The maximum dose rates attributable to liquid releases can be expected to double as concentrations in surface waters will also double. The average individual dose rates can be expected to double, treble or quadruple, depending on the exposure pathway concerned as there will be the added effect of a doubling of river water consumption.

An analysis of the contributions of the various exposure pathways showed, with the exception of the skin, that exposure attributable to gaseous releases for all the organs considered occurred in more than 50% of the cases via the ingestion pathway. The radionuclides H-3 and C-14 were largely responsible; while in the case of the thyroid I-131 occurred as a dominant nuclide. The external plume radiation (mainly attributable to the Kr and Xe isotopes) and external ground radiation (mainly attributable to Cs isotopes) contribute roughly the same amount, which varies between 10 and 20 percent depending on the organ involved. The contribution from inhalation is less than 5%. 75% of the dose rate to the skin is dependent on external plume radiation, the most important radioactive noble gas being Kr-85. Radionuclides H-3, C-14 and Cs-137 are also present to a correspondingly lesser degree. 99% of exposure attributable to liquid releases via external ground radiation is caused by Co and Cs isotopes. The main contributors through the drinking water pathway and the 'irrigated products' pathway are H-3, Sr-90 and I-131 (thyroid gland). As regards the fish pathway, more than 80% of the dose rate is attributable to Cs isotopes and I-131 (thyroid gland).

A comparison of radiological exposure in the region with global exposure

The dose rates attributable to releases in the Rhein-Maas Region should be compared with the dose rates caused by releases from nuclear installations in the world context.

A report by the UK-NRPB [83] shows that the individual dose rates given below can be expected in these latitudes as a result of global releases of radionuclides H-3, C-14 and Kr-85 - to these are added the regional releases once they have gone through the 'first pass' and left the region - :

1985 (580 GWe) :

whole body: 0.6 (-2) mrem/yr; skin: 0.4 mrem/yr

2000 (3160 GWe):

whole body: 3.6 (-2) mrem/yr; skin: 2.5 mrem/yr.

The ratio of the average individual dose rates attributable to regional releases to dose rates attributable to global releases is as follows:

| | | regional releases "first pass" | | global releases |
|---|---|---|---|---|
| 1985: | whole body dose rate | 1 | : | 0.43 |
| | skin dose rate | 1 | : | 11.3 |
| 2000: | whole body dose rate | 1 | : | 0.95 |
| | skin dose rate | 1 | : | 31.0 |

The comparison shows that the whole body dose rate resulting from global releases is of the same order of magnitude as that attributable to regional releases ("first pass"). In the case of the skin dose rate, however, the exposure attributable to global releases is more significant. This is explained by the accumulation of Kr-85 in the atmosphere, it was assumed in the UK-NRPB report that there was total release of this isotope during reprocessing.

The sharp rise in exposure levels attributable to global releases in the period 1985/2000 is based on the assumption that world-wide installed nuclear capacity according to the UK-NRPB report will increase approximately five-fold in the period in question while in the Rhein-Maas Region merely a doubling of capacity has been forecast.

Comparison with statutory levels

The dose rates established

- must be compared with the statutory dose rate limits in order to ensure that the latter are being observed
- can be compared with dose rates from other sources in order to assess the proportion of overall radiological exposure attributable to nuclear technology.

The following statutory limits of the six countries in the Rhein-Maas Region are given below. They appear in a report [155]*) on the statutory limits in a number of European countries.

| | |
|---|---|
| Switzerland: | concentration limits/site |
| Germany: | whole body: 30(+30)mrem/yr/all nuclear installations<br>thyroid gland: 90 mrem/yr/all nuclear installations |
| France: | discharge rate limits/site |
| Luxembourg: | probably as Germany |
| Belgium: | as USA (10CFR50, Annex I) (only LWRs)<br>whole body: gaseous discharge pathway/5 mrem/yr/installation<br>liquid effluent pathway 3mrem/yr/installation<br>skin: gaseous discharge pathway/15 mrem/yr/installation<br>each organ: liquid effluent pathway/10 mrem/yr/installation |

*) This report is of preliminary character. The whole section has to be seen in this light.

each organ: radioiodine 15 mrem/yr/installation

Netherlands: each organ: 30 mrem/yr/site.

These limits apply to the release rates or resultant dose rates

- of any one particular nuclear installation: Belgium (only LWRs)
- of a site with nuclear facilities: Switzerland, France, Netherlands
- of all nuclear installations, Germany, Luxembourg

The third concept is more suited to the problem of limiting radiological exposure in any one region. This should be applied to the whole region in the comparison being attempted.

A comparison with the calculated maximum individual dose rates for 1985/90 shows that even if the maximum values for gaseous discharge and liquid effluent radiation are added together - and it should be remembered that this addition is an overestimate - the total resultant dose rates are still lower by a factor of 13 (whole body dose rate) or 8 (thyroid gland dose rate) than the dose rate limits applied of 30 mrem/yr and 90 mrem/yr respectively. The dose rates which can be expected in 2000/05 - and of the increases so far assumed it is really only the maximum dose rates via the liquid effluent pathway which will double - will still be lower than the dose rate limits applied, viz. by a factor of 9 for the whole body dose rate and a factor of 7.5 for the thyroid gland dose rate.

This comparison shows that on the basis of the assumptions made in this investigation maximum dose rates attributable to releases from nuclear installations in the Rhein-Maas Region and bordering areas may occur by the period 2000/05 which are approximately one order of magnitude lower than the 30/90 mrem/yr dose rate limits applied to the whole region.

If dose rates increase to such an extent that they are close to the statutory limits - and this could occur if

- further nuclear installations are built which consequently increase the total release rates of radioactive substances
- new knowledge makes necessary a revision of the models and the basic parameters used hitherto

- the statutory dose rate limits are lowered

measures will have to be taken, such as a reduction of the amounts of activity released from each nuclear plant, to ensure that the dose rate limits are not exceeded. In order to avoid putting unfavourably situated sites at a disadvantage, for example sites on the lower reaches of rivers, all countries within the region would have to reach agreement, which is a step that this report can do no more than suggest.

An international agreement in a world-wide context will in the long term be equally necessary to limit the global radiological exposure caused by world-scale nuclear technology.

## Radiological exposure attributable to non-nuclear sources

A comparison of dose rates attributable to other sources in terms of whole body exposure is given below

| Type of exposure | Dose rate [mrem/yr] | [%] |
|---|---|---|
| Exposure to natural radiation in the Rhein-Maas Region | 75-260 | approx.63 |
| Exposure to radiation (average level) attributable to medical diagnosis and treatment (1975) | 50-80 | approx.34 |
| Exposure to radiation attributable to nuclear weapon tests (1975) | 1-3 | approx.3 |
| Exposure to radiation (average level) attributable to nuclear installations in the Rhein-Maas Region (2000) | 0.038 (max:3.46) | 0.02 (max : 2) |
| Exposure to radiation attributable to global nuclear technology (2000) | 0.036 | 0.02 |
| Total | approx.175 | 100 |

As the Table shows, the releases from all nuclear installations in the Rhein-Maas Region in 2000/05, will contribute on average 0.038 mrem/yr or approx.0.02% to the total whole-body dose. In the case of persons exposed to maximum dose*) in mathematical terms this increases to 3.46 mrem/yr or 2%. The exposure

*) critical group

Potential risk from nuclear installations in normal operation and natural risk[1)]

| Organ | Damage | Dose-effect relationship [157] [rem$^{-1}$] | Probability of occurrence due to nuclear installations (around 2000/05) [yr$^{-1}$] | Probability of occurence due to natural causes[1)] [157] [yr$^{-1}$] m[2)] | f[2)] | Ratio of probability of occurrence due to nuclear installations / Probability of occurence due to natural causes |
|---|---|---|---|---|---|---|
| Whole body | Leukaemia | 2 (-5) | 7.6 (-10) | 7.8 (-5) | 6.1 (-5) | approx. 1 (-5) |
| Bones | Bone cancer | 0.5 (-5) | 2.9 (-10) | 3.2 (-5) | 1.9 (-5) | approx. 1 (-5) |
| Gastro-intestinal tract | Cancer of the gastro-intestinal tract | 3 to 4 (-5) | 11.4 to 15.2 (-10) | 109.5 (-5) | 87.1 (-5) | approx.0.15 (-5) |
| Lungs | Lung cancer | 2 to 2.5 (-5) | 7.6 to 9.5 (-10) | 109.6 (-5) | 19.9 (-5) | approx.0.15 (-5) |
| Thyroid gland | Cancer of the thyroid gland | 5 to 10 (-5) | 27 to 54 (-10) | 0.8 (-5) | 2.4 (-5) | approx. 25 (-5) |

1) natural risk = genuine natural risk + risk resulting from civilisation

2) m = male, f = female

attributable to nuclear technology in the region should be seen in relation to the non-nuclear exposure, above all natural exposure, which locally fluctuates in the region between 75-260 mrem/yr.

Assessment of the potential risk

As index for risk the probability of damage from low dose exposure is defined. A very conservative model is used in general 'no threshhold dose, linear dose-effect relationship'. This concept is to be understood "as working hypotheses and not as proven facts" [156]. The risk anticipated in 2000/05 on the basis of this conservative concept was estimated with the aid of dose effect relationships [157] and is reviewed here.

As the table shows, the ratio of the anticipated average probability of damage occurring on the basis of the conservative dose-effect model to the probability of a naturally occurring damage[x)] is 1 : 10 000 to 1 : 1 000 000 depending on the type of damage in question. Risks in this realm of probability cannot be processed statistically.

Necessary expansion and development work

The investigation performed on the basis of present knowledge shows that the radiological impact expected up to the end of the century is of an order of magnitude that gives no cause for concern. Natural exposure and the exposure from medical diagnosis and treatment are many times higher than the exposure from nuclear technology. As has already been pointed out in the various sections of the report, the important basic data for investigations of this type must be continuously developed and critically followed up.

The new knowledge gained in the course of this study suggests that the following tasks should be given priority in any further work on this project:

- further study of projected installations and sites and forecasts in the field of nuclear technology as it is likely that the discussions currently in progress will have some bearing on this matter;

x) natural risk = genuine natural risk + risk resulting from civilisation.

- further study of the release rates of operational nuclear installations and any new installations,[*)]
- further study of plans for Pu-recycling in light water reactors and the consideration of the expected changes in the release spectrum caused by this.
- extension of the list of nuclides to include the most important actinides as soon as adequate data are available;
- improvement of the transport, transfer and bioaccumulatic models which describe the path by which the radionuclides released reach man, with improvements to the relevant data;
- more accurate data on the water taken from rivers for irrigation purposes, further work on forecasts of drinking water supply and extensions to irrigated areas as exposure via this pathway will become more significant in future;
- coverage of further links in the nuclear infrastructure, such as the transport of nuclear material and the final storage of waste - wherever relevant data are available.

Possible investigations on radiological exposure beyond the immediate future

This study examined the radiological exposure which can be expected in the Rhein-Maas Region up to the end of the century due to the use of nuclear technology. The period of time covered by the study is thus the immediate future.

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*) "While much research and development work has been done, there remains a shortage of commercial plant operating experience upon which estimates of future performance can be reliably based. This is especially true of those operations that will generate the wastes of greatest concern: fuel preparation, fabrication, and reprocessing." [158]

Energy forecasts suggest, however, that this period represents only the beginning of the large-scale use of nuclear energy. While it was assumed here that within the period under review light-water reactors will predominate, the large-scale use of nuclear energy will essentially be on the basis of breeder reactors. This type of reactor will ensure that effective, long-term exploitation of the heavy elements uranium and thorium is possible via the plutonium-uranium cycle and the uranium-thorium cycle.

The next logical step to follow this study should therefore be an investigation of radiological exposure over and beyond the period 2000/05 and forecasts of the use of advanced reactor types and the supporting nuclear infrastructure should be used as a basis for any investigation of this kind. Questions which have to be answered within these further investigations are:

- are there isotopes which cause long-term concern?
- in this case are additional decontamination measurements required?
- will a state of equilibrium be reached and in what way?

These investigations should be conducted for an economic conglomeration on a larger scale, within which the nuclear power station capacity is backed by corresponding capacity in the main installations of the infrastructure. For this reason it appears appropriate that the investigations should be extended to cover all the industrialized regions of Western and Central Europe.

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Table 3-1: Drinking Water Supply from Surface Water via Direct Treatment, Bank Filtration, and Ground Water Enrichment in the Rhein-Maas Region
(Position and Capacity of Catchment Stations: see Fig. 3-4)
See footnotes at the end of this list.

| NO. | WATER WORKS | POPULAT. 1) | DIRECT TREATMENT WAT.BODY 3) | RD 4) | O/O 5) | BANK FILTRATION WAT.BODY | RD | O/O | GROUND WATER ENRICHMENT WAT.BODY | RD | O/O | DELAY 2) (D) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KONSTANZ | 66000 | BODENSEE | 1 | 100.0 | | | | | | | 0 |
| 2 | KREUZLINGEN | 27000 | BODENSEE | 2 | 91.5 | | | | | | | 0 |
| 3 | STUTTGART | 612300 | BODENSEE | 8 | 59.6 | | | | | | | 15 |
| 4 | ESSLINGEN | 97399 | BODENSEE | 8 | 22.0 | | | | | | | 15 |
| 5 | HEILBRONN | 126300 | BODENSEE | 8 | 34.2 | | | | | | | 15 |
| 6 | KIRCHHEIM TECK | 127199 | BODENSEE | 8 | 39.6 | | | | | | | 15 |
| 7 | PFORZHEIM | 99600 | BODENSEE | 8 | 18.3 | | | | | | | 15 |
| 8 | CRAILSHEIM | 114399 | BODENSEE | 8 | 12.8 | | | | | | | 15 |
| 9 | LUDWIGSBURG | 81800 | BODENSEE | 8 | 43.1 | | | | | | | 15 |
| 10 | KEMNAT | 100000 | BODENSEE | 8 | 59.2 | | | | | | | 15 |
| 11 | REUTLINGEN | 93500 | BODENSEE | 8 | 47.2 | | | | | | | 15 |
| 12 | VILLINGEN-SCHW. | 79399 | BODENSEE | 8 | 69.5 | | | | | | | 15 |
| 13 | SINDELFINGEN | 54899 | BODENSEE | 8 | 91.1 | | | | | | | 15 |
| 14 | TUEBINGEN | 73899 | BODENSEE | 8 | 51.9 | | | | | | | 15 |
| 15 | BOEBLINGEN | 73000 | BODENSEE | 8 | 23.1 | | | | | | | 15 |
| 16 | SINSHEIM | 650000 | BODENSEE | 8 | 16.4 | | | | | | | 15 |
| 17 | BOEBLINGEN | 41600 | BODENSEE | 8 | 49.7 | | | | | | | 15 |
| 18 | EBINGEN | 27300 | BODENSEE | 8 | 20.9 | | | | | | | 15 |
| 19 | HECHINGEN | 44399 | BODENSEE | 8 | 7.8 | | | | | | | 15 |
| 20 | FELLBACH | 42899 | BODENSEE | 8 | 33.5 | | | | | | | 15 |
| 21 | TUTTLINGEN | 32800 | BODENSEE | 8 | 23.6 | | | | | | | 15 |
| 22 | KORNWESTHEIM | 28300 | BODENSEE | 8 | 52.3 | | | | | | | 15 |
| 23 | KORNTAL | 31699 | BODENSEE | 8 | 29.2 | | | | | | | 15 |
| 24 | NUERTINGEN | 24500 | BODENSEE | 8 | 59.8 | | | | | | | 15 |
| 25 | TAILFINGEN | 17000 | BODENSEE | 8 | 64.4 | | | | | | | 15 |
| 26 | NECKARSULM | 22100 | BODENSEE | 8 | 45.1 | | | | | | | 15 |
| 27 | LEONBERG | 25300 | BODENSEE | 8 | 81.3 | | | | | | | 15 |
| 28 | BIETIGHEIM | 23199 | BODENSEE | 8 | 50.3 | | | | | | | 15 |
| 29 | ROTTWEIL | 24600 | BODENSEE | 8 | 81.1 | | | | | | | 15 |
| 30 | UEBERLINGEN | 14199 | BODENSEE | 8 | 74.2 | | | | | | | 10 |
| 31 | GERLINGEN | 18100 | BODENSEE | 8 | 100.0 | | | | | | | 15 |
| 32 | TROSSINGEN | 11399 | BODENSEE | 8 | 100.0 | | | | | | | 15 |
| 33 | ST. GEORGEN | 12000 | BODENSEE | 8 | 54.0 | | | | | | | 15 |
| 34 | MAGSTADT | 8000 | BODENSEE | 8 | 98.2 | | | | | | | 15 |
| 35 | LAUFFEN | 9100 | BODENSEE | 8 | 96.5 | | | | | | | 15 |
| 36 | MEERSBURG | 5000 | BODENSEE | 8 | 97.2 | | | | | | | 0 |
| 37 | FRIEDRICHSHAFEN | 50399 | BODENSEE | 19 | 77.7 | | | | | | | 0 |
| 38 | ST. GALLEN | 80000 | BODENSEE | 25 | 87.1 | | | | | | | 10 |
| 39 | ARBON | 20000 | BODENSEE | 25 | 100.0 | | | | | | | 10 |
| 40 | ROHRSCHACH | 19000 | BODENSEE | 25 | 100.0 | | | | | | | 15 |
| 41 | AMRISWIL | 10000 | BODENSEE | 25 | 89.0 | | | | | | | 5 |
| 42 | THAL | 5000 | BODENSEE | 25 | 100.0 | | | | | | | 15 |
| 43 | ROMANSHORN | 11000 | BODENSEE | 25 | 100.0 | | | | | | | 5 |
| 44 | LINDAU | 24500 | BODENSEE | 38 | 81.8 | | | | | | | 0 |
| 45 | MANNHEIM | 334300 | | | | NECKAR | 10 | 18.9 | | | | 0 |
| 46 | FRANKFURT | 659899 | | | | MAIN | 21 | 5.3 | MAIN | 21 | 9.2 | 0 |
| 47 | BAD HOMBURG | 52800 | | | | MAIN | 21 | 1.5 | MAIN | 21 | 2.6 | 0 |
| 48 | SCHWALBACH TS | 15100 | | | | MAIN | 21 | 4.4 | MAIN | 21 | 7.7 | 0 |
| 49 | FRANKFURT | 200000 | | | | MAIN | 21 | 3.5 | MAIN | 21 | 6.1 | 0 |
| 50 | WUERZBURG | 117000 | MAIN | 260 | 38.7 | | | | | | | 0 |

Table 3-1:(cont.)

| NO. | WATER WORKS | POPULAT. | DIRECT TREATMENT | | | BANK FILTRATION | | | GROUND WATER ENRICHMENT | | | DELAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | WAT.BODY | RD | O/O | WAT.BODY | RD | O/O | WAT.BODY | RD | O/O | (D) |
| 51 | MOSELGEMEINDEN | 95000 | | | | MOSEL | 100 | 60.0 | | | | 0 |
| 52 | TRIER | 109100 | | | | MOSEL | 190 | 0.8 | | | | 0 |
| 53 | BASEL | 270000 | | | | | | | RHEIN | 160 | 95.0 | 0 |
| 54 | SPEYER | 44000 | | | | RHEIN | 393 | 15.2 | | | | 0 |
| 55 | SCHIFFERSTADT | 57199 | | | | RHEIN | 410 | 12.2 | | | | 0 |
| 56 | LUDWIGSHAFEN | 179100 | | | | RHEIN | 422 | 20.0 | | | | 0 |
| 57 | MAINZ | 60000 | | | | RHEIN | 500 | 100.0 | | | | 0 |
| 58 | WIESBADEN | 150000 | | | | | | | RHEIN | 507 | 45.0 | 0 |
| 59 | RHEINLAND-PFALZ | 45000 | | | | RHEIN | 560 | 60.2 | | | | 0 |
| 60 | KOBLENZ | 138000 | | | | RHEIN | 588 | 82.6 | | | | 0 |
| 61 | BENDORF | 15399 | | | | RHEIN | 599 | 61.7 | | | | 0 |
| 62 | WEISSENTHURM | 21600 | | | | RHEIN | 600 | 85.3 | | | | 0 |
| 63 | NEUWIED | 62899 | | | | RHEIN | 606 | 50.0 | | | | 0 |
| 64 | ANDERNACH | 29199 | | | | RHEIN | 609 | 61.7 | | | | 0 |
| 65 | RHEINLAND-PFALZ | 12300 | | | | RHEIN | 620 | 50.0 | | | | 0 |
| 66 | RHEINLAND-PFALZ | 43100 | | | | RHEIN | 630 | 50.1 | | | | 0 |
| 67 | BONN | 64600 | | | | RHEIN | 650 | 50.0 | | | | 0 |
| 68 | KOELN | 573800 | | | | | | | RHEIN | 690 | 17.9 | 0 |
| 69 | NEUSS | 118899 | | | | RHEIN | 730 | 10.0 | | | | 0 |
| 70 | WUPPERTAL | 408699 | | | | RHEIN | 740 | 24.9 | | | | 0 |
| 71 | DUESSELDORF | 675899 | | | | RHEIN | 750 | 60.0 | | | | 0 |
| 72 | DUISBURG | 332199 | | | | RHEIN | 760 | 19.3 | | | | 0 |
| 73 | KREFELD | 225000 | | | | | | | RHEIN | 764 | 21.7 | 0 |
| 74 | DUISBURG-HAMBORN | 105000 | | | | RHEIN | 782 | 29.5 | | | | 0 |
| 75 | DORDRECHT | 105300 | WAAL | 10 | 90.2 | | | | | | | 0 |
| 76 | BERGAMBACHT | 105300 | | | | LEK | 52 | 100.0 | | | | 0 |
| 77 | JUTPHAAS | 1573899 | | | | | | | LEK | 98 | 100.0 | 0 |
| 78 | AMSTERDAM | 315000 | LEK | 98 | 100.0 | | | | | | | 3 |
| 79 | ANDIJK | 200500 | LEK | 146 | 100.0 | | | | | | | 300 |
| 80 | BERGAMBACHT | 684199 | | | | | | | MAAS | 6 | 97.2 | 0 |
| 81 | ROTTERDAM | 621000 | MAAS | 10 | 100.0 | | | | | | | 0 |
| 82 | ANTWERPEN | 600000 | MAAS | 281 | 100.0 | | | | | | | 80 |
| | SUM | 12656376 | | | | | | | | | | |

1) Populat. = number of people who are supplied with water from the Water works
2) Delay = delay between removing from water body and supplying to drinking-water systems
3) Wat.Body = water body from which the surface water is caught
4) RD = river distance of catchment station
5) % = portion of total drinking water supplied by surface water

Table 3-2: Area and Population Data of the Rhein-Maas Region (RMR)

| Country | Total [17] | | | Belonging zu the Rhein-Maas Region | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area [km$^2$] | Population | Population Density [km$^{-2}$] | Area [km$^2$] | % of the Country | % of the RMR | Population | % of the Country | % of the RMR | Population Density [km$^{-2}$] |
| CH | 41 288 | 6 443 000 | 156 | 28 000 | 68 | 12.59 | 5 066 100 | 79 | 8.38 | 181 |
| FL | 156 | 23 600 | 151 | 156 | 100 | 0.07 | 23 600 | 100 | 0.04 | 151 |
| A | 83 850 | 7 530 000 | 90 | 2 600 | 3 | 1.17 | 307 200 | 4 | 0.51 | 118 |
| D | 248 576 | 62 054 000 | 250 | 113 000 | 45 | 50.82 | 35 846 700 | 58 | 59.32 | 317 |
| F | 547 026 | 52 510 000 | 96 | 34 300 | 6 | 15.43 | 4 055 300 | 8 | 6.71 | 118 |
| L | 2 586 | 340 000 | 131 | 2 586 | 100 | 1.16 | 340 000 | 100 | 0.56 | 131 |
| B | 30 513 | 9 800 000 | 321 | 14 900 | 49 | 6.70 | 2 687 600 | 27 | 4.45 | 180 |
| NL | 40 844 | 13 540 000 | 331 | 26 800 | 66 | 12.05 | 12 105 900 | 89 | 20.03 | 452 |
| RMR | | | | 222 342 | | | 60 432 400 | | | 272 |

Table 3-3: Areas and Population of Administration Districts within the Rhein-Maas Region
(Position of the Districts: see Fig. 3-5)
See footnotes at the end of this list

| NO. | NAME OF DISTRICT | | AREA /KM2/ | POPULAT. | COUNTRY |
|---|---|---|---|---|---|
| 1 | AUBONNE | BZ | 153.0 | 7856 | CH |
| 2 | AVENCHES | BZ | 67.7 | 5036 | CH |
| 3 | COSSONAY | BZ | 193.0 | 12508 | CH |
| 4 | ECHALLENS | BZ | 131.0 | 9887 | CH |
| 5 | GRANDSON | BZ | 176.0 | 11982 | CH |
| 6 | MOUDON | BZ | 124.0 | 10197 | CH |
| 7 | ORBE | BZ | 210.0 | 16547 | CH |
| 8 | ORON | BZ | 75.9 | 5664 | CH |
| 9 | PAYERNE | BZ | 107.0 | 12736 | CH |
| 10 | LA VALLEE | BZ | 173.0 | 7703 | CH |
| 11 | YVERDON | BZ | 157.0 | 27647 | CH |
| 12 | LA BROYE | BZ | 227.0 | 15607 | CH |
| 13 | LA GLANE | BZ | 169.0 | 14023 | CH |
| 14 | LA GRUYERE | BZ | 498.0 | 28017 | CH |
| 15 | LA SARINE | BZ | 216.0 | 66587 | CH |
| 16 | SEE | BZ | 160.0 | 20087 | CH |
| 17 | SENSE | BZ | 265.0 | 28134 | CH |
| 18 | LA VEVEYSE | BZ | 134.0 | 7854 | CH |
| 19 | BOUDRY | BZ | 105.0 | 29543 | CH |
| 20 | LA CHAUX-DE-FONDS | BZ | 93.3 | 43518 | CH |
| 21 | LE LOCLE | BZ | 144.0 | 18860 | CH |
| 22 | NEUCHATEL | BZ | 79.7 | 52519 | CH |
| 23 | VAL-DE-RUZ | BZ | 128.0 | 10780 | CH |
| 24 | VAL-DE-TRAVERS | BZ | 166.0 | 13953 | CH |
| 25 | AARBERG | BZ | 153.0 | 25891 | CH |
| 26 | AARWANGEN | BZ | 154.0 | 38513 | CH |
| 27 | BERN | BZ | 233.0 | 255219 | CH |
| 28 | BIEL | BZ | 24.8 | 66247 | CH |
| 29 | BUEREN | BZ | 87.5 | 20142 | CH |
| 30 | BURGDORF | BZ | 197.0 | 41807 | CH |
| 31 | COURTELARY | BZ | 266.0 | 26442 | CH |
| 32 | DELEMONT | BZ | 269.0 | 27549 | CH |
| 33 | ERLACH | BZ | 86.9 | 9228 | CH |
| 34 | LES FRANCHES-MONTAGN. | BZ | 192.0 | 8303 | CH |
| 35 | FRAUBRUNNEN | BZ | 124.0 | 24920 | CH |
| 36 | FRUTIGEN | BZ | 489.0 | 15843 | CH |
| 37 | INTERLAKEN | BZ | 709.0 | 32981 | CH |
| 38 | KONOLFINGEN | BZ | 214.0 | 45444 | CH |
| 39 | LAUFEN | BZ | 82.8 | 14033 | CH |
| 40 | LAUPEN | BZ | 87.5 | 11594 | CH |
| 41 | MOUTIER | BZ | 283.0 | 31909 | CH |
| 42 | LA NEUVEVILLE | BZ | 58.9 | 5756 | CH |
| 43 | NIDAU | BZ | 88.5 | 31425 | CH |
| 44 | NIEDERSIMMENTAL | BZ | 306.0 | 18117 | CH |
| 45 | OBERHASLI | BZ | 551.0 | 7821 | CH |
| 46 | OBERSIMMENTAL | BZ | 333.0 | 7346 | CH |
| 47 | PORRENTRUY | BZ | 317.0 | 26135 | CH |
| 48 | SAANEN | BZ | 241.0 | 7307 | CH |
| 49 | SCHWARZENBURG | BZ | 157.0 | 8345 | CH |
| 50 | SEFTIGEN | BZ | 190.0 | 28127 | CH |
| 51 | SIGNAU | BZ | 320.0 | 24275 | CH |
| 52 | THUN | BZ | 267.0 | 75294 | CH |
| 53 | TRACHSELWALD | BZ | 191.0 | 23511 | CH |
| 54 | WANGEN | BZ | 129.0 | 23772 | CH |
| 55 | BALSTHAL-GAEU | BZ | 62.4 | 11961 | CH |
| 56 | BALSTHAL-TAL | BZ | 139.0 | 14065 | CH |
| 57 | BUCHEGGBERG | BZ | 62.7 | 5812 | CH |
| 58 | DORNECK | BZ | 75.0 | 11805 | CH |
| 59 | GOESGEN | BZ | 68.7 | 20349 | CH |
| 60 | KRIEGSTETTEN | BZ | 76.8 | 40758 | CH |
| 61 | LEBERN | BZ | 117.0 | 42330 | CH |
| 62 | OLTEN | BZ | 80.5 | 47986 | CH |
| 63 | SOLOTHURN | BZ | 6.2 | 17708 | CH |
| 64 | THIERSTEIN | BZ | 102.0 | 11359 | CH |
| 65 | BASEL-STADT | KT | 37.1 | 234945 | CH |
| 66 | ARLESHEIM | BZ | 96.1 | 122958 | CH |
| 67 | LIESTAL | BZ | 85.9 | 45135 | CH |
| 68 | SISSACH | BZ | 141.0 | 24746 | CH |
| 69 | WALDENBURG | BZ | 105.0 | 12050 | CH |
| 70 | ENTLEBUCH | BZ | 411.0 | 18001 | CH |
| 71 | HOCHDORF | BZ | 184.0 | 45206 | CH |
| 72 | LUZERN | BZ | 260.0 | 144129 | CH |
| 73 | SURSEE | BZ | 302.0 | 43049 | CH |
| 74 | WILLISAU | BZ | 338.0 | 39256 | CH |
| 75 | AARAU | BZ | 104.0 | 58747 | CH |
| 76 | BADEN | BZ | 153.0 | 92882 | CH |
| 77 | BREMGARTEN | BZ | 117.0 | 41003 | CH |
| 78 | BRUGG | BZ | 150.0 | 34995 | CH |
| 79 | KULM | BZ | 101.0 | 31138 | CH |
| 80 | LAUFENBURG | BZ | 152.0 | 18568 | CH |
| 81 | LENZBURG | BZ | 103.0 | 36946 | CH |
| 82 | MURI | BZ | 139.0 | 18818 | CH |
| 83 | RHEINFELDEN | BZ | 112.0 | 24145 | CH |
| 84 | ZOFINGEN | BZ | 142.0 | 52617 | CH |
| 85 | ZURZACH | BZ | 130.0 | 23425 | CH |
| 86 | OBWALDEN | KT | 492.0 | 24509 | CH |
| 87 | NIDWALDEN | KT | 274.0 | 25634 | CH |
| 88 | URI | KT | 1080.0 | 34091 | CH |
| 89 | EINSIEDELN | BZ | 110.0 | 10020 | CH |
| 90 | GERSAU | BZ | 14.4 | 1753 | CH |
| 91 | HOEFE | BZ | 37.7 | 14043 | CH |
| 92 | KUESSNACHT | BZ | 29.5 | 7956 | CH |
| 93 | MARCH | BZ | 177.0 | 21627 | CH |
| 94 | SCHWYZ | BZ | 454.0 | 36673 | CH |
| 95 | ZUG | KT | 239.0 | 67996 | CH |
| 96 | AFFOLTERN | BZ | 113.0 | 24131 | CH |
| 97 | ANDELFINGEN | BZ | 166.0 | 20112 | CH |
| 98 | BUELACH | BZ | 185.0 | 84046 | CH |
| 99 | DIELSDORF | BZ | 153.0 | 37654 | CH |
| 100 | HINWIL | BZ | 180.0 | 57910 | CH |

Table 3-3: (cont.)

| NO. | NAME OF DISTRICT | | AREA /KM2/ | POPULAT. | COUNTRY |
|---|---|---|---|---|---|
| 101 | HORGEN | BZ | 104.0 | 92346 | CH |
| 102 | MEILEN | BZ | 76.5 | 62174 | CH |
| 103 | PFAEFFIKON | BZ | 164.0 | 36593 | CH |
| 104 | USTER | BZ | 123.0 | 73019 | CH |
| 105 | WINTERTHUR | BZ | 251.0 | 122570 | CH |
| 106 | ZUERICH | BZ | 156.0 | 497233 | CH |
| 107 | OBERKLETTGAU | BZ | 41.7 | 3055 | CH |
| 108 | REIAT | BZ | 39.5 | 5806 | CH |
| 109 | SCHAFFHAUSEN | BZ | 101.0 | 53052 | CH |
| 110 | SCHLEITHEIM | BZ | 43.5 | 2563 | CH |
| 111 | STEIN | BZ | 31.2 | 4560 | CH |
| 112 | UNTERKLETTGAU | BZ | 41.4 | 3818 | CH |
| 113 | ALBULA | BZ | 723.0 | 7512 | CH |
| 114 | GLENNER | BZ | 697.0 | 11404 | CH |
| 115 | HEINZENBERG | BZ | 264.0 | 8543 | CH |
| 116 | HINTERRHEIN | BZ | 471.0 | 2503 | CH |
| 117 | IMBODEN | BZ | 205.0 | 12692 | CH |
| 118 | OBERLANDQUART | BZ | 670.0 | 18655 | CH |
| 119 | PLESSUR | BZ | 266.0 | 37305 | CH |
| 120 | UNTERLANDQUART | BZ | 347.0 | 18553 | CH |
| 121 | VORDERRHEIN | BZ | 564.0 | 8698 | CH |
| 122 | GLARUS | KT | 684.0 | 38155 | CH |
| 123 | ST.GALLEN | BZ | 71.0 | 88023 | CH |
| 124 | RORSCHACH | BZ | 49.6 | 31960 | CH |
| 125 | UNTERRHEINTAL | BZ | 50.6 | 33166 | CH |
| 126 | OBERRHEINTAL | BZ | 98.3 | 22105 | CH |
| 127 | WERDENBERG | BZ | 207.0 | 23923 | CH |
| 128 | SARGANS | BZ | 518.0 | 28981 | CH |
| 129 | GASTER | BZ | 136.0 | 9815 | CH |
| 130 | SEE | BZ | 122.0 | 32239 | CH |
| 131 | OBERTOGGENBURG | BZ | 224.0 | 11853 | CH |
| 132 | NEUTOGGENBURG | BZ | 103.0 | 14458 | CH |
| 133 | ALTTOGGENBURG | BZ | 121.0 | 13456 | CH |
| 134 | UNTERTOGGENBURG | BZ | 107.0 | 30418 | CH |
| 135 | WIL | BZ | 79.7 | 23685 | CH |
| 136 | GUSSAU | BZ | 77.8 | 20393 | CH |
| 137 | HINTERLAND | BZ | 136.0 | 22184 | CH |
| 138 | MITTELLAND | BZ | 60.2 | 14750 | CH |
| 139 | VORDERLAND | BZ | 46.4 | 12089 | CH |
| 140 | INNERER LANDESTEIL | BZ | 158.0 | 11257 | CH |
| 141 | AEUSSERER LANDESTEIL | BZ | 14.5 | 1667 | CH |
| 142 | ARBON | BZ | 70.0 | 32791 | CH |
| 143 | BISCHOFSZELL | BZ | 92.6 | 24222 | CH |
| 144 | DIESSENHOFEN | BZ | 41.3 | 5186 | CH |
| 145 | FRAUENFELD | BZ | 133.0 | 30701 | CH |
| 146 | KREUZLINGEN | BZ | 137.0 | 28793 | CH |
| 147 | MUENCHWILEN | BZ | 157.0 | 25161 | CH |
| 148 | STECKBORN | BZ | 138.0 | 14919 | CH |
| 149 | WEINFELDEN | BZ | 124.0 | 21062 | CH |
| 150 | LIECHTENSTEIN | | 156.0 | 23645 | FL |
| 151 | BLUDENZ | BZ | 1250.0 | 56135 | A |
| 152 | BREGENZ | BZ | 863.0 | 105175 | A |
| 153 | DORNBIRN | BZ | 172.0 | 68169 | A |
| 154 | FELDKIRCH | BZ | 278.0 | 77739 | A |
| 155 | LINDAU-BODENSEE | SK | 17.3 | 25400 | D |
| 156 | LINDAU-BCOENSEE | LK | 306.0 | 44600 | D |
| 157 | ASCHAFFENBURG | SK | 49.4 | 55300 | D |
| 158 | BAD KISSINGEN | SK | 12.5 | 12300 | D |
| 159 | KITZINGEN | SK | 32.9 | 17800 | D |
| 160 | SCHWEINFURT | SK | 33.0 | 57800 | D |
| 161 | WUERZUBURG | SK | 57.6 | 115600 | D |
| 162 | ALZENAU | LK | 262.0 | 54300 | D |
| 163 | ASCHAFFENBURG | LK | 366.0 | 87600 | D |
| 164 | BAD BRUECKENAU | LK | 338.0 | 19600 | D |
| 165 | BAD KISSINGEN | LK | 455.0 | 46900 | D |
| 166 | BAD NEUSTAD - SAALE | LK | 368.0 | 36100 | D |
| 167 | EBERN | LK | 367.0 | 26600 | D |
| 168 | GEMUENDEN A.MAIN | LK | 353.0 | 21900 | D |
| 169 | GEROLZHOFEN | LK | 477.0 | 41200 | D |
| 170 | HAMMELBURG | LK | 351.0 | 27700 | D |
| 171 | HASSFURT | LK | 427.0 | 47000 | D |
| 172 | HOFHEIM | LK | 301.0 | 18900 | D |
| 173 | KARLSTADT | LK | 476.0 | 41100 | D |
| 174 | KITZINGEN | LK | 326.0 | 38100 | D |
| 175 | KOENIGSHOFEN I.GRABF. | LK | 301.0 | 17800 | D |
| 176 | LOHR A.MAIN | LK | 382.0 | 36800 | D |
| 177 | MARKTHEIDENFELD | LK | 467.0 | 44500 | D |
| 178 | MELLRICHSTADT | LK | 326.0 | 23400 | D |
| 179 | MILTENBERG | LK | 345.0 | 39000 | D |
| 180 | OBERNBURG A.MAIN | LK | 314.0 | 68900 | D |
| 181 | OCHSENFURT | LK | 372.0 | 35500 | D |
| 182 | SCHWEINFURT | LK | 488.0 | 72200 | D |
| 183 | WUERZBURG | LK | 439.0 | 88400 | D |
| 184 | ANSBACH | SK | 22.1 | 33100 | D |
| 185 | ERLANGEN | SK | 36.3 | 85800 | D |
| 186 | FUERTH | SK | 44.6 | 93900 | D |
| 187 | NUERNBERG | SK | 137.0 | 480400 | D |
| 188 | ROTHENBURG-TAUBER | SK | 21.0 | 11900 | D |
| 189 | SCHWABACH | SK | 20.8 | 26900 | D |
| 190 | WEISSENBURG | SK | 31.9 | 14300 | D |
| 191 | ANSBACH | LK | 620.0 | 51800 | D |
| 192 | ERLANGEN | LK | 213.0 | 10900 | D |
| 193 | FUERTH | LK | 304.0 | 82100 | D |
| 194 | HERSBRUCK | LK | 288.0 | 33000 | D |
| 195 | HILPOLTSTEIN | LK | 516.0 | 35800 | D |
| 196 | LAUF-PEGNITZ | LK | 189.0 | 57300 | D |
| 197 | NEUSTADT-AISCH | LK | 493.0 | 42300 | D |
| 198 | NUERNBERG | LK | 292.0 | 69700 | D |
| 199 | ROTHENBURG-TAUBER | LK | 451.0 | 19000 | D |
| 200 | SCHEINFELD | LK | 394.0 | 21500 | D |

Table 3-3:(cont.)

| NO. | NAME OF DISTRICT | | AREA /KM2/ | POPULAT. | COUNTRY |
|---|---|---|---|---|---|
| 201 | SCHWABACH | LK | 507.0 | 76300 | D |
| 202 | UFFENHEIM | LK | 564.0 | 37300 | D |
| 203 | WEISSENBURG | LK | 481.0 | 38400 | D |
| 204 | BAMBERG | SK | 36.1 | 69900 | D |
| 205 | BAYREUTH | SK | 32.2 | 64000 | D |
| 206 | COBURG | SK | 19.3 | 42200 | D |
| 207 | FORCHHEIM | SK | 19.3 | 21900 | D |
| 208 | KULMBACH | SK | 24.7 | 23700 | D |
| 209 | NEUSTADT B.COBURG | SK | 7.3 | 12400 | D |
| 210 | BAMBERG | LK | 899.0 | 95800 | D |
| 211 | BAYREUTH | LK | 551.0 | 49400 | D |
| 212 | COBURG | LK | 508.0 | 73000 | D |
| 213 | EBERMANNSTADT | LK | 429.0 | 28200 | D |
| 214 | FORCHHEIM | LK | 399.0 | 48100 | D |
| 215 | HOECHSTADT A.D.AISCH | LK | 472.0 | 53700 | D |
| 216 | KRONACH | LK | 620.0 | 79600 | D |
| 217 | KULMBACH | LK | 420.0 | 35500 | D |
| 218 | LICHTENFELS | LK | 358.0 | 54000 | D |
| 219 | MUENCHBERG | LK | 297.0 | 40200 | D |
| 220 | NAILA | LK | 235.0 | 35700 | D |
| 221 | PEGNITZ | LK | 558.0 | 39100 | D |
| 222 | STADTSTEINACH | LK | 228.0 | 20200 | D |
| 223 | STAFFELSTEIN | LK | 312.0 | 26400 | D |
| 224 | NEUMARK-OBERPFALZ | SK | 14.5 | 19200 | D |
| 225 | NEUMARK-OBERPFALZ | LK | 641.0 | 42400 | D |
| 226 | CALW | LK | 893.0 | 14900 | D |
| 227 | FREUDENSTADT | LK | 617.0 | 66900 | D |
| 228 | HECHINGEN | LK | 396.0 | 56900 | D |
| 229 | HORB | LK | 358.0 | 49600 | D |
| 230 | RAVENSBURG | LK | 714.0 | 124700 | D |
| 231 | REUTLINGEN | LK | 460.0 | 194500 | D |
| 232 | ROTTWEIL | LK | 555.0 | 139000 | D |
| 233 | TETTNANG | LK | 263.0 | 92500 | D |
| 234 | TUEBINGEN | LK | 482.0 | 135100 | D |
| 235 | TUTTLINGEN | LK | 455.0 | 91800 | D |
| 236 | WANGEN | LK | 754.0 | 82500 | D |
| 237 | BADEN-BADEN | SK | 91.2 | 36900 | D |
| 238 | FREIBURG I.BREISG. | SK | 98.2 | 168200 | D |
| 239 | BUEHL | LK | 375.0 | 93000 | D |
| 240 | DONAUESCHINGEN | LK | 769.0 | 76500 | D |
| 241 | EMMENDINGEN | LK | 666.0 | 122000 | D |
| 242 | FREIBURG | LK | 634.0 | 94600 | D |
| 243 | HOSCHWARZWALD | LK | 696.0 | 46200 | D |
| 244 | KEHL | LK | 317.0 | 63100 | D |
| 245 | KONSTANZ | LK | 516.0 | 194600 | D |
| 246 | LAHR | LK | 445.0 | 89800 | D |
| 247 | LOERRACH | LK | 638.0 | 157500 | D |
| 248 | MUELLHEIM | LK | 439.0 | 65300 | D |
| 249 | OFFENBURG | LK | 461.0 | 114100 | D |
| 250 | RASTATT | LK | 545.0 | 143800 | D |

| NO. | NAME OF DISTRICT | | AREA /KM2/ | POPULAT. | COUNTRY |
|---|---|---|---|---|---|
| 251 | SAECKINGEN | LK | 371.0 | 76300 | D |
| 252 | STOCKACH | LK | 606.0 | 52300 | D |
| 253 | UEBERLINGEN | LK | 563.0 | 77200 | D |
| 254 | VILLINGEN | LK | 473.0 | 102000 | D |
| 255 | WALDSHUT | LK | 594.0 | 74100 | D |
| 256 | WOLFACH | LK | 641.0 | 57800 | D |
| 257 | HEIDELBERG | SK | 94.3 | 122100 | D |
| 258 | KARLSRUHE | SK | 123.0 | 258400 | D |
| 259 | MANNHEIM | SK | 145.0 | 330600 | D |
| 260 | PFORZHEIM | SK | 63.6 | 93100 | D |
| 261 | BRUCHSAL | LK | 463.0 | 143400 | D |
| 262 | BUCHEN | LK | 811.0 | 66800 | D |
| 263 | HEIDELBERG | LK | 487.0 | 187700 | D |
| 264 | KARLSRUHE | LK | 589.0 | 210200 | D |
| 265 | MANNHEIM | LK | 313.0 | 201400 | D |
| 266 | MOSBACH | LK | 454.0 | 77800 | D |
| 267 | PFORZHEIM | LK | 264.0 | 73400 | D |
| 268 | SINSHEIM | LK | 533.0 | 90700 | D |
| 269 | TAUBERBISCHOFSHEIM | LK | 777.0 | 83000 | D |
| 270 | HEILBRONN | SK | 64.0 | 102100 | D |
| 271 | STUTTGART | SK | 207.0 | 632900 | D |
| 272 | AALEN | LK | 1090.0 | 161400 | D |
| 273 | BACKNANG | LK | 589.0 | 111200 | D |
| 274 | BOEBLINGEN | LK | 457.0 | 216500 | D |
| 275 | CRAILSHEIM | LK | 766.0 | 68900 | D |
| 276 | ESSLINGEN | LK | 253.0 | 257400 | D |
| 277 | GOEPPINGEN | LK | 630.0 | 228800 | D |
| 278 | HEIDENHEIM | LK | 624.0 | 126500 | D |
| 279 | HEILBRONN | LK | 878.0 | 198100 | D |
| 280 | KUENZELSAU | LK | 342.0 | 33800 | D |
| 281 | LEONBERG | LK | 290.0 | 137300 | D |
| 282 | LUDWIGSBURG | LK | 424.0 | 312300 | D |
| 283 | MERGENTHEIM | LK | 474.0 | 42600 | D |
| 284 | NUERTINGEN | LK | 380.0 | 164300 | D |
| 285 | OEHRINGEN | LK | 358.0 | 49500 | D |
| 286 | SCHWAEBISCH GMUEND | LK | 443.0 | 111900 | D |
| 287 | SCHWAEBISCH HALL | LK | 568.0 | 64700 | D |
| 288 | VAIHINGEN | LK | 385.0 | 95100 | D |
| 289 | WAIBLINGEN | LK | 438.0 | 250100 | D |
| 290 | DARMSTADT | SK | 117.0 | 141900 | D |
| 291 | FRANKFURT-MAIN | SK | 195.0 | 657800 | D |
| 292 | GIESSEN | SK | 65.9 | 78100 | D |
| 293 | HANAU | SK | 30.2 | 57800 | D |
| 294 | OFFENBACH-MAIN | SK | 45.4 | 120400 | D |
| 295 | WIESBADEN | SK | 164.0 | 252000 | D |
| 296 | BERGSTRASSE | LK | 718.0 | 230900 | D |
| 297 | BIEDENKOPF | LK | 407.0 | 64700 | D |
| 298 | BUEDINGEN | LK | 706.0 | 87800 | D |
| 299 | DARMSTADT | LK | 288.0 | 125300 | D |
| 300 | DIEBURG | LK | 450.0 | 134700 | D |

Table 3-3: (cont.)

| NO. | NAME OF DISTRICT | | AREA /KM2/ | POPULAT. | COUNTRY |
|---|---|---|---|---|---|
| 301 | DILLKREIS | LK | 514.0 | 103800 | D |
| 302 | ERBACH | LK | 596.0 | 76000 | D |
| 303 | FRIEDBERG | LK | 574.0 | 181000 | D |
| 304 | GELNHAUSEN | LK | 645.0 | 93000 | D |
| 305 | GIESSEN | LK | 649.0 | 119400 | D |
| 306 | GROSS-GERAU | LK | 461.0 | 222400 | D |
| 307 | HANAU | LK | 239.0 | 147900 | D |
| 308 | LIMBURG | LK | 568.0 | 93800 | D |
| 309 | MAIN-TAUNUS-KREIS | LK | 307.0 | 200200 | D |
| 310 | OBERLAHNKREIS | LK | 393.0 | 59800 | D |
| 311 | OBERSTAUNUSKREIS | LK | 150.0 | 139300 | D |
| 312 | OFFENBACH | LK | 334.0 | 264400 | D |
| 313 | RHEINGAUKREIS | LK | 272.0 | 61400 | D |
| 314 | SCHLUECHTERN | LK | 466.0 | 44800 | D |
| 315 | UNTERTAUNUSKREIS | LK | 506.0 | 75700 | D |
| 316 | USINGEN | LK | 288.0 | 33900 | D |
| 317 | WETZLAR | LK | 626.0 | 158500 | D |
| 318 | MARBURG-LAHN | SK | 22.9 | 47500 | D |
| 319 | MARBURG-LAHN | LK | 875.0 | 118600 | D |
| 320 | FRANKENTHAL | SK | 43.8 | 42300 | D |
| 321 | KAISERLAUTERN | SK | 139.0 | 101200 | D |
| 322 | LANDAU I.D.PFALZ | SK | 39.7 | 31500 | D |
| 323 | LUDWIGSHAFEN-RHEIN | SK | 68.1 | 175400 | D |
| 324 | MAINZ | SK | 97.6 | 178600 | D |
| 325 | NEUSTADT-WEINSTRASSE | SK | 113.0 | 50800 | D |
| 326 | PIRMASENS | SK | 48.7 | 54800 | D |
| 327 | SPEYER | SK | 42.6 | 42800 | D |
| 328 | WORMS | SK | 109.0 | 76900 | D |
| 329 | ZWEIBRUECKEN | SK | 35.8 | 32500 | D |
| 330 | ALZEY-WORMS | LK | 599.0 | 98300 | D |
| 331 | BAD DUERKHEIM | LK | 592.0 | 116500 | D |
| 332 | DONNERSBERGKREIS | LK | 641.0 | 67600 | D |
| 333 | GERMERSHEIM | LK | 470.0 | 95500 | D |
| 334 | KAISERSLAUTERN | LK | 594.0 | 90800 | D |
| 335 | KUSEL | LK | 582.0 | 82600 | D |
| 336 | LANDAU-BAD BERGZABERN | LK | 671.0 | 104600 | D |
| 337 | LUDWIGSHAFEN | LK | 314.0 | 120800 | D |
| 338 | MAINZ-BINGEN | LK | 593.0 | 152000 | D |
| 339 | PIRMASENS | LK | 786.0 | 81400 | D |
| 340 | ZWEIBRUECKEN | LK | 248.0 | 32200 | D |
| 341 | KOBLENZ | SK | 103.0 | 120000 | D |
| 342 | AHRWEILER | LK | 787.0 | 106000 | D |
| 343 | ALTENKIRCHEN(WESTERW) | LK | 642.0 | 122700 | D |
| 344 | BAD KREUZNACH | LK | 864.0 | 148300 | D |
| 345 | BIRKENFELD | LK | 795.0 | 93000 | D |
| 346 | COCHEM-ZELL | LK | 716.0 | 65500 | D |
| 347 | MAYEN-KOBLENZ | LK | 820.0 | 187900 | D |
| 348 | NEUWIED | LK | 627.0 | 150100 | D |
| 349 | OBERWESTERWALDKREIS | LK | 569.0 | 78600 | D |
| 350 | RHEIN-HUNSRUECK-KREIS | LK | 963.0 | 88600 | D |
| 351 | RHEIN-LAHN-KREIS | LK | 773.0 | 118800 | D |
| 352 | UNTERWESTERWALDKREIS | LK | 432.0 | 87900 | D |
| 353 | TRIER | SK | 117.0 | 103400 | D |
| 354 | BERNKASTEL-WITTLICH | LK | 1180.0 | 109700 | D |
| 355 | BITTBURG-PRUEM | LK | 1630.0 | 93000 | D |
| 356 | DAUN | LK | 910.0 | 56700 | D |
| 357 | TRIER-SAARBURG | LK | 1100.0 | 119400 | D |
| 358 | SAARBRUECKEN | SK | 52.6 | 127500 | D |
| 359 | HOMBURG | LK | 239.0 | 80500 | D |
| 360 | MERZIG-WADERN | LK | 551.0 | 102000 | D |
| 361 | OTTWEILER | LK | 259.0 | 166400 | D |
| 362 | SAARBRUECKEN | LK | 334.0 | 264400 | D |
| 363 | SAARLOUIS | LK | 441.0 | 205700 | D |
| 364 | SANKT INGBERT | LK | 207.0 | 82200 | D |
| 365 | SANKT WENDEL | LK | 484.0 | 93200 | D |
| 366 | AACHEN | SK | 58.7 | 176600 | D |
| 367 | AACHEN | LK | 337.0 | 280700 | D |
| 368 | DUEREN | LK | 542.0 | 162400 | D |
| 369 | ERKELENZ | LK | 321.0 | 98400 | D |
| 370 | JUELICH | LK | 327.0 | 78200 | D |
| 371 | MONSCHAU | LK | 290.0 | 32600 | D |
| 372 | SCHLEIDEN | LK | 823.0 | 65900 | D |
| 373 | SELFKANTKR.-GEILENK. | LK | 359.0 | 139000 | D |
| 374 | BONN | SK | 141.0 | 278800 | D |
| 375 | KOELN | SK | 251.0 | 846500 | D |
| 376 | BERGHEIM-ERFT | LK | 365.0 | 126800 | D |
| 377 | EUSKIRCHEN | LK | 608.0 | 127600 | D |
| 378 | KOELN | LK | 298.0 | 265600 | D |
| 379 | OBERBERGISCHER KREIS | LK | 566.0 | 152200 | D |
| 380 | RHEIN-BERGISCHER KR. | LK | 621.0 | 283500 | D |
| 381 | RHEIN-SIEG KREIS | LK | 1150.0 | 398900 | D |
| 382 | DUESSELDORF | SK | 158.0 | 650400 | D |
| 383 | DUISBURG | SK | 143.0 | 448800 | D |
| 384 | ESSEN | SK | 195.0 | 691800 | D |
| 385 | KREFELD | SK | 116.0 | 222600 | D |
| 386 | LEVERKUSEN | SK | 46.7 | 109000 | D |
| 387 | MOENCHENGLADBACH | SK | 97.0 | 151200 | D |
| 388 | MUEHLHEIM-RUHR | SK | 88.2 | 192900 | D |
| 389 | NEUSS | SK | 53.1 | 117000 | D |
| 390 | OBERHAUSEN | SK | 77.0 | 244900 | D |
| 391 | REMSCHEID | SK | 64.6 | 136700 | D |
| 392 | RHEYDT | SK | 45.1 | 101500 | D |
| 393 | SOLINGEN | SK | 80.0 | 176900 | D |
| 394 | WUPPERTAL | SK | 151.0 | 416700 | D |
| 395 | DINSLAKEN | LK | 221.0 | 143800 | D |
| 396 | DUESSELDORF-METTMANN | LK | 436.0 | 407300 | D |
| 397 | GELDERN | LK | 510.0 | 88200 | D |
| 398 | GREVENBROICH | LK | 558.0 | 276800 | D |
| 399 | KEMPEN-KREFELD | LK | 511.0 | 261400 | D |
| 400 | KLEVE | LK | 501.0 | 109100 | D |

Table 3-3:(cont.)

| NO. | NAME OF DISTRICT | | AREA /KM2/ | POPULAT. | COUNTRY |
|---|---|---|---|---|---|
| 401 | MOERS | LK | 564.0 | 353500 | D |
| 402 | REES | LK | 528.0 | 118600 | D |
| 403 | RHEIN-WUPPER-KREIS | LK | 362.0 | 250300 | D |
| 404 | BOCHUM | SK | 121.0 | 341800 | D |
| 405 | CASTROP-RAUXEL | SK | 44.2 | 83100 | D |
| 406 | DORTMUND | SK | 271.0 | 642400 | D |
| 407 | HAGEN | SK | 90.4 | 199700 | D |
| 408 | HAMM | SK | 45.0 | 84900 | D |
| 409 | HERNE | SK | 30.0 | 104000 | D |
| 410 | ISERLOHN | SK | 30.8 | 57400 | D |
| 411 | LUENEN | SK | 40.8 | 71900 | D |
| 412 | WANNE-EICKEL | SK | 21.3 | 97100 | D |
| 413 | WATTENSCHEID | SK | 23.9 | 81300 | D |
| 414 | WITTEN | SK | 48.4 | 97400 | D |
| 415 | ARNSBERG | LK | 662.0 | 148600 | D |
| 416 | BRILON | LK | 790.0 | 79600 | D |
| 417 | ENNEPE-RUHR-KREIS | LK | 399.0 | 266600 | D |
| 418 | ISERLOHN | LK | 339.0 | 205000 | D |
| 419 | LIPPSTADT | LK | 508.0 | 110700 | D |
| 420 | LUEDENSCHEID | LK | 679.0 | 241000 | D |
| 421 | MESCHEDE | LK | 675.0 | 70800 | D |
| 422 | OLPE | LK | 725.0 | 121900 | D |
| 423 | SIEGEN | LK | 649.0 | 243400 | D |
| 424 | SOEST | LK | 637.0 | 123200 | D |
| 425 | UNNA | LK | 425.0 | 232400 | D |
| 426 | WITTGENSTEIN | LK | 489.0 | 45500 | D |
| 427 | BOCHOLT | SK | 18.9 | 49500 | D |
| 428 | BOTTROP | SK | 42.2 | 105400 | D |
| 429 | GELSENKIRCHEN | SK | 104.0 | 344600 | D |
| 430 | GLADBECK | SK | 35.9 | 82400 | D |
| 431 | RECKLINGHAUSEN | SK | 66.4 | 125400 | D |
| 432 | AHAUS | LK | 683.0 | 121800 | D |
| 433 | BECKUM | LK | 599.0 | 171100 | D |
| 434 | BORKEN | LK | 632.0 | 98100 | D |
| 435 | COESFELD | LK | 612.0 | 97400 | D |
| 436 | LUEDINGHAUSEN | LK | 698.0 | 147000 | D |
| 437 | RECKLINGHAUSEN | LK | 715.0 | 360500 | D |
| 438 | STEINFURT | LK | 772.0 | 191500 | D |
| 439 | BUEREN | LK | 767.0 | 62800 | D |
| 440 | PADERBORN | LK | 554.0 | 146100 | D |
| 441 | ALTKIRCH | AR | 654.0 | 51215 | F |
| 442 | COLMAR | AR | 661.0 | 123207 | F |
| 443 | THANN | AR | 524.0 | 70631 | F |
| 444 | GUEBWILLER | AR | 584.0 | 66030 | F |
| 445 | MULHOUSE | AR | 629.0 | 276356 | F |
| 446 | RIBEAUVILLE | AR | 450.0 | 47070 | F |
| 447 | HAGUENAU | AR | 660.0 | 102925 | F |
| 448 | MOLSHEIM | AR | 735.0 | 71470 | F |
| 449 | SAVERNE | AR | 980.0 | 84164 | F |
| 450 | SELESTAT-ERSTEIN | AR | 978.0 | 114343 | F |
| 451 | STRASBOURG-COMPAGNE | AR | 683.0 | 198838 | F |
| 452 | STRASBOURG-VILLE | AR | 78.3 | 253384 | F |
| 453 | WISSEMBOURG | AR | 587.0 | 56497 | F |
| 454 | EPINAL | AR | 3420.0 | 232267 | F |
| 455 | NEUFCHATEAY | AR | 1010.0 | 68610 | F |
| 456 | SAINT DIE | AR | 1430.0 | 97121 | F |
| 457 | BRIEY | AR | 1390.0 | 192135 | F |
| 458 | LUNEVILLE | AR | 568.0 | 78500 | F |
| 459 | NANCY | AR | 2860.0 | 395593 | F |
| 460 | TOUL | AR | 408.0 | 56359 | F |
| 461 | BOULAY-MOSELLE | AR | 428.0 | 69420 | F |
| 462 | CHATEA-SALINS | AR | 181.0 | 29275 | F |
| 463 | FORBACH | AR | 1170.0 | 189780 | F |
| 464 | METZ-CAMPAGNE | AR | 1190.0 | 192030 | F |
| 465 | SARREBOURG | AR | 377.0 | 61029 | F |
| 466 | SARREGUEMINES | AR | 505.0 | 81793 | F |
| 467 | THIONVILLE-EST | AR | 763.0 | 123643 | F |
| 468 | THIONVILLE-OUEST | AR | 910.0 | 147534 | F |
| 469 | METZ-VILLE | AR | 650.0 | 111969 | F |
| 470 | COMMERCY | AR | 1380.0 | 45082 | F |
| 471 | VERDUM S.MEUSE | AR | 2790.0 | 91376 | F |
| 472 | CHARLEVILLE-MEZIERES | AR | 3050.0 | 180435 | F |
| 473 | SEDAN | AR | 1150.0 | 68240 | F |
| 474 | VOUZIERS | AR | 437.0 | 25887 | F |
| 475 | CAPELLEN | CT | 199.0 | 21381 | L |
| 476 | ESCH | CT | 243.0 | 114778 | L |
| 477 | LUXEMBOURG-VILLE | CT | 51.5 | 76150 | L |
| 478 | LUXEMB-CAMPAGNE | CT | 187.0 | 25495 | L |
| 479 | MERSCH | CT | 224.0 | 13814 | L |
| 480 | CLERVAUX | CT | 302.0 | 9606 | L |
| 481 | DIEKRICH | CT | 239.0 | 19685 | L |
| 482 | REDANGE | CT | 267.0 | 10305 | L |
| 483 | VIANDEN | CT | 54.1 | 2658 | L |
| 484 | WILTZ | CT | 294.0 | 10130 | L |
| 485 | ECHTERNACH | CT | 186.0 | 9934 | L |
| 486 | GREVENMACHER | CT | 211.0 | 15269 | L |
| 487 | REMICH | CT | 128.0 | 10627 | L |
| 488 | ARLON | AR | 321.0 | 48413 | B |
| 489 | BASTAGNE | AR | 989.0 | 35022 | B |
| 490 | MARCHE-EN-FAMENNE | AR | 937.0 | 39519 | B |
| 491 | NEUFCATEAU | AR | 1450.0 | 52541 | B |
| 492 | VIRTON | AR | 717.0 | 41815 | B |
| 493 | DINANT | AR | 1570.0 | 84480 | B |
| 494 | NAMUR | AR | 1120.0 | 237132 | B |
| 495 | PHILIPPEVILLE | AR | 965.0 | 58949 | B |
| 496 | CHARLEROI | AR | 561.0 | 458609 | B |
| 497 | THUIN | AR | 908.0 | 136328 | B |
| 498 | HUY | AR | 710.0 | 92626 | B |
| 499 | LIEGE | AR | 765.0 | 617572 | B |
| 500 | VERVIERS | AR | 2010.0 | 239731 | B |

Table 3-3 (cont.)

| NO. | NAME OF DISTRICT | | AREA /KM2/ | POPULAT. | COUNTRY |
|---|---|---|---|---|---|
| 501 | HASSELT | AR | 904.0 | 319993 | B |
| 502 | WAREMME | AR | 387.0 | 58976 | B |
| 503 | TONGRES | AR | 628.0 | 165940 | B |
| 504 | NOORD-LIMBURG | RE | 853.0 | 236153 | NL |
| 505 | MIDDEN-LIMBURG | RE | 665.0 | 192954 | NL |
| 506 | ZUID-LIMBURG | RE | 690.0 | 614679 | NL |
| 507 | WEST-N-BRABANT | RE | 1260.0 | 492301 | NL |
| 508 | MIDDEN-N-BRABANT | RE | 1050.0 | 391863 | NL |
| 509 | NOORDOOST-N-BRABANT | RE | 1310.0 | 470219 | NL |
| 510 | ZUIDOOST-N-BRABANT | RE | 1370.0 | 586434 | NL |
| 511 | ZEEUWSCH-VLANDEREN | RE | 877.0 | 105104 | NL |
| 512 | OVERIG ZEELAND | RE | 1870.0 | 221500 | NL |
| 513 | VELUWE | RE | 1850.0 | 517827 | NL |
| 514 | ACHTERHOEK | RE | 1530.0 | 340032 | NL |
| 515 | ARNHEM/NIJMEGEN | RE | 990.0 | 594848 | NL |
| 516 | ZUIDWEST-GELDERLAND | RE | 711.0 | 168177 | NL |
| 517 | UTRECHT | RE | 1400.0 | 857666 | NL |
| 518 | AGGLOMERATIE LEIDEN | RE | 239.0 | 320455 | NL |
| 519 | AGGLOMERATIE 'S-GRAVENHAGE | RE | 227.0 | 684792 | NL |
| 520 | DELFT EN WESTLAND | RE | 193.0 | 194293 | NL |
| 521 | OSTELIJK Z-HOLLAND | RE | 520.0 | 266483 | NL |
| 522 | GROOT-RIJNMOND | RE | 1180.0 | 1200944 | NL |
| 523 | ZUIDOOST Z-HOLLAND | RE | 520.0 | 357713 | NL |
| 524 | NOORD/OVERIJSSEL | RE | 1980.0 | 322072 | NL |
| 525 | ZUIDWEST-OVERIJSSEL | RE | 400.0 | 120513 | NL |
| 526 | TWENTE | RE | 1440.0 | 534562 | NL |
| 527 | ZUIDELIJKE IJSSELMEERPLL. | RE | 961.0 | 29574 | NL |
| 528 | KOP VAN NOORD-HOLLAND | RE | 1140.0 | 272858 | NL |
| 529 | ALKMAER E.O. | RE | 323.0 | 174048 | NL |
| 530 | IJMOND | RE | 141.0 | 164621 | NL |
| 531 | AGGLOMERATIE HAARLEM | RE | 144.0 | 237264 | NL |
| 532 | ZAANSTREEK | RE | 95.1 | 137116 | NL |
| 533 | GROOT-AMSTERDAM | RE | 736.0 | 1065490 | NL |
| 534 | GOOI EN VECHTSTREEK | RE | 181.0 | 233432 | NL |

Note:

AR = Arrondissement

BZ = Bezirk

CT = Canton

KT = Kanton

LK = Landkreis

RE = Regio

SK = Stadtkreis

Table 3-4: Population in Age Groups

Basis: State of Equilibrium (Constant Birthrate [1])
Mean Life Expectancy = 70yrs[2]

| Age Group | Age [yrs] | Percentage of Total Population |
|---|---|---|
| Infant | 0-1 | 1.43 |
| Child | 1-10 | 12.86 |
| Teen | 10-20 | 14.28 |
| Adult | over 20 | 71.43 |

1) At the moment decreasing birthrate in most European countries which results in a shift in favour of the older age groups
2) Valid for nearly all Central European Countries

Table 3-5: Employees in the Three Branches of Economy 1974 [31]

| Country | Agriculture and Foresting [ % ] | Industry and Mining [ % ] | Trade, Traffic and Service [ % ] |
|---|---|---|---|
| CH | 7.1 | 46.3 | 46.6 |
| FL | | no data available | |
| A | 16.1 | 40.1 | 43.8 |
| D | 7.3 | 47.6 | 45.1 |
| F | 12.0 | 39.2 | 49.2 |
| L | 6.6 | 49.0 | 44.4 |
| B | 3.7 | 41.2 | 55.1 |
| NL | 6.6 | 35.5 | 57.9 |
| RMR [1] (estimated) | 7.5 | 44 | 48.5 |
| USA | 4.1 | 31.7 | 64.2 |

1) Uncertainty of this estimation: less than 5 %

Table 3-6: Use of Land within Various Land Categories (see Fig. 3-7)
(Evaluated on the Basis [31 to 35])

| Land Category (Color symbols of Fig. 3-7) | Portion within RMR [%] | Land Use $l_x$ [%] | | | | Plant Product Dependent Land Use of Arable- and Grass Land $l_P^{AG}$ [%] Values of $l_{AG} \cdot l_p^{AG}$ are given in brackets | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Arable- and Grass Land $l_{AG}$ | Forest Land $l_F$ | Built up Area $l_B$ | Remainder (Fallow- Barren Land etc.) $l_R$ | Cereals C $l_C^{AG}$ | Root Crops R $l_R^{AG}$ | Vegetables V $l_V^{AG}$ | Fruit F $l_F^{AG}$ | Grass G $l_G^{AG}$ |
| Predominantly Arable Land (orange) | 29.6 | 60 | 20 | 15 | 5 | 55 (33) | 10.5 (6.3) | 2.5 (1.5) | 2 (1.2) | 30 (18) |
| Predominantly Grass Land for Grazing (olive) | 13.8 | 60 | 30 | 9 | 1 | 18 (10.8) | 2.1 (1.26) | 0.75 (0.45) | 0.15 (0.09) | 79 (47.4) |
| Predominantly Forest Land (green) | 19.8 | 30 | 60 | 8 | 2 | 12 (3.6) | 2.1 (0.63) | 0.75 (0.225) | 0.15 (0.045) | 85 (25.5) |
| Mixture of Arable- Grass- and Forest Land (yellow) | 34.1 | 60 | 30 | 9 | 1 | 45 (27) | 8.1 (4.86) | 1.5 (0.9) | 0.4 (0.24) | 45 (27) |

1) The symbols: C= Cereals, R= Root Crops, V= Vegetables, F= Fruit, G= Grass;
P= Pork, B= Beef, M= Milk;
have the meaning defined here only within Tables 3-6 (far right column) and 3-7

2) potatoes: 45%, beet: 55% of acreage for root crops

Table 3-7: Agricultural Products: Yield and Use
( Evaluated on the Basis of [31 to 38])

a) Plant Products

| Plant Products | | Yield $y_P$ [kg/ (m$^2$.yr)] | Use $u_P$ [%] Human Food $u_{P,HF}$ | Animal Food $u_{P,AF}$ Cattle | Swine | Others | Seeds, Losses etc. $u_{P,SL}$ |
|---|---|---|---|---|---|---|---|
| Cereals | C | 0.4 | 15 | 18 | 50 | 3 | 14 |
| Root Crops | R | 5.9[1] | 7[1] | 56[1] | 30[1] | 1[1] | 6[1] |
| Potatoes | | 2.7 | 33 | | | | |
| Beet | | 8.5 | | | | | |
| Vegetables | V | 2.0 | 80 | - | - | | 20 |
| Fruit | F | 3.4 | 85 | - | - | | 15 |
| Grass | G | 2.5 | - | 100 | - | | - |

1) Weighted mean value with respect to proportionate acreage of potatoes and beet (see footnote of Table 3-6)

Table 3-7: (cont.)

b.) Animal Products

| Animal Products | | Yield per Fodder $y_A^{AF}$ [kg/kg] | Yield per Animal $y_A^H$ [kg/yr] | Product Use $u_A$ [%] Meat | Fresh Milk and Fresh Milk Products | Cheese Butter Animal Food etc. |
|---|---|---|---|---|---|---|
| Pork | P | $\frac{0.095 \text{ kg P}}{0.38 \text{ kg C} + 0.62 \text{ kg R}}$ 1) | 115 1) | 100 | - | - |
| Beef | B | $\frac{0.0081 \text{ kg B}}{0.019\text{kgC}+0.160\text{kgR}+0.821\text{kgG}}$ 2) | 93.5 | 100 | - | - |
| Milk | M | $\frac{0.13 \text{ l M}}{0.019\text{kgC}+0.160\text{kgR}+0.821\text{kgG}}$ 2)3) | 1515 3) | - | 2o | 8o |

1) Without slaughtering-fat

2) Food value: 3.5 kg grass corresponds approx. to 1 kg cereals resp. root crops [38]

3) Weighted mean value, dairy cow ( 4o% of cattle): 0.33 l/kg fodder resp. 3787 l/yr

Tab. 3-8: Freshwater Fishery within the Rhein-Maas Region
(Yield and Catch evaluated on the Basis of [42 to 50])

| Water Body | Section (River Distance) | Yield $y_F$ [kg/(km.yr)] | Total Catch [kg/yr] |
|---|---|---|---|
| Alpenrhein | 1 - 23 | 100 1) | 2 300 1) |
| Bodensee | Obersee | 1890 kg/(km$^2$·yr) | 900 000 |
| | Untersee | 4580 kg/(km$^2$·yr) | 293 000 |
| Reuss | 1 - 62 | 100 1) | 6 200 1) |
| Aare | 1 - 165 | 200 1) | 33 000 1) |
| Neckar | 1 - 127 | 100 | 12 700 |
| Main | 1 - 390 | 100 1) | 39 000 1) |
| Mosel | 1 - 255 | 200 1) | 51 000 1) |
| Lippe | 1 - 100 | 65 | 6 500 |
| Rhein | 1 - 45 | 800 | 36 000 |
| | 46 - 165 | 750 | 85 000 |
| | 166 - 226 | 460 | 28 000 |
| | 227 - 292 | 1 100 | 71 000 |
| | 293 - 352 | 1 950 | 120 000 |
| | 353 - 437 | 2 500 | 210 000 |
| | 438 - 540 | 1 720 | 175 000 |
| | >540 | 0 2) | 0 |
| | | | 725 000 3) |
| Maas | 1 - 265 | 1 400 | 370 000 |
| | 266 - 400 | 500 | 68 000 |
| | | | 438 000 3) |
| Waal | 1 - 104 | 0 1)2) | 0 |
| Lek | 1 - 158 | 0 1)2) | 0 |
| Total | | | 2 506 700 |

1) Estimated by comparison with rivers of similar stature
2) Unfit for human consumption [50]
3) Partial sum for the river within all noted sections

**Table 4-1:** **Yearly Total Energy Consumption and Electric Energy Consumption 1974 [51,52]**

| Country | Total Energy Consumption per Country [ $10^6$ tce ] 1) | Total Energy Consumption per Capita [ kgce ] 1) | Electric Energy Consumption per Country [ $10^9$ kWh ] 2) | Electric Energy Consumption per Capita [ kWh ] 2) |
|---|---|---|---|---|
| CH | 31.3 | 4 830 | 34.9 | 5 388 |
| FL | no data available | | no data available | |
| A | 33.4 | 4 437 | 30.9 | 3 580 |
| D | 372.4 | 6 001 | 317.6 | 4 542 |
| F | 250.0 | 4 763 | 188.0 | 3 201 |
| L | 7.9 | 22 132 | 4.8 | 9 588 |
| B | 64.6 | 6 614 | 42.4 | 3 865 |
| NL | 86.1 | 6 354 | 53.9 | 3 601 |
| RMR 3) (estimated) | | 6 000 | | 4 500 |
| USA | 2 460 | 11 600 | 2 105.8 | 8 520 |

1) ce = coal equivalent, 1 kgce ≙ $29,3 \cdot 10^6$ J

2) Wh = watt-hour, 1 kWh ≙ $3,6 \cdot 10^6$ J

3) Uncertainty of this estimation: less than 5 %

Table 4-2: Installed Electric Capacity 1974 [51,52]

| Country | Thermal Power Plant Capacity [MWe] 1) | Hydroelectric Power Plant Capacity [MWe] 1) | Total Capacity [MWe] 1) | Total Capacity per Capita [kWe] 1) |
|---|---|---|---|---|
| CH | 1 400 | 9 200 | 10 600 | 1.65 |
| FL | | no data available | | |
| A | 3 233 | 6 008 | 9 241 | 1.23 |
| D | 61 330 | 4 775 | 66 105 | 1.07 |
| F | 28 291 | 16 334 | 44 625 | 0.85 |
| L | 214 | 972 | 1 186 | 3.49 |
| B | 8 295 | 459 | 8 754 | 0.90 |
| NL | 13 516 | -- | 13 516 | 1.00 |
| RMR 2) (estimated) | | | 60 000 | 1.05 |
| USA | 429 500 | 64 283 | 493 763 | 2.30 |

1) We = watt, electrical

2) Uncertainty of this estimation: less than 5 %

Table 4-3: Nuclear Facilities within the Rhein-Maas Region till 1985/90

| No. | River System [1] | Plant | River | Country | Type [2] Power [3] or Capacity | Proper Name | Commissioning/ Decommissioning [4] | References [5] |
|---|---|---|---|---|---|---|---|---|
| 1 | | Rüthi | Rhein | CH | LWR 900 MWe | | 1981 | atw 1975; 6/74 |
| 2 | Aare | Mühleberg | Aare | CH | BWR 326 MWe | | 1972 | atw 1975 |
| 3 | Aare | Graben-1<br>Graben-2 | Aare | CH | BWR 1214 MWe<br>BWR 1214 MWe | | 1981<br>1983 | atw 1975<br>atw 1975 |
| 4 | Aare | Gösgen-Däniken | Aare | CH | PWR 970 MWe | | 1977 | atw 1976 |
| 5 | Aare | Inwil-1<br>Inwil-2 | Reuss | CH | LWR 1000 MWe<br>LWR 1000 MWe | | 1983<br>"1985" | atw 1975<br>atw 1975 |
| 6 | Aare | Würenlingen Kernforschungs-zentrum | Aare | CH | RR 5 MWth<br>RR 30 MWth | "Saphir"<br>"Diorit" | 1957<br>1960/1977 | P.C. |
| 7 | Aare | Beznau-1<br>Beznau-2 | Aare | CH | PWR 364 MWe<br>PWR 364 MWe | | 1969<br>1971 | atw 1975<br>atw 1975 |
| 8 | | Leibstadt | Rhein | CH | BWR 1000 MWe | | 1980 | atw 1976 |
| 9 | | Menzenschwand | Krunkelbach | D | UMn | | | |
| 10 | | Schwörstadt-1<br>Schwörstadt-2<br>Schwörstadt-3 | Rhein | D | LWR 1200 MWe<br>LWR 1200 MWe<br>LWR 1200 MWe | | "1985"<br>"1985"<br>"1985" | atw 1975<br>atw 7/73<br>atw 7/73 |
| 11 | | Kaiseraugst | Rhein | CH | BWR 925 MWe | | 1981 | atw 1976 |
| 12 | | Heitersheim | Rhein | D | FFP ca.300 t/yr $UO_2$ | "BBR" | 1980 | estim.fr.NIS |
| 13 | | Fessenheim-1<br>Fessenheim-2<br>Fessenheim-3<br>Fessenheim-4 | Rhein | F | PWR 930 MWe<br>PWR 930 MWe<br>PWR 957 MWe<br>PWR 957 MWe | | 1976<br>1977<br>1981<br>1982 | atw 1976<br>atw 1976<br>atw 1975<br>atw 1975 |
| 14 | | Wyhl-1<br>Wyhl-2 | Rhein | D | PWR 1362 MWe<br>PWR 1362 MWe | | 1981<br>1981 | atw 1976<br>atw 1976 |
| 15 | | Lauterbourg | Rhein | F | LWR 1000 MWe | | "1985" | BNN 13.2.75<br>BNN 6.6.75 |
| 16 | | Neupotz-1<br>Neupotz-2 | Rhein | D | PWR 1300 MWe<br>PWR 1300 MWe | | 1982<br>1984 | atw 1976<br>atw 1976 |
| 17 | | Karlsruhe Kernforschungs-zentrum | Rhein | D | RR 40 MWth<br>PHWR 60 MWth<br>FRP 40 t/yr<br>LMFR 20 MWe | "FR 2"<br>"MZFR"<br>"WAK"<br>"KNK" | 1961/1980(estimated)<br>1966/1978<br>1971<br>1973 | atw 6/74 |
| 18 | | Philippsburg-1<br>Philippsburg-2 | Rhein | D | BWR 900 MWe<br>PWR 1362 MWe | | 1977<br>1981 | atw 1976<br>atw 1976 |
| 19 | Neckar | Neckarwestheim-1<br>Neckarwestheim-2 | Neckar | D | PWR 855 MWe<br>PWR 845 MWe | | 1976<br>1982 | atw 1976<br>atw 1976 |
| 20 | Neckar | Obrigheim | Neckar | D | PWR 345 MWe | | 1969 | atw 1975 |
| 21 | | Ludwigshafen-1<br>Ludwigshafen-2 | Rhein | D | PWR 425 MWe<br>PWR 400 MWe | | 1981<br>"1985" | atw 1976<br>atw 1976 |
| 22 | | Kirschgartshausen | Rhein | D | HTR 1150 MWe | | 1984 | atw 1975 |
| 23 | | Biblis-1<br>Biblis-2<br>Biblis-3<br>Biblis-4 | Rhein | D | PWR 1204 MWe<br>PWR 1300 MWe<br>PWR 1300 MWe<br>PWR 1300 MWe | | 1974<br>1976<br>1981<br>1983 | atw 1975<br>atw 1975<br>atw 1975<br>atw 1975 |
| 24 | Main | Bamberg-Viereth | Main | D | LWR 1200 MWe | | 1982 | atw 9/72 |
| 25 | Main | Grafenrheinfeld-1<br>Grafenrheinfeld-2 | Main | D | PWR 1300 MWe<br>PWR 1300 MWe | | 1979<br>1981 | atw 1975<br>atw 1975 |
| 26 | Main | Hörstein-1<br>Hörstein-2 | Main | D | LWR 1300 MWe<br>LWR 1300 MWe | | "1985"<br>"1985" | atw 1975<br>atw 1975 |
| 27 | Main | Kahl | Main | D | BWR 15 MWe | | 1961 | atw 1975 |

Table 4-3 (cont.)

| No. | River System | Plant | River | Country | Type Power or Capacity | Proper Name | Commissioning/ Decommissioning | References |
|---|---|---|---|---|---|---|---|---|
| 28 | Main | Wolfgang | Main | D | FFP 750 t/yr $UO_2$ | "RBU" | 1965/69 | NIS |
| | | | | | FFP ca. 30 t/yr U+Th | "Nukem" | 1962 | P.C. |
| | | | | | FFP 40(10)t/yr $UO_2$+$PuO_2$ | "Alkem" | 1963 | NIS |
| | | | | | FFP ca. 3 t/yr U+Th | "HOBEG" | 1971 | P.C. |
| 29 | Nahe | Ellweiler | Steinaubach | D | UM1 150 t/d | | 1961 | P.C. |
| 30 | Mosel | Sentzich-1 | Mosel | F | PWR 905 MWe | | 1983 | atw 9/10/76 |
| | | Sentzich-2 | | | PWR 905 MWe | | 1984 | atw 9/10/76 |
| 31 | | Remerschen | Mosel | L | PWR 1300 MWe | | 1981 | atw 1976 |
| 32 | | Mülheim-Kärlich | Rhein | D | PWR 1295 MWe | | 1979 | atw 1976 |
| 33 | | Bad Breisig | Rhein | D | LWR 1200 MWe | | "1985" | atw 1/72 |
| 34 | Lippe | Uentrop-1 | Lippe | D | HTR 308 MWe | "THTR" | 1978 | atw 1976 |
| | | Uentrop-2 | | | PWR 1300 MWe | | 1981 | atw 7/75 |
| 35 | | Vahnum-1 | Rhein | D | PWR 1300 MWe | | 1981 | atw 1976 |
| | | Vahnum-2 | | | PWR 1300 MWe | | 1983 | atw 1976 |
| 36 | | Kalkar-1 | Rhein | D | LMFBR 327 MWe | "SNR 300" | 1981 | atw 1976 |
| | | Kalkar-2 | | | LMFBR 1500 MWe | "SNR 2" | "1986" | atw 1976 |
| 37 | Ijssel | Ahaus | Aa | D | FFP ca.150/300 t/yr $UO_2$ | "NB" | "1985" | P.C. 1976 |
| 38 | | Almelo | Overijsselkanal | NL | UEP 35 t/yr $UF_6$ | "DPP" | 1972 | P.C. 1976 |
| | | | | | UEP 40 t/yr $UF_6$ | "UTA 25" | 1973 | |
| | | | | | UEP 500 t/yr $UF_6$ | "B 21" | 1978 | |
| | | | | | UEP 1500 t/yr $UF_6$ | | 1982 | |
| 39 | | Arnhem | Rhein | NL | STR 1 MWth | "KEMA" | 1974 | atw 8/74 |
| 40 | | Dodewaard | Waal | NL | BWR 54 MWe | | 1968 | atw 1975 |
| 41 | NS | Petten | North Sea | NL | RR 45 MWth | "HFR" | 1962 | |
| 42 | Maas | Chooz | Maas | F | PWR 300 MWe | | 1967 | atw 1975 |
| 43 | | Tihange-1 | Maas | B | PWR 920 MWe | | 1975 | atw 1975 |
| | | Tihange-2 | | | PWR 930 MWe | | 1980 | atw 1976 |
| | | Tihange-3 | | | PWR 1000 MWe | | "1985" | CEC 1976 |
| 44 | | Jülich Kernforschungs-zentrum | Rur | D | RR 5 MWth | "Merlin" | 1962 | |
| | | | | | RR 10 MWth | "Dido" | 1962 | |
| | | | | | HTR 15 MWth | "AVR" | 1967 | |
| 45 | Schelde | Borssele-1 | Schelde | NL | PWR 480 MWe | | 1973 | atw 1972 |
| | | Borssele-2 | | | LWR 1000 MWe | | "1985" | atw 5/74 |

1) [dotted box] Rhein, [solid box] Tributary

2) List of Abbreviations see Table 4-6

3) Gross power, if specified

4) "1985" year of commissioning - assumed if not specified in the reference

5) atw = Atomwirtschaft - Atomtechnik, Journal
atw 1975 = atw 20 (1975) 135-151, 187-209
atw 1976 = atw 21 (1976) 114-131, 170-195
atw 6/76 e.g.= atw "yellow pages", Month/Year

BNN = Badische Neueste Nachrichten, Karlsruhe, Daily Newspaper

NIS = "Die Brennelementindustrie" NIS-Report (1975)

P.C. = Private Communication

CEC = Commission of the European Communities
Nuclear Plants in the Countries of the European Communities
Updated December 1976

Table 4-4: Nuclear Facilities close to the Rhein-Maas Region till 1985/90 (Near Distance Zone) 1)

| No. | River System | Plant | River | Country | Type Power or Capacity | Proper Name | Commissioning/ Decommissioning | References |
|---|---|---|---|---|---|---|---|---|
| N01 | Ems | Emden | Ems | D | LWR 1365 MWe | | "1985" | atw 1976 |
| N02 | | Lichtenmoor/ Nienburg 2) | | D | FRP 1500 t/yr | "KEWA" | "1985" | |
| N03 | Ems | Lingen-1 | Ems | D | BWR 252 MWe | | 1968 | atw 1975 |
| | | Lingen-2 | | | FFP | "Exxon" | 1977 | atw 11/1976 |
| N04 | Weser | Grohnde/Hameln | Weser | D | PWR 1361 MWe | | 1981 | atw 1976 |
| N05 | | Würgassen | Weser | D | BWR 670 MWe | | 1972 | atw 1975 |
| N06 | | Borken/Kassel | Fulda | D | PWR 1300 MWe | | 1984 | atw 1976 |
| N07 | Donau | Rehling-1 | Lech | D | LWR 1200 MWe | | "1985" | atw 11/1976 |
| | | Rehling-2 | | | LWR 1200 MWe | | "1985" | atw 11/1976 |
| N08 | | Gundremmingen-1 | Donau | D | BWR 250 MWe | | 1967 | atw 1975 |
| | | Gundremmingen-2 | | | BWR 1310 MWe | | 1980 | atw 1976 |
| | | Gundremmingen-3 | | | BWR 1310 MWe | | 1981 | atw 1976 |
| N09 | | Ispra | Lago Maggiore | I | HWR 40/50 MWth | | 1969 | Nucl.Eng.1976 |
| N10 | Rhône | Creys-Malville | Rhône | F | LMFBR 1200 MWe | "Superphénix" | 1981 | atw 1976 |
| N11 | | Bugey-1 | Rhône | F | GCR 540 MWe | | 1972 | |
| | | Bugey-2 | | | PWR 957 MWe | | 1976 | atw 1976 |
| | | Bugey-3 | | | PWR 957 MWe | | 1977 | atw 1976 |
| | | Bugey-4 | | | PWR 940 MWe | | 1978 | atw 1976 |
| | | Bugey-5 | | | PWR 940 MWe | | 1978 | atw 1976 |
| N12 | Schelde | Geel/Mol/Dessel | Grote Nete | B | | | | |
| | | Geel (ZBNM) | | | ScL | | 1960 | |
| | | Mol (SCK) | | | RR 4 MWth | "BR 1" | 1957 | |
| | | | | | RR 80 MWth | "BR 2" | 1963 | |
| | | | | | RR 40 MWth | "BR 3" | 1962 | |
| | | | | | FRP 300 t/yr | | 1966, "1985" | P.C. |
| | | Dessel | | | FFP 200/800 t/yr $UO_2$ | "Eurofuel" | 1975,1982 | NIS |
| N13 | | Doel-1 | Schelde | B | PWR 410 MWe | | 1974 | atw 1975 |
| | | Doel-2 | | | PWR 410 MWe | | 1975 | |
| | | Doel-3 | | | PWR 930 MWe | | 1980 | |
| | | Doel-4 | | | PWR 1000 MWe | | "1985" | CEC |

1) See footnotes of Table 4-3

2) Alternative Sites:
Wahn/Lathen, Lichtenmoor/Nienburg, Lutterloh/Uelzen, Gorleben/Luchow-Dannenberg

Table 4-5: Nuclear Facilities around the Rhein-Maas Region till 1985/90 (Far Distance Zone) 1)

| No. | Region | Plant | River | Country | Type Power or Capacity | Commissioning/ Decommissioning | References |
|---|---|---|---|---|---|---|---|
| F01 | "Elbe" | Stendal | Elbe | DDR | PWR 440 MWe | "1980" | atw 1976 |
| | | Rheinsberg 1 | Rhin | DDR | PWR 80 MWe | 1966 | |
| | | Lubmin-1 | Baltic Sea | DDR | PWR 440 MWe | 1973 | |
| | | Lubmin-2 | | DDR | PWR 440 MWe | 1975 | |
| | | Esenshamm | Weser | D | PWR 1230 MWe | 1977 | |
| | | Krümmel | Elbe | D | BWR 1316 MWe | 1978/79 | |
| | | Stade | Elbe | D | PWR 662 MWe | 1972 | |
| | | Brokdorf | Elbe | D | PWR 1365 MWe | 1981/82 | |
| | | Brunsbüttel | Elbe | D | BWR 806 MWe | 1976 | |
| | | Cuxhaven | North Sea | D | LWR 1365 MWe | "1985" | |
| F02 | "Donau" | Ohu-1 | Isar | D | BWR 907 MWe | 1977 | |
| | | Ohu-2 | Isar | D | LWR 1250 MWe | "1983/84" | |
| | | Niederaichbach | Isar | D | GCHWR 100 MWe | 1972/1974 | |
| | | Pleinting | Donau | D | PWR 1300 MWe | 1983 | |
| | | Stein/St.Pantaleon | Donau | A | LWR 1000-1300 MWe | 1985/86 | |
| | | Tullnerfeld/ Zwentendorf | Donau | A | BWR 723 MWe | 1977 | |
| | | Dukovany-1 | Jihlawa | CS | PWR 420 MWe | 1979 | |
| | | Dukovany-2 | Jihlawa | CS | PWR 420 MWe | 1980 | |
| F03 | "Po" | Trino Vercellese | Po | I | PWR 270 MWe | 1965 | |
| | | Mezzanone di Caorso | Po | I | BWR 862 MWe | 1976 | |
| | | Brasimone | | I | LMFBR 140 MWth | "1985" | |
| F04 | "Rhône" | Marcoule-1 | Rhône | F | GCR 40 MWe | 1959 | |
| | | Marcoule-2 | Rhône | F | GCR 40 MWe | 1960 | |
| | | Marcoule-3 | Rhône | F | LMFBR 233 MWe | 1973 | |
| | | Tricastin-1 | Rhône | F | PWR 925 MWe | 1979 | |
| | | Tricastin-2 | Rhône | F | PWR 925 MWe | 1979 | |
| | | Tricastin-3 | Rhône | F | PWR 925 MWe | 1980 | |
| | | Tricastin-4 | Rhône | F | PWR 925 MWe | 1980 | |
| | | Grenoble | Isère | F | | | |
| F05 | "Loire" | Chinon-1 | Loire | F | GCR 210 MWe | 1965 | |
| | | Chinon-2 | Loire | F | GCR 400 MWe | 1967 | |
| | | Chinon-3 | Loire | F | PWR 905 MWe | 1981 | |
| | | Chinon-4 | Loire | F | PWR 905 MWe | 1982 | |
| | | St.Laurent-1 | Loire | F | GCR 460 MWe | 1969 | |
| | | St.Laurent-2 | Loire | F | GCR 515 MWe | 1971 | |
| | | St.Laurent-3 | Loire | F | BWR 954 MWe | 1979 | |
| | | St.Laurent-4 | Loire | F | BWR 954 MWe | 1980 | |
| | | Dampierre-1 | Loire | F | PWR 905 MWe | 1979 | |
| | | Dampierre-2 | Loire | F | PWR 905 MWe | 1980 | |
| | | Dampierre-3 | Loire | F | PWR 905 MWe | 1980 | |
| | | Dampierre-4 | Loire | F | PWR 905 MWe | 1981 | |
| F06 | "Channel" | Gravelines-1 | | F | PWR 925 MWe | 1979 | |
| | | Gravelines-2 | | F | PWR 925 MWe | 1979 | |
| | | Gravelines-3 | | F | PWR 925 MWe | 1980 | |
| | | Gravelines-4 | | F | PWR 925 MWe | 1981 | |

Table 4-5: (cont.)

| No. | Site | Plant | River | Country | Type Power or Capacity | Commissioning/ Decommissioning | References |
|---|---|---|---|---|---|---|---|
| F06 | | Bradwell-1 | | GB | GCR 150 MWe | 1962 | |
| | | Bradwell-2 | | GB | GCR 150 MWe | 1962 | |
| | | Dungeness A-1 | | GB | GCR 275 MWe | 1965 | |
| | | Dungeness A-2 | | GB | GCR 275 MWe | 1965 | |
| | | Dungeness B-1 | | GB | AGR 600 MWe | 1978 | |
| | | Dungeness B-2 | | GB | AGR 600 MWe | 1978 | |
| | | Sizewell-1 | | GB | GCR 290 MWe | 1966 | |
| | | Sizewell-2 | | GB | GCR 290 MWe | 1966 | |
| | | Sizewell-3+6 | | GB | SGHWR 4*660 MWe | "1985" | CEC |
| | | Paluel-1 | | F | PWR 1300 MWe | 1982 | |
| | | Paluel-2 | | F | PWR 1300 MWe | "1985" | CEC |
| F07 | | La Hague | | F | FRP 800 t/yr (+800) | (1980) | |
| F08 | | Windscale | | GB | FRP 2800 t/yr (+800) | (1980) | |

1) See footnotes of Table 4-3

Table 4-6: List of Abbreviations for Types of Nuclear Facilities

| | | |
|---|---|---|
| AGR | = | Advanced Gas-Cooled Reactor |
| BWR | = | Boiling Water Reactor |
| FFP | = | Fuel Fabrication Plant |
| FRP | = | Fuel Reprocessing Plant |
| GCR | = | Gas-Cooled Reactor |
| GCHWR | = | Gas Cooled Heavy Water Reactor |
| HTR | = | High-Temperature Gas-Cooled Reactor |
| HWR | = | Heavy Water Reactor |
| LMFBR | = | Liquid Metal Fast Breeder Reactor |
| LMFR | = | Liquid Metal Fast Reactor |
| LWR | = | Light Water Reactor |
| NPP | = | Nuclear Power Plant |
| NRC | = | Nuclear Research Center |
| PHWR | = | Pressurized Heavy Water Reactor |
| PWR | = | Pressurized Water Reactor |
| RC | = | Research Center |
| RR | = | Research Reactor |
| ScL | = | Scientific Laboratory |
| SGHWR | = | Steam Generating Heavy Water Reactor |
| STR | = | Suspension Test Reactor |
| UEP | = | Uranium Enrichment Plant |
| UMl | = | Uranium-Ore Mill |
| UMn | = | Uranium-Ore Mine |

Table 5-1.1: Evaluated Release Rates for Plants already in Operation for some Length of Time
- Gaseous Releases [Ci/yr] -

| No. | Site | H-3 | C-14 | Ar-41 | Co-58 | Co-60 | Kr-85 | Kr-88 | I-129 | I-131 | Xe-133 | Xe-135 | Cs-134 | Cs-137 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Mühleberg 1) | | | | | | | 7000 | | 0.4 | 72000 | 25000 | | |
| 6 | Würenlingen 1) ScL | | | | | | | | | 0.5 | | | | |
| 7 | Beznau 1) | | | | | | | | | 12(-3) | 6300 | | | |
| 17 | Karlsruhe 2) ScL | 100 | | 300 | | | | | | 1.5(-3) | | | | |
| | FRP"WAK" | 1900 | 16 | | | | 50000 | | 4(-3) | | | | | |
| | LMFR"KNK" | 2 | | | | | 16 | 1 | | 2(-4) | 80 | 4 | | |
| 20 | Obrigheim 3) | 10 | | 45 | 3(-3) | 8(-3) | 5 | | | 5(-3) | 5000 | 500 | 8(-5) | 2(-4) |
| 40 | Dodewaard 4) | | | | | | | 550 | | 1.1(-2) | 1350 | 2450 | | |
| 41 | Petten 5) ScL | | | | | 20 | | | | 0.2 | | | | |
| | RR"HFR" | | | 600 | | | | | | | | | | |
| 42 | Chooz 6) | | | | | | | | | | 14000 | 1000 | | |
| 44 | Jülich 7) ScL | 30 | | | | | 50 | | | 1.5(-2) | | | | |
| | RR-1"Merlin" | 60 | | 280 | | | | | | 1.7(-2) | | 110 | | |
| | RR-2"Dido" | | | 330 | | | | | | 1.1(-2) | | 10 | | |
| | HTR"AVR" | 6 | | | | | 5 | | | | | 20 | | |

Evaluated on the Basis of:
1) Reports: KUER-18 (1975), KUER-19 (1976)
2) Reports: KFK-1565 (1972), KFK-1818 (1973), KFK-1973 (1974), KFK-2155 (1975), KFK-2266 (1976)
3) Reports: STH-4/74 (1974), STH-11/74 (1974), STH-6/75 (1975), STH-2/76 (1976), STH-5/76 (1976) among others
4) H. Wijker, Private Communication (1976)
5) J.A. Goedkoop, Private Communication (1976)
6) L. Maesen, J. Grangetas, Private Communication (1975)
7) Report: JUEL ZST-209 (1975)

Table 5-1.2: Evaluated Release Rates for Plants already in Operation for some Length of Time
- Liquid Releases [ Ci/yr ] -

| No. | Site | H-3 | Co-58 | Co-60 | Sr-89 | Sr-90 | Ru-106 | J-131 | Cs-134 | Cs-137 | Ce-144 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Mühleberg 1)8) | 0.0 | 1.3o(-2) | 1.04 | 0.0 | 0.0 | 0.0 | 6.3o(-2) | 0.0 | 7.5o(-1) | 0.0 |
| 6 | Würenlingen 1)8)ScL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.oo(-1) | 0.0 | 0.0 | 0.0 |
| 7 | Beznau 1)8) | 840 | 3.8 | 1.2 | 0.0 | 0.0 | 0.0 | 2.oo(-1) | 4.oo(-1) | 2.70 | 1.4o(-1) |
| 17 | Karlsruhe 2) | 4000 1o) | 0.0 | 2.oo(-3) | 0.0 | 1.1o(-2) | 1.oo(-3) | 0.0 | 3.4o(-2) | 1.47(-1) | 7.oo(-3) |
| 20 | Obrigheim 9) | 240 | 8.oo(-1) | 5.oo(-1) | 7.oo(-3) | 5.oo(-3) | 0.0 | 1.oo(-1) | 4.7o(-1) | 7.9o(-1) | 4.oo(-2) |
| 40 | Dodewaard 4) | 5 | 0.0 | 1.35(-1) | 3.oo(-3) | 7.5o(-4) | 0.0 | 0.0 | 6.5o(-2) | 1.40(-1) | 0.0 |
| 42 | Chooz 6) | 1500 | 8.00(-2) | 5.6o(-1) | 0.0 | 8.oo(-5) | 0.0 | 6.oo(-2) | 3.oo | 3.5o | 1.6o |
| 44 | Jülich 7) | 237 | 0.0 | 5.78(-3) | 0.0 | 0.0 | 0.0 | 1.43(-1) | 4.32(-3) | 4.27(-2) | 2.37(-2) |

1) to 7) see Table 5-1.1

8) S. Chakraborty, Private Communication (1976)

9) Report: WaBoLu 18/74 (1975)

1o) assumed to be released by the FRP "WAK" in full operation

Table 5-2.1: Evaluated Expected Release Rates for Modern 1000 MWe Power Plants - Gaseous Releases [Ci/(yr · 1000 MWe)] -

| Nuclide | USAEC [1) ] "Mississippi Study" [1] | USAEC "Tennessee Study" [6] | "Karlsruhe Set" [78 to 82] | "Jülich [++)] Set" [5] | UK-NRPB for the EC [83] | This Study |
|---|---|---|---|---|---|---|
| | 1000 MWe - PWR | | | | | |
| H-3 | 0 | 1 040 | 12 | 20 | 12 | 20 |
| C-14 | 0 | 0 | 6.5 | 11.1 [2)] | 6.0 | 12 |
| Ar-41 | 8.4 (-28) | -- | -- | -- | -- | 30 |
| Co-58 | 0 | 0 | -- | -- | -- | 2(-3) [3)] |
| Co-60 | 0 | 0 | -- | -- | -- | 2(-3) [3)] |
| Kr-85 | 3 413 | 905 | 1 300 | 700 | -- | 1 200 |
| Kr-88 | 3.0(-27) | 20.1 | 50 | -- | -- | 40 |
| I-131 | 1.8(-1) | 7.9(-3) | 6(-2) | 5(-2) | -- | 6(-2) |
| Xe-133 | 3 491 | 299 | 3 200 | 2 500 | -- | 2 800 |
| Xe-135 | 1.7(-18) | 24.2 | 300 | -- | -- | 200 |
| Cs-134 | 0 | 0 | 4.0 (-3) | -- | -- | 2 (-3) [3)] |
| Cs-137 | 0 | 0 | 7.0 (-3) | -- | -- | 2 (-3) [3)] |
| | 1000 MWe - BWR | | | | | |
| H-3 | 2.6 (-2) | 41.5 | 18 | 30 | ca.60 | 20 |
| C-14 | 0 | 0 | 7.5 | 11.2 [2)] | 10.6 | 12 |
| Ar-41 | 896 | -- | -- | -- | -- | 30 |
| Co-58 | 0 | 0 | -- | -- | -- | 2(-3) [3)] |
| Co-60 | 0 | 0 | -- | -- | -- | 2(-3) [3)] |
| Kr-85 | 4 413 | 723 | 1 200 | 700 | -- | 1 200 |
| Kr-88 | 118 | 19.2 | 4 | -- | -- | 40 |
| I-131 | 19 | 6.1(-2) | 3(-1) | 1(-1) | -- | 3(-1) |
| Xe-133 | 17 979 | 3 320 | 2 400 | 2 500 | -- | 2 800 |
| Xe-135 | 8.5(-2) | 383 | 200 | -- | -- | 200 |
| Cs-134 | 0 | 0 | 4.0 (-3) | -- | -- | 2(-3) [3)] |
| Cs-137 | 0 | 0 | 7.0 (-3) | -- | -- | 2(-3) [3)] |

Table 5-2.1t (cont.)

| Nuclide | USAEC "Mississippi Study [1] | USAEC "Tennessee Study [6] | "Karlsruhe Set" [78 to 82] | "Jülich Set" [5] | UK-NRPB for the EC [83] | This Study |
|---|---|---|---|---|---|---|
| | 1000 MWe - HTR | | | | | |
| H-3 | not under consideration | 66.6 | 50 | 10 | < 8 500 | 20 |
| C-14 | | 0 | 0 | 0.1 [2)] | 1.8 | 0 |
| Ar-41 | | -- | -- | -- | -- | 30 |
| Co-58 | | 0 | -- | -- | -- | 0 |
| Co-60 | | 0 | -- | -- | -- | 0 |
| Kr-85 | | 2 550 | 1 300 | 120 | -- | 800 |
| Kr-88 | | 38.2 | 400 | -- | -- | 40 |
| I-131 | | 8.9(-4) | ca.1(-2) | 3(-4) | -- | 1(-3) |
| Xe-133 | | 58.0 | 450 | 40 | -- | 40 |
| Xe-135 | | 7.0 | ca. 200 | -- | -- | 20 |
| Cs-134 | | 0 | -- | -- | -- | 0 |
| Cs-137 | | 2.1 (-6) | -- | -- | -- | 0 |
| | 1000 MWe - LMFBR | | | | | |
| H-3 | 3.4 (-4) | 54.0 | 330 | -- | <25 000 | 100 |
| C-14 | 6.3 (-15) | 0 | 1 | 1 [2)] | -- | 1 |
| Ar-41 | 2.3 (-25) | -- | -- | -- | -- | -- |
| Co-58 | 0 | 5.9(-9) | -- | -- | -- | 0 |
| Co-60 | 0 | 4.7(-11) | -- | -- | -- | 0 |
| Kr-85 | 20.5 | 3.6(-1) | 350 | 1 000 | -- | 800 |
| Kr-88 | 5.8 (-29) | | 0 | -- | -- | 40 |
| I-131 | 12.3 | 2.6(-9) | ca.1(-2) | 9(-3) | -- | 1(-2) |
| Xe-133 | 139 | 2.4(-2) | 4 200 | 7 000 | -- | 4 000 |
| Xe-135 | 8.4(-2o) | 0 | 250 | -- | -- | 200 |
| Cs-134 | 8.4 (-1) | 9.9 (-9) | -- | -- | -- | 0 |
| Cs-137 | 9.2 (-1) | 3.8 (-8) | -- | -- | -- | 0 |

1) In the Mississippi Study two sets of release rates are evaluated, for the PWR-type as well as for the BWR-type. The first set, presented in this table, is evaluated for the modern contemporary power reactors, whereas the second set is evaluated for the advanced power reactors of the same type, that will be commissioned from the year 1985. The release rates of fission products of the second set are approximately two times higher than the corresponding release rates of the first set. The release rates of activation products remain almost unchanged.

2) C-14 values derived from: H. Bonka et al., Production and Emission of Carbon-14 from Nuclear Power Stations and Reprocessing Plants and its Radiological Significance, IVth IRPA Congress, Paris 1977.

3) The figures, which overestimate the actual release rates of these Co and Cs-isotopes, stand in place of all aerosol release rates.

Table 5-2.2: Evaluated Expected Release Rates for Modern 1000 MWe Power Plants - Liquid Releases [Ci/(yr · 1000 MWe)] -

| Nuclide | USAEC 1) "Mississippi Study [1] | USAEC "Tennessee Study [6] | "Karlsruhe Set" [78 to 82] | "Jülich Set" [5] | UK-NRPB for the EC [83] | This Study |
|---|---|---|---|---|---|---|
| | 1000 MWe - PWR | | | | | |
| H-3 | 486 | 1 040 | 1 180 | 900 | 1 180 | 950 |
| Co-58 | 1,8 (-2) | 4.2 (-5) | -- | 2.3 (-1) | -- | 2 (-1) |
| Co-60 | 3,6 (-4) | 0 | -- | 1,1 (-1) | -- | 2 (-1) |
| Sr-89 | 2,2 (-3) | 0 | 5,0 (-1) | -- | -- | 1 (-1) |
| Sr-90 | 6,0 (-5) | 0 | 5,0 (-2) | -- | -- | 5 (-2) |
| Ru-106 | 1,6 (-2) | 0 | 1,0 (-2) | -- | -- | 1 (-3) |
| I-131 | 1,5 | 1,8 (-3) | ca.1 (-1) | 1,6 (-1) | -- | 2 (-1) |
| Cs-134 | 1,6 (-1) | 1,3 (-4) | 2,5 | 1,0 (-1) | -- | 1 (-1) |
| Cs-137 | 9,7 (-1) | 1,0 (-4) | 4,0 | 2,3 (-1) | -- | 1 (-1) |
| Ce-144 | 1,8 (-4) | 0 | 1,0 (-1) | 2 (-2) | -- | 5 (-2) |
| | 1000 MWe - BWR | | | | | |
| H-3 | 129 | 41,5 | 162 | 150 | ca. 150 | 130 |
| Co-58 | 1,1 (-2) | 2,1 (-5) | -- | 2 (-2) | -- | 2 (-1) |
| Co-60 | 2,2 (-5) | 0 | -- | 1.5 (-1) | -- | 2 (-1) |
| Sr-89 | 9.3 (-3) | 2,1 (-5) | 5,0 (-1) | 2,7 (-1) | -- | 1 (-1) |
| Sr-90 | 5.4 (-4) | 0 | 5,0 (-2) | 2,6 (-1) | -- | 5 (-2) |
| Ru-106 | 1.7 (-2) | 0 | 1,0 (-2) | -- | -- | 1 (-3) |
| I-131 | 1,6 | 7,1 (-4) | ca. 1 (-1) | 8,8 (-2) | -- | 3 (-1) |
| Cs-134 | 4.0 (-1) | 5.2 (-5) | 2,5 | 7,8 (-2) | -- | 1 (-1) |
| Cs-137 | 1.8 | 4.2 (-5) | 4,0 | 1,7 (-1) | -- | 1 (-1) |
| Ce-144 | 1,2 (-3) | 0 | 1,0 (-1) | -- | -- | 5 (-2) |

Table 5-2.2(cont.)

| Nuclide | USAEC 1) "Mississippi Study" [1] | USAEC "Tennessee Study" [6] | "Karlsruhe Set" [78 to 82] | "Jülich Set" [5] | UK-NRPB for the EC [13] | This Study |
|---|---|---|---|---|---|---|
| | 1000 MWe - HTR | | | | | |
| H-3 | not under consideration | 66.6 | 3 000 | 900 | < 8 500 | 950 |
| Co-58 | | 0 | -- | -- | -- | 4 (-2) |
| Co-60 | | 0 | -- | 8 (-3) | -- | 4 (-2) |
| Sr-89 | | 5.7 (-5) | -- | -- | -- | 1 (-1) |
| Sr-90 | | 3.5 (-4) | -- | -- | -- | 1 (-2) |
| Ru-106 | | 0 | -- | -- | -- | 2 (-4) |
| I-131 | | 0 | -- | -- | -- | 4 (-2) |
| Cs-134 | | 7.6 (-3) | -- | -- | -- | 1 (-1) |
| Cs-137 | | 7.6 (-3) | -- | 1.3 (-2) | -- | 2 (-1) |
| Ce-144 | | 8.1 (-6) | -- | -- | -- | 1 (-2) |
| | 1000 MWe - LMFBR | | | | | |
| H-3 | No liquid releases | 54 | 210 | 100 | < 25 000 | 100 |
| Co-58 | | 0 | -- | 8.8 (-2) | -- | 2 (-1) |
| Co-60 | | 0 | -- | 8.8 (-2) | -- | 2 (-1) |
| Sr-89 | | 0 | -- | -- | -- | 1 (-1) |
| Sr-90 | | 0 | -- | -- | -- | 5 (-2) |
| Ru-106 | | 0 | -- | -- | -- | 1 (-3) |
| I-131 | | 0 | -- | 2.1 (-1) | -- | 2 (-1) |
| Cs-134 | | 0 | -- | 1.2 (-1) | -- | 1 (-1) |
| Cs-137 | | 0 | -- | 2.0 (-1) | -- | 1 (-1) |
| Ce-144 | | 0 | -- | -- | -- | 5 (-2) |

1) In the Mississippi Study two sets of release rates are evaluated, for the PWR-type as well as for the BWR-type. The first set, presented in this table, is evaluated for modern contemporary power reactors, whereas the second set is evaluated for advanced power reactors of the same type, that will be commissioned from the year 1985. The release rates of fission products of the second set are approximately two times higher than the corresponding release rates of the first set. The release rates of activation products remain almost unchanged.

Table 5-3: Evaluated Expected Release Rates for a Modern Reprocessing Plant (Fuel Burn-up: 30 000 MWd/t)
- Gaseous Releases [Ci/(yr · 1500 t/yr)] -

| Nuclide | Release Rate [Ci/yr] | Assumed Decontamination Factor |
|---|---|---|
| H-3 | 70 000 | 10 |
| C-14 | 600 | 1 |
| Kr-85 | 190 000 | $10^2$ |
| J-129 | 0,14 | $3 \cdot 10^2$ |
| Cs-134 | 0.6 | $3 \cdot 10^8$ |
| Cs-137 | 0,5 | $3 \cdot 10^8$ |

Table 5-4: Assumed Release Rates of the Reprocessing Plants at Windscale (GB) and La Hague (F)
- Gaseous Releases [Ci/(yr · 800 t/yr)] -

| Nuclide | Release Rate [Ci/yr] | Assumed Decontamination Factor |
|---|---|---|
| H-3 | 350 000 | 1 |
| C-14 | 300 | 1 |
| Kr-85 | 9 500 000 | 1 |
| J-129 | 0,7 | $3 \cdot 10$ |
| Cs-134 | 0,3 | $3 \cdot 10^8$ |
| Cs-137 | 0.25 | $3 \cdot 10^8$ |

Table 5-5: Frequencies and Mixing Layer Heights of the Various Weather Categories

<table>
<tr><th rowspan="2">Weather Category</th><th colspan="4">Frequency [ % ]</th><th rowspan="2">Mixing Layer Height [ 94 ] [m]</th></tr>
<tr><th>Switzerland Area [ 89 ]</th><th>Upper Rhein Area [ 90 ]</th><th>Lower Rhein Area [ 91 ]</th><th>Rhein-Maas-Delta Area [ 92 ]</th></tr>
<tr><td>A</td><td rowspan="2">9</td><td>2</td><td>1</td><td>2.0</td><td>1500</td></tr>
<tr><td>B</td><td>7</td><td>8</td><td>8.3</td><td>1500</td></tr>
<tr><td>C</td><td rowspan="2">38</td><td>14</td><td>13</td><td>15.8</td><td>1000</td></tr>
<tr><td>D</td><td>42</td><td>55</td><td>54.3</td><td>500</td></tr>
<tr><td>E</td><td rowspan="2">53</td><td>21</td><td>8</td><td>9.7</td><td>200</td></tr>
<tr><td>F</td><td>14</td><td>15</td><td>9.9</td><td>200</td></tr>
</table>

Table 5-6: Effective Residence Times of Deposited Material in the Upper Layer of the Soil

| Nuclide | Effective Residence Time $\tau_{S_{eff}}$ [yr] |
|---|---|
| Co-58 | 0.24 [96] |
| Co-60 | 1.25 [96] |
| Sr-89 | 0.2 [99] |
| Sr-90 | 14.3 [99] |
| Ru-106 | 0.73 [96] |
| I-129 | 1.00 [97] |
| I-131 | 0.032 = $\tau_r$ only rad. decay considered |
| Cs-134 | 2.89 [98] |
| Cs-137 | 32.3 [98] |
| Ce-144 | 1.1 = $\tau_r$ only rad. decay considered |

Table 5-7: Distribution Coefficients Sediments/Water (Evaluated on the Basis of [68, 103, 118 to 121])

| Element | Distribution Coefficient $K_d$ [$m^3/t$] |
|---|---|
| H | 1 |
| Co | 1000 |
| Sr | 10 |
| Ru | 150 |
| I | 1 |
| Cs | 2000 |
| Ce | 620 |

Table 5-8.1: Bioaccumulation and Transfer Factors [71]

| Element | Soil→Plant $B_{S,P}$ $\left[\frac{kg}{kg}\right]$ | Freshwater→Fish $B_F$ $\left[\frac{l}{kg}\right]$ | Daily Intake→Meat $T_{A,meat}$ $\left[\frac{d}{kg}\right]$ | Daily Intake→Milk $T_{A,milk}$ $\left[\frac{d}{l}\right]$ |
|---|---|---|---|---|
| H | 4.8 | 0,9 | 0.012 | 0,01 |
| C | 5.5 | 4600 | 0.031 | 0.012 |
| Co | 0.0094 | 50 | 0.013 | 0.001 |
| Sr | 0,017 | 30 | 0.0004 | 0.0008 |
| Ru | 0.05 | 10 | 0.4 | $1 \cdot 10^{-6}$ |
| I | 0.02 | 15 | 0.0029 | 0.006 |
| Cs | 0.01 | 2000 | 0.004 | 0.012 |
| Ce | 0.0025 | 1 | 0.0012 | 0.0006 |

Table 5-8.2: Bioaccumulation Factors

| Nuclide | Air → Plant $B_P \left[\frac{m^3}{kg}\right]$ | | Water → Irrigated Plant $B_{IP} \left[\frac{m^3}{kg}\right] / \left[\frac{\text{100 mm irrigation}}{\text{growing season}}\right]$ | |
|---|---|---|---|---|
| | Leafy Vegetables 1) | Other Plant Products 2) | Leafy Vegetables 1) | Other Plant Products 2) |
| H-3 | 83.3 3) | | 7.5(-4) 3)4) | |
| C-14 | 687.5 3) | | 1.8(-2) | 1.4(-2) |
| Co-58 | 4120 | 1.40 | 4.2(-3) | 5.7(-6) |
| Co-60 | 4126 | 7.29 | 4.2(-3) | 3.0(-5) |
| Sr-89 | 4121 | 2.11 | 4.2(-3) | 8.6(-6) |
| Sr-90 | 4270 | 151 | 4.8(-3) | 6.2(-4) |
| Ru-106 | 4141 | 22.6 | 4.3(-3) | 9.3(-5) |
| I-129 | 4164 | 27.6 | 4.2(-3) | 5.1(-5) |
| I-131 | 1497 | 0.15 | 1.5(-3) | 4.1(-8) |
| Cs-134 | 4137 | 17.9 | 4.3(-3) | 7.3(-5) |
| Cs-137 | 4319 | 200 | 5.0(-3) | 8.2(-4) |
| Ce-144 | 4121 | 1.70 | 4.2(-3) | 7.0(-6) |

1) Deposit on leaves and uptake by roots

2) Uptake by roots

3) Ratio radioisotope/stable isotope in the vegetation assumed to be the same as in the atmosphere res. irrigation water

4) Independent of irrigation rate

Table 5-9: Dose Factors for External Irradiation

| Nuclide | Immersion in Contaminated Cloud $g_{EG}\left[\frac{rem \cdot m^3}{s \cdot Ci}\right]$ Whole Body (γ) [1] | Skin (β) derived from [1] | Standing on Contaminated Ground $g_{EG}\left[\frac{rem \cdot m^2}{s \cdot Ci}\right]$ 1) Whole Body (γ) derived from [122] | Immersion in Contaminated Water $g_{EWV}\left[\frac{rem \cdot m^3}{s \cdot Ci}\right]$ 2) Whole Body (γ) [1] | Skin (β) derived from [1] |
|---|---|---|---|---|---|
| H-3 | 0 | 0 | 0 | 0 | 0 |
| C-14 | 0 | 9.7 (-1) | 0 | 0 | 1.06 (-3) |
| Ar-41 | 3.1 (-1) | 1.4 (-1) | -- | -- | -- |
| Co-58 | 2.3 (-1) | 0.8 (-1) | 1.7(-3) | 5.0 (-4) | 1.4 (-4) |
| Co-60 | 5.6 (-1) | 1.3 (-1) | 4.9(-3) | 1.3 (-3) | 0.2 (-3) |
| Kr-85 | 6.1 (-4) | 4.2 (-2) | - | -- | -- |
| Kr-88 | 4.2 (-1) | 1.4 (-1) | - | -- | -- |
| Sr-89 | 5.8 (-2) | 0.7 (-1) | 1.9(-7) | 1.3 (-6) | 1.5 (-4) |
| Sr-90 | 6.7 (-5) | 3.6 (-2) | 0 | 1.5 (-7) | 4.2 (-5) |
| Ru-106 | 4.7 (-2) | 4.0 (-1) | 4.3(-4) | 1.1 (-4) | 4.2 (-4) |
| I-129 | 3.1 (-4) | 0.8 (-3) | 7.9(-5) | 5.8 (-7) | 1.1 (-6) |
| I-131 | 8.6 (-2) | 0.5 (-1) | 7.8(-4) | 1.9 (-4) | 0.7 (-4) |
| Xe-133 | 6.9 (-3) | 1.2 (-2) | -- | -- | -- |
| Xe-135 | 5.8 (-2) | 0.8 (-1) | -- | -- | -- |
| Cs-134 | 3.6 (-1) | 1.1 (-1) | 3.4(-3) | 8.1 (-4) | 1.6 (-4) |
| Cs-137 | 1.3 (-1) | 0.6 (-1) | 1.1(-3) | 2.8 (-4) | 1.1 (-4) |
| Ce-144 | 3.9 (-3) | 0.7 (-2) | 1.1(-4) | 8.3 (-6) | 0.9 (-6) |

1) This dose factor takes into account an exponential distribution through depth with a relaxation length of 3 cm

2) The whole body dose factors for external water surface irradiation $g_{EWS}$ are taken as one-half those of water immersion [1].

Table 5-10: Inhalation Dose Factors in Age Groups [rem/Ci] (from [71] and [123])

| NUCLIDE | AGE GROUP | TOT.BODY | BONE | GI-TRACT | LIVER | LUNG | THYROID |
|---|---|---|---|---|---|---|---|
| H - 3 | INFANT | 3.07E+02 | 0.0 | 3.07E+02 | 3.07E+02 | 3.07E+02 | 3.07E+02 |
| | CHILD | 2.03E+02 | 0.0 | 2.03E+02 | 2.03E+02 | 2.03E+02 | 2.03E+02 |
| | TEEN | 1.06E+02 | 0.0 | 1.06E+02 | 1.06E+02 | 1.06E+02 | 1.06E+02 |
| | ADULT | 1.34E+02 | 0.0 | 1.34E+02 | 1.34E+02 | 1.34E+02 | 1.34E+02 |
| C - 14 | INFANT | 3.60E+03 | 3.60E+03 | 3.60E+03 | 3.60E+03 | 3.60E+03 | 3.60E+03 |
| | CHILD | 1.69E+03 | 1.69E+03 | 1.69E+03 | 1.69E+03 | 1.69E+03 | 1.69E+03 |
| | TEEN | 5.66E+02 | 5.66E+02 | 5.66E+02 | 5.66E+02 | 5.66E+02 | 5.66E+02 |
| | ADULT | 4.27E+02 | 2.28E+03 | 4.27E+02 | 4.27E+02 | 4.27E+02 | 4.27E+02 |
| CO- 58 | INFANT | 1.20E+02 | 0.0 | 8.67E+03 | 8.39E+01 | 6.28E+05 | 0.0 |
| | CHILD | 7.23E+01 | 0.0 | 9.78E+03 | 4.11E+01 | 3.04E+05 | 0.0 |
| | TEEN | 2.93E+01 | 0.0 | 1.19E+04 | 2.20E+01 | 1.71E+05 | 0.0 |
| | ADULT | 2.59E+02 | 0.0 | 1.33E+04 | 1.98E+02 | 1.16E+05 | 0.0 |
| CO- 60 | INFANT | 8.38E+02 | 0.0 | 2.34E+04 | 6.00E+02 | 3.98E+06 | 0.0 |
| | CHILD | 5.07E+02 | 0.0 | 2.53E+04 | 2.90E+02 | 1.87E+06 | 0.0 |
| | TEEN | 2.06E+02 | 0.0 | 2.94E+04 | 1.55E+02 | 1.07E+06 | 0.0 |
| | ADULT | 1.85E+03 | 0.0 | 3.56E+04 | 1.44E+03 | 7.47E+05 | 0.0 |
| SR- 89 | INFANT | 8.85E+02 | 3.08E+04 | 4.86E+04 | 0.0 | 1.65E+06 | 0.0 |
| | CHILD | 4.16E+02 | 1.45E+04 | 4.56E+04 | 0.0 | 6.06E+05 | 0.0 |
| | TEEN | 1.39E+02 | 4.84E+03 | 4.42E+04 | 0.0 | 3.13E+05 | 0.0 |
| | ADULT | 1.09E+03 | 3.80E+04 | 4.37E+04 | 0.0 | 1.75E+05 | 0.0 |
| SR- 90 | INFANT | 5.76E+05 | 9.44E+06 | 9.89E+04 | 0.0 | 1.09E+07 | 0.0 |
| | CHILD | 2.70E+05 | 4.43E+06 | 9.31E+04 | 0.0 | 4.00E+06 | 0.0 |
| | TEEN | 9.04E+04 | 1.48E+06 | 9.05E+04 | 0.0 | 2.07E+06 | 0.0 |
| | ADULT | 7.62E+05 | 1.24E+07 | 9.02E+04 | 0.0 | 1.20E+06 | 0.0 |
| RU-106 | INFANT | 8.16E+02 | 6.65E+03 | 1.26E+05 | 0.0 | 1.07E+07 | 0.0 |
| | CHILD | 3.88E+02 | 3.12E+03 | 1.18E+05 | 0.0 | 3.93E+06 | 0.0 |
| | TEEN | 1.32E+02 | 1.05E+03 | 1.16E+05 | 0.0 | 2.05E+06 | 0.0 |
| | ADULT | 1.09E+03 | 8.64E+03 | 1.14E+05 | 0.0 | 1.18E+06 | 0.0 |
| I -129 | INFANT | 1.16E+04 | 2.23E+04 | 2.23E+02 | 1.62E+04 | 0.0 | 1.04E+07 |
| | CHILD | 5.71E+03 | 1.05E+04 | 2.15E+02 | 6.40E+03 | 0.0 | 4.28E+06 |
| | TEEN | 4.90E+03 | 3.53E+03 | 2.16E+02 | 2.94E+03 | 0.0 | 3.66E+06 |
| | ADULT | 6.91E+03 | 2.48E+03 | 2.22E+02 | 2.11E+03 | 0.0 | 5.54E+06 |
| I -131 | INFANT | 1.40E+04 | 2.59E+04 | 7.66E+02 | 3.05E+04 | 0.0 | 1.06E+07 |
| | CHILD | 7.37E+03 | 1.23E+04 | 7.17E+02 | 1.25E+04 | 0.0 | 4.39E+06 |
| | TEEN | 3.30E+03 | 4.21E+03 | 7.45E+02 | 5.90E+03 | 0.0 | 1.83E+06 |
| | ADULT | 2.56E+03 | 3.15E+03 | 7.85E+02 | 4.47E+03 | 0.0 | 1.49E+06 |
| CS-134 | INFANT | 5.23E+04 | 3.43E+05 | 9.80E+02 | 5.89E+05 | 7.22E+04 | 0.0 |
| | CHILD | 6.02E+04 | 1.68E+05 | 1.02E+03 | 2.69E+05 | 3.21E+04 | 0.0 |
| | TEEN | 6.80E+04 | 6.04E+04 | 1.12E+03 | 1.38E+05 | 1.80E+04 | 0.0 |
| | ADULT | 9.11E+04 | 4.67E+04 | 1.30E+03 | 1.06E+05 | 1.22E+04 | 0.0 |
| CS-137 | INFANT | 3.15E+04 | 4.90E+05 | 9.45E+02 | 5.22E+05 | 6.75E+04 | 0.0 |
| | CHILD | 3.38E+04 | 2.34E+05 | 9.22E+02 | 2.16E+05 | 2.71E+04 | 0.0 |
| | TEEN | 3.79E+04 | 8.02E+04 | 9.60E+02 | 1.03E+05 | 1.47E+04 | 0.0 |
| | ADULT | 5.36E+04 | 5.98E+04 | 1.05E+03 | 7.77E+04 | 9.41E+03 | 0.0 |
| CE-144 | INFANT | 1.78E+04 | 3.34E+05 | 1.15E+05 | 1.30E+05 | 9.06E+06 | 0.0 |
| | CHILD | 8.37E+03 | 1.57E+05 | 1.08E+05 | 4.91E+04 | 3.32E+06 | 0.0 |
| | TEEN | 2.80E+03 | 5.24E+04 | 1.05E+05 | 2.17E+04 | 1.72E+06 | 0.0 |
| | ADULT | 2.30E+04 | 4.29E+05 | 1.02E+05 | 1.79E+05 | 9.73E+05 | 0.0 |

Table 5-11: Ingestion Dose Factors in Age Groups [rem/Ci] (from [71] and [123])

| NUCLIDE | AGE GROUP | TOT.BODY | BONE | GI-TRACT | LIVER | LUNG | THYROID |
|---|---|---|---|---|---|---|---|
| H - 3 | INFANT | 3.07E+02 | 0.0 | 3.07E+02 | 3.07E+02 | 3.07E+02 | 3.07E+02 |
| | CHILD | 2.03E+02 | 0.0 | 2.03E+02 | 2.03E+02 | 2.03E+02 | 2.03E+02 |
| | TEEN | 1.06E+02 | 0.0 | 1.06E+02 | 1.06E+02 | 1.06E+02 | 1.07E+02 |
| | ADULT | 1.34E+02 | 0.0 | 1.34E+02 | 1.34E+02 | 1.34E+02 | 1.34E+02 |
| C - 14 | INFANT | 4.81E+03 | 4.81E+03 | 4.81E+03 | 4.81E+03 | 4.81E+03 | 4.81E+03 |
| | CHILD | 2.26E+03 | 2.26E+03 | 2.26E+03 | 2.26E+03 | 2.26E+03 | 2.26E+03 |
| | TEEN | 7.55E+02 | 7.55E+02 | 7.55E+02 | 7.55E+02 | 7.55E+02 | 7.55E+02 |
| | ADULT | 5.69E+02 | 2.84E+03 | 5.69E+02 | 5.69E+02 | 5.69E+02 | 5.69E+02 |
| CO- 58 | INFANT | 9.26E+03 | 0.0 | 9.79E+03 | 3.78E+03 | 0.0 | 0.0 |
| | CHILD | 5.58E+03 | 0.0 | 1.10E+04 | 1.85E+03 | 0.0 | 0.0 |
| | TEEN | 2.26E+03 | 0.0 | 1.34E+04 | 9.92E+02 | 0.0 | 0.0 |
| | ADULT | 1.67E+03 | 0.0 | 1.51E+04 | 7.46E+02 | 0.0 | 0.0 |
| CO- 60 | INFANT | 2.56E+04 | 0.0 | 2.64E+04 | 1.07E+04 | 0.0 | 0.0 |
| | CHILD | 1.55E+04 | 0.0 | 2.86E+04 | 5.17E+03 | 0.0 | 0.0 |
| | TEEN | 6.30E+03 | 0.0 | 3.31E+04 | 2.76E+03 | 0.0 | 0.0 |
| | ADULT | 4.72E+03 | 0.0 | 4.02E+04 | 2.16E+03 | 0.0 | 0.0 |
| SR- 89 | INFANT | 8.42E+04 | 2.93E+06 | 5.48E+04 | 0.0 | 0.0 | 0.0 |
| | CHILD | 3.95E+04 | 1.38E+06 | 5.15E+04 | 0.0 | 0.0 | 0.0 |
| | TEEN | 1.32E+04 | 4.60E+05 | 4.99E+04 | 0.0 | 0.0 | 0.0 |
| | ADULT | 8.85E+03 | 3.09E+05 | 4.94E+04 | 0.0 | 0.0 | 0.0 |
| SR- 90 | INFANT | 6.40E+06 | 2.51E+07 | 2.43E+05 | 0.0 | 0.0 | 0.0 |
| | CHILD | 4.36E+06 | 1.72E+07 | 2.29E+05 | 0.0 | 0.0 | 0.0 |
| | TEEN | 2.57E+06 | 1.04E+07 | 2.20E+05 | 0.0 | 0.0 | 0.0 |
| | ADULT | 1.86E+06 | 7.61E+06 | 1.02E+05 | 0.0 | 0.0 | 0.0 |
| RU-106 | INFANT | 3.12E+03 | 2.54E+04 | 1.97E+05 | 0.0 | 0.0 | 0.0 |
| | CHILD | 1.48E+03 | 1.19E+04 | 1.85E+05 | 0.0 | 0.0 | 0.0 |
| | TEEN | 5.03E+02 | 4.00E+03 | 1.81E+05 | 0.0 | 0.0 | 0.0 |
| | ADULT | 3.48E+02 | 2.75E+03 | 1.78E+05 | 0.0 | 0.0 | 0.0 |
| I -129 | INFANT | 1.55E+04 | 2.95E+04 | 4.46E+02 | 2.16E+04 | 0.0 | 1.36E+07 |
| | CHILD | 7.62E+03 | 1.39E+04 | 4.29E+02 | 8.54E+03 | 0.0 | 5.58E+06 |
| | TEEN | 6.54E+03 | 4.66E+03 | 4.31E+02 | 3.92E+03 | 0.0 | 4.77E+06 |
| | ADULT | 9.21E+03 | 3.27E+03 | 4.44E+02 | 2.81E+03 | 0.0 | 7.23E+06 |
| I -131 | INFANT | 1.86E+04 | 3.42E+04 | 1.53E+03 | 4.07E+04 | 0.0 | 1.39E+07 |
| | CHILD | 9.82E+03 | 1.63E+04 | 1.43E+03 | 1.67E+04 | 0.0 | 5.72E+06 |
| | TEEN | 4.40E+03 | 5.57E+03 | 1.49E+03 | 7.87E+03 | 0.0 | 2.39E+06 |
| | ADULT | 3.41E+03 | 4.16E+03 | 1.57E+03 | 5.96E+03 | 0.0 | 1.95E+06 |
| CS-134 | INFANT | 6.97E+04 | 4.58E+05 | 1.96E+03 | 8.24E+05 | 9.42E+04 | 0.0 |
| | CHILD | 8.02E+04 | 2.24E+05 | 2.04E+03 | 3.77E+05 | 4.19E+04 | 0.0 |
| | TEEN | 9.06E+04 | 8.05E+04 | 2.24E+03 | 1.94E+05 | 2.35E+04 | 0.0 |
| | ADULT | 1.21E+05 | 6.22E+04 | 2.59E+03 | 1.48E+05 | 1.59E+04 | 0.0 |
| CS-137 | INFANT | 4.20E+04 | 6.53E+05 | 1.89E+03 | 7.31E+05 | 8.81E+04 | 0.0 |
| | CHILD | 4.50E+04 | 3.12E+05 | 1.84E+03 | 3.02E+05 | 3.54E+04 | 0.0 |
| | TEEN | 5.05E+04 | 1.07E+05 | 1.92E+03 | 1.44E+05 | 1.91E+04 | 0.0 |
| | ADULT | 7.15E+04 | 7.98E+04 | 2.10E+03 | 1.09E+05 | 1.23E+04 | 0.0 |
| CE-144 | INFANT | 2.42E+02 | 4.49E+03 | 1.85E+05 | 1.77E+03 | 0.0 | 0.0 |
| | CHILD | 1.14E+02 | 2.14E+03 | 1.74E+05 | 6.70E+02 | 0.0 | 0.0 |
| | TEEN | 3.83E+01 | 7.22E+02 | 1.70E+05 | 2.96E+02 | 0.0 | 0.0 |
| | ADULT | 2.62E+01 | 4.89E+02 | 1.65E+05 | 2.04E+02 | 0.0 | 0.0 |

Table 5-12: Food Ingestion Rates in Age Groups (Evaluated in [124])

| Food | Food Ingestion Rates G [kg/yr] Infant | Child | Teen | Adult | Average Person | Exceeding Factor 1) |
|---|---|---|---|---|---|---|
| Cereals | 20 | 36 | 57 | 80 | 70 | 2 |
| Potatoes | - | 21 | 48 | 89 | 73 | 3 |
| Vegetables | 18 | 41 | 49 | 56 | 52 | 2 |
| Above Ground Vegetable | 6 | 25 | 31 | 37 | 34 | 2 |
| Root Vegetable | 12 | 16 | 18 | 19 | 18 | 2 |
| Fruit | 40 | 84 | 96 | 90 | 90 | 1.2 |
| Meat and Meat Products | 3 | 30 | 55 | 79 | 68 | 1.2 |
| Milk and Milk Products (Without Butter) | 216 | 96 | 86 | 104 | 102 | 4 |
| Fresh Drinking Milk | 216 | 76 | 61 | 71 | 72 | 4 |
| Fish and Fish Products -Saltwater | - | 2.8 | 4.7 | 6.6 | 5.7 | 4 |
| Fish and Fish Products -Freshwater | - | 0.15 | 0.26 | 0.37 | 0.32 | 65 |
| Drinking Water | 180 | 330 | 440 | 440 | 422 | |
| Inhalation Air 2) | 1900 | 3700 | 6300 | 6620 | 6130 | |

1) Explanation see chapter 5.3.6

2) Taken from [125], Unit = $\frac{m^3}{yr}$

**Table 6-1:** Average Individual Dose Rates and Dose Yields from Gaseous Releases via the Ingestion Pathway within the Administration Districts around the Years 1985/90 for the Organs: Whole Body, Bone, and Thyroid

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 1 | AUBONNE | BZ | PROD. FOREST LAND | 2.74E-03 | 5.56E-03 | 8.07E-03 | 4.49E-02 | 9.28E-02 | 1.59E-01 |
| 2 | AVENCHES | BZ | PROD. ARABLE LAND | 4.79E-03 | 1.10E-02 | 6.27E-02 | 9.49E-02 | 2.19E-01 | 1.10E+00 |
| 3 | COSSONAY | BZ | PROD. FOREST LAND | 2.59E-03 | 6.26E-03 | 1.01E-02 | 6.34E-02 | 1.35E-01 | 2.62E-01 |
| 4 | ECHALLENS | BZ | PROD. FOREST LAND | 2.22E-03 | 6.93E-03 | 1.25E-02 | 4.53E-02 | 9.90E-02 | 2.16E-01 |
| 5 | GRANDSON | BZ | PROD. GRASS LAND | 3.01E-03 | 7.38E-03 | 1.87E-02 | 6.53E-02 | 1.53E-01 | 4.11E-01 |
| 6 | MOUDON | BZ | PROD. GRASS LAND | 3.49E-03 | 7.46E-03 | 1.46E-02 | 4.50E-02 | 1.02E-01 | 2.34E-01 |
| 7 | ORBE | BZ | PROD. FOREST LAND | 3.19E-03 | 6.76E-03 | 1.22E-02 | 7.19E-02 | 1.55E-01 | 3.38E-01 |
| 8 | ORON | BZ | PROD. GRASS LAND | 3.14E-03 | 6.77E-03 | 1.11E-02 | 2.59E-02 | 5.68E-02 | 1.07E-01 |
| 9 | PAYERNE | BZ | PROD. GRASS LAND | 3.54E-03 | 8.93E-03 | 2.45E-02 | 4.61E-02 | 1.06E-01 | 3.49E-01 |
| 10 | LA VALLEE | BZ | PROD. FOREST LAND | 2.77E-03 | 5.55E-03 | 8.24E-03 | 5.11E-02 | 1.05E-01 | 1.84E-01 |
| 11 | YVERDON | BZ | PROD. ARABLE LAND | 3.51E-03 | 7.67E-03 | 1.64E-02 | 1.64E-01 | 3.55E-01 | 6.83E-01 |
| 12 | LA BROYE | BZ | PROD. ARABLE LAND | 4.37E-03 | 1.01E-02 | 5.98E-02 | 3.65E-01 | 8.35E-01 | 2.93E+00 |
| 13 | LA GLANE | BZ | PROD. GRASS LAND | 3.54E-03 | 7.39E-03 | 1.53E-02 | 8.09E-02 | 1.83E-01 | 4.28E-01 |
| 14 | LA GRUYERE | BZ | MIXED USED LAND | 3.57E-03 | 8.05E-03 | 1.23E-02 | 4.09E-01 | 9.20E-01 | 1.36E+00 |
| 15 | LA SARINE | BZ | PROD. GRASS LAND | 4.04E-03 | 9.26E-03 | 2.45E-02 | 1.18E-01 | 2.74E-01 | 8.58E-01 |
| 16 | SEE | BZ | PROD. ARABLE LAND | 5.02E-03 | 1.17E-02 | 1.11E-01 | 2.91E-01 | 6.78E-01 | 4.33E+00 |
| 17 | SENSE | BZ | PROD. GRASS LAND | 4.57E-03 | 1.07E-02 | 3.36E-02 | 1.62E-01 | 3.85E-01 | 1.18E+00 |
| 18 | LA VEVEYSE | BZ | PROD. GRASS LAND | 3.23E-03 | 7.09E-03 | 1.09E-02 | 5.95E-02 | 1.30E-01 | 2.30E-01 |
| 19 | BOUDRY | BZ | PROD. GRASS LAND | 4.29E-03 | 9.76E-03 | 3.41E-02 | 4.93E-02 | 1.13E-01 | 4.72E-01 |
| 20 | LA CHAUX-DE-FONDS | BZ | PROD. FOREST LAND | 4.80E-03 | 1.11E-02 | 2.55E-02 | 4.82E-02 | 1.13E-01 | 3.19E-01 |
| 21 | LE LOCLE | BZ | PROD. FOREST LAND | 4.17E-03 | 9.39E-03 | 2.54E-02 | 6.46E-02 | 1.47E-01 | 4.93E-01 |
| 22 | NEUCHATEL | BZ | PROD. ARABLE LAND | 4.91E-03 | 1.14E-02 | 5.11E-02 | 1.27E-01 | 2.99E-01 | 9.74E-01 |
| 23 | VAL-DE-RUZ | BZ | PROD. GRASS LAND | 5.00E-03 | 1.17E-02 | 3.77E-02 | 7.01E-02 | 1.66E-01 | 6.36E-01 |
| 24 | VAL-DE-TRAVERS | BZ | PROD. FOREST LAND | 3.69E-03 | 8.05E-03 | 1.89E-02 | 6.56E-02 | 1.46E-01 | 4.20E-01 |
| 25 | AARBERG | BZ | MIXED USED LAND | 6.66E-03 | 1.63E-02 | 1.05E-01 | 1.93E-01 | 4.73E-01 | 2.68E+00 |
| 26 | AARWANGEN | BZ | PROD. GRASS LAND | 2.39E-02 | 6.39E-02 | 2.58E-01 | 3.58E-01 | 9.55E-01 | 4.52E+00 |
| 27 | BERN | BZ | PROD. GRASS LAND | 6.47E-03 | 1.59E-02 | 8.55E-02 | 1.67E-01 | 4.15E-01 | 2.55E+00 |
| 28 | BIEL | BZ | MIXED USED LAND | 7.27E-03 | 1.80E-02 | 5.42E-02 | 3.41E-02 | 8.47E-02 | 2.46E-01 |
| 29 | BUEREN | BZ | MIXED USED LAND | 8.33E-03 | 2.10E-02 | 6.80E-02 | 1.34E-01 | 3.37E-01 | 1.07E+00 |
| 30 | BURGDORF | BZ | PROD. GRASS LAND | 1.03E-02 | 2.67E-02 | 9.11E-02 | 2.32E-01 | 6.02E-01 | 2.45E+00 |
| 31 | COURTELARY | BZ | PROD. FOREST LAND | 6.52E-03 | 1.59E-02 | 3.80E-02 | 1.87E-01 | 4.62E-01 | 1.36E+00 |
| 32 | DELEMONT | BZ | PROD. FOREST LAND | 8.85E-03 | 2.23E-02 | 5.17E-02 | 2.58E-01 | 6.54E-01 | 1.87E+00 |
| 33 | ERLACH | BZ | PROD. ARABLE LAND | 5.56E-03 | 1.32E-02 | 8.53E-02 | 1.47E-01 | 3.49E-01 | 1.86E+00 |
| 34 | LES FRANCHES-MONTAGN. | BZ | PROD. FOREST LAND | 6.32E-03 | 1.53E-02 | 3.22E-02 | 1.31E-01 | 3.20E-01 | 8.27E-01 |
| 35 | FRAUBRUNNEN | BZ | PROD. GRASS LAND | 8.25E-03 | 2.08E-02 | 8.75E-02 | 1.14E-01 | 2.89E-01 | 1.35E+00 |
| 36 | FRUTIGEN | BZ | PROD. BARREN LAND | 3.66E-03 | 8.48E-03 | 1.70E-02 | 1.95E-01 | 4.53E-01 | 6.56E-01 |
| 37 | INTERLAKEN | BZ | PROD. BARREN LAND | 4.36E-03 | 1.04E-02 | 1.47E-02 | 3.78E-01 | 8.18E-01 | 1.33E+00 |
| 38 | KONOLFINGEN | BZ | PROD. GRASS LAND | 6.72E-03 | 1.68E-02 | 4.44E-02 | 1.58E-01 | 3.57E-01 | 1.25E+00 |
| 39 | LAUFEN | BZ | PROD. FOREST LAND | 1.13E-02 | 3.05E-02 | 8.11E-02 | 1.05E-01 | 2.72E-01 | 8.82E-01 |
| 40 | LAUPEN | BZ | PROD. GRASS LAND | 5.45E-03 | 1.27E-02 | 1.77E-01 | 5.96E-02 | 1.37E-01 | 4.57E+00 |
| 41 | MOUTIER | BZ | PROD. FOREST LAND | 8.77E-03 | 2.21E-02 | 5.70E-02 | 2.69E-01 | 6.83E-01 | 2.18E+00 |
| 42 | LA NEUVEVILLE | BZ | PROD. FOREST LAND | 5.89E-03 | 1.42E-02 | 4.65E-02 | 3.98E-02 | 9.75E-02 | 3.40E-01 |
| 43 | NIDAU | BZ | PROD. ARABLE LAND | 6.93E-03 | 1.72E-02 | 5.59E-02 | 1.73E-01 | 4.23E-01 | 1.38E+00 |
| 44 | NIEDERSIMMENTAL | BZ | MIXED USED LAND | 4.09E-03 | 9.59E-03 | 1.40E-02 | 2.32E-01 | 5.44E-01 | 7.69E-01 |
| 45 | OBERHASLI | BZ | PROD. BARREN LAND | 4.39E-03 | 1.06E-02 | 1.52E-02 | 2.65E-01 | 6.45E-01 | 1.07E+00 |
| 46 | OBERSIMMENTAL | BZ | MIXED USED LAND | 3.47E-03 | 7.90E-03 | 1.02E-02 | 2.15E-01 | 4.88E-01 | 6.11E-01 |
| 47 | PORRENTRUY | BZ | MIXED USED LAND | 6.92E-03 | 1.69E-02 | 3.24E-02 | 4.07E-01 | 9.93E-01 | 1.83E+00 |
| 48 | SAANEN | BZ | PROD. FOREST LAND | 3.22E-03 | 7.20E-03 | 9.00E-03 | 8.23E-02 | 1.89E-01 | 2.78E-01 |
| 49 | SCHWARZENBURG | BZ | PROD. GRASS LAND | 4.66E-03 | 1.11E-02 | 2.24E-02 | 8.01E-02 | 1.92E-01 | 4.56E-01 |
| 50 | SEFTIGEN | BZ | PROD. GRASS LAND | 5.36E-03 | 1.30E-02 | 2.75E-02 | 1.12E-01 | 2.73E-01 | 6.79E-01 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 51 | SIGNAU | BZ | PRED. FOREST LAND | 7.30E-03 | 1.84E-02 | 4.28E-02 | 2.53E-01 | 6.42E-01 | 1.84E+00 |
| 52 | THUN | BZ | PRED. FOREST LAND | 5.09E-03 | 1.24E-02 | 2.10E-02 | 1.47E-01 | 3.60E-01 | 7.43E-01 |
| 53 | TRACHSELWALD | BZ | PRED. GRASS LAND | 1.18E-02 | 3.09E-02 | 9.60E-02 | 2.61E-01 | 6.86E-01 | 2.50E+00 |
| 54 | WANGEN | BZ | PRED. GRASS LAND | 1.91E-02 | 5.08E-02 | 1.97E-01 | 2.98E-01 | 7.95E-01 | 3.85E+00 |
| 55 | BALSTHAL-GAEU | BZ | PRED. ARABLE LAND | 1.36E-02 | 3.55E-02 | 1.20E-01 | 2.20E-01 | 5.76E-01 | 1.70E+00 |
| 56 | BALSTHAL-TAL | BZ | PRED. FOREST LAND | 1.21E-02 | 3.13E-02 | 9.64E-02 | 1.55E-01 | 4.00E-01 | 1.47E+00 |
| 57 | BUCHEGGBERG | BZ | MIXED USED LAND | 5.11E-03 | 2.32E-02 | 8.45E-02 | 9.76E-02 | 2.49E-01 | 8.42E-01 |
| 58 | DORNECK | BZ | PRED. ARABLE LAND | 1.44E-02 | 3.77E-02 | 1.08E-01 | 3.03E-01 | 7.95E-01 | 2.11E+00 |
| 59 | GOESGEN | BZ | PRED. ARABLE LAND | 1.43E-02 | 3.74E-02 | 1.15E-01 | 2.29E-01 | 5.95E-01 | 1.71E+00 |
| 60 | KRIEGSTETTEN | BZ | MIXED USED LAND | 1.24E-02 | 3.21E-02 | 1.15E-01 | 1.69E-01 | 4.43E-01 | 1.54E+00 |
| 61 | LEBERN | BZ | MIXED USED LAND | 1.02E-02 | 2.62E-02 | 8.27E-02 | 2.26E-01 | 5.86E-01 | 1.82E+00 |
| 62 | OLTEN | BZ | PRED. ARABLE LAND | 1.47E-02 | 3.85E-02 | 1.15E-01 | 3.01E-01 | 7.89E-01 | 2.09E+00 |
| 63 | SOLOTHURN | BZ | MIXED USED LAND | 1.19E-02 | 3.07E-02 | 1.02E-01 | 1.24E-02 | 3.22E-02 | 1.05E-01 |
| 64 | THIERSTEIN | BZ | MIXED USED LAND | 1.16E-02 | 3.01E-02 | 8.14E-02 | 2.03E-01 | 5.26E-01 | 1.40E+00 |
| 65 | BASEL-STADT | KT | PRED. ARABLE LAND | 1.53E-02 | 3.95E-02 | 1.09E-01 | 6.50E-02 | 1.71E-01 | 4.16E-01 |
| 66 | ARLESHEIM | BZ | PRED. ARABLE LAND | 1.54E-02 | 4.04E-02 | 1.15E-01 | 4.39E-01 | 1.15E+00 | 2.93E+00 |
| 67 | LIESTAL | BZ | PRED. ARABLE LAND | 2.05E-02 | 5.43E-02 | 1.84E-01 | 4.10E-01 | 1.08E+00 | 3.01E+00 |
| 68 | SISSACH | BZ | PRED. ARABLE LAND | 1.33E-02 | 3.46E-02 | 1.09E-01 | 5.08E-01 | 1.32E+00 | 3.71E+00 |
| 69 | WALDENBURG | BZ | PRED. GRASS LAND | 1.29E-02 | 3.34E-02 | 9.85E-02 | 1.49E-01 | 3.89E-01 | 1.36E+00 |
| 70 | ENTLEBUCH | BZ | PRED. FOREST LAND | 7.19E-03 | 1.82E-02 | 4.29E-02 | 3.96E-01 | 1.01E+00 | 2.87E+00 |
| 71 | HOCHDORF | BZ | PRED. GRASS LAND | 1.27E-02 | 3.33E-02 | 1.10E-01 | 2.52E-01 | 6.51E-01 | 2.51E+00 |
| 72 | LUZERN | BZ | PRED. GRASS LAND | 1.41E-02 | 3.70E-02 | 1.17E-01 | 4.22E-01 | 1.10E+00 | 3.97E+00 |
| 73 | SURSEE | BZ | PRED. GRASS LAND | 1.05E-02 | 2.71E-02 | 8.36E-02 | 4.35E-01 | 1.13E+00 | 4.14E+00 |
| 74 | WILLISAU | BZ | PRED. GRASS LAND | 1.25E-02 | 3.27E-02 | 1.03E-01 | 5.65E-01 | 1.48E+00 | 5.54E+00 |
| 75 | AARAU | BZ | PRED. ARABLE LAND | 1.05E-02 | 2.70E-02 | 1.11E-01 | 2.98E-01 | 7.59E-01 | 3.08E+00 |
| 76 | BADEN | BZ | PRED. ARABLE LAND | 6.94E-03 | 1.70E-02 | 1.47E-01 | 3.16E-01 | 7.74E-01 | 5.50E+00 |
| 77 | BREMGARTEN | BZ | PRED. ARABLE LAND | 7.37E-03 | 1.39E-02 | 8.38E-02 | 2.62E-01 | 6.56E-01 | 2.71E+00 |
| 78 | BRUGG | BZ | PRED. ARABLE LAND | 8.25E-03 | 1.59E-02 | 4.41E-01 | 3.65E-01 | 9.00E-01 | 1.02E+01 |
| 79 | KULM | BZ | PRED. GRASS LAND | 9.52E-03 | 2.43E-02 | 8.50E-02 | 1.06E-01 | 2.72E-01 | 1.16E+00 |
| 80 | LAUFENBURG | BZ | PRED. ARABLE LAND | 1.05E-02 | 2.70E-02 | 9.73E-02 | 5.07E-01 | 1.31E+00 | 3.90E+00 |
| 81 | LENZBURG | BZ | PRED. ARABLE LAND | 3.51E-03 | 2.14E-02 | 1.21E-01 | 2.67E-01 | 6.75E-01 | 2.97E+00 |
| 82 | MURI | BZ | PRED. GRASS LAND | 8.64E-03 | 2.20E-02 | 7.44E-02 | 1.27E-01 | 3.24E-01 | 1.26E+00 |
| 83 | RHEINFELDEN | BZ | PRED. ARABLE LAND | 2.48E-02 | 6.62E-02 | 2.30E-01 | 7.44E-01 | 1.99E+00 | 5.96E+00 |
| 84 | ZOFINGEN | BZ | PRED. ARABLE LAND | 1.34E-02 | 3.50E-02 | 1.11E-01 | 6.69E-01 | 1.77E+00 | 4.54E+00 |
| 85 | ZURZACH | BZ | PRED. ARABLE LAND | 9.03E-03 | 2.22E-02 | 3.75E-01 | 3.11E-01 | 7.34E-01 | 2.07E+01 |
| 86 | OBWALDEN | KT | MIXED USED LAND | 6.41E-03 | 1.61E-02 | 3.26E-02 | 5.84E-01 | 1.47E+00 | 2.86E+00 |
| 87 | NIDWALDEN | KT | PRED. FOREST LAND | 7.78E-03 | 1.59E-02 | 4.45E-02 | 2.09E-01 | 5.37E-01 | 1.48E+00 |
| 88 | URI | KT | PRED. FOREST LAND | 4.46E-03 | 1.08E-02 | 1.81E-02 | 3.46E-01 | 8.48E-01 | 1.72E+00 |
| 89 | EINSIEDELN | BZ | PRED. GRASS LAND | 6.22E-03 | 1.55E-02 | 3.78E-02 | 7.53E-02 | 1.89E-01 | 5.44E-01 |
| 90 | GERSAU | BZ | PRED. FOREST LAND | 6.81E-03 | 2.27E-02 | 6.12E-02 | 1.39E-02 | 3.56E-02 | 1.19E-01 |
| 91 | HOEFE | BZ | PRED. ARABLE LAND | 5.88E-03 | 1.46E-02 | 3.40E-02 | 6.56E-02 | 1.62E-01 | 3.38E-01 |
| 92 | KUESSNACHT | BZ | PRED. GRASS LAND | 1.49E-02 | 3.93E-02 | 1.31E-01 | 4.85E-02 | 1.28E-01 | 5.10E-01 |
| 93 | MARCH | BZ | PRED. GRASS LAND | 5.13E-03 | 1.26E-02 | 2.69E-02 | 9.97E-02 | 2.46E-01 | 6.19E-01 |
| 94 | SCHWYZ | BZ | MIXED USED LAND | 6.04E-03 | 1.51E-02 | 3.60E-02 | 5.53E-01 | 1.38E+00 | 3.17E+00 |
| 95 | ZUG | KT | PRED. GRASS LAND | 8.33E-03 | 2.12E-02 | 6.35E-02 | 2.00E-01 | 5.11E-01 | 1.81E+00 |
| 96 | AFFOLTERN | BZ | PRED. ARABLE LAND | 6.93E-03 | 1.73E-02 | 4.99E-02 | 2.35E-01 | 5.88E-01 | 1.52E+00 |
| 97 | ANDELFINGEN | BZ | PRED. ARABLE LAND | 5.10E-03 | 1.22E-02 | 3.85E-02 | 2.51E-01 | 5.95E-01 | 1.68E+00 |
| 98 | BUELACH | BZ | MIXED USED LAND | 5.68E-03 | 1.38E-02 | 4.50E-02 | 1.95E-01 | 4.72E-01 | 1.48E+00 |
| 99 | DIELSDORF | BZ | MIXED USED LAND | 6.08E-03 | 1.49E-02 | 4.90E-02 | 1.81E-01 | 4.44E-01 | 1.81E+00 |
| 100 | HINWIL | BZ | PRED. FOREST LAND | 4.82E-03 | 1.17E-02 | 2.50E-02 | 9.40E-02 | 2.29E-01 | 6.02E-01 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-5) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 101 | HORGEN | BZ | PRED. ARABLE LAND | 6.12E-03 | 1.51E-02 | 3.90E-02 | 1.98E-01 | 4.65E-01 | 1.07E+00 |
| 102 | MEILEN | BZ | PRED. GRASS LAND | 5.56E-03 | 1.36E-02 | 3.12E-02 | 4.67E-02 | 1.15E-01 | 3.12E-01 |
| 103 | PFAEFFIKON | BZ | PRED. FOREST LAND | 4.83E-03 | 1.16E-02 | 2.72E-02 | 8.55E-02 | 2.07E-01 | 5.98E-01 |
| 104 | USTER | BZ | PRED. GRASS LAND | 5.24E-03 | 1.27E-02 | 2.95E-02 | 6.90E-02 | 1.69E-01 | 4.62E-01 |
| 105 | WINTERTHUR | BZ | MIXED USED LAND | 4.95E-03 | 1.18E-02 | 3.12E-02 | 2.21E-01 | 5.50E-01 | 1.40E+00 |
| 106 | ZUERICH | BZ | PRED. ARABLE LAND | 5.86E-03 | 1.44E-02 | 3.46E-02 | 2.80E-01 | 6.87E-01 | 1.47E+00 |
| 107 | OBERKLETTGAU | BZ | PRED. ARABLE LAND | 5.66E-03 | 1.36E-02 | 5.84E-02 | 7.00E-02 | 1.67E-01 | 6.35E-01 |
| 108 | REIAT | BZ | MIXED USED LAND | 4.69E-03 | 1.09E-02 | 3.37E-02 | 3.44E-02 | 7.99E-02 | 2.37E-01 |
| 109 | SCHAFFHAUSEN | BZ | PRED. ARABLE LAND | 5.00E-03 | 1.13E-02 | 4.07E-02 | 1.50E-01 | 3.51E-01 | 1.08E+00 |
| 110 | SCHLEITHEIM | BZ | MIXED USED LAND | 5.22E-03 | 1.26E-02 | 5.02E-02 | 4.29E-02 | 1.02E-01 | 3.87E-01 |
| 111 | STEIN | BZ | PRED. ARABLE LAND | 4.47E-03 | 1.04E-02 | 2.78E-02 | 4.15E-02 | 9.59E-02 | 2.29E-01 |
| 112 | UNTERKLETTGAU | BZ | PRED. ARABLE LAND | 6.19E-03 | 1.50E-02 | 7.85E-02 | 7.59E-02 | 1.33E-01 | 8.45E-01 |
| 113 | ALBULA | BZ | PRED. FOREST LAND | 2.21E-03 | 4.83E-03 | 6.48E-03 | 1.55E-01 | 3.45E-01 | 5.46E-01 |
| 114 | GLENNER | BZ | PRED. GRASS LAND | 2.95E-03 | 6.77E-03 | 1.00E-02 | 2.03E-01 | 4.72E-01 | 8.05E-01 |
| 115 | HEINZENBERG | BZ | PRED. FOREST LAND | 2.76E-03 | 6.26E-03 | 9.25E-03 | 7.08E-02 | 1.63E-01 | 2.89E-01 |
| 116 | HINTERRHEIN | BZ | PRED. FOREST LAND | 2.43E-03 | 5.40E-03 | 7.30E-03 | 1.11E-01 | 2.51E-01 | 4.02E-01 |
| 117 | IMBODEN | BZ | PRED. FOREST LAND | 3.09E-03 | 7.15E-03 | 1.16E-02 | 6.18E-02 | 1.45E-01 | 2.83E-01 |
| 118 | OBERLANDQUART | BZ | PRED. FOREST LAND | 2.49E-03 | 5.57E-03 | 8.45E-03 | 1.62E-01 | 3.68E-01 | 6.67E-01 |
| 119 | PLESSUR | BZ | PRED. FOREST LAND | 2.75E-03 | 6.25E-03 | 9.82E-03 | 7.12E-02 | 1.64E-01 | 3.05E-01 |
| 120 | UNTERLANDQUART | BZ | PRED. FOREST LAND | 3.17E-03 | 7.36E-03 | 1.31E-02 | 1.07E-01 | 2.52E-01 | 5.44E-01 |
| 121 | VORDERRHEIN | BZ | PRED. FOREST LAND | 3.52E-03 | 8.29E-03 | 1.25E-02 | 1.94E-01 | 4.61E-01 | 8.34E-01 |
| 122 | GLARUS | KT | MIXED USED LAND | 3.89E-03 | 9.25E-03 | 1.64E-02 | 4.95E-01 | 1.17E+00 | 2.00E+00 |
| 123 | ST.GALLEN | BZ | PRED. GRASS LAND | 3.97E-03 | 9.35E-03 | 1.88E-02 | 3.75E-02 | 9.02E-02 | 2.31E-01 |
| 124 | RORSCHACH | BZ | PRED. ARABLE LAND | 5.01E-03 | 1.22E-02 | 2.98E-02 | 8.14E-02 | 1.97E-01 | 4.34E-01 |
| 125 | UNTERRHEINTAL | BZ | PRED. ARABLE LAND | 5.58E-03 | 1.38E-02 | 3.66E-02 | 9.12E-02 | 2.25E-01 | 5.31E-01 |
| 126 | OBERRHEINTAL | BZ | PRED. ARABLE LAND | 1.22E-02 | 3.19E-02 | 1.07E-01 | 3.28E-01 | 8.53E-01 | 2.46E+00 |
| 127 | WERDENBERG | BZ | PRED. ARABLE LAND | 4.40E-03 | 1.06E-02 | 2.40E-02 | 2.83E-01 | 6.75E-01 | 1.28E+00 |
| 128 | SARGANS | BZ | MIXED USED LAND | 3.72E-03 | 8.80E-03 | 1.65E-02 | 3.92E-01 | 9.25E-01 | 1.67E+00 |
| 129 | GASTER | BZ | PRED. GRASS LAND | 4.31E-03 | 1.03E-02 | 1.99E-02 | 7.04E-02 | 1.70E-01 | 3.84E-01 |
| 130 | SEE | BZ | PRED. GRASS LAND | 4.62E-03 | 1.11E-02 | 2.27E-02 | 6.77E-02 | 1.64E-01 | 3.94E-01 |
| 131 | OBERTOGGENBURG | BZ | PRED. GRASS LAND | 4.01E-03 | 9.51E-03 | 1.80E-02 | 1.08E-01 | 2.58E-01 | 5.70E-01 |
| 132 | NEUTOGGENBURG | BZ | PRED. GRASS LAND | 4.10E-03 | 9.70E-03 | 1.87E-02 | 5.07E-02 | 1.21E-01 | 2.73E-01 |
| 133 | ALTTOGGENBURG | BZ | PRED. GRASS LAND | 4.28E-03 | 1.01E-02 | 2.06E-02 | 6.22E-02 | 1.49E-01 | 3.54E-01 |
| 134 | UNTERTOGGENBURG | BZ | PRED. GRASS LAND | 4.02E-03 | 9.43E-03 | 1.85E-02 | 5.15E-02 | 1.22E-01 | 2.80E-01 |
| 135 | WIL | BZ | PRED. GRASS LAND | 4.04E-03 | 9.45E-03 | 1.92E-02 | 3.86E-02 | 9.12E-02 | 2.18E-01 |
| 136 | GOSSAU | BZ | PRED. GRASS LAND | 3.91E-03 | 9.14E-03 | 1.79E-02 | 3.65E-02 | 8.61E-02 | 1.98E-01 |
| 137 | HINTERLAND | BZ | PRED. GRASS LAND | 3.93E-03 | 9.24E-03 | 1.78E-02 | 7.21E-02 | 1.71E-01 | 3.80E-01 |
| 138 | MITTELLAND | BZ | PRED. GRASS LAND | 4.48E-03 | 1.08E-02 | 2.41E-02 | 3.41E-02 | 8.17E-02 | 2.04E-01 |
| 139 | VORDERLAND | BZ | PRED. ARABLE LAND | 5.59E-03 | 1.38E-02 | 3.64E-02 | 9.69E-02 | 2.39E-01 | 5.69E-01 |
| 140 | INNERER LANDESTEIL | BZ | PRED. GRASS LAND | 4.07E-03 | 9.67E-03 | 2.00E-02 | 8.39E-02 | 2.00E-01 | 4.61E-01 |
| 141 | AEUSSERER LANDESTEIL | BZ | PRED. ARABLE LAND | 6.09E-03 | 1.52E-02 | 4.18E-02 | 3.36E-02 | 8.41E-02 | 2.10E-01 |
| 142 | ARBON | BZ | PRED. ARABLE LAND | 4.31E-03 | 1.02E-02 | 2.21E-02 | 9.82E-02 | 2.31E-01 | 4.48E-01 |
| 143 | BISCHOFSZELL | BZ | PRED. GRASS LAND | 3.95E-03 | 9.29E-03 | 1.76E-02 | 4.39E-02 | 1.04E-01 | 2.31E-01 |
| 144 | DIESSENHOFEN | BZ | PRED. ARABLE LAND | 4.73E-03 | 1.11E-02 | 3.24E-02 | 6.35E-02 | 1.48E-01 | 3.85E-01 |
| 145 | FRAUENFELD | BZ | MIXED USED LAND | 4.40E-03 | 1.03E-02 | 2.46E-02 | 1.19E-01 | 2.79E-01 | 6.39E-01 |
| 146 | KREUZLINGEN | BZ | PRED. ARABLE LAND | 4.04E-03 | 9.40E-03 | 1.57E-02 | 1.41E-01 | 3.25E-01 | 6.13E-01 |
| 147 | MUENCHWILEN | BZ | PRED. GRASS LAND | 4.20E-03 | 9.83E-03 | 2.14E-02 | 7.90E-02 | 1.87E-01 | 4.78E-01 |
| 148 | STECKBORN | BZ | PRED. ARABLE LAND | 4.28E-03 | 9.97E-03 | 2.38E-02 | 1.92E-01 | 4.45E-01 | 9.45E-01 |
| 149 | WEINFELDEN | BZ | PRED. ARABLE LAND | 3.96E-03 | 9.16E-03 | 1.93E-02 | 1.60E-01 | 3.67E-01 | 6.95E-01 |
| | SCHWEIZ | | | 5.89E-03 | 1.45E-02 | 4.38E-02 | 2.68E+01 | 6.64E+01 | 2.25E+02 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 150 | LIECHTENSTEIN | | PRED. ARABLE LAND | 4.34E-03 | 1.05E-02 | 2.37E-02 | 8.32E-02 | 2.02E-01 | 4.36E-01 |
| | LIECHTENSTEIN | | | 4.34E-03 | 1.05E-02 | 2.37E-02 | 8.32E-02 | 2.02E-01 | 4.36E-01 |
| 151 | BLUDENZ | BZ | PRED. GRASS LAND | 2.07E-03 | 5.99E-03 | 9.60E-03 | 4.12E-01 | 9.36E-01 | 1.73E+00 |
| 152 | BREGENZ | BZ | PRED. FOREST LAND | 2.84E-03 | 6.35E-03 | 1.07E-02 | 7.88E-01 | 6.55E-01 | 1.33E+00 |
| 153 | DORNBIRN | BZ | PRED. FOREST LAND | 4.40E-03 | 1.06E-02 | 2.46E-02 | 6.90E-02 | 1.62E-01 | 3.88E-01 |
| 154 | FELDKIRCH | BZ | PRED. GRASS LAND | 4.21E-03 | 1.01E-02 | 2.36E-02 | 1.18E-01 | 2.83E-01 | 7.31E-01 |
| | OESTERREICH | | | 3.50E-03 | 6.86E-03 | 1.25E-02 | 8.88E-01 | 2.04E+00 | 4.19E+00 |
| 155 | LINDAU-BODENSEE | SK | PRED. ARABLE LAND | 4.26E-03 | 1.01E-02 | 2.28E-02 | 2.71E-02 | 6.40E-02 | 1.29E-01 |
| 156 | LINDAU-BODENSEE | LK | PRED. GRASS LAND | 3.49E-03 | 8.04E-03 | 1.55E-02 | 1.45E-01 | 3.37E-01 | 7.61E-01 |
| 157 | ASCHAFFENBURG | SK | MIXED USED LAND | 7.97E-03 | 1.79E-02 | 3.71E-02 | 6.63E-02 | 1.48E-01 | 2.96E-01 |
| 158 | BAD KISSINGEN | SK | MIXED USED LAND | 5.03E-03 | 1.01E-02 | 1.39E-02 | 1.06E-02 | 2.11E-02 | 2.84E-02 |
| 159 | KITZINGEN | SK | PRED. ARABLE LAND | 5.19E-03 | 1.10E-02 | 1.63E-02 | 4.61E-02 | 9.68E-02 | 1.31E-01 |
| 160 | SCHWEINFURT | SK | PRED. ARABLE LAND | 6.21E-03 | 1.39E-02 | 2.11E-02 | 5.61E-02 | 1.22E-01 | 1.70E-01 |
| 161 | WUERZBURG | SK | PRED. ARABLE LAND | 5.57E-03 | 1.18E-02 | 1.74E-02 | 8.68E-02 | 1.81E-01 | 2.46E-01 |
| 162 | ALZENAU | LK | PRED. FOREST LAND | 1.07E-02 | 2.54E-02 | 6.73E-02 | 2.23E-01 | 5.16E-01 | 1.46E+00 |
| 163 | ASCHAFFENBURG | LK | PRED. FOREST LAND | 7.21E-03 | 1.61E-02 | 3.03E-02 | 2.56E-01 | 5.68E-01 | 1.27E+00 |
| 164 | BAD BRUECKENAU | LK | MIXED USED LAND | 5.20E-03 | 1.04E-02 | 1.48E-02 | 2.97E-01 | 5.87E-01 | 8.14E-01 |
| 165 | BAD KISSINGEN | LK | PRED. ARABLE LAND | 4.87E-03 | 9.67E-03 | 1.31E-02 | 6.01E-01 | 1.17E+00 | 1.48E+00 |
| 166 | BAD NEUSTAD - SAALE | LK | MIXED USED LAND | 4.76E-03 | 9.26E-03 | 1.23E-02 | 2.96E-01 | 5.70E-01 | 7.40E-01 |
| 167 | EBERN | LK | MIXED USED LAND | 4.47E-03 | 9.17E-03 | 1.37E-02 | 2.76E-01 | 5.57E-01 | 7.76E-01 |
| 168 | GEMUENDEN A.MAIN | LK | PRED. FOREST LAND | 5.82E-03 | 1.21E-02 | 1.85E-02 | 2.00E-01 | 4.23E-01 | 7.65E-01 |
| 169 | GEROLZHOFEN | LK | PRED. FOREST LAND | 5.72E-03 | 1.25E-02 | 1.95E-02 | 2.59E-01 | 5.69E-01 | 1.06E+00 |
| 170 | HAMMELBURG | LK | MIXED USED LAND | 5.37E-03 | 1.10E-02 | 1.57E-02 | 3.23E-01 | 6.57E-01 | 9.22E-01 |
| 171 | HASSFURT | LK | PRED. FOREST LAND | 5.37E-03 | 1.16E-02 | 1.90E-02 | 2.22E-01 | 4.85E-01 | 9.20E-01 |
| 172 | HOFHEIM | LK | MIXED USED LAND | 4.95E-03 | 1.02E-02 | 1.44E-02 | 2.51E-01 | 5.15E-01 | 7.05E-01 |
| 173 | KARLSTADT | LK | MIXED USED LAND | 6.05E-03 | 1.29E-02 | 1.92E-02 | 4.82E-01 | 1.02E+00 | 1.47E+00 |
| 174 | KITZINGEN | LK | PRED. ARABLE LAND | 5.39E-03 | 1.16E-02 | 1.72E-02 | 4.74E-01 | 1.00E+00 | 1.37E+00 |
| 175 | KOENIGSHOFEN I.GRABF. | LK | PRED. ARABLE LAND | 4.49E-03 | 8.76E-03 | 1.14E-02 | 3.67E-01 | 7.01E-01 | 8.49E-01 |
| 176 | LOHR A.MAIN | LK | PRED. FOREST LAND | 6.22E-03 | 1.32E-02 | 2.08E-02 | 2.31E-01 | 4.97E-01 | 9.36E-01 |
| 177 | MARKTHEIDENFELD | LK | MIXED USED LAND | 6.14E-03 | 1.29E-02 | 1.97E-02 | 4.84E-01 | 1.01E+00 | 1.50E+00 |
| 178 | MELLRICHSTADT | LK | PRED. FOREST LAND | 4.51E-03 | 8.55E-03 | 1.09E-02 | 1.43E-01 | 2.76E-01 | 4.06E-01 |
| 179 | MILTENBERG | LK | PRED. FOREST LAND | 6.80E-03 | 1.43E-02 | 2.20E-02 | 2.28E-01 | 4.88E-01 | 8.91E-01 |
| 180 | OBERNBURG A.MAIN | LK | PRED. FOREST LAND | 6.79E-03 | 1.46E-02 | 2.36E-02 | 2.07E-01 | 4.53E-01 | 8.76E-01 |
| 181 | OCHSENFURT | LK | PRED. ARABLE LAND | 5.09E-03 | 1.08E-02 | 1.56E-02 | 5.12E-01 | 1.07E+00 | 1.43E+00 |
| 182 | SCHWEINFURT | LK | PRED. ARABLE LAND | 7.14E-03 | 1.61E-02 | 2.51E-02 | 8.30E-01 | 1.80E+00 | 2.51E+00 |
| 183 | WUERZBURG | LK | PRED. ARABLE LAND | 5.59E-03 | 1.19E-02 | 1.75E-02 | 6.61E-01 | 1.38E+00 | 1.86E+00 |
| 184 | ANSBACH | SK | MIXED USED LAND | 3.84E-03 | 8.13E-03 | 1.25E-02 | 1.58E-02 | 3.33E-02 | 4.98E-02 |
| 185 | ERLANGEN | SK | PRED. ARABLE LAND | 3.67E-03 | 7.57E-03 | 1.14E-02 | 3.98E-02 | 8.08E-02 | 1.12E-01 |
| 186 | FUERTH | SK | PRED. ARABLE LAND | 3.53E-03 | 7.31E-03 | 1.08E-02 | 4.71E-02 | 9.58E-02 | 1.31E-01 |
| 187 | NUERNBERG | SK | PRED. FOREST LAND | 3.41E-03 | 7.04E-03 | 1.03E-02 | 5.03E-02 | 1.05E-01 | 1.83E-01 |
| 188 | ROTHENBURG-TAUBER | SK | MIXED USED LAND | 4.46E-03 | 9.47E-03 | 1.40E-02 | 1.75E-02 | 3.68E-02 | 5.30E-02 |
| 189 | SCHWABACH | SK | MIXED USED LAND | 3.37E-03 | 7.01E-03 | 1.05E-02 | 1.31E-02 | 2.70E-02 | 3.91E-02 |
| 190 | WEISSENBURG | SK | MIXED USED LAND | 3.33E-03 | 7.12E-03 | 1.22E-02 | 1.96E-02 | 4.20E-02 | 6.98E-02 |
| 191 | ANSBACH | LK | MIXED USED LAND | 3.80E-03 | 8.01E-03 | 1.22E-02 | 4.39E-01 | 9.18E-01 | 1.35E+00 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 192 | ERLANGEN | LK | PROD. ARABLE LAND | 3.50E-03 | 7.26E-03 | 1.07E-02 | 2.25E-01 | 4.54E-01 | 6.19E-01 |
| 193 | FUERTH | LK | PROD. ARABLE LAND | 3.57E-03 | 7.40E-03 | 1.10E-02 | 3.24E-01 | 6.61E-01 | 9.04E-01 |
| 194 | HERSBRUCK | LK | PROD. FOREST LAND | 3.19E-03 | 6.23E-03 | 8.71 E-03 | 9.57E-02 | 1.97E-01 | 3.22E-01 |
| 195 | HILPOLTSTEIN | LK | MIXED USED LAND | 3.05E-03 | 6.46E-03 | 1.00E-02 | 2.97E-01 | 6.16E-01 | 9.31E-01 |
| 196 | LAUF-PEGNITZ | LK | PROD. FOREST LAND | 3.28E-03 | 6.57E-03 | 9.51E-03 | 6.67E-02 | 1.38E-01 | 2.31E-01 |
| 197 | NEUSTADT-AISCH | LK | MIXED USED LAND | 4.03E-03 | 8.43E-03 | 1.27E-02 | 3.73E-01 | 7.69E-01 | 1.12E+00 |
| 198 | NUERNBERG | LK | PROD. FOREST LAND | 2.15E-03 | 6.44E-03 | 9.25E-03 | 9.32E-02 | 2.06E-01 | 3.48E-01 |
| 199 | ROTHENBURG-TAUBER | LK | MIXED USED LAND | 4.27E-03 | 9.08E-03 | 1.37E-02 | 3.59E-01 | 7.58E-01 | 1.11E+00 |
| 200 | SCHEINFELD | LK | MIXED USED LAND | 4.59E-03 | 9.69E-03 | 1.47E-02 | 3.37E-01 | 7.06E-01 | 1.04E+00 |
| 201 | SCHWABACH | LK | MIXED USED LAND | 3.33E-03 | 6.94E-03 | 1.05E-02 | 3.14E-01 | 6.50E-01 | 9.58E-01 |
| 202 | UFFENHEIM | LK | MIXED USED LAND | 4.40E-03 | 9.28E-03 | 1.36E-02 | 4.63E-01 | 9.69E-01 | 1.38E+00 |
| 203 | WEISSENBURG | LK | MIXED USED LAND | 3.30E-03 | 7.05E-03 | 1.19E-02 | 2.96E-01 | 6.28E-01 | 1.03E+00 |
| 204 | BAMBERG | SK | MIXED USED LAND | 5.93E-03 | 1.31E-02 | 3.04E-02 | 3.91E-02 | 8.78E-02 | 1.96E-01 |
| 205 | BAYREUTH | SK | MIXED USED LAND | 3.29E-03 | 6.54E-03 | 9.27E-03 | 1.98E-02 | 3.89E-02 | 5.38E-02 |
| 206 | COBURG | SK | MIXED USED LAND | 3.96E-03 | 7.71E-03 | 1.01E-02 | 1.43E-02 | 2.75E-02 | 3.52E-02 |
| 207 | FORCHHEIM | SK | MIXED USED LAND | 3.80E-03 | 7.86E-03 | 1.22E-02 | 1.40E-02 | 2.88E-02 | 4.26E-02 |
| 208 | KULMBACH | SK | MIXED USED LAND | 3.46E-03 | 6.81E-03 | 9.52E-03 | 1.60E-02 | 3.11E-02 | 4.25E-02 |
| 209 | NEUSTADT B.COBURG | SK | MIXED USED LAND | 3.76E-03 | 7.18E-03 | 9.14E-03 | 5.12E-03 | 9.68E-03 | 1.21E-02 |
| 210 | BAMBERG | LK | MIXED USED LAND | 5.01E-03 | 1.09E-02 | 2.19E-02 | 8.91E-01 | 1.97E+00 | 4.08E+00 |
| 211 | BAYREUTH | LK | MIXED USED LAND | 3.20E-03 | 6.32E-03 | 8.79E-03 | 3.29E-01 | 6.43E-01 | 8.74E-01 |
| 212 | COBURG | LK | MIXED USED LAND | 3.91E-03 | 7.59E-03 | 9.83E-03 | 3.71E-01 | 7.11E-01 | 9.04E-01 |
| 213 | EBERMANNSTADT | LK | PROD. ARABLE LAND | 3.79E-03 | 7.81E-03 | 1.25E-02 | 4.86E-01 | 9.84E-01 | 1.45E+00 |
| 214 | FORCHHEIM | LK | MIXED USED LAND | 3.56E-03 | 7.30E-03 | 1.08E-02 | 2.65E-01 | 5.38E-01 | 7.75E-01 |
| 215 | HOECHSTADT A.D.AISCH | LK | MIXED USED LAND | 4.17E-03 | 8.78E-03 | 1.43E-02 | 3.67E-01 | 7.67E-01 | 1.21E+00 |
| 216 | KRONACH | LK | PROD. FOREST LAND | 3.50E-03 | 6.64E-03 | 8.57E-03 | 2.32E-01 | 4.51E-01 | 6.73E-01 |
| 217 | KULMBACH | LK | MIXED USED LAND | 3.46E-03 | 6.84E-03 | 9.69E-03 | 2.71E-01 | 5.30E-01 | 7.25E-01 |
| 218 | LICHTENFELS | LK | MIXED USED LAND | 3.85E-03 | 7.69E-03 | 1.14E-02 | 2.64E-01 | 5.23E-01 | 7.54E-01 |
| 219 | MUENCHBERG | LK | MIXED USED LAND | 3.06E-03 | 5.82E-03 | 7.43E-03 | 1.70E-01 | 3.19E-01 | 3.99E-01 |
| 220 | NAILA | LK | MIXED USED LAND | 3.18E-03 | 5.94E-03 | 7.35E-03 | 1.40E-01 | 2.58E-01 | 3.14E-01 |
| 221 | PEGNITZ | LK | PROD. FOREST LAND | 3.33E-03 | 6.72E-03 | 9.76E-03 | 2.00E-01 | 4.11E-01 | 7.01E-01 |
| 222 | STADTSTEINACH | LK | PROD. FOREST LAND | 3.21E-03 | 6.35E-03 | 8.34E-03 | 8.10E-02 | 1.59E-01 | 2.41E-01 |
| 223 | STAFFELSTEIN | LK | PROD. ARABLE LAND | 4.26E-03 | 8.69E-03 | 1.34E-02 | 3.91E-01 | 7.76E-01 | 1.05E+00 |
| 224 | NEUMARK-OBERPFALZ | SK | MIXED USED LAND | 2.94E-03 | 6.01E-03 | 8.74E-03 | 7.18E-03 | 1.46E-02 | 2.06E-02 |
| 225 | NEUMARK-OBERPFALZ | LK | MIXED USED LAND | 2.92E-03 | 5.96E-03 | 8.52E-03 | 3.16E-01 | 6.38E-01 | 8.90E-01 |
| | BAYERN | | | 4.54E-03 | 9.50E-03 | 1.49E-02 | 1.70E+01 | 3.53E+01 | 5.42E+01 |
| 226 | CALW | LK | MIXED USED LAND | 5.93E-03 | 1.30E-02 | 1.77E-02 | 9.96E-01 | 2.15E+00 | 2.85E+00 |
| 227 | FREUDENSTADT | LK | PROD. FOREST LAND | 6.06E-03 | 1.38E-02 | 1.88E-02 | 4.02E-01 | 9.29E-01 | 1.50E+00 |
| 228 | HECHINGEN | LK | MIXED USED LAND | 4.62E-03 | 1.03E-02 | 1.52E-02 | 3.41E-01 | 7.58E-01 | 1.08E+00 |
| 229 | HORB | LK | MIXED USED LAND | 5.19E-03 | 1.16E-02 | 1.61E-02 | 3.46E-01 | 7.73E-01 | 1.04E+00 |
| 230 | RAVENSBURG | LK | PROD. ARABLE LAND | 3.55E-03 | 8.06E-03 | 1.57E-02 | 7.56E-01 | 1.70E+00 | 2.99E+00 |
| 231 | REUTLINGEN | LK | MIXED USED LAND | 4.16E-03 | 9.26E-03 | 1.44E-02 | 3.57E-01 | 7.89E-01 | 1.15E+00 |
| 232 | ROTTWEIL | LK | MIXED USED LAND | 5.15E-03 | 1.18E-02 | 1.99E-02 | 5.32E-01 | 1.21E+00 | 1.89E+00 |
| 233 | TETTNANG | LK | PROD. ARABLE LAND | 3.97E-03 | 9.27E-03 | 1.96E-02 | 3.10E-01 | 7.19E-01 | 1.37E+00 |
| 234 | TUEBINGEN | LK | MIXED USED LAND | 4.55E-03 | 1.01E-02 | 1.45E-02 | 4.09E-01 | 9.04E-01 | 1.26E+00 |
| 235 | TUTTLINGEN | LK | MIXED USED LAND | 4.21E-03 | 9.71E-03 | 1.90E-02 | 3.65E-01 | 8.18E-01 | 1.55E+00 |
| 236 | WANGEN | LK | PROD. GRASS LAND | 3.31E-03 | 7.50E-03 | 1.41E-02 | 2.73E-01 | 6.26E-01 | 1.37E+00 |
| 237 | BADEN-BADEN | SK | PROD. FOREST LAND | 6.91E-03 | 1.50E-02 | 2.24E-02 | 5.47E-02 | 1.21E-01 | 2.15E-01 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 238 | FREIBURG I.BREISG. | SK | MIXED USED LAND | 1.09E-02 | 2.75E-02 | 4.56E-02 | 1.60E-01 | 4.06E-01 | 6.48E-01 |
| 239 | BUEHL | LK | PRED. FOREST LAND | 6.70E-03 | 1.46E-02 | 2.39E-02 | 2.21E-01 | 4.90E-01 | 8.31E-01 |
| 240 | DONAUESCHINGEN | LK | MIXED USED LAND | 4.42E-03 | 1.00E-02 | 2.84E-02 | 5.12E-01 | 1.16E+00 | 3.15E+00 |
| 241 | EMMENDINGEN | LK | PRED. FOREST LAND | 8.82E-03 | 2.16E-02 | 3.16E-02 | 6.93E-01 | 1.76E+00 | 3.17E+00 |
| 242 | FREIBURG | LK | PRED. FOREST LAND | 1.31E-02 | 3.35E-02 | 5.73E-02 | 4.69E-01 | 1.17E+00 | 2.57E+00 |
| 243 | HOSCHWARZWALD | LK | PRED. FOREST LAND | 5.42E-03 | 1.27E-02 | 4.42E-02 | 3.36E-01 | 7.98E-01 | 3.65E+00 |
| 244 | KEHL | LK | MIXED USED LAND | 6.70E-03 | 1.49E-02 | 2.02E-02 | 3.20E-01 | 7.11E-01 | 9.32E-01 |
| 245 | KONSTANZ | LK | PRED. ARABLE LAND | 4.23E-03 | 9.76E-03 | 2.42E-02 | 5.26E-01 | 1.20E+00 | 2.66E+00 |
| 246 | LAHR | LK | PRED. ARABLE LAND | 6.15E-03 | 1.96E-02 | 2.76E-02 | 8.24E-01 | 1.95E+00 | 2.48E+00 |
| 247 | LOERRACH | LK | MIXED USED LAND | 1.22E-02 | 3.14E-02 | 8.06E-02 | 1.19E+00 | 3.08E+00 | 7.06E+00 |
| 248 | MUELLHEIM | LK | PRED. ARABLE LAND | 1.42E-02 | 3.67E-02 | 6.33E-02 | 1.68E+00 | 4.40E+00 | 6.49E+00 |
| 249 | OFFENBURG | LK | PRED. FOREST LAND | 6.55E-03 | 1.50E-02 | 2.03E-02 | 2.63E-01 | 6.09E-01 | 9.75E-01 |
| 250 | RASTATT | LK | PRED. FOREST LAND | 7.88E-03 | 1.68E-02 | 2.75E-02 | 3.34E-01 | 7.33E-01 | 1.34E+00 |
| 251 | SAECKINGEN | LK | MIXED USED LAND | 1.19E-02 | 3.08E-02 | 9.88E-02 | 7.87E-01 | 2.06E+00 | 6.26E+00 |
| 252 | STOCKACH | LK | PRED. ARABLE LAND | 3.67E-03 | 8.66E-03 | 1.77E-02 | 5.66E-01 | 1.25E+00 | 2.31E+00 |
| 253 | UEBERLINGEN | LK | PRED. ARABLE LAND | 3.86E-03 | 8.82E-03 | 1.79E-02 | 5.24E-01 | 1.18E+00 | 2.17E+00 |
| 254 | VILLINGEN | LK | MIXED USED LAND | 5.54E-03 | 1.29E-02 | 2.33E-02 | 3.95E-01 | 9.17E-01 | 1.60E+00 |
| 255 | WALDSHUT | LK | PRED. FOREST LAND | 7.47E-03 | 1.84E-02 | 1.16E-01 | 3.78E-01 | 9.29E-01 | 7.54E+00 |
| 256 | WOLFACH | LK | PRED. FOREST LAND | 7.10E-03 | 1.69E-02 | 2.40E-02 | 3.98E-01 | 9.55E-01 | 1.62E+00 |
| 257 | HEIDELBERG | SK | PRED. ARABLE LAND | 1.07E-02 | 2.22E-02 | 4.07E-02 | 2.60E-01 | 5.59E-01 | 9.45E-01 |
| 258 | KARLSRUHE | SK | PRED. ARABLE LAND | 2.62E-02 | 4.13E-02 | 8.75E-02 | 8.95E-01 | 1.36E+00 | 2.67E+00 |
| 259 | MANNHEIM | SK | PRED. ARABLE LAND | 1.03E-02 | 2.38E-02 | 3.72E-02 | 4.02E-01 | 9.19E-01 | 1.31E+00 |
| 260 | PFORZHEIM | SK | MIXED USED LAND | 6.20E-03 | 1.36E-02 | 2.06E-02 | 6.64E-02 | 1.45E-01 | 2.13E-01 |
| 261 | BRUCHSAL | LK | PRED. ARABLE LAND | 1.45E-02 | 2.91E-02 | 6.11E-02 | 2.05E+00 | 3.68E+00 | 6.57E+00 |
| 262 | BUCHEN | LK | PRED. ARABLE LAND | 6.18E-03 | 1.29E-02 | 1.95E-02 | 1.39E+00 | 2.85E+00 | 3.97E+00 |
| 263 | HEIDELBERG | LK | PRED. FOREST LAND | 1.08E-02 | 2.28E-02 | 4.25E-02 | 5.08E-01 | 1.10E+00 | 2.47E+00 |
| 264 | KARLSRUHE | LK | PRED. ARABLE LAND | 1.45E-02 | 2.65E-02 | 5.07E-02 | 2.01E+00 | 3.61E+00 | 6.43E+00 |
| 265 | MANNHEIM | LK | MIXED USED LAND | 1.08E-02 | 2.41E-02 | 4.62E-02 | 5.05E-01 | 1.13E+00 | 1.88E+00 |
| 266 | MOSBACH | LK | MIXED USED LAND | 7.19E-03 | 1.49E-02 | 2.46E-02 | 5.75E-01 | 1.19E+00 | 1.84E+00 |
| 267 | PFORZHEIM | LK | MIXED USED LAND | 6.52E-03 | 1.42E-02 | 2.22E-02 | 2.90E-01 | 6.28E-01 | 9.54E-01 |
| 268 | SINSHEIM | LK | PRED. ARABLE LAND | 6.15E-03 | 1.69E-02 | 2.87E-02 | 1.29E+00 | 2.58E+00 | 4.09E+00 |
| 269 | TAUBERBISCHOFSHEIM | LK | PRED. FOREST LAND | 5.66E-03 | 1.19E-02 | 1.76E-02 | 4.27E-01 | 9.11E-01 | 1.60E+00 |
| 270 | HEILBRONN | SK | PRED. ARABLE LAND | 6.36E-03 | 1.41E-02 | 2.21E-02 | 1.33E-01 | 2.91E-01 | 4.18E-01 |
| 271 | STUTTGART | SK | PRED. ARABLE LAND | 4.83E-03 | 1.07E-02 | 1.54E-02 | 3.27E-01 | 7.14E-01 | 9.42E-01 |
| 272 | AALEN | LK | PRED. FOREST LAND | 4.26E-03 | 9.50E-03 | 1.89E-02 | 5.48E-01 | 1.24E+00 | 2.99E+00 |
| 273 | BACKNANG | LK | PRED. FOREST LAND | 4.99E-03 | 1.11E-02 | 1.73E-02 | 3.44E-01 | 7.75E-01 | 1.44E+00 |
| 274 | BOEBLINGEN | LK | MIXED USED LAND | 5.00E-03 | 1.11E-02 | 1.53E-02 | 4.67E-01 | 1.03E+00 | 1.38E+00 |
| 275 | CRAILSHEIM | LK | MIXED USED LAND | 4.54E-03 | 9.75E-03 | 1.48E-02 | 7.10E-01 | 1.51E+00 | 2.23E+00 |
| 276 | ESSLINGEN | LK | MIXED USED LAND | 4.51E-03 | 9.98E-03 | 1.49E-02 | 2.33E-01 | 5.12E-01 | 7.40E-01 |
| 277 | GOEPPINGEN | LK | MIXED USED LAND | 4.31E-03 | 9.64E-03 | 1.75E-02 | 5.53E-01 | 1.23E+00 | 2.16E+00 |
| 278 | HEIDENHEIM | LK | MIXED USED LAND | 4.81E-03 | 1.12E-02 | 2.84E-02 | 6.10E-01 | 1.41E+00 | 3.46E+00 |
| 279 | HEILBRONN | LK | PRED. ARABLE LAND | 6.61E-03 | 1.46E-02 | 2.30E-02 | 1.86E+00 | 4.12E+00 | 5.93E+00 |
| 280 | KUENZELSAU | LK | PRED. ARABLE LAND | 5.36E-03 | 1.14E-02 | 1.70E-02 | 6.00E-01 | 1.26E+00 | 1.73E+00 |
| 281 | LEONBERG | LK | PRED. ARABLE LAND | 5.46E-03 | 1.21E-02 | 1.73E-02 | 5.18E-01 | 1.14E+00 | 1.48E+00 |
| 282 | LUDWIGSBURG | LK | PRED. ARABLE LAND | 6.21E-03 | 1.41E-02 | 2.17E-02 | 8.18E-01 | 1.82E+00 | 2.51E+00 |
| 283 | MERGENTHEIM | LK | PRED. ARABLE LAND | 5.02E-03 | 1.06E-02 | 1.56E-02 | 7.79E-01 | 1.63E+00 | 2.19E+00 |
| 284 | NUERTINGEN | LK | MIXED USED LAND | 4.28E-03 | 9.50E-03 | 1.50E-02 | 3.32E-01 | 7.32E-01 | 1.12E+00 |
| 285 | OEHRINGEN | LK | PRED. FOREST LAND | 5.65E-03 | 1.24E-02 | 1.88E-02 | 2.65E-01 | 5.89E-01 | 1.07E+00 |
| 286 | SCHWAEBISCH GMUEND | LK | MIXED USED LAND | 4.42E-03 | 9.84E-03 | 1.73E-02 | 3.99E-01 | 8.84E-01 | 1.50E+00 |
| 287 | SCHWAEBISCH HALL | LK | PRED. FOREST LAND | 4.73E-03 | 1.03E-02 | 1.60E-02 | 3.16E-01 | 7.02E-01 | 1.30E+00 |

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Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 288 | VAIHINGEN | LK | PRED. ARABLE LAND | 6.26E-03 | 1.38E-02 | 2.08E-02 | 7.78E-01 | 1.68E+00 | 2.32E+00 |
| 289 | WAIBLINGEN | LK | PRED. FOREST LAND | 4.77E-03 | 1.06E-02 | 1.63E-02 | 2.46E-01 | 5.54E-01 | 1.02E+00 |
| | BADEN-WUERTTEMBERG | | | 6.53E-03 | 1.+7E-02 | 2.82E-02 | 3.72E+01 | 8.17E+01 | 1.49E+02 |
| 290 | DARMSTADT | SK | MIXED USED LAND | 8.64E-03 | 1.98E-02 | 3.30E-02 | 1.52E-01 | 3.47E-01 | 5.09E-01 |
| 291 | FRANKFURT-MAIN | SK | PRED. ARABLE LAND | 6.90E-03 | 1.49E-02 | 2.63E-02 | 3.25E-01 | 6.92E-01 | 1.11E+00 |
| 292 | GIESSEN | SK | MIXED USED LAND | 5.40E-03 | 1.03E-02 | 1.45E-02 | 5.38E-02 | 1.01E-01 | 1.40E-01 |
| 293 | HANAU | SK | MIXED USED LAND | 9.18E-03 | 2.12E-02 | 5.01E-02 | 4.17E-02 | 9.60E-02 | 2.18E-01 |
| 294 | OFFENBACH-MAIN | SK | PRED. FOREST LAND | 7.39E-03 | 1.63E-02 | 3.07E-02 | 2.93E-02 | 6.54E-02 | 1.49E-01 |
| 295 | WIESBADEN | SK | MIXED USED LAND | 5.94E-03 | 1.21E-02 | 1.73E-02 | 1.47E-01 | 2.98E-01 | 4.14E-01 |
| 296 | BERGSTRASSE | LK | MIXED USED LAND | 9.69E-03 | 2.23E-02 | 3.41E-02 | 9.35E-01 | 2.12E+00 | 3.10E+00 |
| 297 | BIEDENKOPF | LK | PRED. FOREST LAND | 5.21E-03 | 9.23E-03 | 1.24E-02 | 1.84E-01 | 3.33E-01 | 5.16E-01 |
| 298 | BUEDINGEN | LK | MIXED USED LAND | 5.73E-03 | 1.16E-02 | 1.79E-02 | 5.93E-01 | 1.17E+00 | 1.69E+00 |
| 299 | DARMSTADT | LK | MIXED USED LAND | 8.74E-03 | 2.00E-02 | 3.03E-02 | ?.92E-01 | 9.02E-01 | 1.33E+00 |
| 300 | DIEBURG | LK | MIXED USED LAND | 7.49E-03 | 1.66E-02 | 2.69E-02 | 5.03E-01 | 1.11E+00 | 1.70E+00 |
| 301 | DILLKREIS | LK | PRED. FOREST LAND | 5.47E-03 | 1.01E-02 | 1.42E-02 | 2.44E-01 | 4.59E-01 | 7.53E-01 |
| 302 | ERBACH | LK | PRED. FOREST LAND | 7.27E-03 | 1.56E-02 | 2.42E-02 | 3.74E-01 | 8.15E-01 | 1.51E+00 |
| 303 | FRIEDBERG | LK | PRED. ARABLE LAND | 6.22E-03 | 1.29E-02 | 2.17E-02 | 8.46E-01 | 1.71E+00 | 2.59E+00 |
| 304 | GELNHAUSEN | LK | PRED. FOREST LAND | 6.85E-03 | 1.48E-02 | 2.78E-02 | 3.65E-01 | 7.89E-01 | 1.67E+00 |
| 305 | GIESSEN | LK | PRED. ARABLE LAND | 5.26E-03 | 9.93E-03 | 1.37E-02 | 8.30E-01 | 1.53E+00 | 1.98E+00 |
| 306 | GROSS-GERAU | LK | PRED. ARABLE LAND | 7.34E-03 | 1.62E-02 | 2.41E-02 | 7.63E-01 | 1.63E+00 | 2.17E+00 |
| 307 | HANAU | LK | MIXED USED LAND | 7.94E-03 | 1.78E-02 | 3.80E-02 | 3.18E-01 | 6.93E-01 | 1.33E+00 |
| 308 | LIMBURG | LK | PRED. ARABLE LAND | 6.07E-03 | 1.22E-02 | 1.84E-02 | 5.42E-01 | 1.07E+00 | 1.49E+00 |
| 309 | MAIN-TAUNUS-KREIS | LK | PRED. ARABLE LAND | 6.14E-03 | 1.27E-02 | 1.91E-02 | 4.56E-01 | 9.32E-01 | 1.29E+00 |
| 310 | OBERLAHNKREIS | LK | MIXED USED LAND | 6.01E-03 | 1.20E-02 | 1.81E-02 | 3.57E-01 | 7.03E-01 | 1.04E+00 |
| 311 | OBERSTAUNUSKREIS | LK | MIXED USED LAND | 6.32E-03 | 1.32E-02 | 2.20E-02 | 1.53E-01 | 3.17E-01 | 5.11E-01 |
| 312 | OFFENBACH | LK | MIXED USED LAND | 8.07E-03 | 1.82E-02 | 3.60E-02 | 4.01E-01 | 8.98E-01 | 1.64E+00 |
| 313 | RHEINGAUKREIS | LK | MIXED USED LAND | 5.18E-03 | 1.00E-02 | 1.36E-02 | 2.13E-01 | 4.09E-01 | 5.40E-01 |
| 314 | SCHLUECHTERN | LK | MIXED USED LAND | 5.73E-03 | 1.17E-02 | 1.83E-02 | 4.03E-01 | 8.17E-01 | 1.24E+00 |
| 315 | UNTERTAUNUSKREIS | LK | PRED. FOREST LAND | 5.84E-03 | 1.18E-02 | 1.70E-02 | 2.57E-01 | 5.26E-01 | 8.98E-01 |
| 316 | USINGEN | LK | PRED. FOREST LAND | 6.07E-03 | 1.24E-02 | 1.95E-02 | 1.52E-01 | 3.15E-01 | 5.89E-01 |
| 317 | WETZLAR | LK | MIXED USED LAND | 5.62E-03 | 1.08E-02 | 1.57E-02 | 5.32E-01 | 1.01E+00 | 1.44E+00 |
| 318 | MARBURG-LAHN | SK | MIXED USED LAND | 5.13E-03 | 9.06E-03 | 1.21E-02 | 1.95E-02 | 3.46E-02 | 4.54E-02 |
| 319 | MARBURG-LAHN | LK | MIXED USED LAND | 5.12E-03 | 9.04E-03 | 1.20E-02 | 7.58E-01 | 1.32E+00 | 1.73E+00 |
| | HESSEN | | | 6.47E-03 | 1.34E-02 | 2.11E-02 | 1.13E+01 | 2.32E+01 | 3.53E+01 |
| 320 | FRANKENTHAL | SK | PRED. ARABLE LAND | 1.02E-02 | 2.38E-02 | 3.45E-02 | 1.33E-01 | 3.07E-01 | 4.07E-01 |
| 321 | KAISERLAUTERN | SK | PRED. ARABLE LAND | 6.09E-03 | 1.29E-02 | 1.80E-02 | 2.53E-01 | 5.29E-01 | 6.79E-01 |
| 322 | LANDAU I.D.PFALZ | SK | PRED. ARABLE LAND | 1.09E-02 | 2.46E-02 | 4.85E-02 | 1.29E-01 | 2.88E-01 | 5.13E-01 |
| 323 | LUDWIGSHAFEN-RHEIN | SK | PRED. ARABLE LAND | 1.11E-02 | 2.58E-02 | 3.79E-02 | 2.24E-01 | 5.18E-01 | 6.95E-01 |
| 324 | MAINZ | SK | PRED. ARABLE LAND | 6.09E-03 | 1.26E-02 | 1.77E-02 | 1.78E-01 | 3.63E-01 | 4.70E-01 |
| 325 | NEUSTADT-WEINSTRASSE | SK | PRED. FOREST LAND | 9.17E-03 | 2.07E-02 | 3.68E-02 | 1.11E-01 | 2.55E-01 | 5.48E-01 |
| 326 | PIRMASENS | SK | PRED. ARABLE LAND | 6.31E-03 | 1.34E-02 | 1.81E-02 | 9.20E-02 | 1.93E-01 | 2.40E-01 |
| 327 | SPEYER | SK | PRED. ARABLE LAND | 1.38E-02 | 3.20E-02 | 7.38E-02 | 1.75E-01 | 4.02E-01 | 8.32E-01 |
| 328 | WORMS | SK | PRED. ARABLE LAND | 1.20E-02 | 2.88E-02 | 4.17E-02 | 3.88E-01 | 9.26E-01 | 1.22E+00 |
| 329 | ZWEIBRUECKEN | SK | PRED. ARABLE LAND | 5.38E-03 | 1.10E-02 | 1.40E-02 | 5.78E-02 | 1.16E-01 | 1.37E-01 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 330 | ALZEY-WORMS | LK | PRED. ARABLE LAND | 6.96E-03 | 1.51E-02 | 2.14E-02 | 1.09E+00 | 2.22E+00 | 2.83E+00 |
| 331 | BAD DUERKHEIM | LK | PRED. FOREST LAND | 8.45E-03 | 1.88E-02 | 3.00E-02 | 4.97E-01 | 1.11E+00 | 1.99E+00 |
| 332 | DONNERSBERGKREIS | LK | PRED. ARABLE LAND | 5.60E-03 | 1.15E-02 | 1.53E-02 | 1.08E+00 | 2.16E+00 | 2.68E+00 |
| 333 | GERMERSHEIM | LK | PRED. ARABLE LAND | 1.84E-02 | 4.00E-02 | 9.16E-02 | 2.82E+00 | 5.59E+00 | 1.01E+01 |
| 334 | KAISERSLAUTERN | LK | PRED. ARABLE LAND | 5.77E-03 | 1.21E-02 | 1.62E-02 | 1.03E+00 | 2.11E+00 | 2.63E+00 |
| 335 | KUSEL | LK | PRED. ARABLE LAND | 4.87E-03 | 9.57E-03 | 1.23E-02 | 8.42E-01 | 1.61E+00 | 1.94E+00 |
| 336 | LANDAU-BAD BERGZABERN | LK | PRED. FOREST LAND | 1.02E-02 | 2.28E-02 | 4.28E-02 | 7.34E-01 | 1.67E+00 | 3.81E+00 |
| 337 | LUDWIGSHAFEN | LK | PRED. ARABLE LAND | 1.10E-02 | 2.52E-02 | 4.67E-02 | 9.23E-01 | 2.08E+00 | 3.06E+00 |
| 338 | MAINZ-BINGEN | LK | PRED. ARABLE LAND | 5.79E-03 | 1.18E-02 | 1.60E-02 | 9.80E-01 | 1.93E+00 | 2.40E+00 |
| 339 | PIRMASENS | LK | PRED. ARABLE LAND | 7.01E-03 | 1.52E-02 | 2.19E-02 | 1.65E+00 | 3.51E+00 | 4.66E+00 |
| 340 | ZWEIBRUECKEN | LK | PRED. ARABLE LAND | 5.60E-03 | 1.16E-02 | 1.49E-02 | 4.16E-01 | 8.47E-01 | 1.01E+00 |
| 341 | KOBLENZ | SK | PRED. ARABLE LAND | 5.51E-03 | 1.06E-02 | 1.69E-02 | 1.38E-01 | 2.59E-01 | 3.83E-01 |
| 342 | AHRWEILER | LK | PRED. FOREST LAND | 5.48E-03 | 1.01E-02 | 1.92E-02 | 3.21E-01 | 5.55E-01 | 9.66E-01 |
| 343 | ALTENKIRCHEN(WESTERW) | LK | PRED. FOREST LAND | 5.46E-03 | 9.80E-03 | 1.56E-02 | 3.04E-01 | 5.58E-01 | 1.04E+00 |
| 344 | BAD KREUZNACH | LK | MIXED USED LAND | 4.73E-03 | 8.94E-03 | 1.14E-02 | 6.19E-01 | 1.16E+00 | 1.45E+00 |
| 345 | BIRKENFELD | LK | MIXED USED LAND | 4.47E-03 | 8.33E-03 | 1.10E-02 | 5.36E-01 | 9.82E-01 | 1.28E+00 |
| 346 | COCHEM-ZELL | LK | PRED. FOREST LAND | 4.36E-03 | 7.52E-03 | 9.78E-03 | 2.65E-01 | 4.77E-01 | 7.08E-01 |
| 347 | MAYEN-KOBLENZ | LK | PRED. FOREST LAND | 6.40E-03 | 1.29E-02 | 2.19E-02 | 3.26E-01 | 5.80E-01 | 8.84E-01 |
| 348 | NEUWIED | LK | PRED. FOREST LAND | 7.36E-03 | 1.53E-02 | 3.40E-02 | 4.23E-01 | 9.08E-01 | 2.74E+00 |
| 349 | OBERWESTERWALDKREIS | LK | MIXED USED LAND | 6.01E-03 | 1.16E-02 | 1.83E-02 | 5.17E-01 | 9.89E-01 | 1.52E+00 |
| 350 | RHEIN-HUNSRUECK-KREIS | LK | MIXED USED LAND | 4.48E-03 | 8.06E-03 | 1.03E-02 | 6.55E-01 | 1.16E+00 | 1.46E+00 |
| 351 | RHEIN-LAHN-KREIS | LK | MIXED USED LAND | 5.89E-03 | 1.17E-02 | 1.81E-02 | 6.86E-01 | 1.35E+00 | 2.00E+00 |
| 352 | UNTERWESTERWALDKREIS | LK | MIXED USED LAND | 7.20E-03 | 1.51E-02 | 2.64E-02 | 4.68E-01 | 9.71E-01 | 1.67E+00 |
| 353 | TRIER | SK | PRED. ARABLE LAND | 4.76E-03 | 8.77E-03 | 1.50E-02 | 1.52E-01 | 2.73E-01 | 4.31E-01 |
| 354 | BERNKASTEL-WITTLICH | LK | PRED. FOREST LAND | 4.39E-03 | 7.75E-03 | 1.09E-02 | 5.00E-01 | 9.06E-01 | 1.47E+00 |
| 355 | BITTBURG-PRUEM | LK | PRED. FOREST LAND | 4.19E-03 | 6.57E-03 | 8.98E-03 | 6.55E-01 | 1.06E+00 | 1.64E+00 |
| 356 | DAUN | LK | PRED. FOREST LAND | 4.31E-03 | 7.07E-03 | 9.62E-03 | 3.77E-01 | 6.38E-01 | 9.88E-01 |
| 357 | TRIER-SAARBURG | LK | PRED. ARABLE LAND | 5.00E-03 | 9.55E-03 | 1.66E-02 | 1.50E+00 | 2.79E+00 | 4.47E+00 |
| | RHEINLAND-PFALZ | | | 6.10E-03 | 1.22E-02 | 1.97E-02 | 2.22E+01 | 4.44E+01 | 6.79E+01 |
| 358 | SAARBRUECKEN | SK | PRED. ARABLE LAND | 4.55E-03 | 9.77E-03 | 1.49E-02 | 6.46E-02 | 1.37E-01 | 1.91E-01 |
| 359 | HOMBURG | LK | PRED. ARABLE LAND | 5.13E-03 | 1.04E-02 | 1.30E-02 | 3.33E-01 | 6.60E-01 | 7.74E-01 |
| 360 | MERZIG-WADERN | LK | PRED. ARABLE LAND | 5.52E-03 | 1.11E-02 | 2.18E-02 | 7.82E-01 | 1.51E+00 | 2.63E+00 |
| 361 | OTTWEILER | LK | PRED. ARABLE LAND | 4.70E-03 | 9.11E-03 | 1.21E-02 | 3.32E-01 | 6.28E-01 | 7.81E-01 |
| 362 | SAARBRUECKEN | LK | PRED. ARABLE LAND | 4.62E-03 | 8.95E-03 | 1.17E-02 | 4.21E-01 | 7.96E-01 | 9.75E-01 |
| 363 | SAARLOUIS | LK | PRED. ARABLE LAND | 4.57E-03 | 8.70E-03 | 1.31E-02 | 5.50E-01 | 1.02E+00 | 1.43E+00 |
| 364 | SANKT INGBERT | LK | PRED. FOREST LAND | 4.95E-03 | 9.90E-03 | 1.23E-02 | 9.91E-02 | 2.02E-01 | 2.92E-01 |
| 365 | SANKT WENDEL | LK | MIXED USED LAND | 4.67E-03 | 8.95E-03 | 1.24E-02 | 3.81E-01 | 7.21E-01 | 9.64E-01 |
| | SAARLAND | | | 4.90E-03 | 9.62E-03 | 1.45E-02 | 2.96E+00 | 5.68E+00 | 8.04E+00 |
| 366 | AACHEN | SK | PRED. FOREST LAND | 4.94E-03 | 7.16E-03 | 1.05E-02 | 3.37E-02 | 5.06E-02 | 8.39E-02 |
| 367 | AACHEN | LK | PRED. FOREST LAND | 4.90E-03 | 7.08E-03 | 1.08E-02 | 1.92E-01 | 2.88E-01 | 4.92E-01 |
| 368 | DUEREN | LK | PRED. ARABLE LAND | 4.74E-03 | 7.07E-03 | 1.15E-02 | 8.52E-01 | 1.22E+00 | 1.83E+00 |
| 369 | ERKELENZ | LK | PRED. ARABLE LAND | 5.02E-03 | 6.99E-03 | 1.07E-02 | 5.35E-01 | 7.16E-01 | 1.05E+00 |
| 370 | JUELICH | LK | PRED. ARABLE LAND | 5.02E-03 | 6.99E-03 | 1.78E-02 | 5.54E-01 | 7.29E-01 | 1.86E+00 |
| 371 | MONSCHAU | LK | MIXED USED LAND | 4.72E-03 | 7.18E-03 | 1.01E-02 | 2.82E-01 | 4.20E-01 | 5.84E-01 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 372 | SCHLEIDEN | LK | PRED. FOREST LAND | 4.55E-03 | 7.16E-03 | 9.83E-03 | 4.36E-01 | 7.08E-01 | 1.10E+00 |
| 373 | SELFKANTKR.-GEILENK. | LK | PRED. ARABLE LAND | 5.13E-03 | 7.05E-03 | 1.11E-02 | 6.78E-01 | 8.94E-01 | 1.37E+00 |
| 374 | BONN | SK | PRED. ARABLE LAND | 4.78E-03 | 7.81E-03 | 1.16E-02 | 2.24E-01 | 3.53E-01 | 4.94E-01 |
| 375 | KOELN | SK | PRED. ARABLE LAND | 4.67E-03 | 7.05E-03 | 1.01E-02 | 3.90E-01 | 5.66E-01 | 7.79E-01 |
| 376 | BERGHEIM-ERFT | LK | PRED. ARABLE LAND | 4.81E-03 | 7.06E-03 | 1.26E-02 | 5.85E-01 | 8.24E-01 | 1.35E+00 |
| 377 | EUSKIRCHEN | LK | MIXED USED LAND | 4.69E-03 | 7.43E-03 | 1.09E-02 | 5.87E-01 | 9.12E-01 | 1.32E+00 |
| 378 | KOELN | LK | PRED. ARABLE LAND | 4.71E-03 | 7.18E-03 | 1.07E-02 | 4.67E-01 | 6.77E-01 | 9.75E-01 |
| 379 | OBERBERGISCHER KREIS | LK | PRED. FOREST LAND | 4.83E-03 | 7.70E-03 | 1.04E-02 | 3.19E-01 | 5.24E-01 | 8.04E-01 |
| 380 | RHEIN-BERGISCHER KR. | LK | MIXED USED LAND | 4.64E-03 | 7.05E-03 | 9.39E-03 | 5.91E-01 | 8.78E-01 | 1.15E+00 |
| 381 | RHEIN-SIEG KREIS | LK | MIXED USED LAND | 4.83E-03 | 7.93E-03 | 1.15E-02 | 1.10E+00 | 1.73E+00 | 2.36E+00 |
| 382 | DUESSELDORF | SK | PRED. ARABLE LAND | 4.81E-03 | 6.95E-03 | 9.70E-03 | 2.53E-01 | 3.51E-01 | 4.73E-01 |
| 383 | DUISBURG | SK | PRED. ARABLE LAND | 4.97E-03 | 7.21E-03 | 9.95E-03 | 2.37E-01 | 3.29E-01 | 4.40E-01 |
| 384 | ESSEN | SK | MIXED USED LAND | 5.01E-03 | 7.29E-03 | 1.00E-02 | 2.01E-01 | 2.86E-01 | 3.91E-01 |
| 385 | KREFELD | SK | PRED. ARABLE LAND | 4.98E-03 | 7.18E-03 | 9.97E-03 | 1.92E-01 | 2.66E-01 | 3.57E-01 |
| 386 | LEVERKUSEN | SK | MIXED USED LAND | 4.66E-03 | 6.94E-03 | 9.67E-03 | 4.48E-02 | 6.53E-02 | 9.04E-02 |
| 387 | MOENCHENGLADBACH | SK | PRED. ARABLE LAND | 4.94E-03 | 7.02E-03 | 9.96E-03 | 1.60E-01 | 2.17E-01 | 2.98E-01 |
| 388 | MUEHLHEIM-RUHR | SK | PRED. ARABLE LAND | 4.93E-03 | 7.12E-03 | 9.78E-03 | 1.45E-01 | 2.00E-01 | 2.67E-01 |
| 389 | NEUSS | SK | PRED. ARABLE LAND | 4.83E-03 | 6.96E-03 | 9.84E-03 | 8.54E-02 | 1.18E-01 | 1.61E-01 |
| 390 | OBERHAUSEN | SK | MIXED USED LAND | 5.01E-03 | 7.27E-03 | 1.00E-02 | 7.94E-02 | 1.13E-01 | 1.55E-01 |
| 391 | REMSCHEID | SK | PRED. FOREST LAND | 4.71E-03 | 6.93E-03 | 9.27E-03 | 3.54E-02 | 5.40E-02 | 8.01E-02 |
| 392 | RHEYDT | SK | PRED. ARABLE LAND | 4.70E-03 | 6.93E-03 | 9.22E-03 | 7.05E-02 | 9.99E-02 | 1.29E-01 |
| 393 | SOLINGEN | SK | PRED. FOREST LAND | 4.70E-03 | 6.90E-03 | 9.33E-03 | 4.38E-02 | 6.65E-02 | 1.01E-01 |
| 394 | WUPPERTAL | SK | MIXED USED LAND | 4.77E-03 | 6.94E-03 | 9.33E-03 | 1.48E-01 | 2.11E-01 | 2.83E-01 |
| 395 | DINSLAKEN | LK | MIXED USED LAND | 5.45E-03 | 8.30E-03 | 1.20E-02 | 2.45E-01 | 3.63E-01 | 5.16E-01 |
| 396 | DUESSELDORF-METTMANN | LK | PRED. ARABLE LAND | 4.81E-03 | 6.97E-03 | 9.55E-03 | 6.96E-01 | 9.67E-01 | 1.28E+00 |
| 397 | GELDERN | LK | MIXED USED LAND | 5.31E-03 | 7.71E-03 | 1.11E-02 | 5.65E-01 | 8.13E-01 | 1.17E+00 |
| 398 | GREVENBROICH | LK | PRED. ARABLE LAND | 4.83E-03 | 6.96E-03 | 1.03E-02 | 8.95E-01 | 1.24E+00 | 1.76E+00 |
| 399 | KEMPEN-KREFELD | LK | PRED. ARABLE LAND | 5.03E-03 | 7.12E-03 | 9.99E-03 | 8.62E-01 | 1.16E+00 | 1.58E+00 |
| 400 | KLEVE | LK | MIXED USED LAND | 5.59E-03 | 8.37E-03 | 1.26E-02 | 5.82E-01 | 8.65E-01 | 1.29E+00 |
| 401 | MOERS | LK | PRED. ARABLE LAND | 5.58E-03 | 8.66E-03 | 1.27E-02 | 9.97E-01 | 1.44E+00 | 1.97E+00 |
| 402 | REES | LK | PRED. GRASS LAND | 6.45E-03 | 1.09E-02 | 1.68E-02 | 5.61E-01 | 1.13E+00 | 2.10E+00 |
| 403 | RHEIN-WUPPER-KREIS | LK | MIXED USED LAND | 4.69E-03 | 6.94E-03 | 9.38E-03 | 3.49E-01 | 5.05E-01 | 6.72E-01 |
| 404 | BOCHUM | SK | PRED. ARABLE LAND | 5.09E-03 | 7.47E-03 | 1.02E-02 | 2.04E-01 | 2.88E-01 | 3.80E-01 |
| 405 | CASTROP-RAUXEL | SK | MIXED USED LAND | 5.20E-03 | 7.68E-03 | 1.05E-02 | 4.72E-02 | 6.84E-02 | 9.33E-02 |
| 406 | DORTMUND | SK | PRED. ARABLE LAND | 5.16E-03 | 7.63E-03 | 1.04E-02 | 4.64E-01 | 6.59E-01 | 8.66E-01 |
| 407 | HAGEN | SK | MIXED USED LAND | 4.94E-03 | 7.26E-03 | 9.64E-03 | 9.19E-02 | 1.32E-01 | 1.75E-01 |
| 408 | HAMM | SK | MIXED USED LAND | 6.16E-03 | 9.78E-03 | 1.42E-02 | 5.69E-02 | 8.86E-02 | 1.27E-01 |
| 409 | HERNE | SK | MIXED USED LAND | 5.17E-03 | 7.64E-03 | 1.05E-02 | 3.19E-02 | 4.61E-02 | 6.30E-02 |
| 410 | ISERLOHN | SK | PRED. FOREST LAND | 5.03E-03 | 7.48E-03 | 9.90E-03 | 1.81E-02 | 2.78E-02 | 4.11E-02 |
| 411 | LUENEN | SK | MIXED USED LAND | 5.43E-03 | 8.14E-03 | 1.13E-02 | 4.56E-02 | 6.68E-02 | 9.22E-02 |
| 412 | WANNE-EICKEL | SK | MIXED USED LAND | 5.12E-03 | 7.52E-03 | 1.03E-02 | 2.24E-02 | 3.23E-02 | 4.40E-02 |
| 413 | WATTENSCHEID | SK | MIXED USED LAND | 5.07E-03 | 7.42E-03 | 1.01E-02 | 2.49E-02 | 3.57E-02 | 4.85E-02 |
| 414 | WITTEN | SK | PRED. ARABLE LAND | 5.03E-03 | 7.38E-03 | 9.93E-03 | 8.08E-02 | 1.14E-01 | 1.49E-01 |
| 415 | ARNSBERG | LK | PRED. FOREST LAND | 5.20E-03 | 7.84E-03 | 1.04E-02 | 4.02E-01 | 6.26E-01 | 9.35E-01 |
| 416 | BRILON | LK | PRED. FOREST LAND | 5.25E-03 | 8.19E-03 | 1.11E-02 | 4.86E-01 | 7.80E-01 | 1.20E+00 |
| 417 | ENNEPE-RUHR-KREIS | LK | MIXED USED LAND | 4.89E-03 | 7.17E-03 | 9.56E-03 | 3.99E-01 | 5.72E-01 | 7.58E-01 |
| 418 | ISERLOHN | LK | MIXED USED LAND | 5.07E-03 | 7.53E-03 | 1.00E-02 | 3.54E-01 | 5.16E-01 | 6.83E-01 |
| 419 | LIPPSTADT | LK | PRED. ARABLE LAND | 5.66E-03 | 8.38E-03 | 1.17E-02 | 9.52E-01 | 1.36E+00 | 1.83E+00 |
| 420 | LUEDENSCHEID | LK | MIXED USED LAND | 4.87E-03 | 7.38E-03 | 9.66E-03 | 6.80E-01 | 1.01E+00 | 1.32E+00 |
| 421 | MESCHEDE | LK | MIXED USED LAND | 5.14E-03 | 7.99E-03 | 1.06E-02 | 7.12E-01 | 1.09E+00 | 1.43E+00 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 422 | OLPE | LK | PRED. FOREST LAND | 5.04E-03 | 8.06E-03 | 1.07E-02 | 4.28E-01 | 7.04E-01 | 1.06E+00 |
| 423 | SIEGEN | LK | PRED. FOREST LAND | 5.29E-03 | 9.23E-03 | 1.29E-02 | 4.02E-01 | 7.19E-01 | 1.15E+00 |
| 424 | SOEST | LK | PRED. ARABLE LAND | 5.63E-03 | 8.48E-03 | 1.17E-02 | 1.17E+00 | 1.69E+00 | 2.24E+00 |
| 425 | UNNA | LK | PRED. ARABLE LAND | 5.59E-03 | 8.50E-03 | 1.18E-02 | 7.85E-01 | 1.15E+00 | 1.54E+00 |
| 426 | WITTGENSTEIN | LK | PRED. FOREST LAND | 5.16E-03 | 8.59E-03 | 1.14E-02 | 2.96E-01 | 5.05E-01 | 7.62E-01 |
| 427 | BOCHOLT | SK | PRED. GRASS LAND | 6.43E-03 | 1.08E-02 | 1.67E-02 | 1.45E-02 | 2.49E-02 | 4.31E-02 |
| 428 | BOTTROP | SK | MIXED USED LAND | 5.16E-03 | 7.60E-03 | 1.06E-02 | 4.48E-02 | 6.47E-02 | 8.94E-02 |
| 429 | GELSENKIRCHEN | SK | MIXED USED LAND | 5.14E-03 | 7.56E-03 | 1.04E-02 | 1.10E-01 | 1.58E-01 | 2.17E-01 |
| 430 | GLADBECK | SK | MIXED USED LAND | 5.32E-03 | 8.00E-03 | 1.13E-02 | 3.93E-02 | 5.79E-02 | 8.11E-02 |
| 431 | RECKLINGHAUSEN | SK | MIXED USED LAND | 5.30E-03 | 7.89E-03 | 1.10E-02 | 7.24E-02 | 1.06E-01 | 1.46E-01 |
| 432 | AHAUS | LK | PRED. GRASS LAND | 5.61E-03 | 8.30E-03 | 1.32E-02 | 4.55E-01 | 6.92E-01 | 1.21E+00 |
| 433 | BECKUM | LK | MIXED USED LAND | 6.13E-03 | 9.16E-03 | 1.31E-02 | 7.66E-01 | 1.14E+00 | 1.63E+00 |
| 434 | BORKEN | LK | PRED. GRASS LAND | 6.01E-03 | 9.65E-03 | 1.46E-02 | 4.48E-01 | 7.30E-01 | 1.23E+00 |
| 435 | COESFELD | LK | MIXED USED LAND | 5.60E-03 | 8.25E-03 | 1.24E-02 | 7.04E-01 | 1.02E+00 | 1.52E+00 |
| 436 | LUEDINGHAUSEN | LK | MIXED USED LAND | 5.63E-03 | 8.33E-03 | 1.18E-02 | 8.03E-01 | 1.17E+00 | 1.64E+00 |
| 437 | RECKLINGHAUSEN | LK | MIXED USED LAND | 5.46E-03 | 8.24E-03 | 1.17E-02 | 8.02E-01 | 1.19E+00 | 1.67E+00 |
| 438 | STEINFURT | LK | MIXED USED LAND | 5.50E-03 | 8.55E-03 | 1.44E-02 | 9.43E-01 | 1.34E+00 | 2.27E+00 |
| 439 | BUEREN | LK | PRED. ARABLE LAND | 5.81E-03 | 8.69E-03 | 1.27E-02 | 1.47E+00 | 2.12E+00 | 2.99E+00 |
| 440 | PADERBORN | LK | PRED. FOREST LAND | 6.39E-03 | 9.16E-03 | 1.35E-02 | 4.15E-01 | 6.15E-01 | 1.02E+00 |
| | NORDRHEIN-WESTFALEN | | | 5.24E-03 | 7.96E-03 | 1.15E-02 | 3.05E+01 | 4.50E+01 | 6.60E+01 |
| 441 | ALTKIRCH | AR | PRED. ARABLE LAND | 9.21E-03 | 2.32E-02 | 4.63E-02 | 1.78E+00 | 4.47E+00 | 8.01E+00 |
| 442 | COLMAR | AR | PRED. ARABLE LAND | 6.91E-03 | 1.64E-02 | 2.40E-02 | 1.36E+00 | 3.19E+00 | 4.26E+00 |
| 443 | THANN | AR | PRED. FOREST LAND | 9.44E-03 | 2.33E-02 | 3.56E-02 | 3.37E-01 | 7.96E-01 | 1.40E+00 |
| 444 | GUEBWILLER | AR | PRED. ARABLE LAND | 9.35E-03 | 2.32E-02 | 3.48E-02 | 1.49E+00 | 3.65E+00 | 4.87E+00 |
| 445 | MULHOUSE | AR | PRED. ARABLE LAND | 9.58E-03 | 2.41E-02 | 4.08E-02 | 2.09E+00 | 5.35E+00 | 8.71E+00 |
| 446 | RIBEAUVILLE | AR | PRED. FOREST LAND | 5.48E-03 | 1.23E-02 | 1.61E-02 | 2.48E-01 | 5.54E-01 | 8.54E-01 |
| 447 | HAGUENAU | AR | MIXED USED LAND | 7.34E-03 | 1.58E-02 | 2.25E-02 | 8.45E-01 | 1.81E+00 | 2.38E+00 |
| 448 | MOLSHEIM | AR | PRED. ARABLE LAND | 5.73E-03 | 1.26E-02 | 1.52E-02 | 1.26E+00 | 2.73E+00 | 3.05E+00 |
| 449 | SAVERNE | AR | PRED. ARABLE LAND | 5.33E-03 | 1.11E-02 | 1.31E-02 | 1.57E+00 | 3.19E+00 | 3.53E+00 |
| 450 | SELESTAT-ERSTEIN | AR | PRED. ARABLE LAND | 8.38E-03 | 2.01E-02 | 2.77E-02 | 2.29E+00 | 5.39E+00 | 6.66E+00 |
| 451 | STRASBOURG-CAMPAGNE | AR | PRED. ARABLE LAND | 6.71E-03 | 1.48E-02 | 1.91E-02 | 1.37E+00 | 2.99E+00 | 3.55E+00 |
| 452 | STRASBOURG-VILLE | AR | PRED. ARABLE LAND | 6.88E-03 | 1.54E-02 | 2.02E-02 | 1.61E-01 | 3.56E-01 | 4.28E-01 |
| 453 | WISSEMBOURG | AR | PRED. FOREST LAND | 9.42E-03 | 2.03E-02 | 3.55E-02 | 5.09E-01 | 1.11E+00 | 2.04E+00 |
| 454 | EPINAL | AR | MIXED USED LAND | 3.28E-03 | 6.27E-03 | 7.49E-03 | 2.17E+00 | 3.98E+00 | 4.67E+00 |
| 455 | NEUFCHATEAU | AR | MIXED USED LAND | 3.01E-03 | 4.91E-03 | 5.78E-03 | 5.72E-01 | 9.17E-01 | 1.07E+00 |
| 456 | SAINT DIE | AR | MIXED USED LAND | 4.01E-03 | 8.12E-03 | 1.01E-02 | 1.07E+00 | 2.15E+00 | 2.61E+00 |
| 457 | BRIEY | AR | PRED. ARABLE LAND | 4.39E-03 | 7.72E-03 | 1.50E-02 | 1.85E+00 | 3.15E+00 | 5.64E+00 |
| 458 | LUNEVILLE | AR | MIXED USED LAND | 3.63E-03 | 6.71E-03 | 7.93E-03 | 3.86E-01 | 7.06E-01 | 8.19E-01 |
| 459 | NANCY | AR | PRED. ARABLE LAND | 3.28E-03 | 5.48E-03 | 6.87E-03 | 2.85E+00 | 4.61E+00 | 5.50E+00 |
| 460 | TOUL | AR | PRED. ARABLE LAND | 4.12E-03 | 7.95E-03 | 9.27E-03 | 5.07E-01 | 9.55E-01 | 1.05E+00 |
| 461 | BOULAY-MOSELLE | AR | PRED. ARABLE LAND | 4.42E-03 | 8.29E-03 | 1.36E-02 | 5.56E-01 | 1.01E+00 | 1.42E+00 |
| 462 | CHATEA-SALINS | AR | PRED. ARABLE LAND | 3.89E-03 | 7.18E-03 | 8.96E-03 | 2.13E-01 | 3.82E-01 | 4.49E-01 |
| 463 | FORBACH | AR | PRED. ARABLE LAND | 4.24E-03 | 8.00E-03 | 9.79E-03 | 1.50E+00 | 2.75E+00 | 3.17E+00 |
| 464 | METZ-CAMPAGNE | AR | PRED. ARABLE LAND | 4.12E-03 | 7.42E-03 | 1.26E-02 | 1.48E+00 | 2.60E+00 | 4.09E+00 |
| 465 | SARREBOURG | AR | MIXED USED LAND | 4.54E-03 | 9.12E-03 | 1.05E-02 | 3.20E-01 | 6.37E-01 | 7.17E-01 |
| 466 | SARREGUEMINES | AR | PRED. ARABLE LAND | 5.41E-03 | 1.12E-02 | 1.37E-02 | 8.20E-01 | 1.66E+00 | 1.90E+00 |
| 467 | THIONVILLE-EST | AR | PRED. ARABLE LAND | 7.63E-03 | 1.68E-02 | 4.64E-02 | 2.35E+00 | 5.49E+00 | 1.52E+01 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 468 | THIONVILLE-OUEST | AR | PRED. ARABLE LAND | 5.48E-03 | 1.08E-02 | 2.51E-02 | 1.45E+00 | 2.86E+00 | 5.97E+00 |
| 469 | METZ-VILLE | AR | PRED. ARABLE LAND | 4.18E-03 | 7.54E-03 | 1.32E-02 | 8.71E-01 | 1.53E+00 | 2.48E+00 |
| 470 | COMMERCY | AR | MIXED USED LAND | 3.32E-03 | 5.09E-03 | 7.07E-03 | 8.64E-01 | 1.30E+00 | 1.78E+00 |
| 471 | VERDUN S.MEUSE | AR | MIXED USED LAND | 3.63E-03 | 5.39E-03 | 8.40E-03 | 1.91E+00 | 2.78E+00 | 4.27E+00 |
| 472 | CHARLEVILLE-MEZIERES | AR | PRED. FOREST LAND | 3.69E-03 | 4.06E-03 | 5.96E-03 | 1.44E+00 | 1.65E+00 | 2.60E+00 |
| 473 | SEDAN | AR | PRED. FOREST LAND | 3.52E-03 | 4.26E-03 | 6.12E-03 | 4.24E-01 | 5.38E-01 | 8.42E-01 |
| 474 | VOUZIERS | AR | MIXED USED LAND | 3.47E-03 | 4.15E-03 | 6.00E-03 | 3.56E-01 | 4.14E-01 | 5.55E-01 |
| | FRANCE | | | 4.79E-03 | 9.28E-03 | 1.42E-02 | 3.93E+01 | 7.77E+01 | 1.17E+02 |
| 475 | CAPELLEN | CT | MIXED USED LAND | 3.60E-03 | 5.29E-03 | 7.50E-03 | 1.35E-01 | 1.94E-01 | 2.73E-01 |
| 476 | ESCH | CT | PRED. ARABLE LAND | 4.19E-03 | 7.08E-03 | 1.26E-02 | 3.17E-01 | 5.31E-01 | 8.96E-01 |
| 477 | LUXEMBOURG-VILLE | CT | PRED. ARABLE LAND | 3.64E-03 | 5.25E-03 | 7.80E-03 | 5.72E-02 | 7.93E-02 | 1.13E-01 |
| 478 | LUXEMB-CAMPAGNE | CT | PRED. GRASS LAND | 4.44E-03 | 7.76E-03 | 1.50E-02 | 9.59E-02 | 1.78E-01 | 4.25E-01 |
| 479 | MERSCH | CT | PRED. ARABLE LAND | 4.11E-03 | 6.64E-03 | 1.10E-02 | 2.79E-01 | 4.37E-01 | 6.80E-01 |
| 480 | CLERVAUX | CT | PRED. FOREST LAND | 3.98E-03 | 5.81E-03 | 8.22E-03 | 1.27E-01 | 1.92E-01 | 3.06E-01 |
| 481 | DIEKIRCH | CT | MIXED USED LAND | 4.06E-03 | 6.40E-03 | 9.96E-03 | 1.82E-01 | 2.82E-01 | 4.32E-01 |
| 482 | REDANGE | CT | MIXED USED LAND | 3.68E-03 | 5.26E-03 | 7.63E-03 | 1.85E-01 | 2.59E-01 | 3.73E-01 |
| 483 | VIANDEN | CT | MIXED USED LAND | 4.07E-03 | 6.40E-03 | 9.68E-03 | 4.14E-02 | 6.39E-02 | 9.52E-02 |
| 484 | WILTZ | CT | PRED. FOREST LAND | 3.82E-03 | 5.50E-03 | 7.92E-03 | 1.19E-01 | 1.77E-01 | 2.87E-01 |
| 485 | ECHTERNACH | CT | PRED. ARABLE LAND | 4.41E-03 | 7.63E-03 | 1.28E-02 | 2.48E-01 | 4.17E-01 | 6.52E-01 |
| 486 | GREVENMACHER | CT | PRED. GRASS LAND | 4.86E-03 | 8.98E-03 | 1.69E-02 | 1.13E-01 | 2.14E-01 | 4.71E-01 |
| 487 | REMICH | CT | PRED. ARABLE LAND | 7.31E-03 | 1.58E-02 | 3.72E-02 | 2.36E-01 | 4.77E-01 | 1.02E+00 |
| | LUXEMBOURG | | | 4.24E-03 | 6.95E-03 | 1.19E-02 | 2.14E+00 | 3.50E+00 | 6.03E+00 |
| 488 | ARLON | AR | MIXED USED LAND | 3.52E-03 | 4.88E-03 | 6.69E-03 | 1.42E-01 | 1.93E-01 | 2.63E-01 |
| 489 | BASTAGNE | AR | MIXED USED LAND | 3.91E-03 | 5.38E-03 | 7.47E-03 | 4.87E-01 | 6.54E-01 | 9.04E-01 |
| 490 | MARCHE-EN-FAMENNE | AR | MIXED USED LAND | 4.07E-03 | 5.37E-03 | 7.48E-03 | 4.79E-01 | 6.18E-01 | 8.59E-01 |
| 491 | NEUFCATEAU | AR | MIXED USED LAND | 3.60E-03 | 4.41E-03 | 6.01E-03 | 6.58E-01 | 7.85E-01 | 1.07E+00 |
| 492 | VIRTON | AR | MIXED USED LAND | 3.54E-03 | 4.74E-03 | 6.78E-03 | 3.20E-01 | 4.18E-01 | 5.95E-01 |
| 493 | DINANT | AR | MIXED USED LAND | 4.02E-03 | 4.84E-03 | 6.94E-03 | 1.22E+00 | 1.38E+00 | 2.03E+00 |
| 494 | NAMUR | AR | PRED. ARABLE LAND | 5.09E-03 | 6.84E-03 | 1.02E-02 | 1.71E+00 | 2.15E+00 | 3.12E+00 |
| 495 | PHILIPPEVILLE | AR | MIXED USED LAND | 4.02E-03 | 4.41E-03 | 6.65E-03 | 7.28E-01 | 7.70E-01 | 1.17E+00 |
| 496 | CHARLEROI | AR | PRED. ARABLE LAND | 4.63E-03 | 5.39E-03 | 8.24E-03 | 9.88E-01 | 1.09E+00 | 1.64E+00 |
| 497 | THUIN | AR | PRED. GRASS LAND | 4.18E-03 | 4.41E-03 | 6.91E-03 | 5.01E-01 | 5.52E-01 | 9.17E-01 |
| 498 | HUY | AR | MIXED USED LAND | 6.58E-03 | 1.14E-02 | 1.80E-02 | 7.49E-01 | 1.16E+00 | 1.76E+00 |
| 499 | LIEGE | AR | MIXED USED LAND | 5.79E-03 | 9.16E-03 | 1.37E-02 | 8.15E-01 | 1.24E+00 | 1.82E+00 |
| 500 | VERVIERS | AR | MIXED USED LAND | 4.89E-03 | 7.59E-03 | 1.05E-02 | 1.85E+00 | 2.81E+00 | 3.87E+00 |
| 501 | HASSELT | AR | PRED. GRASS LAND | 7.00E-03 | 8.48E-03 | 1.23E-02 | 5.55E-01 | 6.94E-01 | 1.08E+00 |
| 502 | WAREMME | AR | PRED. ARABLE LAND | 5.73E-03 | 8.10E-03 | 1.23E-02 | 6.90E-01 | 9.53E-01 | 1.39E+00 |
| 503 | TONGRES | AR | PRED. ARABLE LAND | 5.76E-03 | 7.68E-03 | 1.11E-02 | 9.91E-01 | 1.13E+00 | 1.60E+00 |
| | BELGIE/BELGIQUE | | | 4.68E-03 | 6.30E-03 | 9.17E-03 | 1.28E+01 | 1.66E+01 | 2.41E+01 |
| 504 | NOORD-LIMBURG | RE | MIXED USED LAND | 5.18E-03 | 6.99E-03 | 9.91E-03 | 9.10E-01 | 1.20E+00 | 1.70E+00 |
| 505 | MIDDEN-LIMBURG | RE | MIXED USED LAND | 5.42E-03 | 7.08E-03 | 1.03E-02 | 7.43E-01 | 9.47E-01 | 1.38E+00 |

Table 6-1: (cont.)

| NO. | NAME OF DISTRICT | | LAND CATEGORY (SEE TAB.3-6) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|---|
| 506 | ZUID-LIMBURG | RE | PRED. ARABLE LAND | 5.29E-03 | 7.29E-03 | 1.06E-02 | 1.22E+00 | 1.60E+00 | 2.26E+00 |
| 507 | WEST-N-BRABANT | RE | PRED. ARABLE LAND | 6.21E-03 | 8.00E-03 | 1.53E-02 | 2.95E+00 | 3.63E+00 | 6.64E+00 |
| 508 | MIDDEN-N-BRABANT | RE | MIXED USED LAND | 5.86E-03 | 7.11E-03 | 1.11E-02 | 1.44E+00 | 1.69E+00 | 2.66E+00 |
| 509 | NOORDOOST-N-BRABANT | RE | MIXED USED LAND | 5.20E-03 | 6.89E-03 | 1.01E-02 | 1.63E+00 | 2.06E+00 | 3.03E+00 |
| 510 | ZUIDOOST-N-BRABANT | RE | PRED. GRASS LAND | 6.23E-03 | 7.61E-03 | 1.11E-02 | 1.14E+00 | 1.44E+00 | 2.25E+00 |
| 511 | ZEEUWSCH-VLAANDEREN | RE | PRED. ARABLE LAND | 5.63E-03 | 7.00E-03 | 1.65E-02 | 1.40E+00 | 1.75E+00 | 3.90E+00 |
| 512 | OVERIG ZEELAND | RE | PRED. ARABLE LAND | 5.78E-03 | 7.75E-03 | 1.98E-02 | 2.85E+00 | 3.49E+00 | 7.67E+00 |
| 513 | VELUWE | RE | PRED. GRASS LAND | 4.39E-03 | 5.39E-03 | 8.45E-03 | 9.52E-01 | 1.20E+00 | 2.03E+00 |
| 514 | ACHTERHOEK | RE | PRED. GRASS LAND | 5.01E-03 | 6.93E-03 | 1.05E-02 | 9.10E-01 | 1.29E+00 | 2.16E+00 |
| 515 | ARNHEM/NIJMEGEN | RE | PRED. GRASS LAND | 4.79E-03 | 6.17E-03 | 9.60E-03 | 5.57E-01 | 7.38E-01 | 1.26E+00 |
| 516 | ZUIDWEST-GELDERLAND | RE | PRED. GRASS LAND | 4.90E-03 | 6.00E-03 | 9.37E-03 | 4.10E-01 | 5.16E-01 | 8.58E-01 |
| 517 | UTRECHT | RE | PRED. GRASS LAND | 4.44E-03 | 5.17E-03 | 8.25E-03 | 7.28E-01 | 8.78E-01 | 1.51E+00 |
| 518 | AGGLOMERATIE LEIDEN | RE | PRED. ARABLE LAND | 4.18E-03 | 4.54E-03 | 7.98E-03 | 3.37E-01 | 3.46E-01 | 5.96E-01 |
| 519 | AGGLOMERATIE 'S-GRAVEN. | RE | PRED. ARABLE LAND | 4.36E-03 | 4.81E-03 | 8.48E-03 | 3.34E-01 | 3.48E-01 | 6.00E-01 |
| 520 | DELFT EN WESTLAND | RE | PRED. ARABLE LAND | 4.50E-03 | 5.03E-03 | 9.01E-03 | 2.92E-01 | 3.09E-01 | 5.41E-01 |
| 521 | OSTELIJK Z-HOLLAND | RE | PRED. ARABLE LAND | 4.43E-03 | 5.03E-03 | 8.43E-03 | 7.75E-01 | 8.32E-01 | 1.37E+00 |
| 522 | GROOT-RIJNMOND | RE | PRED. ARABLE LAND | 4.86E-03 | 5.71E-03 | 1.01E-02 | 1.93E+00 | 2.14E+00 | 3.68E+00 |
| 523 | ZUIDOOST Z-HOLLAND | RE | PRED. GRASS LAND | 4.89E-03 | 5.79E-03 | 9.40E-03 | 3.00E-01 | 3.68E-01 | 6.47E-01 |
| 524 | NOORD/OVERIJSSEL | RE | PRED. GRASS LAND | 4.33E-03 | 5.35E-03 | 8.68E-03 | 1.15E+00 | 1.46E+00 | 2.59E+00 |
| 525 | ZUIDWEST-OVERIJSSEL | RE | PRED. GRASS LAND | 4.60E-03 | 5.92E-03 | 9.32E-03 | 2.47E-01 | 3.27E-01 | 5.62E-01 |
| 526 | TWENTE | RE | PRED. GRASS LAND | 5.14E-03 | 7.08E-03 | 1.23E-02 | 9.73E-01 | 1.36E+00 | 2.58E+00 |
| 527 | ZUIDELIJKE IJSSELMEERP. | RE | PRED. ARABLE LAND | 4.09E-03 | 4.75E-03 | 7.78E-03 | 1.09E+00 | 1.20E+00 | 1.93E+00 |
| 528 | KOP VAN NOORD-HOLLAND | RE | PRED. GRASS LAND | 2.68E-03 | 3.88E-03 | 1.28E-02 | 4.89E-01 | 5.35E-01 | 1.80E+00 |
| 529 | ALKMAER E.O. | RE | PRED. BARREN LAND | 2.73E-03 | 3.86E-03 | 1.23E-02 | 1.41E-01 | 1.52E-01 | 5.31E-01 |
| 530 | IJMOND | RE | PRED. BARREN LAND | 2.84E-03 | 4.02E-03 | 8.48E-03 | 6.34E-02 | 6.93E-02 | 1.60E-01 |
| 531 | AGGLOMERATIE HAARLEM | RE | PRED. BARREN LAND | 2.46E-03 | 3.39E-03 | 1.13E-02 | 5.82E-02 | 5.97E-02 | 2.25E-01 |
| 532 | ZAANSTREEK | RE | PRED. GRASS LAND | 2.88E-03 | 4.15E-03 | 8.23E-03 | 4.33E-02 | 4.82E-02 | 1.04E-01 |
| 533 | GROOT-AMSTERDAM | RE | PRED. GRASS LAND | 2.97E-03 | 4.31E-03 | 7.91E-03 | 3.43E-01 | 3.88E-01 | 7.72E-01 |
| 534 | GOOI EN VECHTSTREEK | RE | PRED. GRASS LAND | 4.16E-03 | 4.71E-03 | 7.80E-03 | 8.86E-02 | 1.04E-01 | 1.86E-01 |
| | NEDERLANDEN | | | 4.95E-03 | 6.18E-03 | 1.10E-02 | 2.65E+01 | 3.25E+01 | 5.82E+01 |
| | RHEIN-MAAS-REGION | | | | | | 2.30E+02 | 4.34E+02 | 8.15E+02 |

Table 6-2: Maximum and Average Individual Dose Rates and Collective Dose Rates from Gaseous Releases around the Years 1985/90

| Organ | Age Group | Maximum Individual Dose Rate [mrem/yr] CV 1) | DV 1) | Average Individual Dose Rate [mrem/yr] 2) | Collective Dose Rate [man·rem/yr] |
|---|---|---|---|---|---|
| Whole Body | I 3) | 1.02 | 0.61 | 1.92(-2) | |
| | Ch | 0.81 | " | 1.66(-2) | |
| | T | 0,61 | " | 9.67(-3) | |
| | A | 0.61 | " | 8.42(-3) | |
| | P | | | 9.80(-3) | 592 |
| Bone | I | 1.08 | 0,61 | 1,81(-2) | |
| | Ch | 0.85 | " | 1,42(-2) | |
| | T | 0.61 | " | 7,70(-3) | |
| | A | 0.98 | " | 1.58(-2) | |
| | P | | | 1,44(-2) | 872 |
| GI-Tract | I | 1,02 | 0,61 | 1,92(-2) | |
| | Ch | 0.81 | " | 1,64(-2) | |
| | T | 0,61 | " | 9.50(-3) | |
| | A | 0,61 | " | 8,19(-3) | |
| | P | | | 9.60(-3) | 580 |
| Gonads | I | 1,02 | 0,61 | 1,92(-2) | |
| | Ch | 0,81 | " | 1,66(-2) | |
| | T | 0.61 | " | 9.67(-3) | |
| | A | 0,61 | " | 8,42(-3) | |
| | P | | | 9.80(-3) | 592 |
| Liver | I | 1,02 | 0,61 | 1.89(-2) | |
| | Ch | 0,81 | " | 1.63(-2) | |
| | T | 0,61 | " | 9,46(-3) | |
| | A | 0,61 | " | 8,18(-3) | |
| | P | | | 9.57(-3) | 578 |
| Lung | I | 1,13 | 0,61 | 2,17(-2) | |
| | Ch | 0.85 | " | 1.76(-2) | |
| | T | 0,61 | " | 9,98(-3) | |
| | A | 0,61 | " | 8,51(-3) | |
| | P | | | 1,01(-2) | 609 |
| Skin | I | 1.26 | 0,98 | 4.05(-2) | |
| | Ch | 1,08 | " | 3.79(-2) | |
| | T | 0,98 | " | 3.10(-2) | |
| | A | 0,98 | " | 2.97(-2) | |
| | P | | | 3,11(-2) | 1882 |
| Thyroid | I | 10,8 | 2,24 | 9.02(-2) | |
| | Ch | 5,62 | 1,17 | 5,31(-2) | |
| | T | 2,14 | 0,77 | 2.38(-2) | |
| | A | 1,55 | 0,74 | 1,87(-2) | |
| | P | | | 2.49(-2) | 1498 |

1) CV = Contribution from Ingestion: dependent on strict Community Values
DV = Contribution from Ingestion: dependent on averaged District Values

2) The Extrapolated Dose Rates for around 2000/05 can be obtained by multiplying these Figures with a Factor of 2

3) I = Infant, Ch = Child, T = Teen, A = Adult
P = Average Person (in Case of Individual Dose Rate) or Total Population (in Case of Collective Dose Rate)

Tab. 6-3: Collective Dose Rates and Average Individual Dose Rates from Gaseous Releases around the Years 1985/90[1] with Regard to the Two Ingestion Dose Rate Models

| Organ | Agricultural Autarchy Model | | | Actual Agricultural Model | | |
|---|---|---|---|---|---|---|
| | Collective Dose Rate [man · rem/yr] | | Ave. Individual Dose Rate [mrem/yr] | Collective Dose Rate [man · rem/yr] | | Ave. Individual Dose Rate [mrem/yr] |
| | via Ingestion only | total (Table 6-2) | total (Table 6-2) | via Ingestion only (Table 6-1) | total | total |
| Whole Body | 350 | 592 | 9.80(-3) | 230 | 472 | 7.81(-3) |
| Bone | 647 | 872 | 1.44(-2) | 434 | 659 | 1.09(-2) |
| Skin | 350 | 1882 | 3.11(-2) | 230 | 1762 | 2.92(-2) |
| Thyroid | 1230 | 1498 | 2.49(-2) | 815 | 1083 | 1.79(-2) |

[1] The extrapolated Dose Rates for around 2000/05 can be obtained by multiplying these figures with a factor of 2.

Table 6-4.1: Contributions of the Various Radionuclides via the Various Pathways to the Whole Body-Dose Rate from Gaseous Releases

| Nuclide | External Cloud Exposure | External Ground Exposure[1] | Internal Exposure due to Inhalation | Internal Exposure due to Ingestion | Sum over Exposure Pathways |
|---|---|---|---|---|---|
| H-3 | 0 | 0 | 5.01 | 21.08 | 26.09 |
| C-14 | 0 | 0 | 0.43 | 27.39 | 27.82 |
| Ar-41 | 1.93 | 0 | 0 | 0 | 1.93 |
| Co-58[2] | 6.37(-5) | 5.07(-2) | 1.23(-5) | 7.03(-3) | 5.84(-2) |
| Co-60[2] | 1.62(-4) | 0.80 | 9.20(-5) | 2.09(-2) | 0.83 |
| Kr-85 | 2.26 | 0 | 0 | 0 | 2.26 |
| Kr-88 | 6.55 | 0 | 0 | 0 | 6.55 |
| I-129 | 1.73(-8) | 4.58(-3) | 7.43(-5) | 5.63(-3) | 1.03(-2) |
| I-131 | 1.19(-3) | 0.25 | 8.25(-3) | 0.28 | 0.54 |
| Xe-133 | 6.87 | 0 | 0 | 0 | 6.87 |
| Xe-135 | 6.12 | 0 | 0 | 0 | 6.12 |
| Cs-134[2] | 3.44 | 4.29 | 1.65(-2) | 1.69 | 5.99 |
| Cs-137[2] | 11.12(-5) | 13.99 | 8.65(-3) | 0.94 | 14.94 |
| Sum over Nuclides | 23.73 | 19.38 | 5.47 | 51.41 | 100 |

[1] State of equilibrium is assumed

[2] See comment on the release rates of Table 5-2.1

Table 6-4.2: Contributions of the Various Radionuclides via the Various Pathways to the Bone-Dose Rate from Gaseous Releases

| Nuclide | External Cloud Exposure | External Ground Exposure [1] | Internal Exposure due to Inhalation | Internal Exposure due to Ingestion | Sum over Exposure Pathways |
|---|---|---|---|---|---|
| H-3 | 0 | 0 | 0 | 0 | 0 |
| C-14 | 0 | 0 | 1.15 | 52.94 | 54.09 |
| Ar-41 | 1.88 | 0 | 0 | 0 | 1.88 |
| Co-58 [2] | 6.22(-5) | 4.95(-2) | 0 | 0 | 4.95(-2) |
| Co-60 [2] | 1.58(-4) | 0.77 | 0 | 0 | 0.77 |
| Kr-85 | 2.20 | 0 | 0 | 0 | 2.20 |
| Kr-88 | 6.38 | 0 | 0 | 0 | 6.38 |
| I-129 | 1.69(-8) | 4.48(-3) | 3.42(-5) | 3.50(-3) | 8.01(-3) |
| I-131 | 1.17(-3) | 0.25 | 1.06(-2) | 0.38 | 0.64 |
| Xe-133 | 6.71 | 0 | 0 | 0 | 6.71 |
| Xe-135 | 5.99 | 0 | 0 | 0 | 5.99 |
| Cs-134 [2] | 3.36(-4) | 4.20 | 1.05(-2) | 1.50 | 5.71 |
| Cs-137 [2] | 1.09(-4) | 13.67 | 1.23(-2) | 1.89 | 15.58 |
| Sum over Nuclides | 23.16 | 18.94 | 1.18 | 56.71 | 100 |

[1] State of equilibrium is assumed

[2] See comment on the release rates of Table 5-2.1

Table 6-4.3: Contributions of the Various Radionuclides via the Various Pathways to the Skin-Dose Rate from Gaseous Releases

| Nuclide | External Cloud Exposure | External Ground Exposure[1)] | Internal Exposure due to Inhalation | Internal Exposure due to Ingestion | Sum over Exposure Pathways |
|---|---|---|---|---|---|
| H-3 | 7.03(-2) | 0 | 1.45 | 6.09 | 7.61 |
| C-14 | 1.42(-2) | 0 | 0.14 | 9.00 | 9.15 |
| Ar-41 | 0.63 | 0 | 0 | 0 | 0.63 |
| Co-58[2)] | 2.13(-5) | 1.47(-2) | 3.75(-6) | 2.03(-3) | 1.67(-2) |
| Co-60[2)] | 4.89(-5) | 0.23 | 2.66(-5) | 6.04(-3) | 0.24 |
| Kr-85 | 61.39 | 0 | 0 | 0 | 61.39 |
| Kr-88 | 2.28 | 0 | 0 | 0 | 2.28 |
| I-129 | 1.91(-7) | 1.32(-3) | 2.15(-5) | 1.62(-3) | 2.97(-3) |
| I-131 | 5.25(-4) | 7.13(-2) | 2.38(-3) | 7.98(-2) | 0.16 |
| Xe-133 | 8.55 | 0 | 0 | 0 | 8.55 |
| Xe-135 | 3.93 | 0 | 0 | 0 | 3.93 |
| Cs-134[2)] | 1.14(-4) | 1.24 | 4.77(-3) | 0.49 | 1.73 |
| Cs-137[2)] | 4.27(-5) | 4.04 | 2.50(-3) | 0.27 | 4.31 |
| Sum over Nuclides | 76.86 | 5.60 | 1.60 | 15.94 | 100 |

1) State of equilibrium is assumed

2) See comment on the release rates of Table 5-2.1

Table 6-4.4: Contributions of the Various Radionuclides via the Various Pathways to the Thyroid-Dose Rate from Gaseous Releases

| Nuclide | External Cloud Exposure | External Ground Exposure[1)] | Internal Exposure due to Inhalation | Internal Exposure due to Ingestion | Sum over Exposure Pathways |
|---|---|---|---|---|---|
| H-3 | 0 | 0 | 1.86 | 7.81 | 9.67 |
| C-14 | 0 | 0 | 0.17 | 11.40 | 11.57 |
| Ar-41 | 0.71 | 0 | 0 | 0 | 0.71 |
| Co-58[2)] | 2.36(-5) | 1.88(-2) | 0 | 0 | 1.88(-2) |
| Co-60[2)] | 6.01(-5) | 0.29 | 0 | 0 | 0.29 |
| Kr-85 | 0.84 | 0 | 0 | 0 | 0.84 |
| Kr-88 | 2.42 | 0 | 0 | 0 | 2.42 |
| I-129 | 6.41(-9) | 1.70(-3) | 2.19(-2) | 1.62 | 1.64 |
| I-131 | 4.44(-4) | 9.16(-2) | 1.79 | 59.36 | 61.24 |
| Xe-133 | 2.55 | 0 | 0 | 0 | 2.55 |
| Xe-135 | 2.27 | 0 | 0 | 0 | 2.27 |
| Cs-134 [2)] | 1.27(-4) | 1.59 | 0 | 0 | 1.59 |
| Cs-137 [2)] | 4.13(-5) | 5.19 | 0 | 0 | 5.19 |
| Sum over Nuclides | 8.79 | 7.18 | 3.84 | 80.19 | 100 |

1) State of equilibrium is assumed

2) See comment on the release rates of Table 5-2.1

Table 6-5: Average Individual Dose Rates and Dose Yields from Liquid Releases via the Drinking Water Pathway within the Supply Districts around the Years 1985/90 for the Organs: Whole Body, Bone, and Thyroid

| NO. | WATER WORKS | WATER PROCESSING (SEE TAB. 3-1) | AVERAGE INDIVIDUAL DOSE RATE WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | DOSE YIELD WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
|---|---|---|---|---|---|---|---|---|
| 1 | KONSTANZ | DIRECT TREATMENT | 5.41E-03 | 9.65E-03 | 3.21E-03 | 3.57E-01 | 6.37E-01 | 2.12E-01 |
| 2 | KREUZLINGEN | DIRECT TREATMENT | 4.98E-03 | 8.88E-03 | 2.97E-03 | 1.34E-01 | 2.40E-01 | 8.01E-02 |
| 3 | STUTTGART | DIRECT TREATMENT | 3.38E-03 | 6.01E-03 | 1.96E-03 | 2.07E+00 | 3.68E+00 | 1.20E+00 |
| 4 | ESSLINGEN | DIRECT TREATMENT | 1.25E-03 | 2.22E-03 | 7.24E-04 | 1.21E-01 | 2.16E-01 | 7.06E-02 |
| 5 | HEILBRONN | DIRECT TREATMENT | 1.94E-03 | 3.45E-03 | 1.13E-03 | 2.45E-01 | 4.35E-01 | 1.42E-01 |
| 6 | KIRCHHEIM TECK | DIRECT TREATMENT | 2.24E-03 | 3.99E-03 | 1.30E-03 | 2.85E-01 | 5.08E-01 | 1.66E-01 |
| 7 | PFORZHEIM | DIRECT TREATMENT | 1.04E-03 | 1.84E-03 | 6.03E-04 | 1.03E-01 | 1.84E-01 | 6.00E-02 |
| 8 | CRAILSHEIM | DIRECT TREATMENT | 7.25E-04 | 1.29E-03 | 4.21E-04 | 8.30E-02 | 1.48E-01 | 4.82E-02 |
| 9 | LUDWIGSBURG | DIRECT TREATMENT | 2.44E-03 | 4.35E-03 | 1.42E-03 | 2.00E-01 | 3.55E-01 | 1.16E-01 |
| 10 | KEMNAT | DIRECT TREATMENT | 3.35E-03 | 5.97E-03 | 1.95E-03 | 3.35E-01 | 5.97E-01 | 1.95E-01 |
| 11 | REUTLINGEN | DIRECT TREATMENT | 2.67E-03 | 4.76E-03 | 1.55E-03 | 2.50E-01 | 4.45E-01 | 1.45E-01 |
| 12 | VILLINGEN-SCHW. | DIRECT TREATMENT | 3.94E-03 | 7.01E-03 | 2.29E-03 | 3.13E-01 | 5.56E-01 | 1.82E-01 |
| 13 | SINDELFINGEN | DIRECT TREATMENT | 5.16E-03 | 9.18E-03 | 3.00E-03 | 2.83E-01 | 5.04E-01 | 1.65E-01 |
| 14 | TUEBINGEN | DIRECT TREATMENT | 2.94E-03 | 5.23E-03 | 1.71E-03 | 2.17E-01 | 3.87E-01 | 1.26E-01 |
| 15 | BOEBLINGEN | DIRECT TREATMENT | 1.31E-03 | 2.33E-03 | 7.61E-04 | 9.56E-02 | 1.70E-01 | 5.55E-02 |
| 16 | SINSHEIM | DIRECT TREATMENT | 5.29E-04 | 1.65E-03 | 5.40E-04 | 6.04E-01 | 1.07E+00 | 3.51E-01 |
| 17 | BOEBLINGEN | DIRECT TREATMENT | 2.82E-03 | 5.01E-03 | 1.64E-03 | 1.17E-01 | 2.08E-01 | 6.81E-02 |
| 18 | EBINGEN | DIRECT TREATMENT | 1.18E-03 | 2.11E-03 | 6.88E-04 | 3.23E-02 | 5.75E-02 | 1.88E-02 |
| 19 | HECHINGEN | DIRECT TREATMENT | 4.42E-04 | 7.86E-04 | 2.57E-04 | 1.96E-02 | 3.49E-02 | 1.14E-02 |
| 20 | FELLBACH | DIRECT TREATMENT | 1.90E-03 | 3.38E-03 | 1.10E-03 | 8.14E-02 | 1.45E-01 | 4.73E-02 |
| 21 | TUTTLINGEN | DIRECT TREATMENT | 1.34E-03 | 2.38E-03 | 7.77E-04 | 4.39E-02 | 7.80E-02 | 2.55E-02 |
| 22 | KORNWESTHEIM | DIRECT TREATMENT | 2.96E-03 | 5.27E-03 | 1.72E-03 | 8.39E-02 | 1.49E-01 | 4.87E-02 |
| 23 | KORNTAL | DIRECT TREATMENT | 1.65E-03 | 2.94E-03 | 9.62E-04 | 5.25E-02 | 9.33E-02 | 3.05E-02 |
| 24 | NUERTINGEN | DIRECT TREATMENT | 3.39E-03 | 6.03E-03 | 1.97E-03 | 8.30E-02 | 1.48E-01 | 4.82E-02 |
| 25 | TAILFINGEN | DIRECT TREATMENT | 3.65E-03 | 6.49E-03 | 2.12E-03 | 6.20E-02 | 1.10E-01 | 3.61E-02 |
| 26 | NECKARSULM | DIRECT TREATMENT | 2.56E-03 | 4.55E-03 | 1.49E-03 | 5.65E-02 | 1.00E-01 | 3.28E-02 |
| 27 | LEONBERG | DIRECT TREATMENT | 4.61E-03 | 8.20E-03 | 2.68E-03 | 1.17E-01 | 2.07E-01 | 6.77E-02 |
| 28 | BIETIGHEIM | DIRECT TREATMENT | 2.85E-03 | 5.07E-03 | 1.66E-03 | 6.61E-02 | 1.18E-01 | 3.84E-02 |
| 29 | ROTTWEIL | DIRECT TREATMENT | 4.60E-03 | 8.18E-03 | 2.67E-03 | 1.13E-01 | 2.01E-01 | 6.57E-02 |
| 30 | UEBERLINGEN | DIRECT TREATMENT | 4.21E-03 | 7.50E-03 | 2.48E-03 | 5.98E-02 | 1.07E-01 | 3.52E-02 |
| 31 | GERLINGEN | DIRECT TREATMENT | 5.67E-03 | 1.01E-02 | 3.29E-03 | 1.03E-01 | 1.82E-01 | 5.96E-02 |
| 32 | TROSSINGEN | DIRECT TREATMENT | 5.67E-03 | 1.01E-02 | 3.29E-03 | 6.46E-02 | 1.15E-01 | 3.75E-02 |
| 33 | ST. GEORGEN | DIRECT TREATMENT | 3.06E-03 | 5.44E-03 | 1.78E-03 | 3.67E-02 | 6.53E-02 | 2.13E-02 |
| 34 | MAGSTADT | DIRECT TREATMENT | 5.57E-03 | 9.90E-03 | 3.23E-03 | 4.45E-02 | 7.92E-02 | 2.59E-02 |
| 35 | LAUFFEN | DIRECT TREATMENT | 5.47E-03 | 9.73E-03 | 3.18E-03 | 4.98E-02 | 8.85E-02 | 2.89E-02 |
| 36 | MEERSBURG | DIRECT TREATMENT | 5.52E-03 | 9.89E-03 | 3.44E-03 | 2.76E-02 | 4.95E-02 | 1.72E-02 |
| 37 | FRIEDRICHSHAFEN | DIRECT TREATMENT | 4.86E-03 | 8.91E-03 | 7.00E-03 | 2.45E-01 | 4.49E-01 | 3.53E-01 |
| 38 | ST. GALLEN | DIRECT TREATMENT | 5.71E-03 | 1.05E-02 | 6.84E-03 | 4.57E-01 | 8.36E-01 | 5.47E-01 |
| 39 | ARBON | DIRECT TREATMENT | 6.56E-03 | 1.20E-02 | 7.85E-03 | 1.31E-01 | 2.40E-01 | 1.57E-01 |
| 40 | ROHRSCHACH | DIRECT TREATMENT | 6.55E-03 | 1.19E-02 | 6.40E-03 | 1.24E-01 | 2.27E-01 | 1.22E-01 |
| 41 | AMRISWIL | DIRECT TREATMENT | 5.85E-03 | 1.07E-02 | 8.98E-03 | 5.85E-02 | 1.07E-01 | 8.98E-02 |
| 42 | THAL | DIRECT TREATMENT | 6.55E-03 | 1.19E-02 | 6.40E-03 | 3.28E-02 | 5.97E-02 | 3.20E-02 |
| 43 | ROMANSHORN | DIRECT TREATMENT | 6.57E-03 | 1.21E-02 | 1.01E-02 | 7.23E-02 | 1.33E-01 | 1.11E-01 |
| 44 | LINDAU | DIRECT TREATMENT | 6.11E-03 | 1.14E-02 | 2.13E-02 | 1.50E-01 | 2.78E-01 | 5.23E-01 |
| 45 | MANNHEIM | BANK FILTRATION | 8.04E-03 | 9.77E-03 | 6.32E-03 | 2.69E+00 | 3.27E+00 | 2.11E+00 |
| 46 | FRANKFURT | GROUND WATER ENR. | 7.14E-03 | 1.07E-02 | 4.82E-03 | 4.71E+00 | 7.08E+00 | 3.18E+00 |
| 47 | BAD HOMBURG | GROUND WATER ENR. | 2.02E-03 | 3.03E-03 | 1.36E-03 | 1.07E-01 | 1.60E-01 | 7.19E-02 |
| 48 | SCHWALBACH TS | GROUND WATER ENR. | 5.96E-03 | 8.95E-03 | 4.02E-03 | 8.99E-02 | 1.35E-01 | 6.07E-02 |
| 49 | FRANKFURT | GROUND WATER ENR. | 4.73E-03 | 7.10E-03 | 3.19E-03 | 9.45E-01 | 1.42E+00 | 6.38E-01 |
| 50 | WUERZBURG | DIRECT TREATMENT | 2.74E-02 | 4.02E-02 | 8.23E-02 | 3.21E+00 | 4.70E+00 | 9.62E+00 |

Table 6-5: (cont.)

| NO. | WATER WORKS | WATER PROCESSING | AVERAGE INDIVIDUAL DOSE RATE | | | DOSE YIELD | | |
|---|---|---|---|---|---|---|---|---|
| | | (SEE TAB. 3-1) | WH. BODY MREM/YR | BONE MREM/YR | THYROID MREM/YR | WH. BODY REM/YR | BONE REM/YR | THYROID REM/YR |
| 51 | MOSELGEMEINDEN | BANK FILTRATION | 9.40E-03 | 1.41E-02 | 7.03E-03 | 8.93E-01 | 1.34E+00 | 6.68E-01 |
| 52 | TRIER | BANK FILTRATION | 1.33E-04 | 2.00E-04 | 1.02E-04 | 1.45E-02 | 2.18E-02 | 1.11E-02 |
| 53 | BASEL | GROUND WATER ENR. | 1.60E-02 | 3.06E-02 | 8.20E-03 | 4.31E+00 | 8.27E+00 | 2.22E+00 |
| 54 | SPEYER | BANK FILTRATION | 6.66E-03 | 9.24E-03 | 5.24E-03 | 2.93E-01 | 4.06E-01 | 2.31E-01 |
| 55 | SCHIFFERSTADT | BANK FILTRATION | 5.30E-03 | 7.35E-03 | 4.16E-03 | 3.03E-01 | 4.20E-01 | 2.38E-01 |
| 56 | LUDWIGSHAFEN | BANK FILTRATION | 8.63E-03 | 1.20E-02 | 6.78E-03 | 1.55E+00 | 2.14E+00 | 1.21E+00 |
| 57 | MAINZ | BANK FILTRATION | 5.55E-02 | 7.47E-02 | 4.33E-02 | 3.33E+00 | 4.48E+00 | 2.60E+00 |
| 58 | WIESBADEN | GROUND WATER ENR. | 2.47E-02 | 3.26E-02 | 1.66E-02 | 3.71E+00 | 4.89E+00 | 2.49E+00 |
| 59 | BOPPARD U. A. | BANK FILTRATION | 3.22E-02 | 4.34E-02 | 2.50E-02 | 1.45E+00 | 1.95E+00 | 1.12E+00 |
| 60 | KOBLENZ | BANK FILTRATION | 4.23E-02 | 5.70E-02 | 3.28E-02 | 5.84E+00 | 7.86E+00 | 4.52E+00 |
| 61 | BENDORF | BANK FILTRATION | 2.86E-02 | 3.88E-02 | 2.21E-02 | 4.41E-01 | 5.97E-01 | 3.40E-01 |
| 62 | WEISSENTHURM | BANK FILTRATION | 3.96E-02 | 5.36E-02 | 3.05E-02 | 8.62E-01 | 1.17E+00 | 6.65E-01 |
| 63 | NEUWIED | BANK FILTRATION | 2.37E-02 | 3.21E-02 | 1.83E-02 | 1.49E+00 | 2.02E+00 | 1.15E+00 |
| 64 | ANDERNACH | BANK FILTRATION | 2.92E-02 | 3.95E-02 | 2.25E-02 | 8.53E-01 | 1.15E+00 | 6.58E-01 |
| 65 | BAD HOENNINGEN | BANK FILTRATION | 2.35E-02 | 3.17E-02 | 1.81E-02 | 2.88E-01 | 3.90E-01 | 2.22E-01 |
| 66 | REMAGEN U. A. | BANK FILTRATION | 2.38E-02 | 3.23E-02 | 1.83E-02 | 1.02E+00 | 1.39E+00 | 7.88E-01 |
| 67 | BONN | BANK FILTRATION | 2.33E-02 | 3.17E-02 | 1.79E-02 | 1.51E+00 | 2.05E+00 | 1.16E+00 |
| 68 | KOELN | GROUND WATER ENR. | 8.04E-03 | 1.07E-02 | 5.38E-03 | 4.61E+00 | 6.15E+00 | 3.09E+00 |
| 69 | NEUSS | BANK FILTRATION | 4.48E-03 | 6.09E-03 | 3.40E-03 | 5.32E-01 | 7.24E-01 | 4.05E-01 |
| 70 | WUPPERTAL | BANK FILTRATION | 1.11E-02 | 1.51E-02 | 8.44E-03 | 4.54E+00 | 6.18E+00 | 3.45E+00 |
| 71 | DUESSELDORF | BANK FILTRATION | 2.67E-02 | 3.63E-02 | 2.02E-02 | 1.81E+01 | 2.46E+01 | 1.37E+01 |
| 72 | DUISBURG | BANK FILTRATION | 8.58E-03 | 1.17E-02 | 6.49E-03 | 2.85E+00 | 3.87E+00 | 2.16E+00 |
| 73 | KREFELD | GROUND WATER ENR. | 9.57E-03 | 1.28E-02 | 6.41E-03 | 2.15E+00 | 2.87E+00 | 1.44E+00 |
| 74 | DUISBURG-HAMBORN | BANK FILTRATION | 1.24E-02 | 1.69E-02 | 9.39E-03 | 1.31E+00 | 1.77E+00 | 9.86E-01 |
| 75 | DORDRECHT | DIRECT TREATMENT | 3.86E-02 | 5.22E-02 | 8.20E-02 | 4.07E+00 | 5.50E+00 | 8.63E+00 |
| 76 | BERGAMBACHT | BANK FILTRATION | 4.54E-02 | 6.15E-02 | 3.39E-02 | 4.78E+00 | 6.47E+00 | 3.57E+00 |
| 77 | JUTPHAAS | GROUND WATER ENR. | 4.51E-02 | 5.99E-02 | 3.03E-02 | 7.13E+01 | 9.46E+01 | 4.78E+01 |
| 78 | AMSTERDAM | DIRECT TREATMENT | 4.58E-02 | 6.36E-02 | 8.67E-02 | 1.45E+01 | 2.01E+01 | 2.74E+01 |
| 79 | ANDIJK | DIRECT TREATMENT | 4.38E-02 | 5.72E-02 | 2.92E-02 | 9.21E+00 | 1.20E+01 | 6.14E+00 |
| 80 | BERGAMBACHT | GROUND WATER ENR. | 2.14E-02 | 1.79E-02 | 1.60E-02 | 1.46E+01 | 1.22E+01 | 1.09E+01 |
| 81 | ROTTERDAM | DIRECT TREATMENT | 2.23E-02 | 1.94E-02 | 2.81E-02 | 1.39E+01 | 1.21E+01 | 1.75E+01 |
| 82 | ANTWERPEN | DIRECT TREATMENT | 3.21E-02 | 2.68E-02 | 2.38E-02 | 2.12E+01 | 1.77E+01 | 1.57E+01 |
| | SUM | | | | | 2.36E+02 | 2.99E+02 | 2.05E+02 |

Table 6-6: Maximum and Average Individual Dose Rates and Collective Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90

| Organ | Age Group | Maximum Individual Dose Rate [mrem/yr] | Average Individual Dose Rate [mrem/yr] SP [1] | TP [1] | Collective Dose Rate [man·rem/yr] [2] |
|---|---|---|---|---|---|
| Whole Body | I [3] | 5,75(-2) | 1,89(-2) | | |
| | Ch | 7,24(-2) | 2,33(-2) | | |
| | T | 5,25(-2) | 1,71(-2) | | |
| | A | 5,50(-2) | 1.81(-2) | | |
| | P | | 1,86(-2) | 3,89(-3) | 235 |
| Bone | I | 1,00(-1) | 3,02(-2) | | |
| | Ch | 1,20(-1) | 3.62(-2) | | |
| | T | 9,12(-2) | 2,79(-2) | | |
| | A | 6,61(-2) | 2,04(-2) | | |
| | P | | 2,36(-2) | 4,94(-3) | 299 |
| GI-Tract | I | 3.63(-2) | 1.22(-2) | | |
| | Ch | 4,37(-2) | 1.47(-2) | | |
| | T | 3,02(-2) | 1,02(-2) | | |
| | A | 3.80(-2) | 1,28(-2) | | |
| | P | | 1.27(-2) | 2,66(-3) | 161 |
| Gonads | I | 5,75(-2) | 1,89(-2) | | |
| | Ch | 7,24(-2) | 2,33(-2) | | |
| | T | 5,25(-2) | 1,71(-2) | | |
| | A | 5,50(-2) | 1,81(-2) | | |
| | P | | 1,86(-2) | 3,89(-3) | 235 |
| Liver | I | 3,80(-2) | 1,26(-2) | | |
| | Ch | 4,79(-2) | 1,57(-2) | | |
| | T | 3,47(-2) | 1,17(-2) | | |
| | A | 4,17(-2) | 1,42(-2) | | |
| | P | | 1,40(-2) | 2,93(-3) | 177 |
| Lung | I | 3,98(-2) | 1,40(-2) | | |
| | Ch | 4.57(-2) | 1,61(-2) | | |
| | T | 3,16(-2) | 1,11(-2) | | |
| | A | 3,98(-2) | 1,36(-2) | | |
| | P | | 1,35(-2) | 2,82(-3) | 171 |
| Skin | I | 5,75(-2) | 1,89(-2) | | |
| | Ch | 7,24(-2) | 2.33(-2) | | |
| | T | 5,25(-2) | 1,71(-2) | | |
| | A | 5,50(-2) | 1,81(-2) | | |
| | P | | 1,86(-2) | 3,89(-3) | 235 |
| Thyroid | I | 1,74(-1) | 2,06(-2) | | |
| | Ch | 1,38(-1) | 2,10(-2) | | |
| | T | 8,32(-2) | 1,38(-2) | | |
| | A | 7,94(-2) | 1,57(-2) | | |
| | P | | 1,62(-2) | 3,39(-3) | 205 |

1) SP = Average Dose Rate related to the Population supplied with Surface Water (12.6 Mio)
TP = Average Dose Rate related to the total Population (60.4 Mio)

2) The Extrapolated Dose Rates for around 2000/05 can be obtained by multiplying these Figures with a Factor of 2 to 4 (see section 6.2.2)

3) See the Corresponding Footnote of Table 6-2

Table 6-7: Collective Dose Rates and Average Individual Dose Rates from Liquid Releases around the Years 1985/90

| Organ | Collective Dose Rates via the various Pathways[1) ] [man • rem/yr] | | | | | Average Individual Dose Rate[2)] [mrem/yr] |
|---|---|---|---|---|---|---|
| | External Exposure | Drinking Water | Fish Consumption | Consumption of Irrig. Vegetables | total | |
| Whole Body | 6 | 235 | 73 | 61 | 375 | 6.21(-3) |
| Bone | 6 | 299 | 103 | 201 | 609 | 1.01(-2) |
| Skin[3)] | 6 | 235 | 73 | 61 | 375 | 6.21(-3) |
| Thyroid | 6 | 205 | 7 | 65 | 283 | 4.69(-3) |

1) The extrapolated Dose Rates for around 2000/05 can be obtained by multiplying these figures with a factor of 2. (External Exposure, Fish Consumption) resp. 4 (Drinking Water, Consumption of Irrigated Vegetables)

2) The Average Dose Rates are related to the Total Population (60.4 Mio)

3) The Figures of the Whole Body are filled in this line

Table 6-8.1: Contributions of the various Radionuclides via the various Pathways to the Whole Body-Dose Rate from Liquid Releases

| Nuclide | External Exposure due to Water Surface and Sediment Irradiation | Internal Exposure due to Ingestion of | | |
|---|---|---|---|---|
| | | Drinking Water | Fish | Irrigated Products |
| H-3 | 0 | 45.70 | 0.18 | 33.44 |
| Co-58 | 10.25 | 0.23 | 4.69(-2) | 0.47 |
| Co-60 | 48.46 | 0.63 | 0.13 | 1.29 |
| Sr-89 | 8.20(-5) | 0.47 | 5.54(-2) | 0.36 |
| Sr-90 | 4.56(-6) | 42.26 | 5.31 | 50.16 |
| Ru-106 | 2.24(-3) | 1.89(-4) | 7.42(-6) | 8.55(-3) |
| J-131 | 2.56(-2) | 0.32 | 1.94(-2) | 0.11 |
| Cs-134 | 23.11 | 5.00 | 45.16 | 5.28 |
| Cs-137 | 18.03 | 5.44 | 49.27 | 8.83 |
| Ce-144 | 0.11 | 7.46(-4) | 2.92(-6) | 6.36(-4) |
| Sum over Nuclides | 100 | 100 | 100 | 100 |

Table 6-8.2: Contributions of the various Radionuclides via the various Pathways to the Bone-Dose Rate from Liquid Releases

| Nuclide | External Exposure due to Water Surface and Sediment Irradiation | Internal Exposure due to Ingestion of | | |
|---|---|---|---|---|
| | | Drinking Water | Fish | Irrigated Products |
| H-3 | 0 | 0 | 0 | 0 |
| Co-58 | 10.25 | 0 | 0 | 0 |
| Co-60 | 48.46 | 0 | 0 | 0 |
| Sr-89 | 8.20(-5) | 8.22 | 1.53 | 5.34 |
| Sr-90 | 4.56(-6) | 85.15 | 17.07 | 85.53 |
| Ru-106 | 2.24(-3) | 7.48(-4) | 4.66(-5) | 2.88(-2) |
| I-131 | 2.56(-2) | 0.21 | 2.00(-2) | 6.55(-2) |
| Cs-134 | 23.11 | 1.86 | 23.57 | 1.88 |
| Cs-137 | 18.03 | 4.58 | 57.52 | 7.11 |
| Ce-144 | 0.11 | 6.88(-3) | 4.32(-5) | 5.02(-3) |
| Sum over Nuclides | 100 | 100 | 100 | 100 |

Table 6-8.3: Contributions of the various Radionuclides via the various Pathways to the Thyroid-Dose Rate from Liquid Releases

| Nuclide | External Exposure due to Water Surface and Sediment Irradiation | Internal Exposure due to Ingestion of | | |
|---|---|---|---|---|
| | | Drinking Water | Fish | Irrigated Products |
| H-3 | 0 | 20.16 | 1.60 | 34.02 |
| Co-58 | 10.25 | 0 | 0 | 0 |
| Co-60 | 48.46 | 0 | 0 | 0 |
| Sr-89 | 8.20(-5) | 0 | 0 | 0 |
| Sr-90 | 4.56(-6) | 0 | 0 | 0 |
| Ru-106 | 2.24(-3) | 0 | 0 | 0 |
| J-131 | 2.56(-2) | 79.84 | 98.40 | 65.98 |
| Cs-134 | 23.11 | 0 | 0 | 0 |
| Cs-137 | 18.03 | 0 | 0 | 0 |
| Ce-144 | 0.11 | 0 | 0 | 0 |
| Sum over Nuclides | 100 | 100 | 100 | 100 |

Table 6-9: Dose Rates around the Years 1985/90 (White Fields) and around the Years 2000/05 (Grey Fields)[1)]

a) Maximum Individual Dose Rates

| Organ | Gaseous Releases [mrem/yr] (Tab.6-2) | | Liquid Releases [mrem/yr]: External Exposure (Section 6.2.1, Part aa)) | | Drinking Water (Tab.6-6) | | Fish Consumption (Section 6.2.1, Part ac) | | Irrig. Product Consumption (Section 6.2.1, Part ac) | | Mathematical Sum | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole Body | 1.02÷0.61 | unessential change expected | 0.24 | approx. doubling expected | 0.07÷0.05 | approx. doubling expected | 0.85 | approx. doubling expected | 0.06 | approx. doubling expected | 1.22÷1.20 | approx. doubling expected |
| Bone | 1.08÷0.61 | | " | | 0.12÷0.07 | | 1.11 | | 0.15 | | 1.62÷1.57 | |
| Skin | 1.26÷0.98 | | " | | 0.07÷0.05 | | 0.85 | | 0.06 | | 1.22÷1.20 | |
| Thyroid | 10.8÷1.55 | | " | | 0.17÷0.08 | | 0.10 | | 0.06 | | 0.57÷0.48 | |

b) Average Individual Dose Rates Related to the total Population of the Region

| Organ | Gaseous Releases [mrem/yr] (Tab.6-3) | x 2 | Liquid Releases [mrem/yr]: External Exposure (d.f.Tab.6-7) | x 2 | Drinking Water (Tab.6-6) | x 4 | Fish Consumption (d.f.Tab.6-7) | x 2 | Irrig. Product Consumption (d.f.Tab.6-7) | x 4 | Sum (Tab.6-7) | | Total [mrem/yr] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole Body | 7.81(-3) | 1.56(-2) | 9.9(-5) | 1.98(-4) | 3.89(-3) | 1.56(-2) | 1.21(-3) | 2.42(-3) | 1.01(-3) | 4.04(-3) | 6.21(-3) | 2.22(-2) | 1.40(-2) | 3.79(-2) |
| Bone | 1.09(-2) | 2.18(-2) | " | " | 4.94(-3) | 1.98(-2) | 1.71(-3) | 3.42(-3) | 3.33(-3) | 1.33(-2) | 1.01(-2) | 3.47(-2) | 2.10(-2) | 5.85(-2) |
| Skin | 2.92(-2) | 5.84(-2) | " | " | 3.89(-3) | 1.56(-2) | 1.21(-3) | 2.42(-3) | 1.01(-3) | 4.04(-3) | 6.21(-3) | 2.22(-2) | 3.54(-2) | 8.06(-2) |
| Thyroid | 1.79(-2) | 3.58(-2) | " | " | 3.39(-3) | 1.36(-2) | 1.16(-3) | 2.32(-3) | 1.08(-3) | 4.32(-3) | 4.69(-3) | 1.83(-2) | 2.26(-2) | 5.42(-2) |

d.f. = derived from

c) Collective Dose Rates

| Organ | Gaseous Releases [man·rem/yr] (Tab.6-3) | x 2 | Liquid Releases [man·rem/yr]: External Exposure (Tab.6-7) | x 2 | Drinking Water (Tab.6-7) | x 4 | Fish Consumption (Tab.6-7) | x 2 | Irrig. Product Consumption (Tab.6-7) | x 4 | Sum (Tab.6-7) | | Total [man·rem/yr] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole Body | 472 | 944 | 6 | 12 | 235 | 940 | 73 | 146 | 61 | 244 | 375 | 1342 | 847 | 2286 |
| Bone | 659 | 1318 | " | " | 299 | 1196 | 103 | 206 | 201 | 804 | 609 | 2218 | 1268 | 3536 |
| Skin | 1762 | 3524 | " | " | 235 | 940 | 73 | 146 | 61 | 244 | 375 | 1342 | 2137 | 4866 |
| Thyroid | 1083 | 2166 | " | " | 205 | 820 | 7 | 14 | 65 | 260 | 283 | 1106 | 1366 | 3272 |

1) The Factor given above several of the Grey Fields is the Factor by which the Figures in the respective preceeding White Field were multiplied to obtain the Figures in the Grey Field.
"a÷b" stands for "a to b"

Table 8-1: Evaluated Release Rates for the Total Nuclear Fuel Cycle

| Nuclide | Release Rate [Ci/(yr·1000MWt)] 1) UK-NRPB [83] gaseous | liquid | total 2) | Source Strengths Determined in this Study total 2) |
|---|---|---|---|---|
| H-3 | 1800 | 5200 | 7000 | 5700 |
| C-14 | 4 | -- | 4 | 8 |
| Kr-85 | 110000 | -- | 110000 | 150000 |

1) Corresponding to approx. [Ci/(yr·333 MWe)]. Mean Discharge based on the Distribution among the Reactor Types in the Year 2000 [83]

2) Assuming DF = 1

Table 8-2: Expected Dose Rates in the Rhein-Maas Region Resulting from the Global Release of H-3, C-14 and Kr-85 1)

| Year | Gonad Dose Rate [mrem/yr] UK-NRPB [83] | Gonad Dose Rate [mrem/yr] According to the Source Strengths in this Study 2) | Skin Dose Rate [mrem/yr] UK-NRPB [83] | Skin Dose Rate [mrem/yr] According to the Source Strengths in this Study 2) |
|---|---|---|---|---|
| 1985 +(3to5 yrs) | 5.5(-3) | 9.6(-3) | 4.0(-1) | 5.4(-1) |
| 2000 +(7to12yrs) | 3.6(-2) | 6.3(-2) | 2.5 | 3.4 |

1) The Dose Rates due to the 'first pass' of the Releases of the Nuclear Facilities in the Rhein-Maas Region and the Surrounding Region (see Fig. 4-4) have been excluded

2) See Table 8-1

Table 9-1: Natural External Exposure via Cosmic Irradiation [146]

| Height above Sea-Level [m] | Whole Body-Dose Rate [mrem/yr] |
|---|---|
| 0 | 30 |
| 400 | 36 |
| 800 | 45 |
| 1200 | 54 |
| 1600 | 67 |
| 2000 | 80 |
| 2400 | 95 |

Table 9-2: Natural Internal Exposure-Contributions of the Various Radionuclides [152]

| Nuclide | Gonad-Dose Rate 1) [mrad/yr] |
|---|---|
| H-3 | 0.001 |
| C-14 | 0.7 |
| K-40 | 19 |
| Rb-87 | 0.3 |
| Po-210 | 0.6 |
| Rn + Decay Products | ≈ 0.1 |
| Sum | ≈ 21 |

1) Approx. Whole Body-Dose Rate

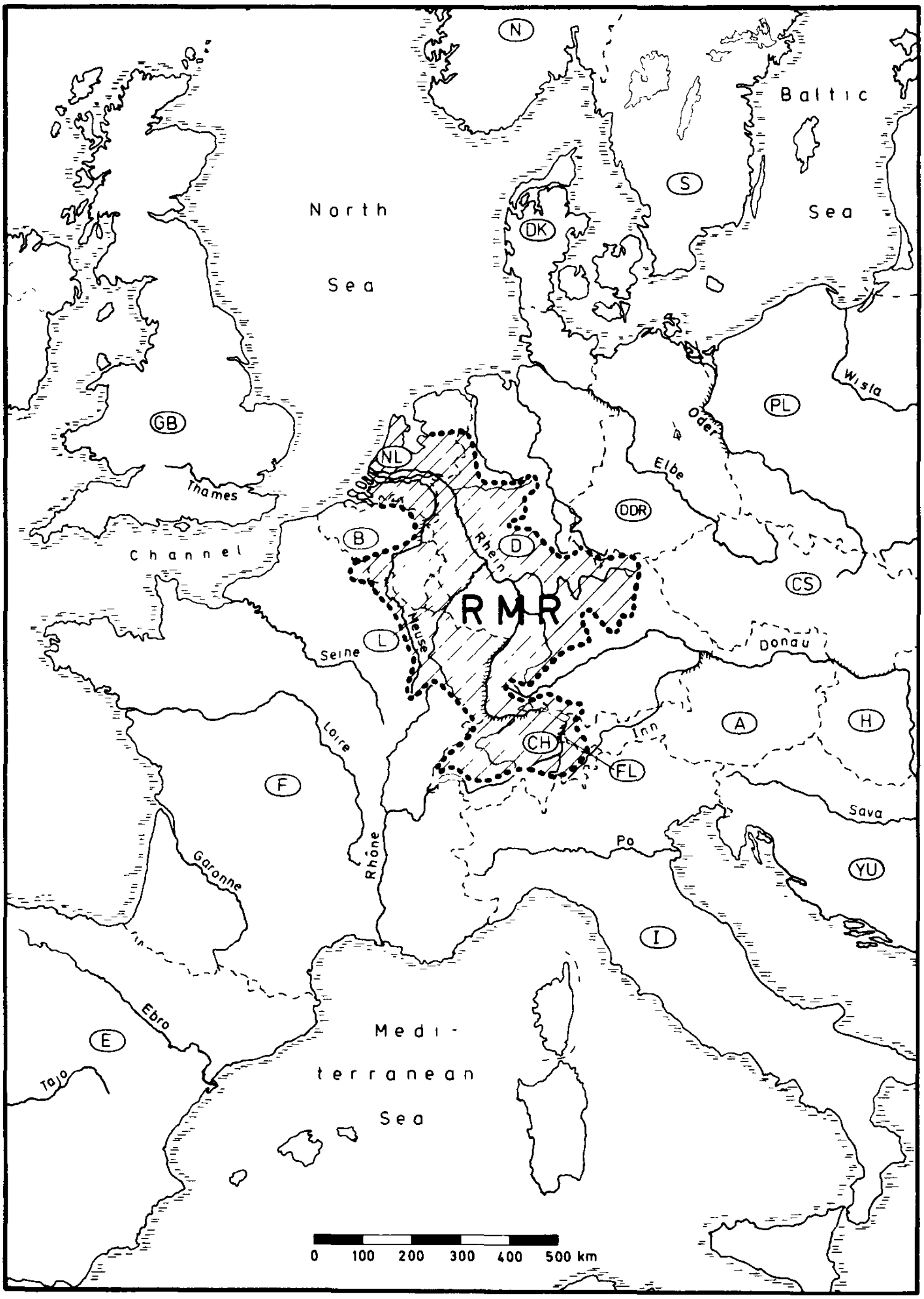



Fig. 1-1: The Position of the Rhein-Maas Region (RMR) within Western Europe

| | Site Studies | Regional Studies | Global Studies |
|---|---|---|---|
| Sites | Individual Site | All Sites in a Given Region | All Sites |
| Radioisotopes | of Local and Regional Importance | | of Global Importance |
| Transport | Locality-Dependent Dispersion of Activity after Release ("first pass") | | Homogeneous Mixture of Activity in the Transport Medium (global or within a geographical zone) |
| Exposure Pathways Population | Fine Structure around Site | Structure Simplified within Region | Structure Globally Simplified (homogenised) |

Fig. 2-1: Characteristics of Radiological Studies

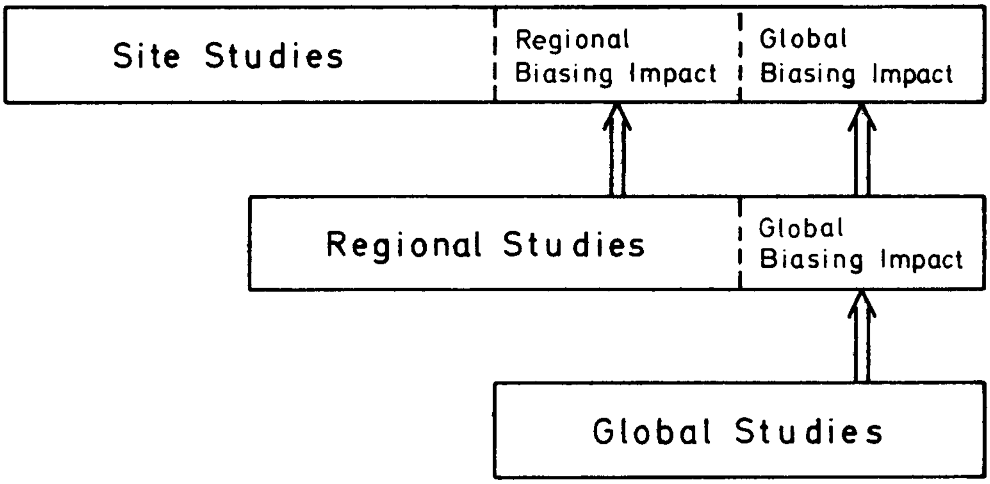



Fig. 2-2: The Linking of Site, Regional and Global Studies

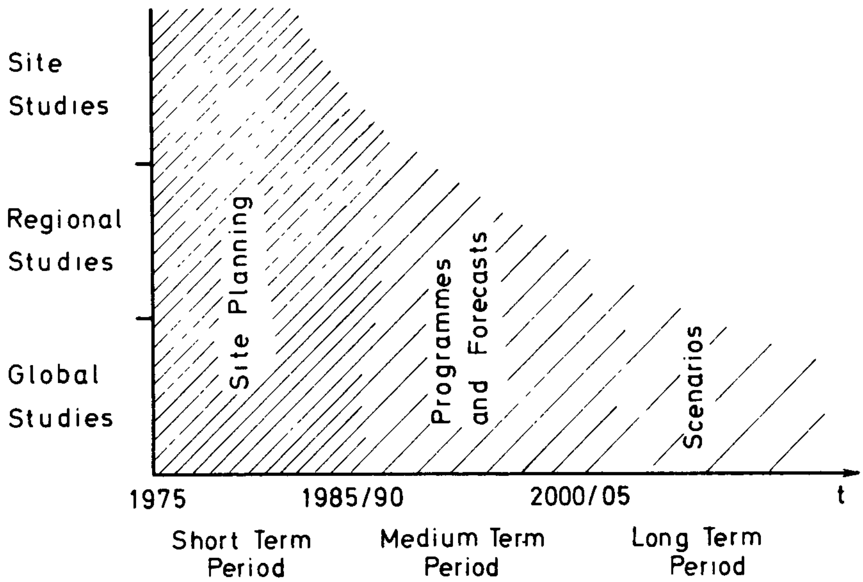
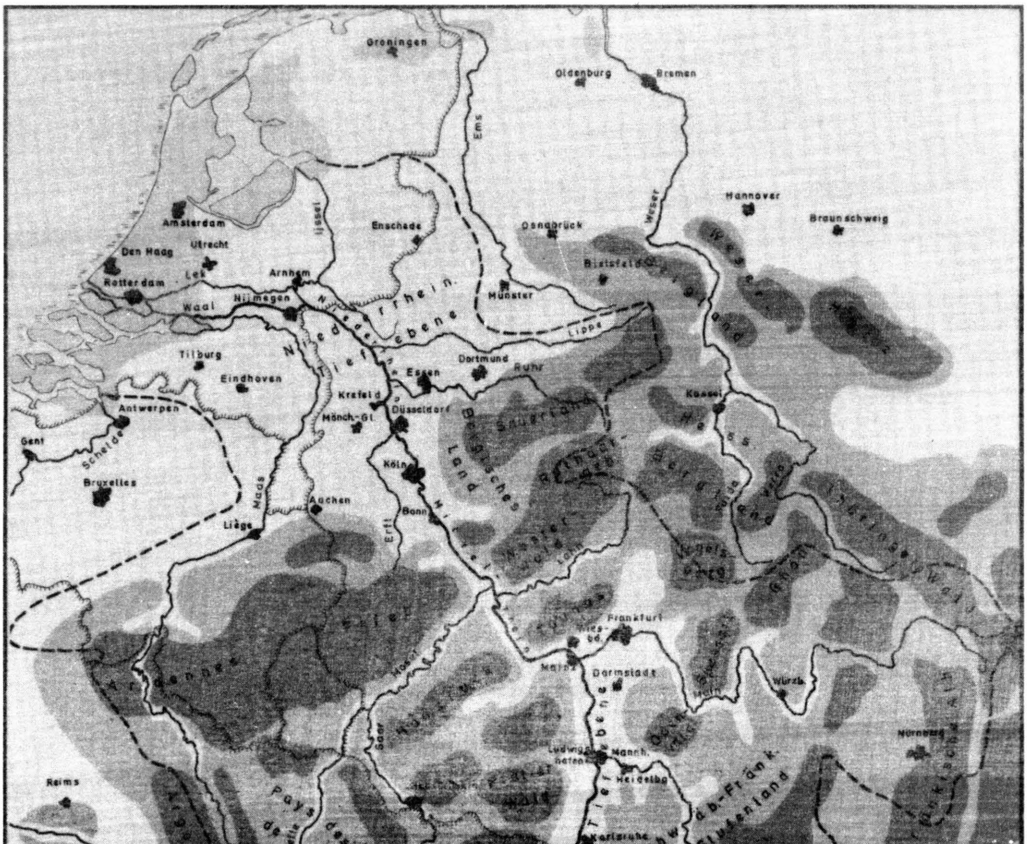



Fig. 2-3: Periods for Forecasting Studies




<u>Fig. 3-1:</u> Topographical Structure of the Rhein-Maas Region

----- Boundary of the Rhein-Maas Region

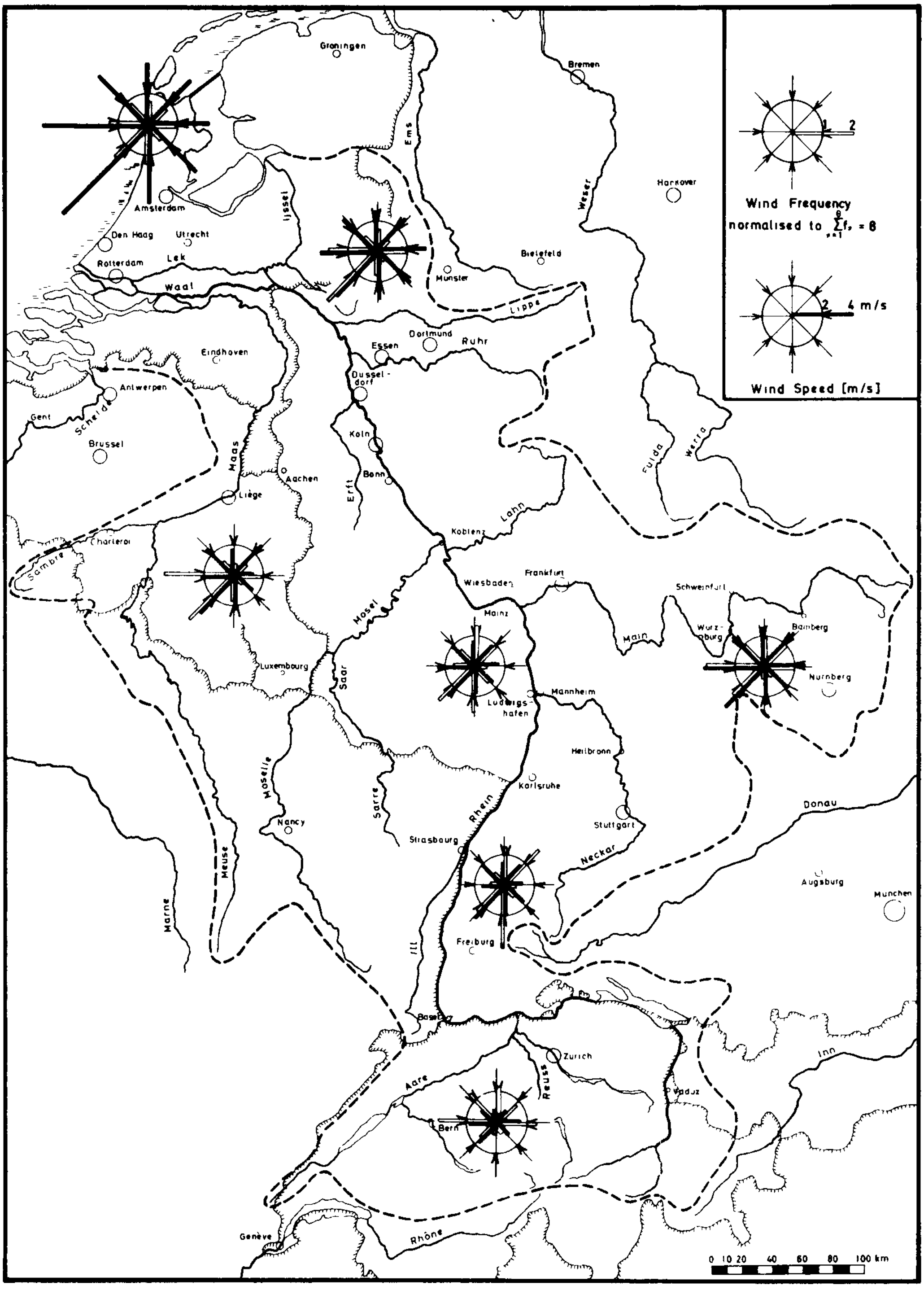



Fig. 3-2: Typical Windroses within the Rhein-Maas Region

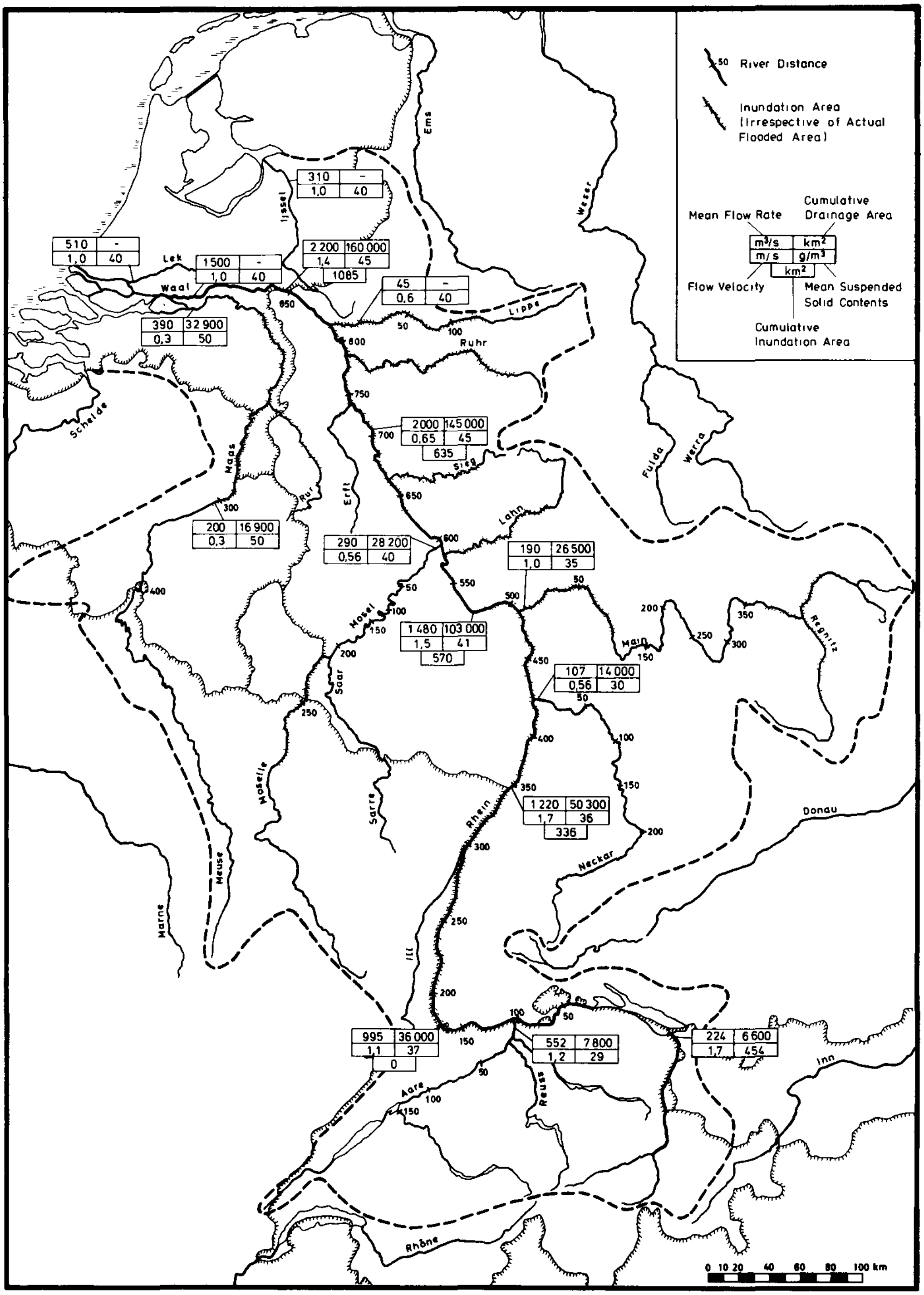
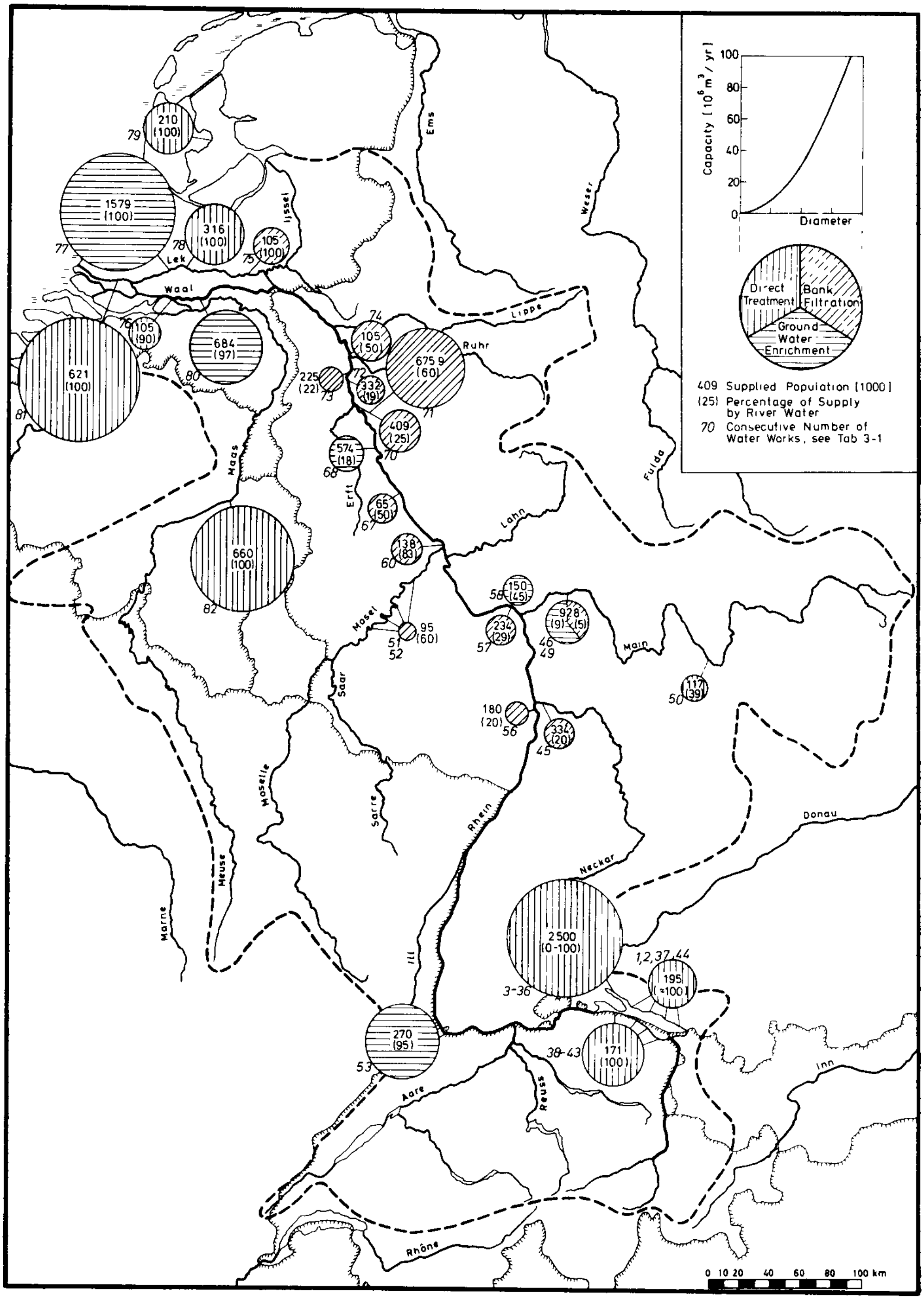



Fig. 3-3: Hydrological Characteristics of the Rhein-Maas Region




<u>Fig. 3-4:</u> Water Catchment from Rivers and Processing for Drinking Water in the Rhein-Maas Region

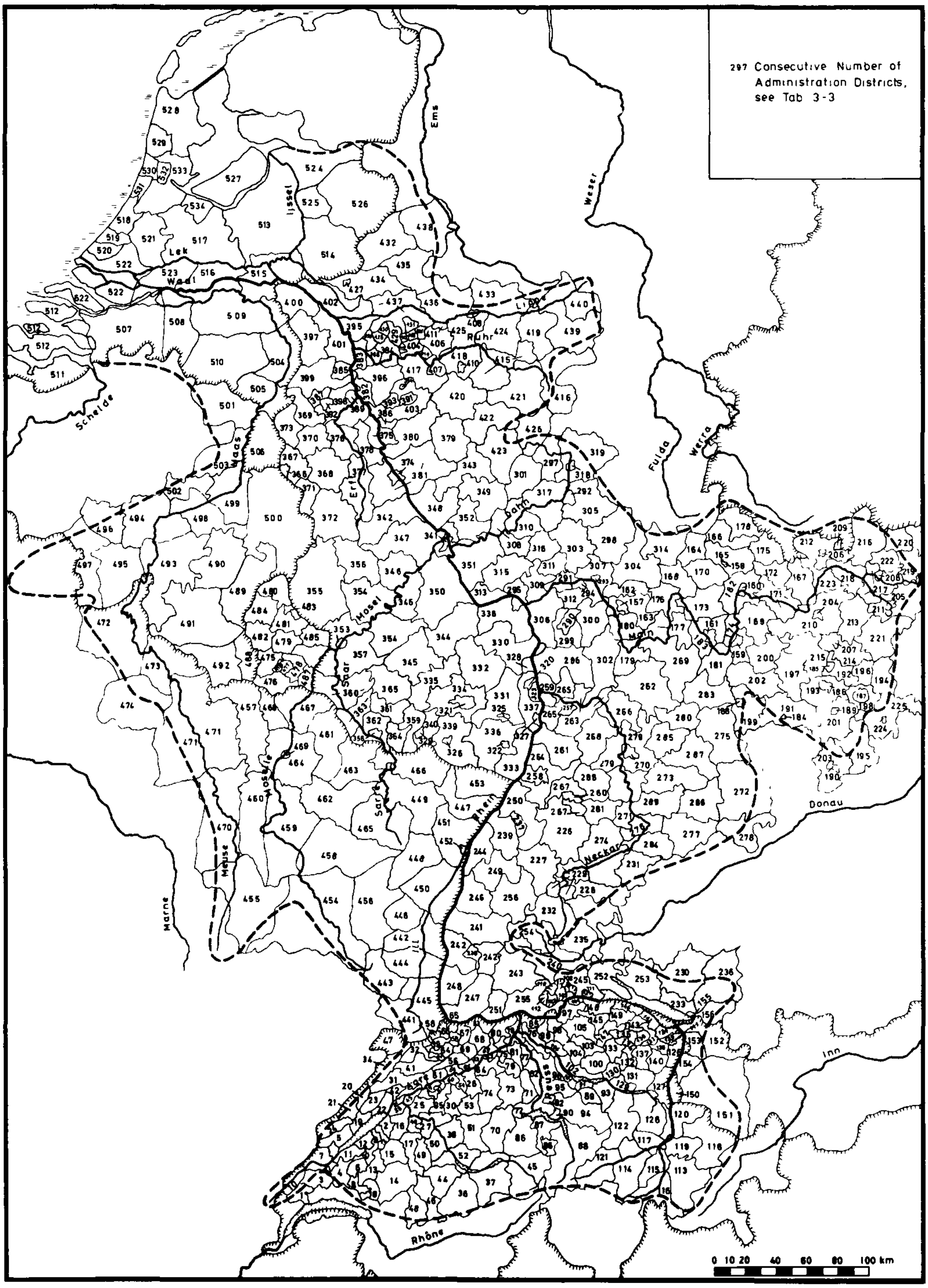



Fig. 3-5: Administration Districts of the Rhein-Maas Region

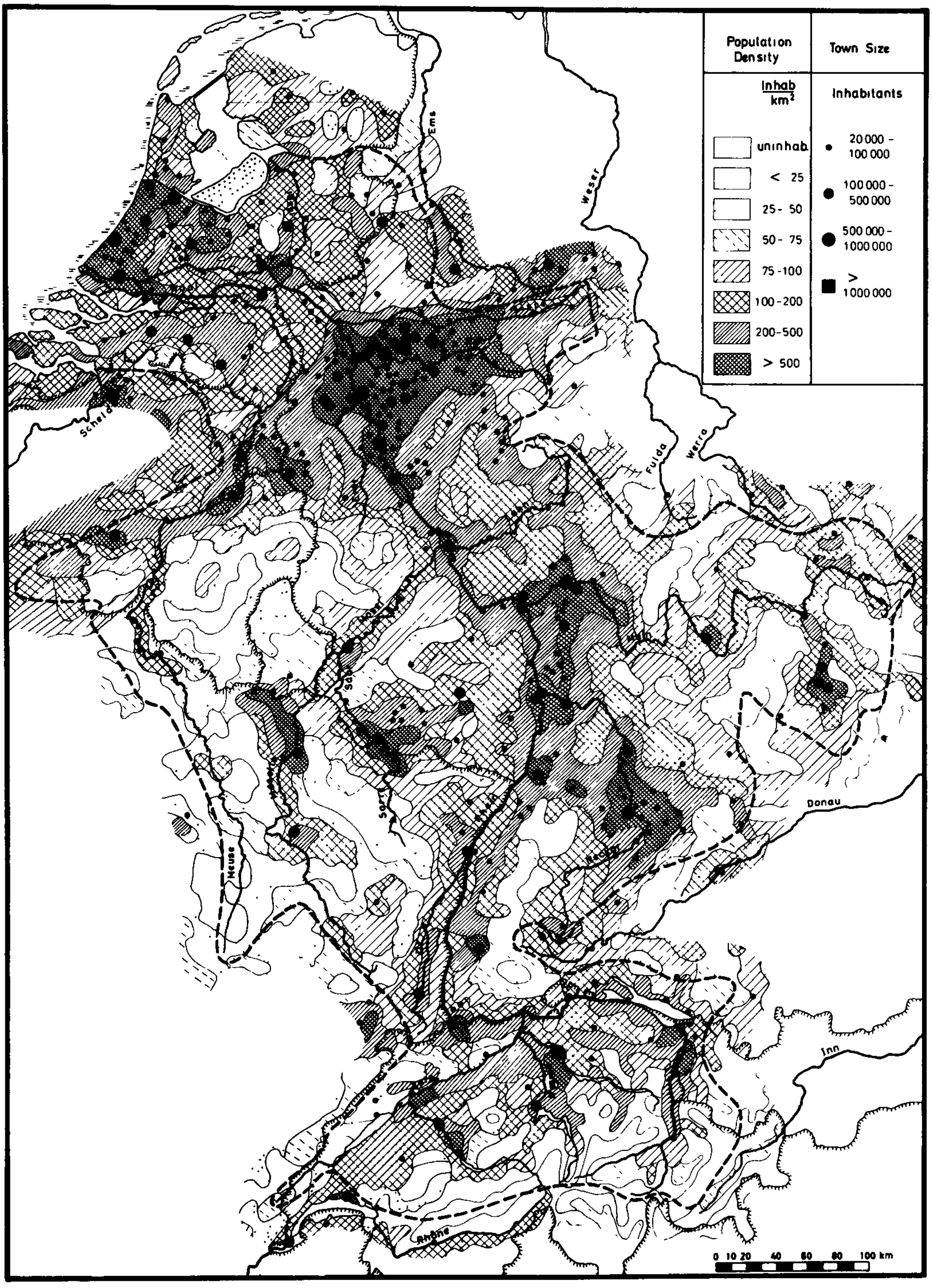



Fig. 3-6: Population Density Distribution within the Rhein-Maas Region
( adapted from: Westermanns-Schulatlas, Braunschweig (1975))

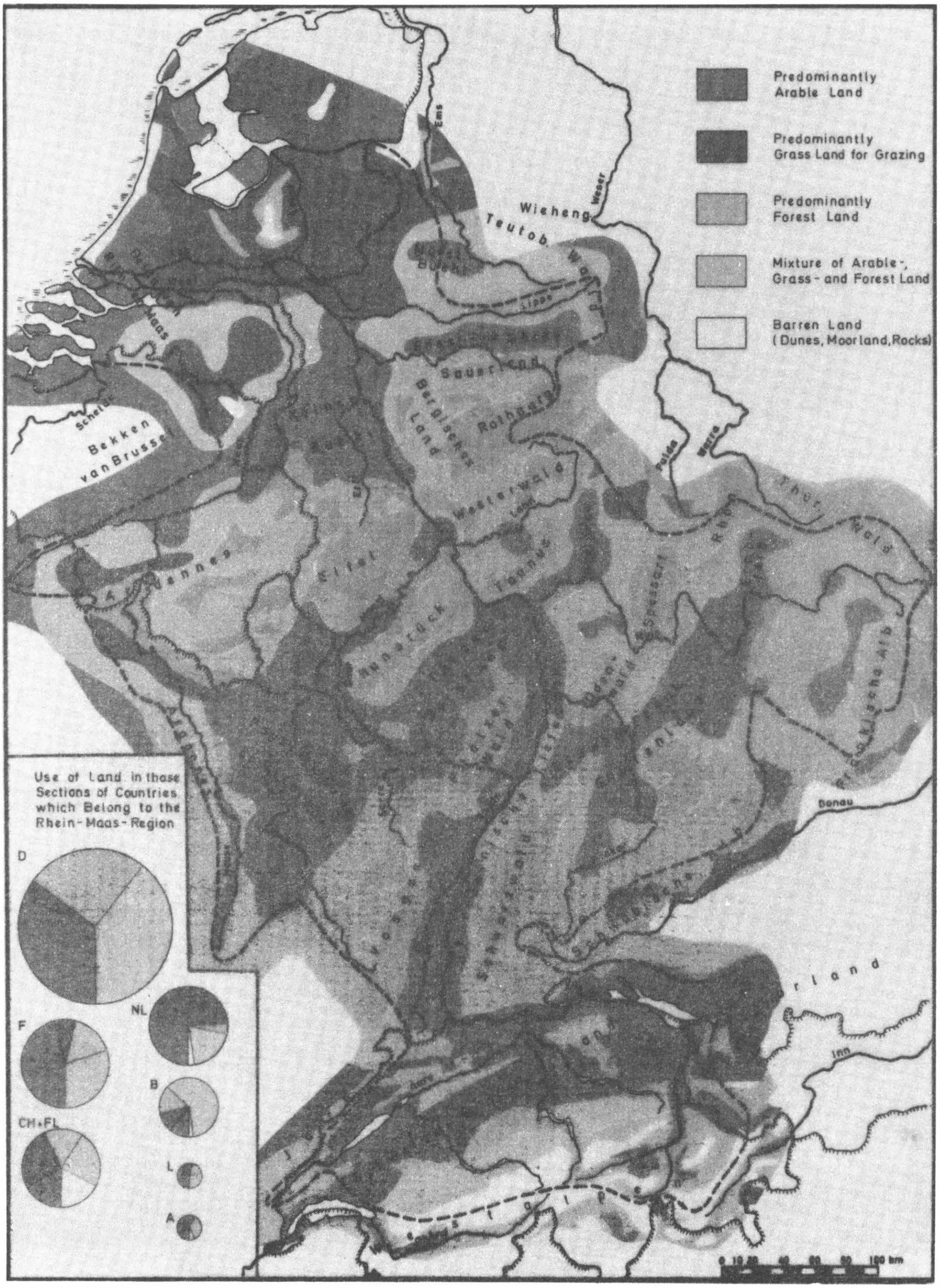



Fig. 3-7: Agricultural Structure of the Rhein-Maas Region
( adapted from: Herders-Handatlas, Freiburg (1966))
For Further Details on Use of Land see Table 3-6

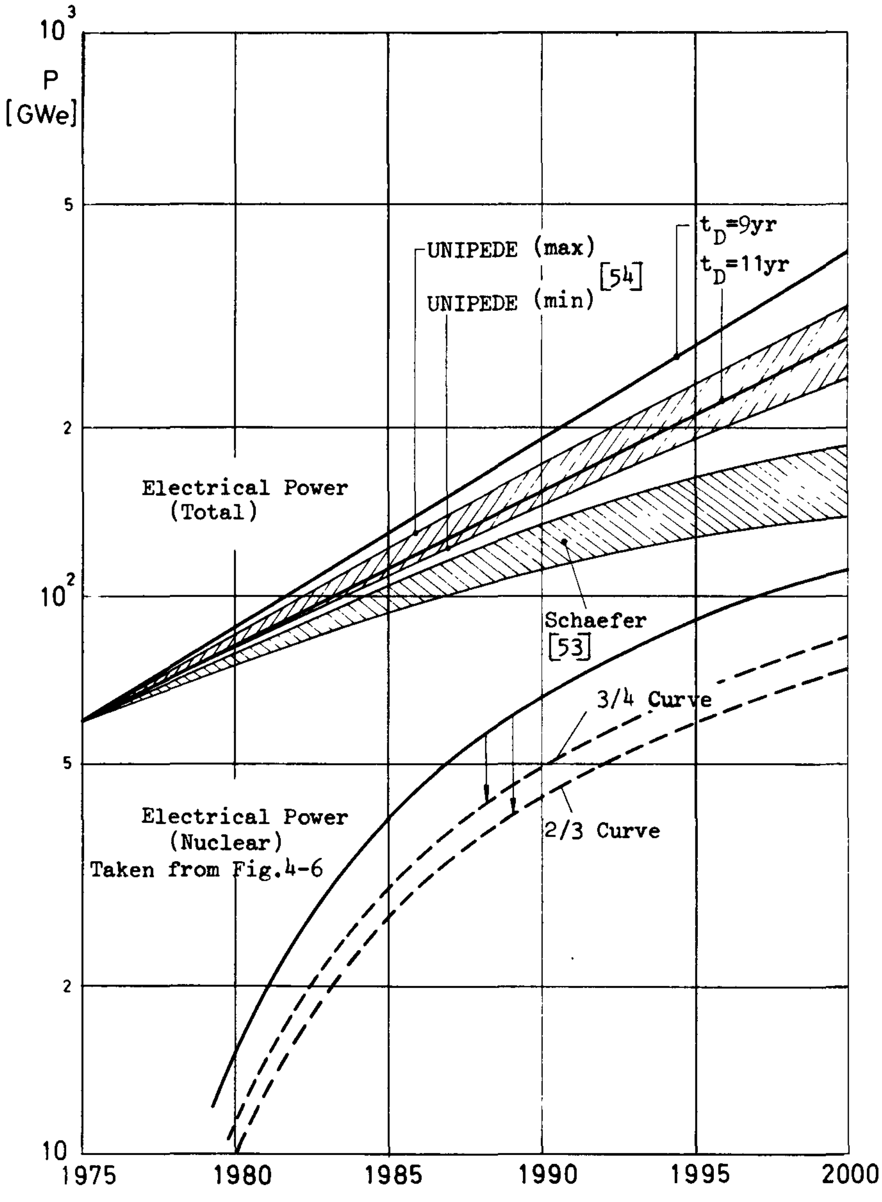
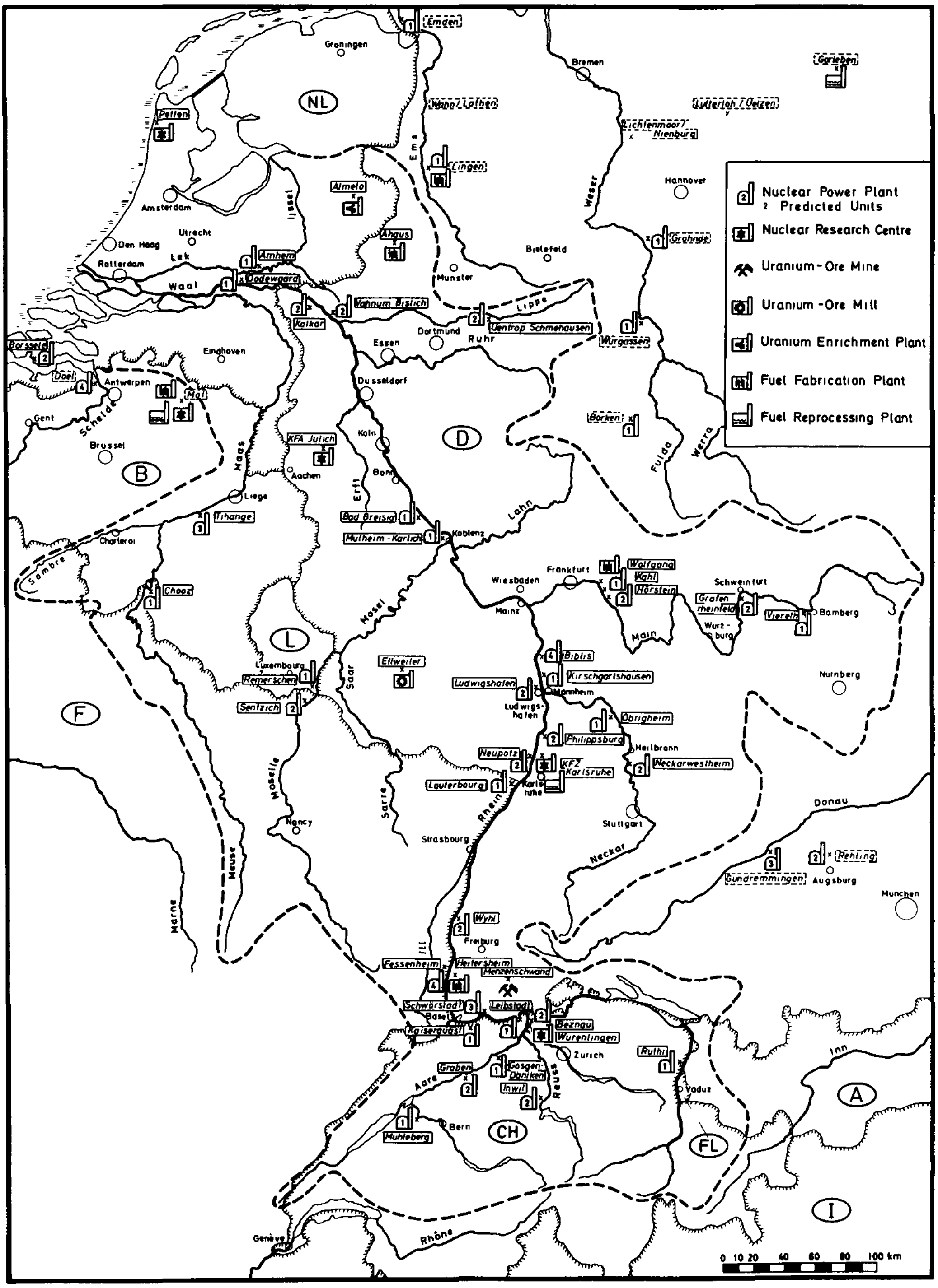



Fig. 4-1: Forecasted Installed Electrical Power within the Rhein-Maas Region (Total and Nuclear)

The UNIPEDE-Forecast [54] (made for Western Europe) and the Schaefer-Forecast [53] (made for Germany) have been applied to the installed electrical power of the RMR.

Doubling times $t_D$=9yrs to 11yrs of electric energy consumption are characteristic for most West European countries during the past decade.

The 2/3-3/4 Curves enclose the revised forecast for the Rhein-Maas-Region (see Section 4.2.3.)




<u>Fig. 4-2:</u> Sites of Nuclear Facilities within the Rhein-Maas Region till 1985/90 (see Tab. 4-3)

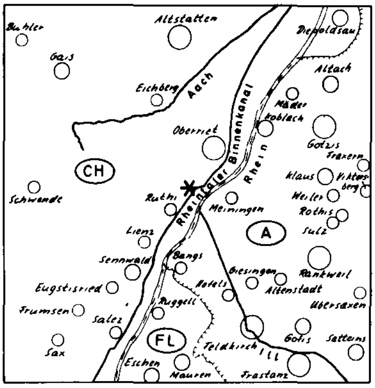



Fig. 4-3.1: Rüthi (No.1)

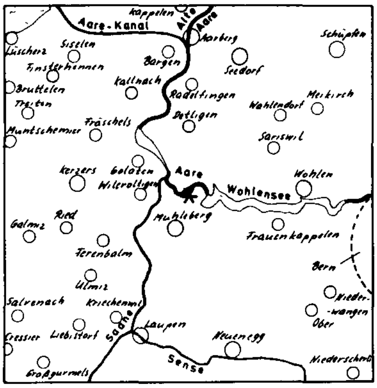



Fig. 4-3.2: Mühleberg (No.2)

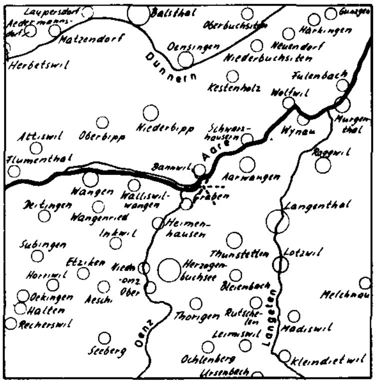




Fig. 4-3.3: Graben (No.3)

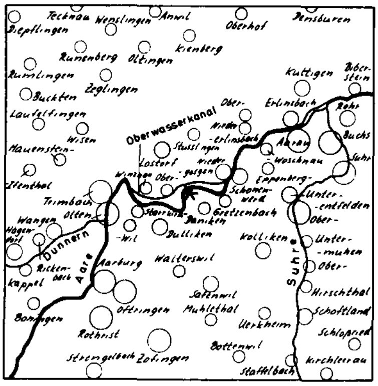



Fig. 4-3.4: Gösgen (No.4)

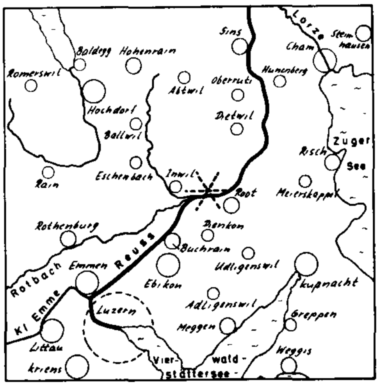



Fig. 4-3.5: Inwil (No.5)

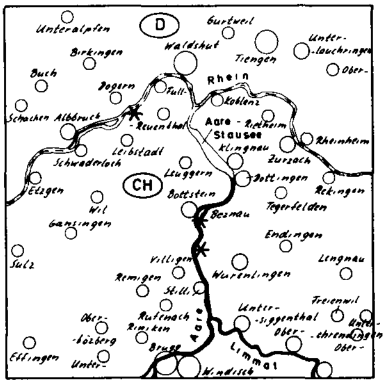



Fig. 4-3.6: Würenlingen (No.6)
Beznau (No.7)
Leibstadt (No.8)

Fig. 4-3: Detailed Maps of the Various Sites
Asterisks and their meaning see footnote at end of this figure
( in brackets: consecutive numbers of Table 4-3 )

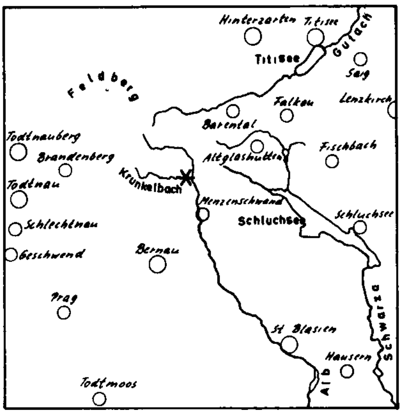



Fig. 4-3.7: Menzenschwand (No.9)

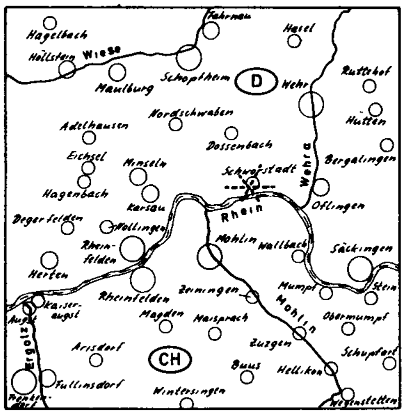



Fig. 4-3.8: Schwörstadt (No.10)

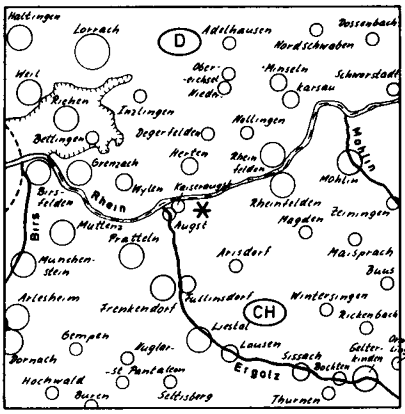



Fig. 4-3.9: Kaiseraugst (No.11)

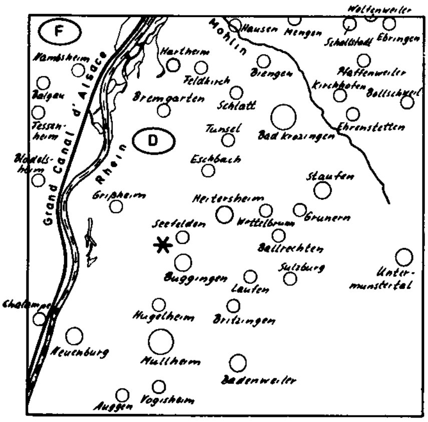




Fig. 4-3.10: Heitersheim (No.12)

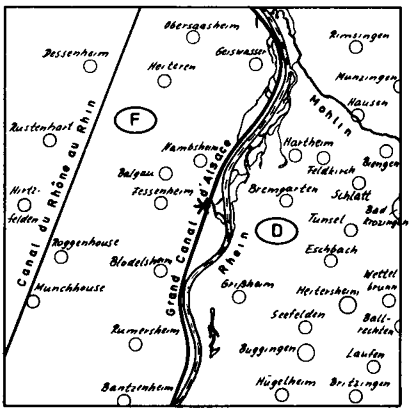



Fig. 4-3.11:Fessenheim (No.13)

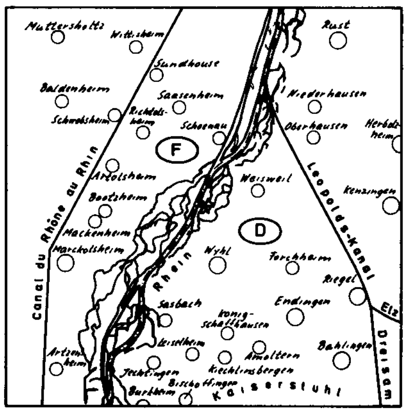



Fig. 4-3.12 Wyhl (No.14)

Fig. 4-3 (cont.)

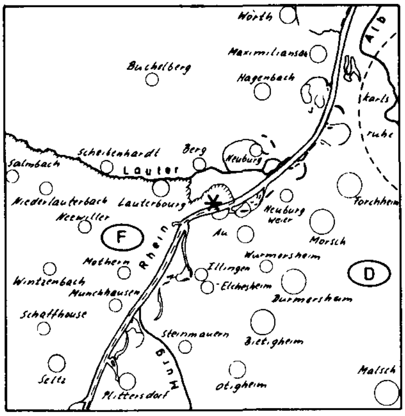


Fig. 4-3.13: Lauterbourg (No.15)

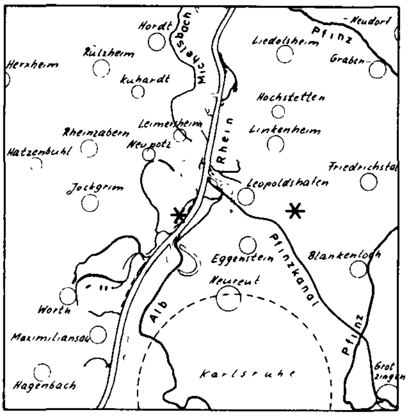


Fig. 4-3.14: Neupotz (No.16)
Karlsruhe (No.17)

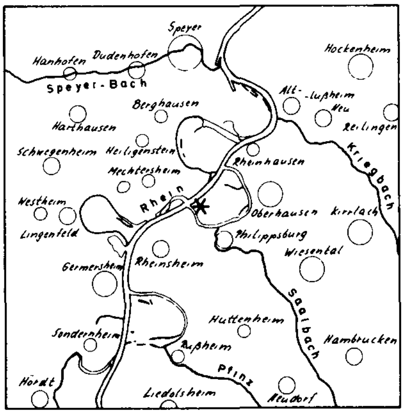


Fig. 4-3.15: Philippsburg (No.18)

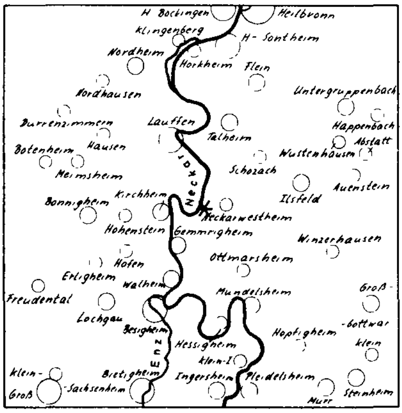



Fig. 4-3.16 Neckarwestheim (No.19)

Fig. 4-3.17: Obrigheim (No.20)

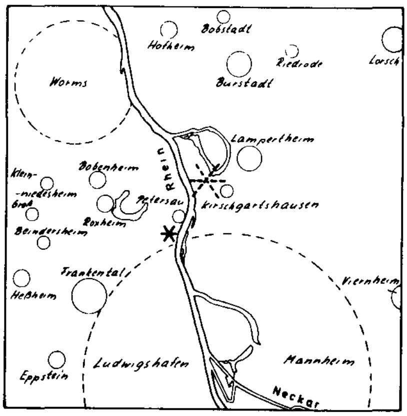


Fig. 4-3.18: Ludwigshafen (No.21)
Kirschgartshausen (No.22)

Fig. 4-3 (cont.)

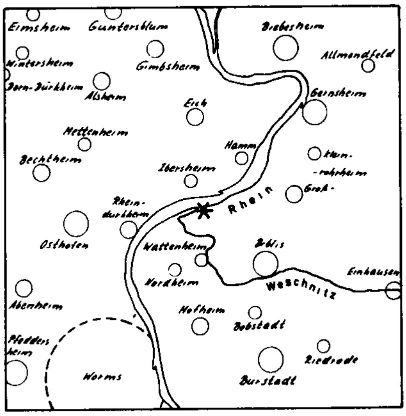



Fig. 4-3.19 Biblis (No.23)

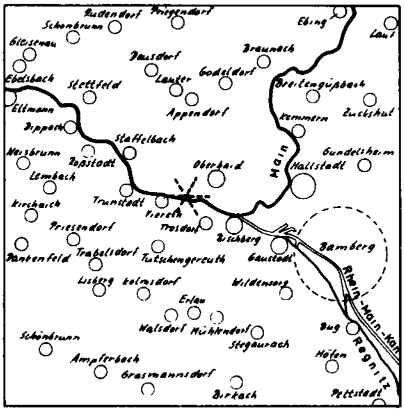



Fig. 4-3.20 Bamberg-Viereth (No.24)

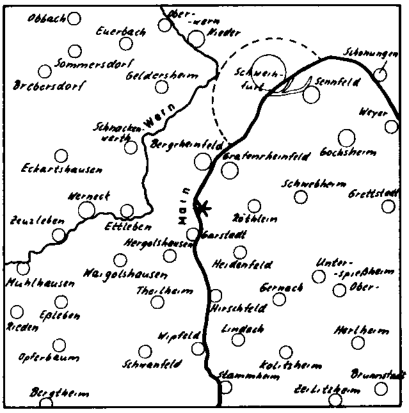




Fig. 4-3.21  Grafenrheinfeld (No. 25)

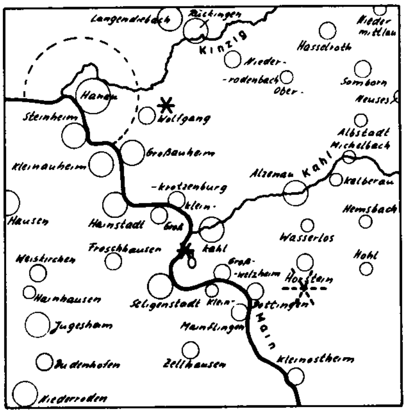



Fig. 4-3.22 Hörstein (No.26)
Kahl (No.27)
Wolfgang (No.28)

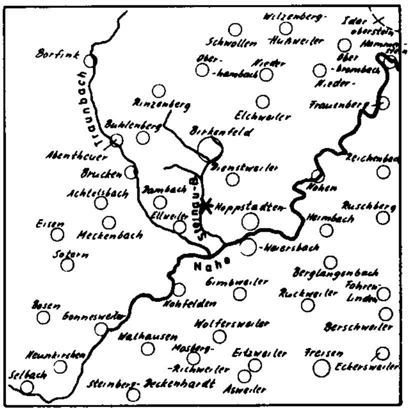



Fig. 4-3.23 Ellweiler (No.29)

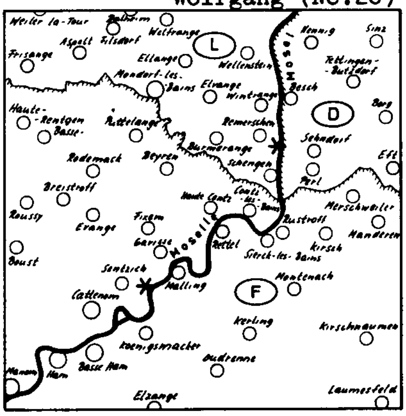



Fig. 4-3.24 Sentzich (No.30)
Remerschen (No.31)

Fig. 4-3 (cont.)

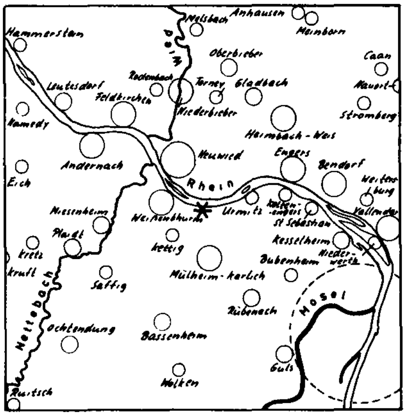



Fig. 4-3.25: Mülheim-Kärlich (No.32)

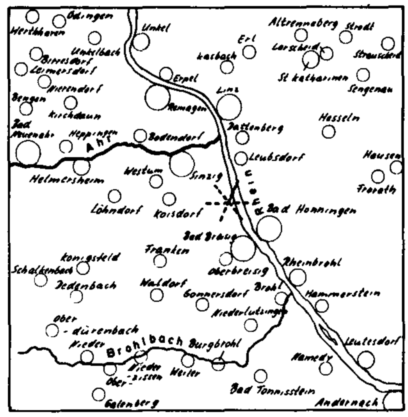



Fig. 4-3.26: Bad Breisig (No.33)

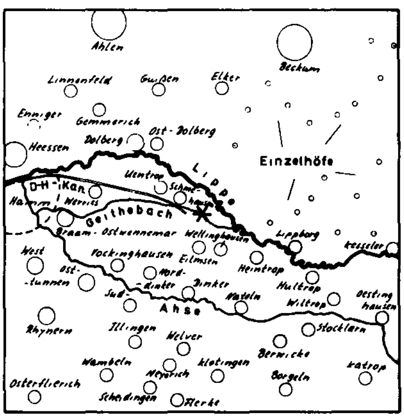




Fig. 4-3.27: Uentrop (No.34)

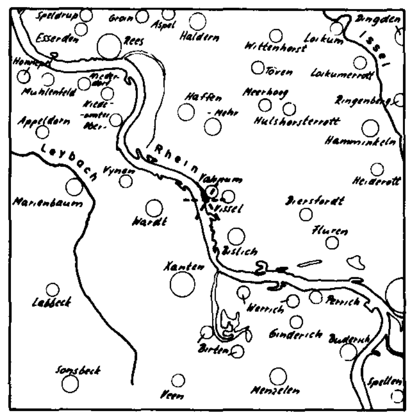



Fig. 4-3.28: Vahnum (No.35)

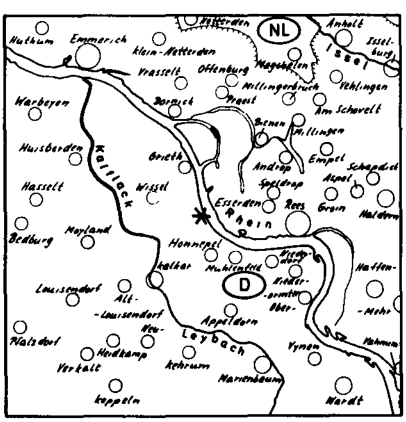



Fig. 4-3.29: Kalkar (No.36)

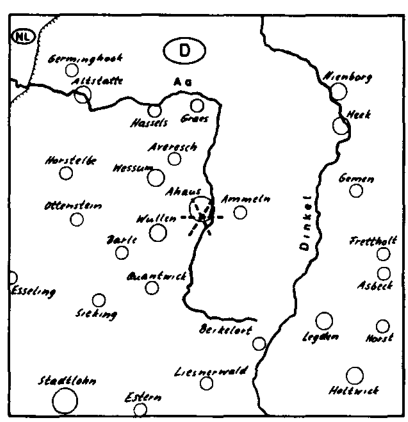



Fig. 4-3.30 Ahaus (No.37)

Fig. 4-3 (cont.)

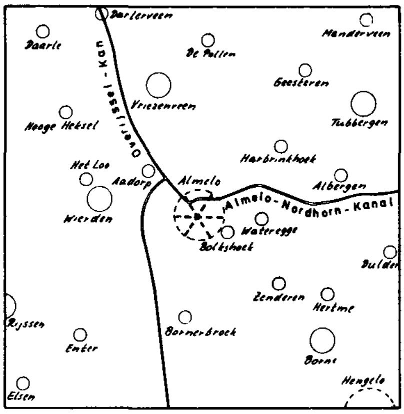



Fig. 4-3.31: Almelo (No.38)

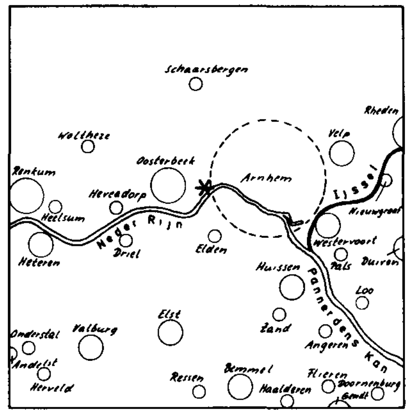



Fig. 4-3.32: Arnhem (No.39)

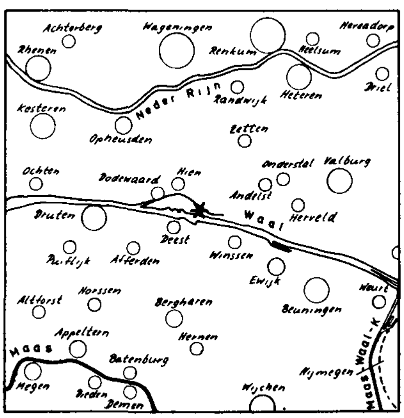



Fig. 4-3.33: Dodewaard (No.40)

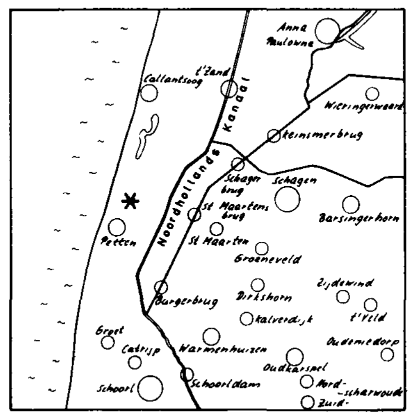




Fig. 4-3.34: Petten (No.41)

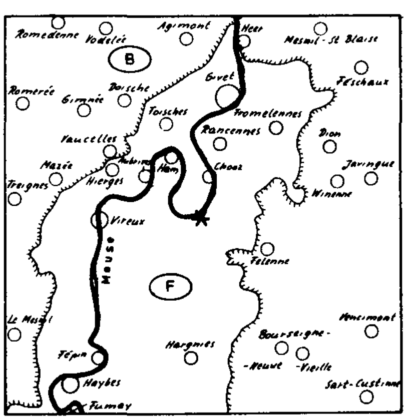



Fig. 4-3.35: Chooz (No.42)

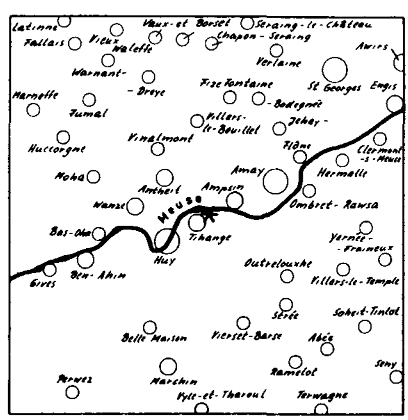



Fig. 4-3.36: Tihange (No.43)

Fig. 4-3 (cont.)

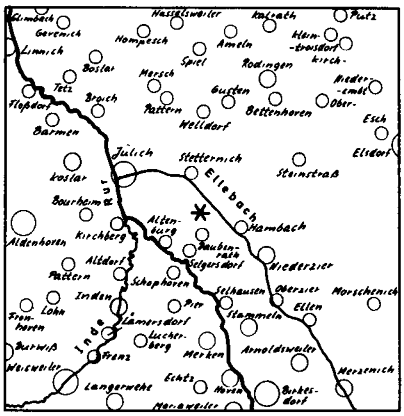





Fig. 4-3.37 Jülich (No.44)

Fig. 4-3.38 Borssele (No.45)

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✱ site defined (final or tentative)

site undefined

Fig. 4-3 (cont.)

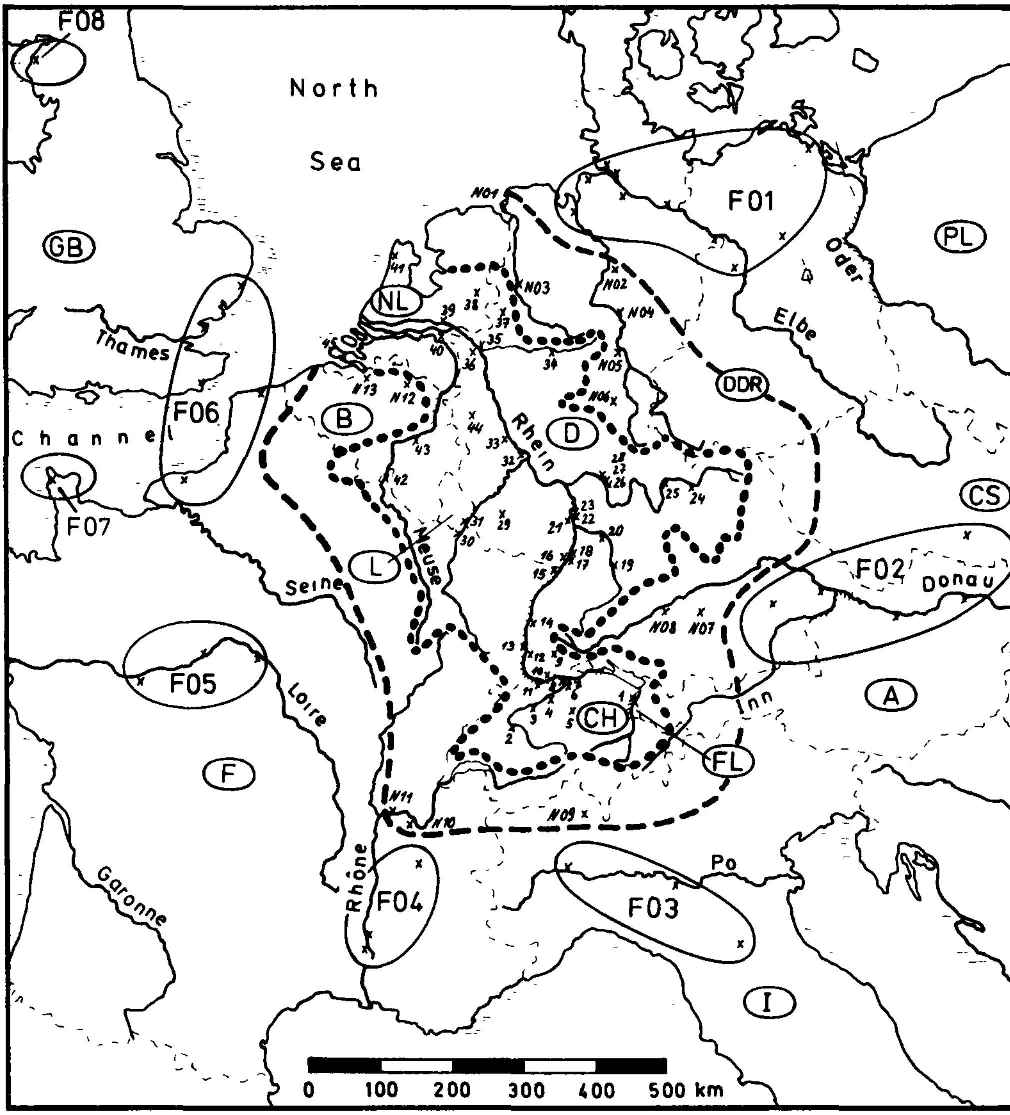



Fig. 4-4: Sites of Nuclear Power Facilities within the Rhein-Maas Region and the Surrounding Region till 1985/90

within dotted line:
Rhein-Maas-Region (Explanation of site figures see Tab. 4-3)
between dashed and dotted line:
Near Distance Zone N (Explanation of site figures see Tab. 4-4)
outside dashed line:
Far Distance Zone F (Explanation of site figures see Tab. 4-5)

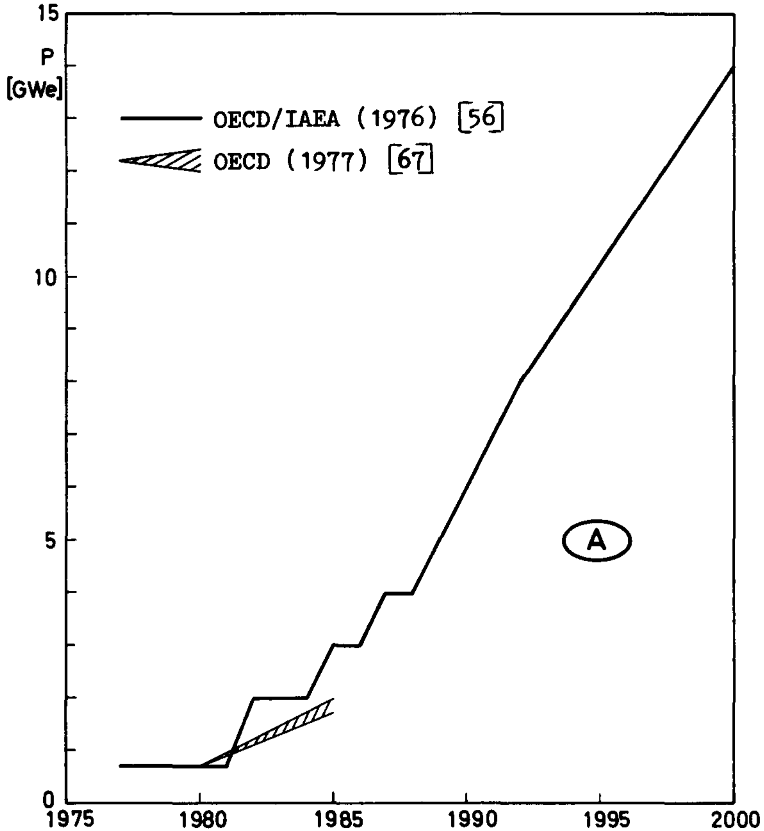



Fig. 4-5.1: Forecasted Installed Electrical Power on a Nuclear Basis within Austria

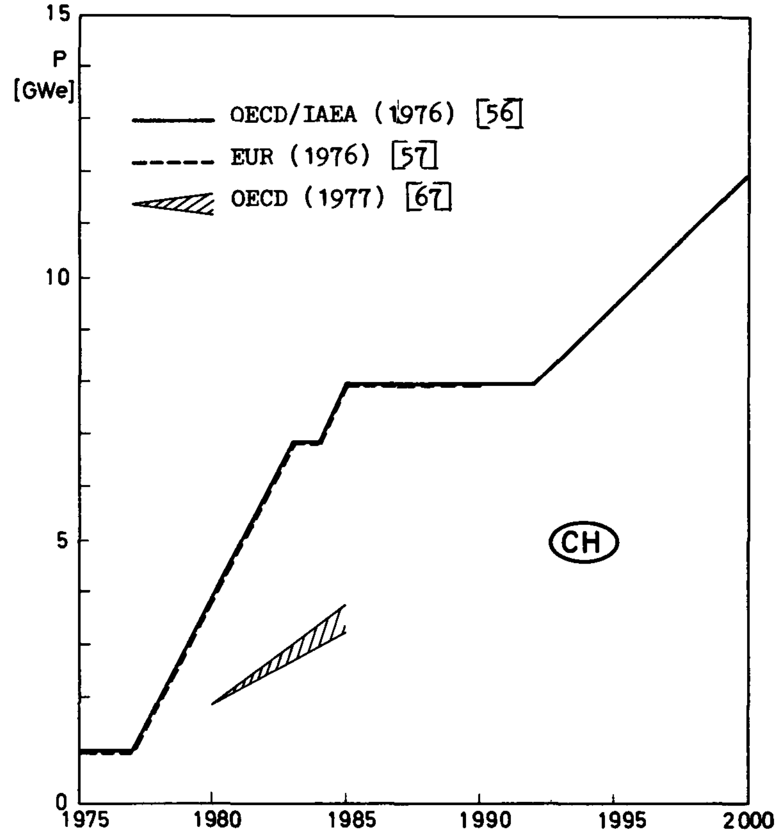



Fig. 4-5.2: Forecasted Installed Electrical Power on a Nuclear Basis within Switzerland

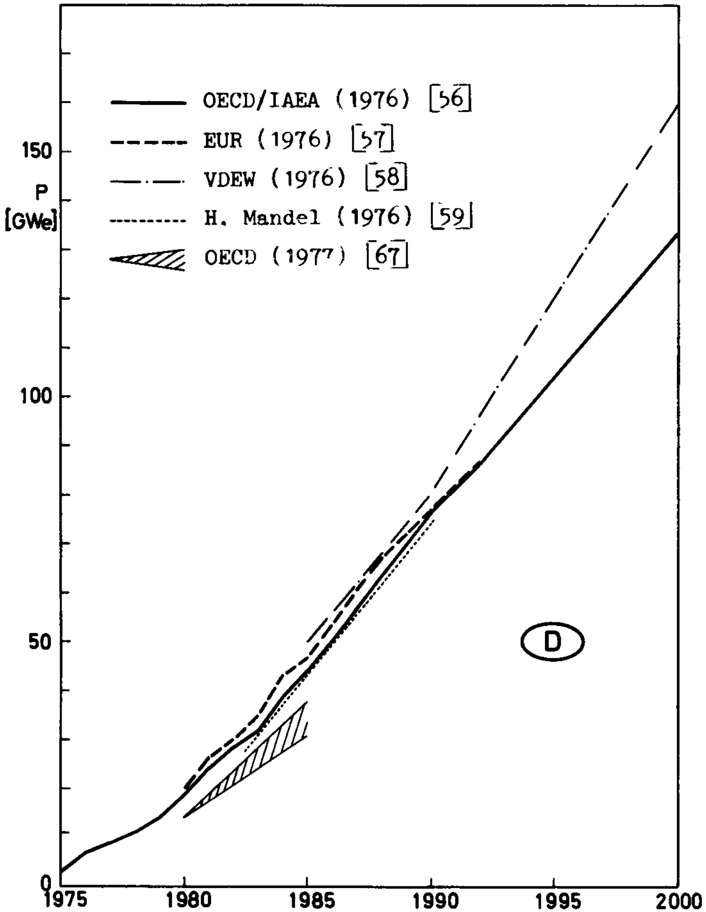



Fig. 4-5.3: Forecasted Installed Electrical Power on a Nuclear Basis within Germany

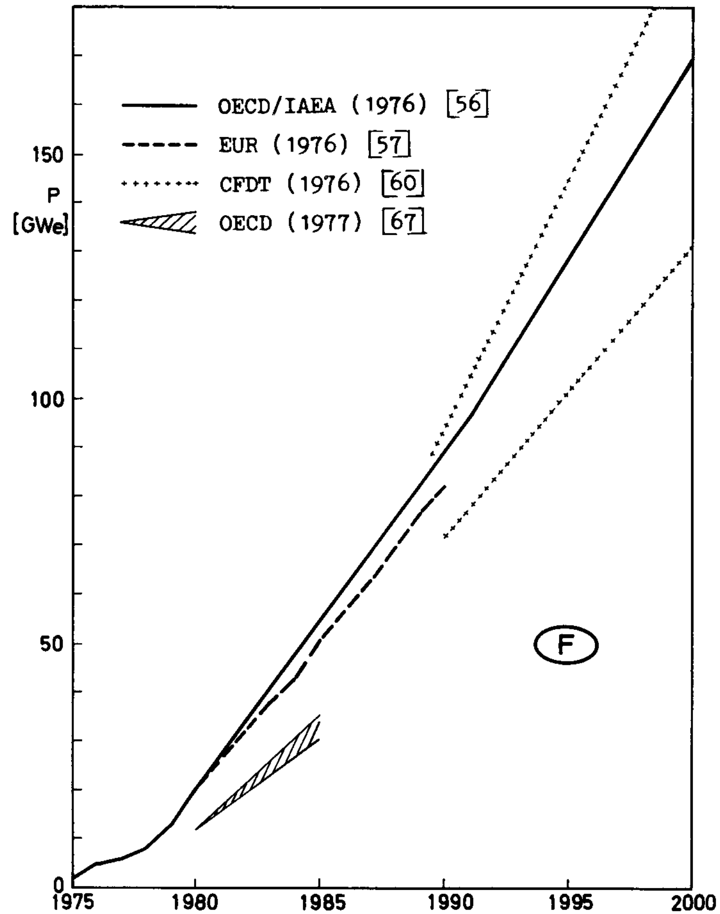



Fig. 4-5.4: Forecasted Installed Electrical Power on a Nuclear Basis within France

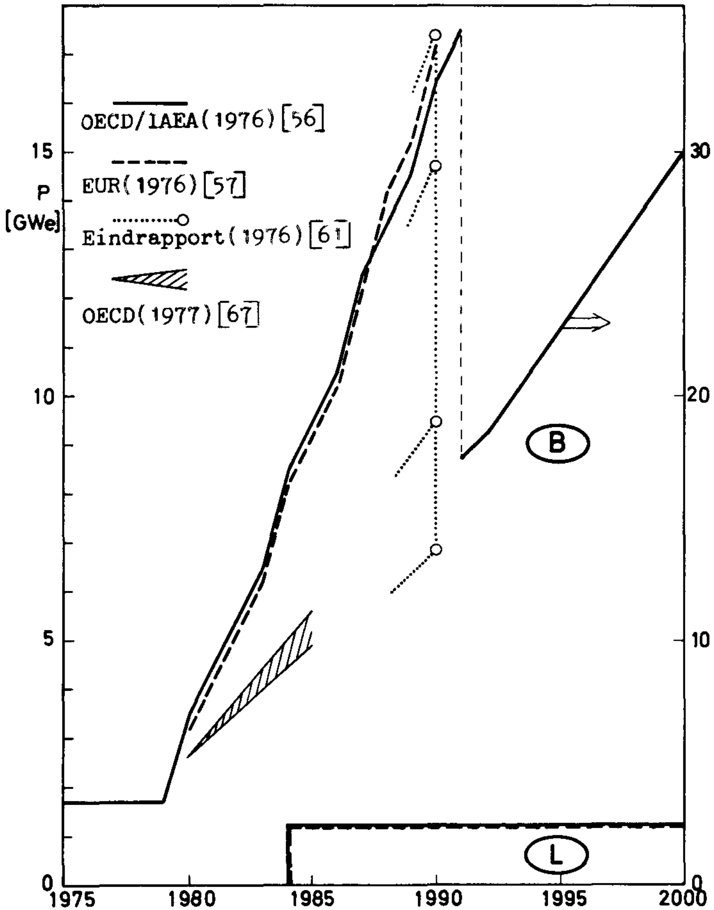



**Fig. 4-5.5:** Forecasted Installed Electrical Power on a Nuclear Basis within Belgium and Luxembourg

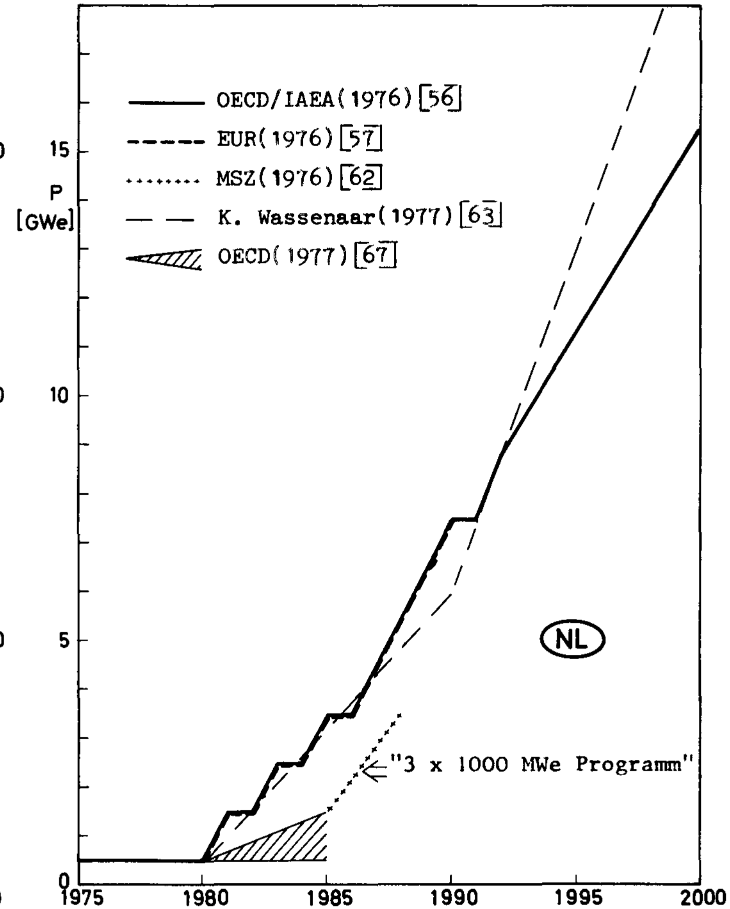



**Fig. 4-5.6:** Forecasted Installed Electrical Power on a Nuclear Basis within the Netherlands

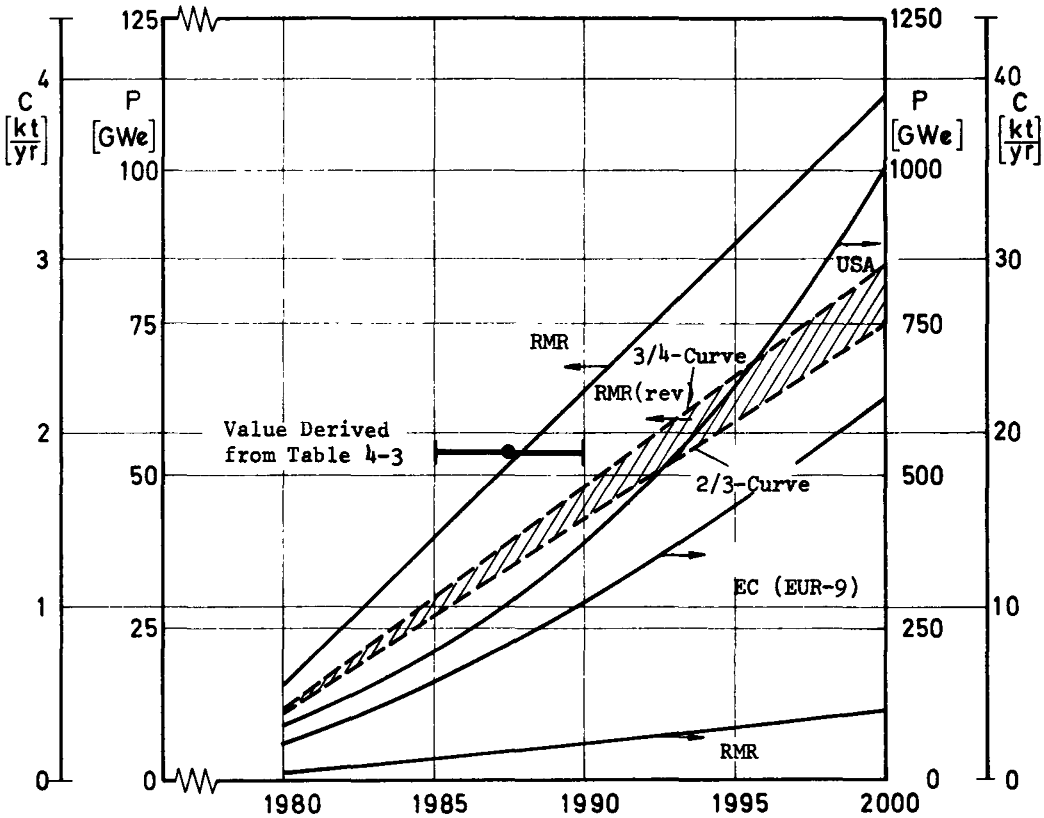



Fig. 4-6: Forecasted Installed Electrical Power (P) on a Nuclear Basis and the Annual Fuel Throughput (C) for the Rhein-Maas Region (RMR), the European Community (EC), and the USA (see Section 4.2.2)

The 2/3 - 3/4 Curves enclose the revised forecast for the Rhein-Maas Region (see Section 4.2.3)

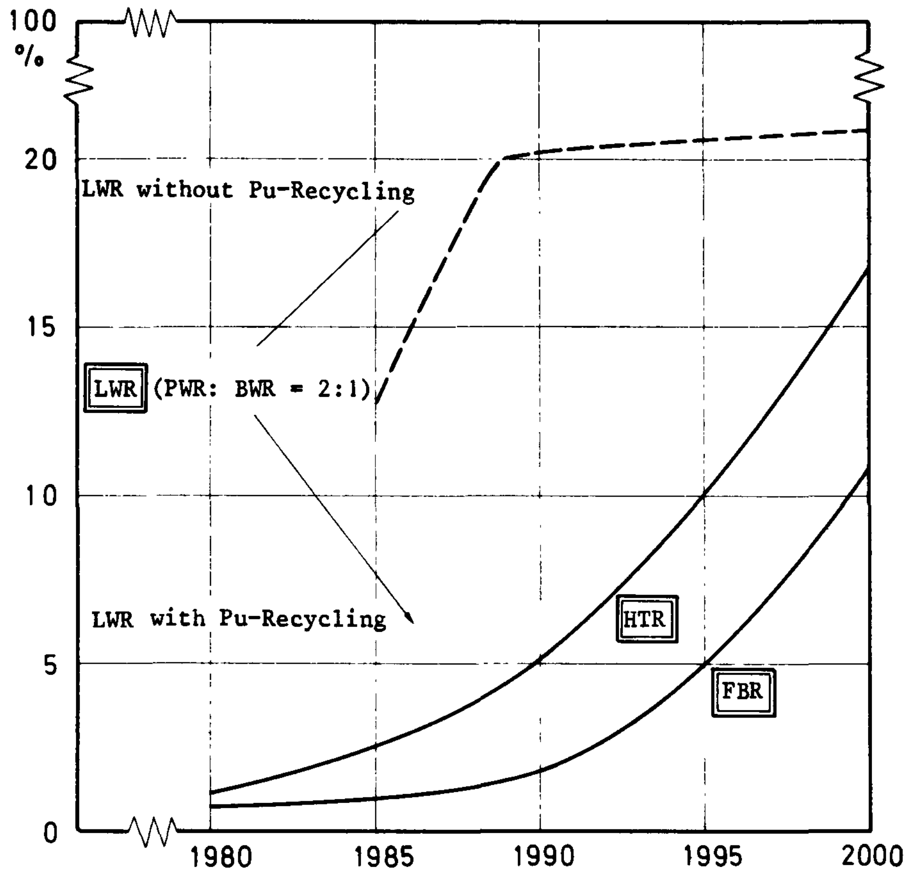



Fig. 4-7: Forecasted Contribution of Various Reactor Types to the Installed Nuclear Power (see Section 4.2.2)

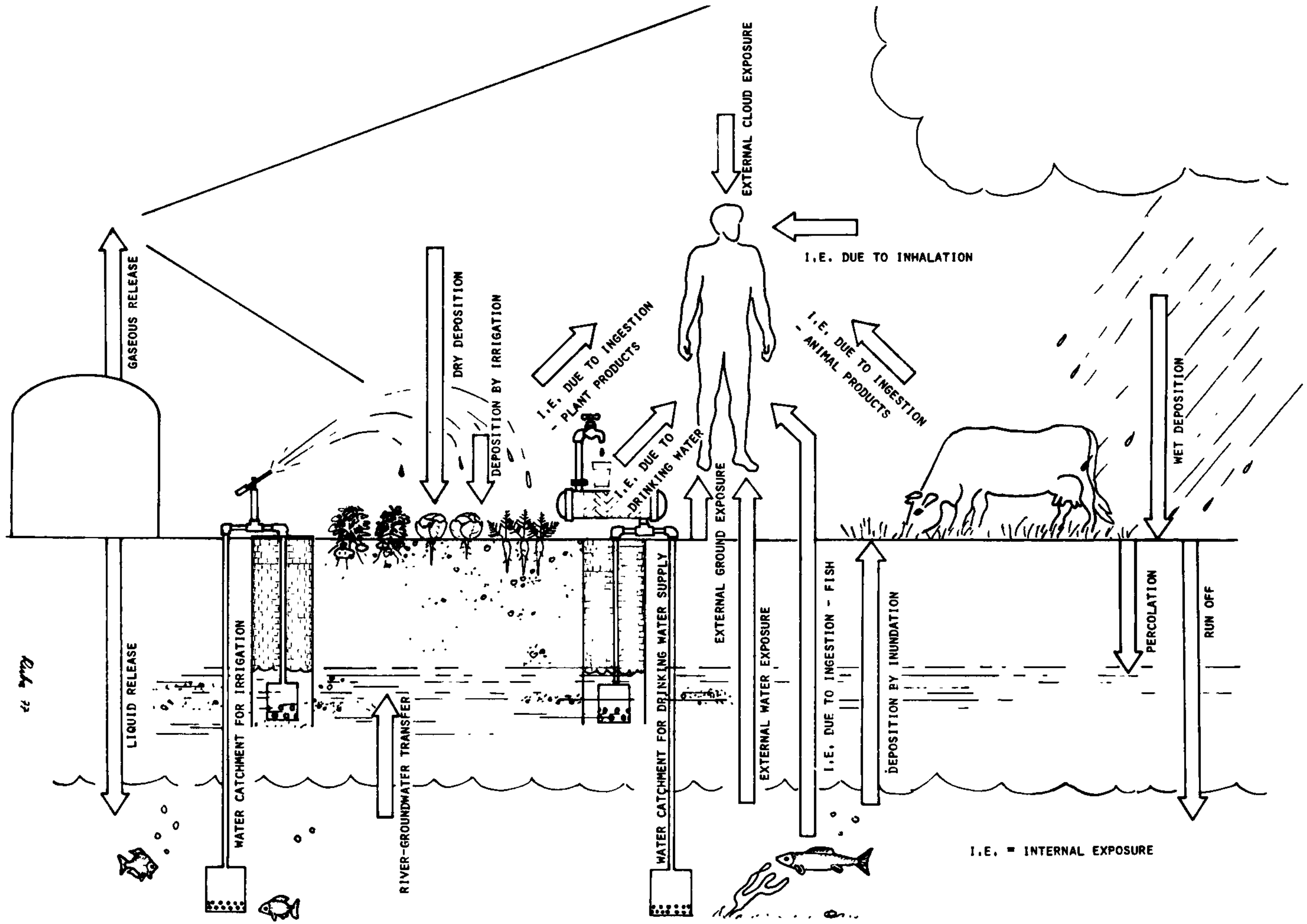



Fig. 5-1: The Various Exposure Pathways - Artist's View

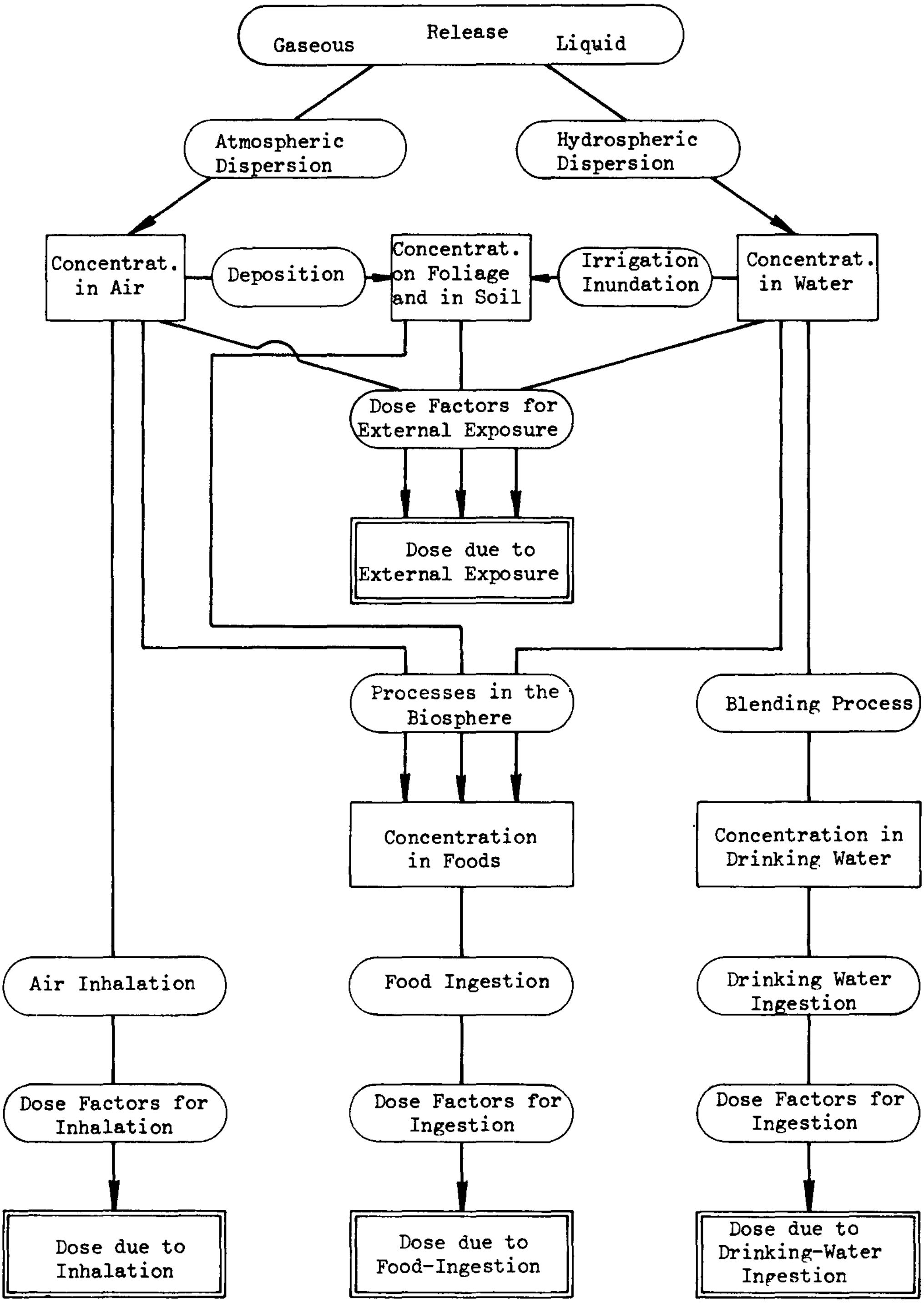



Fig. 5-2: The Various Exposure Pathways - Flow Scheme

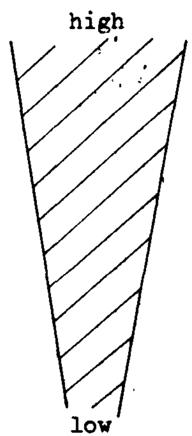
| Dose Rate Concept | Extent of Information | Criteria | Examples of Application |
|---|---|---|---|
| Location Dependent Individual Dose Rate Equs.(5.2-13 to 16) |   | Correlation between Location Dose Rates and Individuals is given | Low Mobility Rate of the Population, Self-Supply of Food |
| Mean Individual Dose Rate Equs. (5.2-18and19) | | Correlation between Dose Rates and the Population within a Defined Area is given | Mobility Mainly within a Defined Area, Production and Supply of Foods Mainly within a Defined Area |
| Collective Dose Rate Equs.(5.2-22and23) | | No Correlation Possible | Production is Known, Supply and Consumption can not be Evaluated |

Fig. 5-3: Criteria for the Application of Dose Rate Concepts (For details see Chapter 5.2)

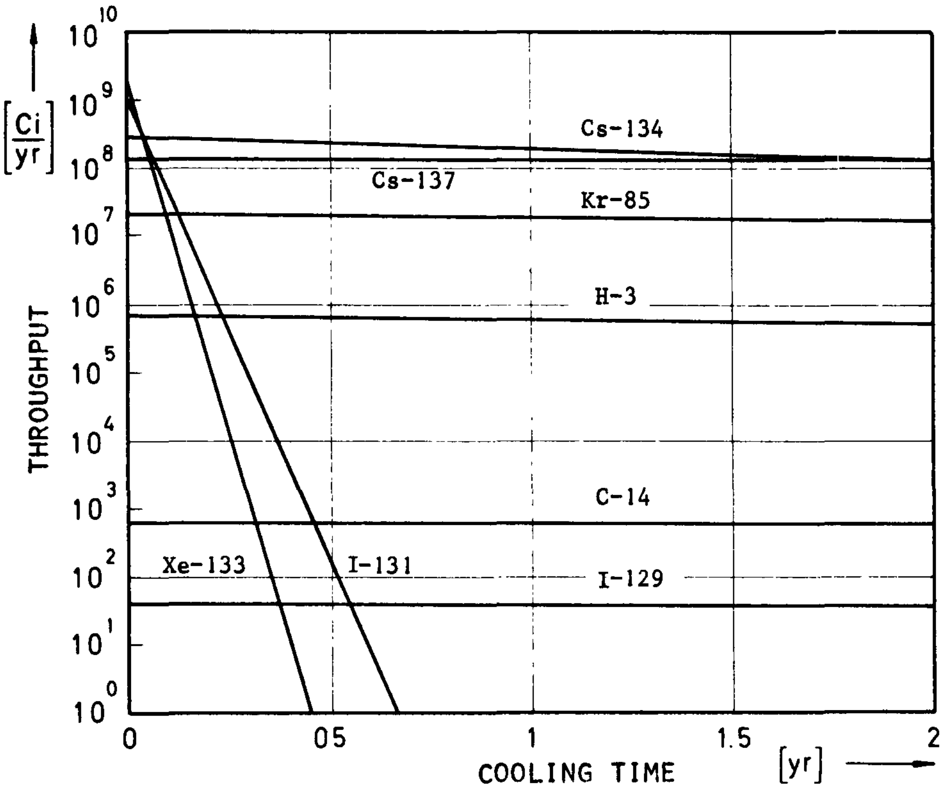



Fig. 5-4: Throughput of Several Important Radionuclides in a 1500 t/yr - Reprocessing Plant as a Function of Cooling Time of the Spent Fuel (Fuel Burn-up: 30 000 MWd/t)

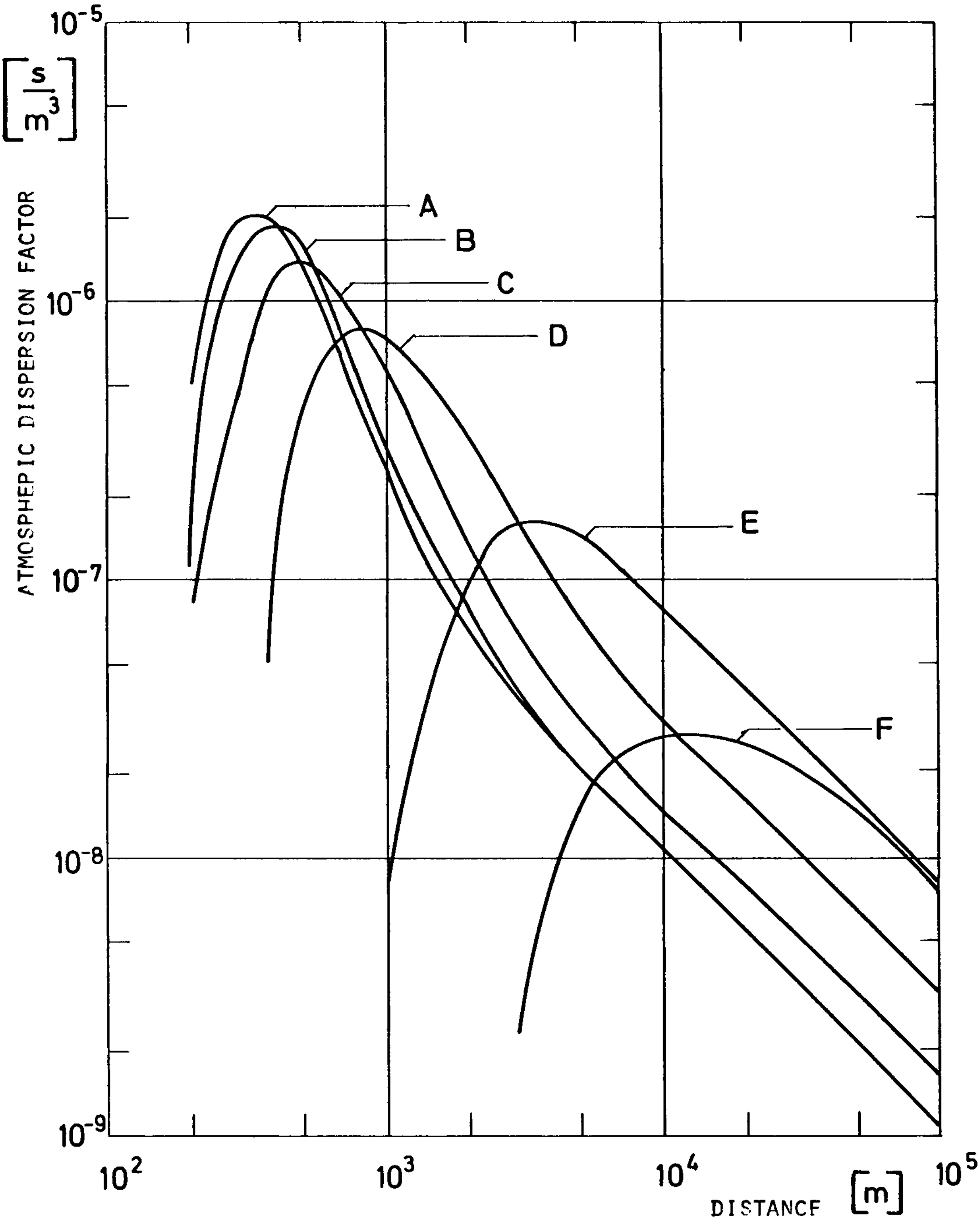



Fig. 5-5: Atmospheric Dispersion Factors for Continuous Release as a Function of Weather Category
Assumptions: Isotropic Windrose
Windspeed: 1m/s
Roughness Degree: 3 (Low Forest, Buildings) [93]

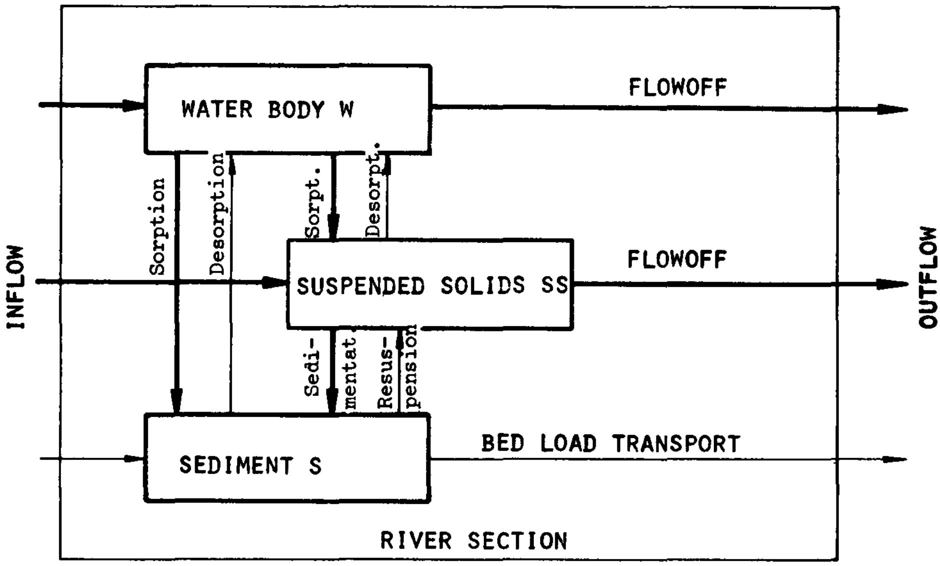



Fig. 5-6: Transport and Transfer Processes of Radionuclides within a River Section (Box-Model) [101]

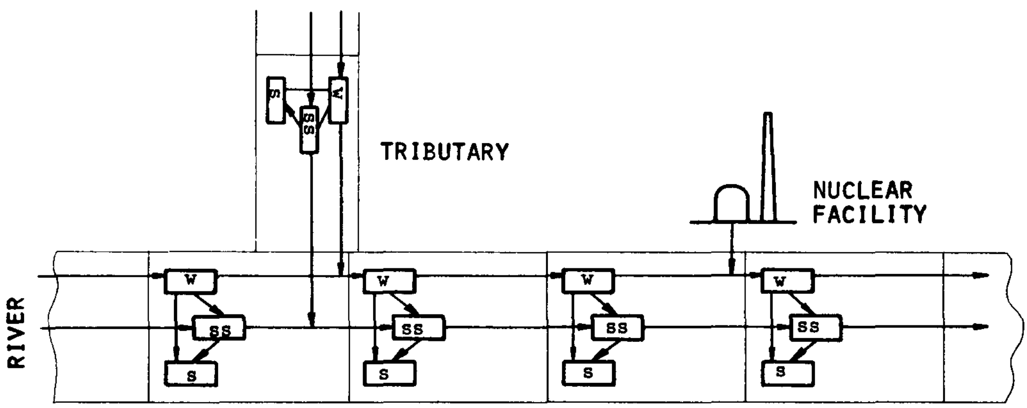



Fig. 5-7: Linking of River Sections, Tributaries and Inflow Sources (disregarding the bed load transport) [101]

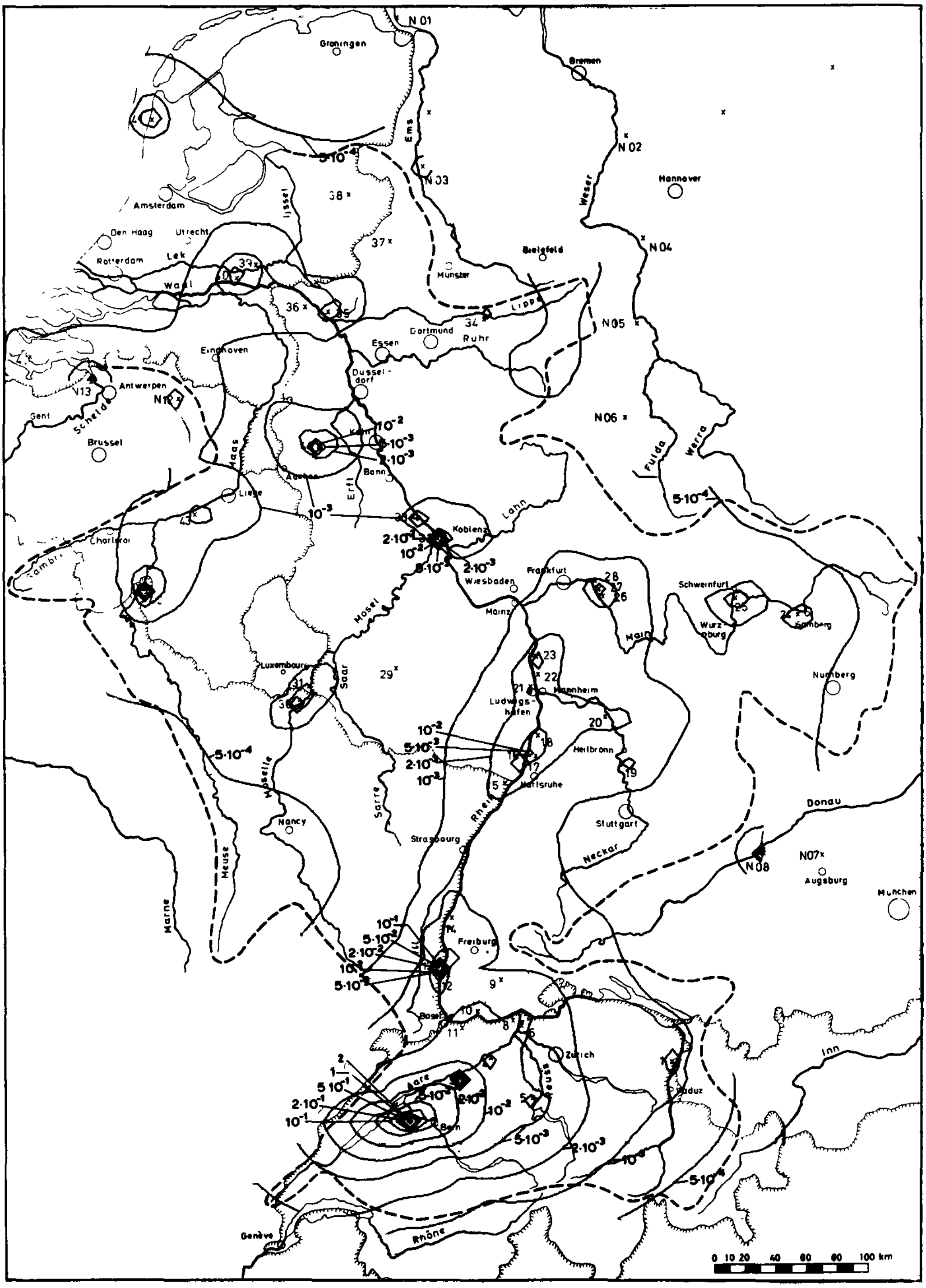


Fig. 6-1.1: Regional Pattern of Whole Body-Dose Rates [mrem/yr] from External Cloud Exposure around the Years 1985/90

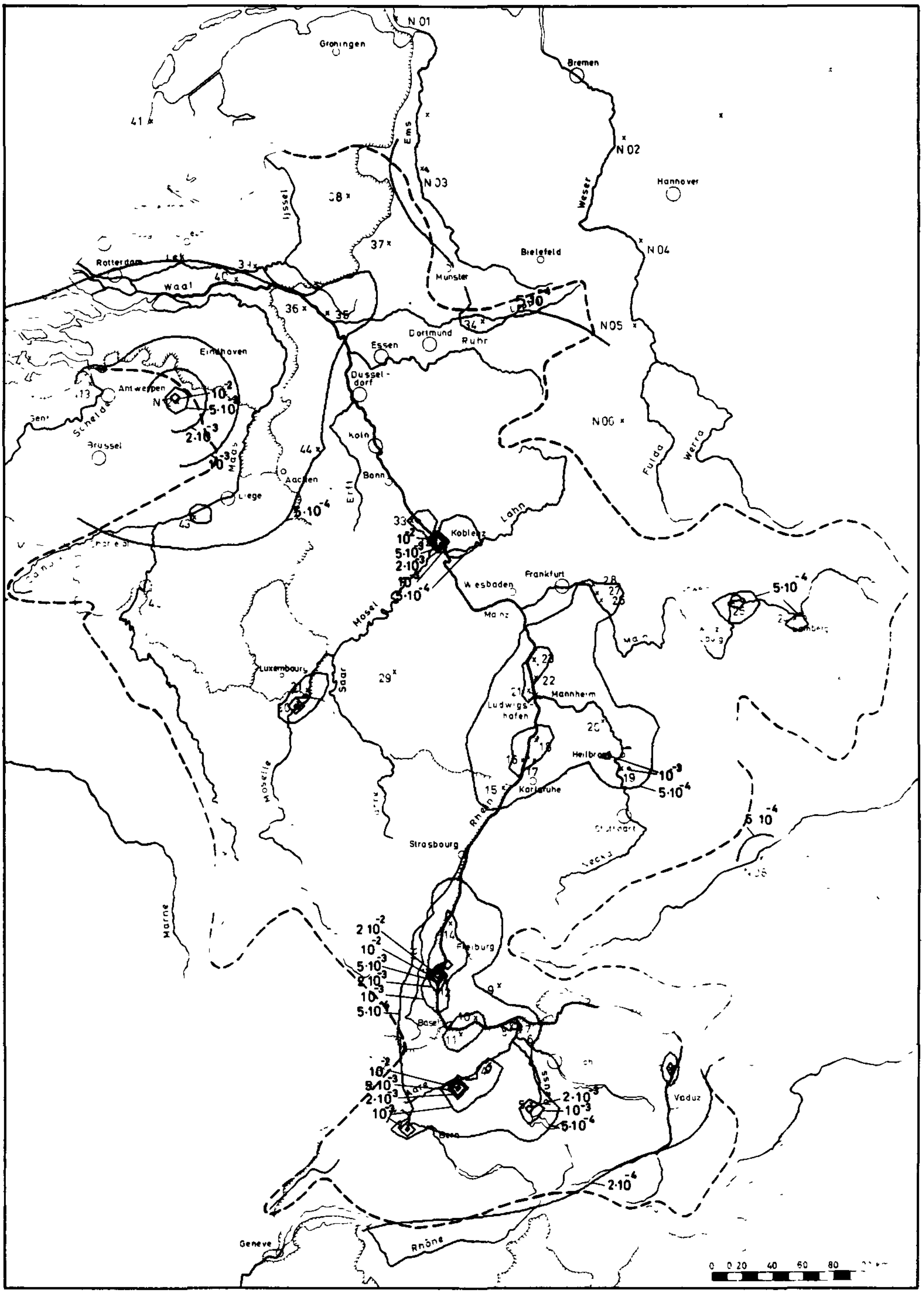



**Fig. 6-1.2a:** Regional Pattern of Whole Body-Dose Rates [mrem/yr] from External Ground Exposure around the Years 1985/90

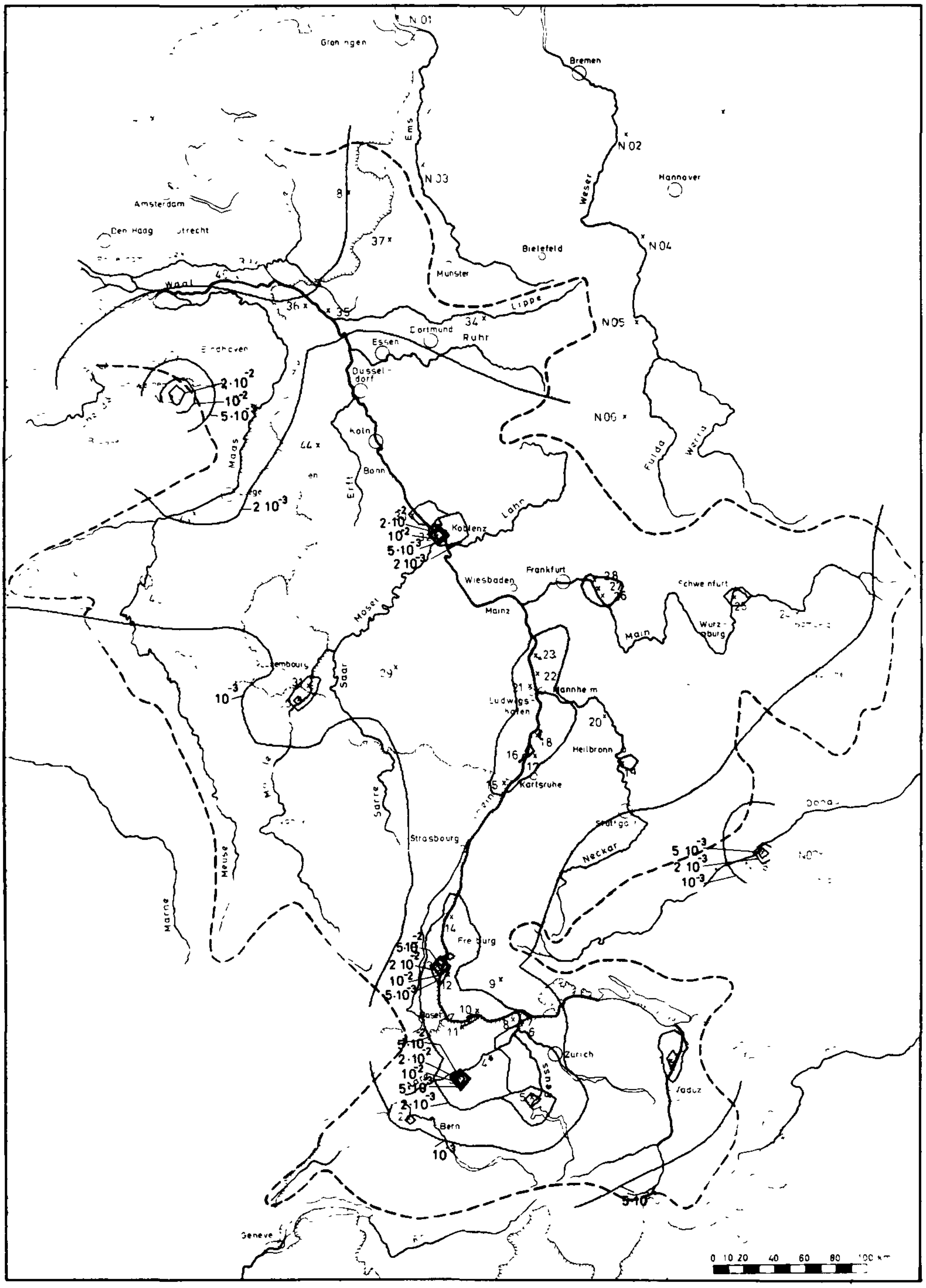
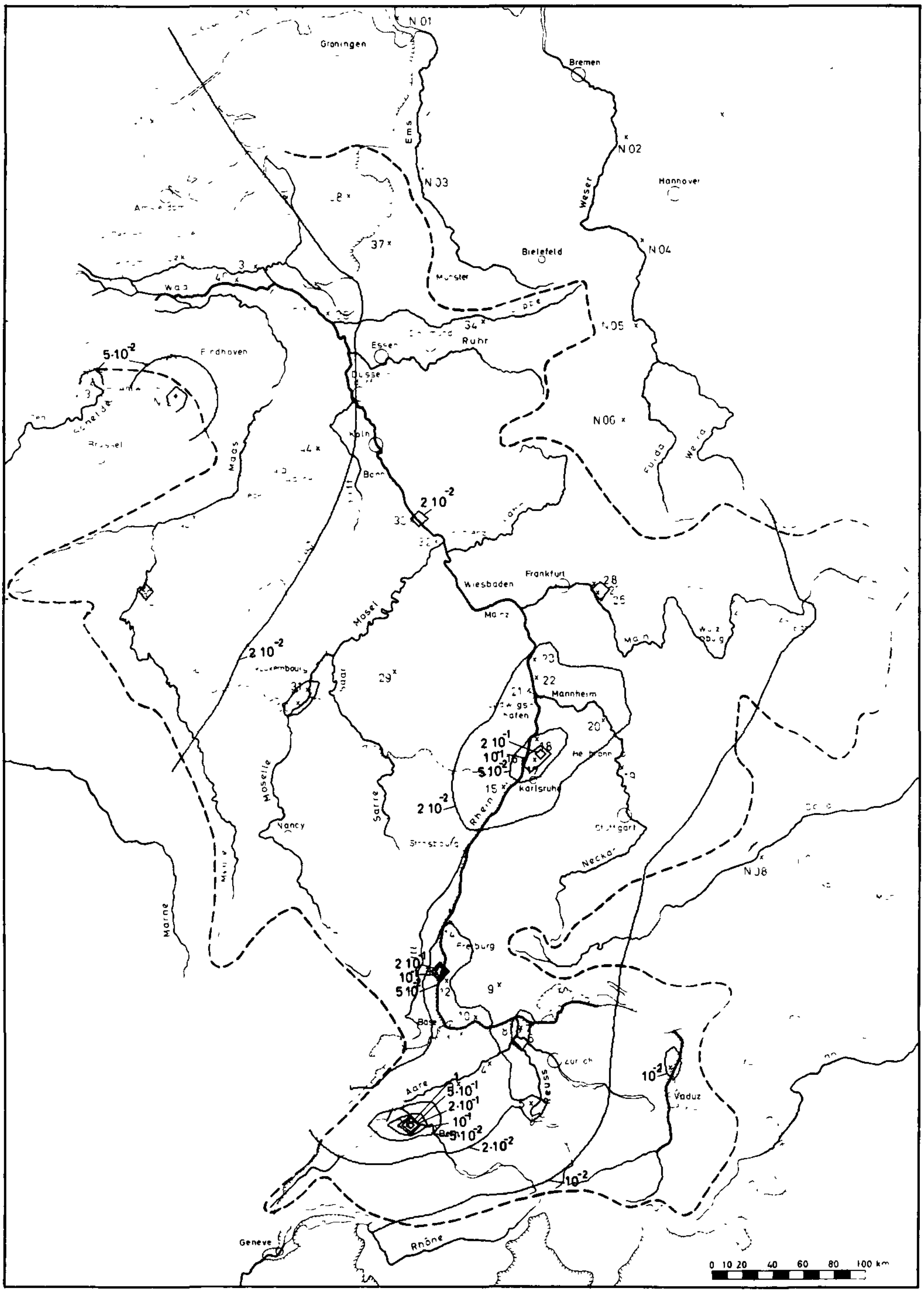
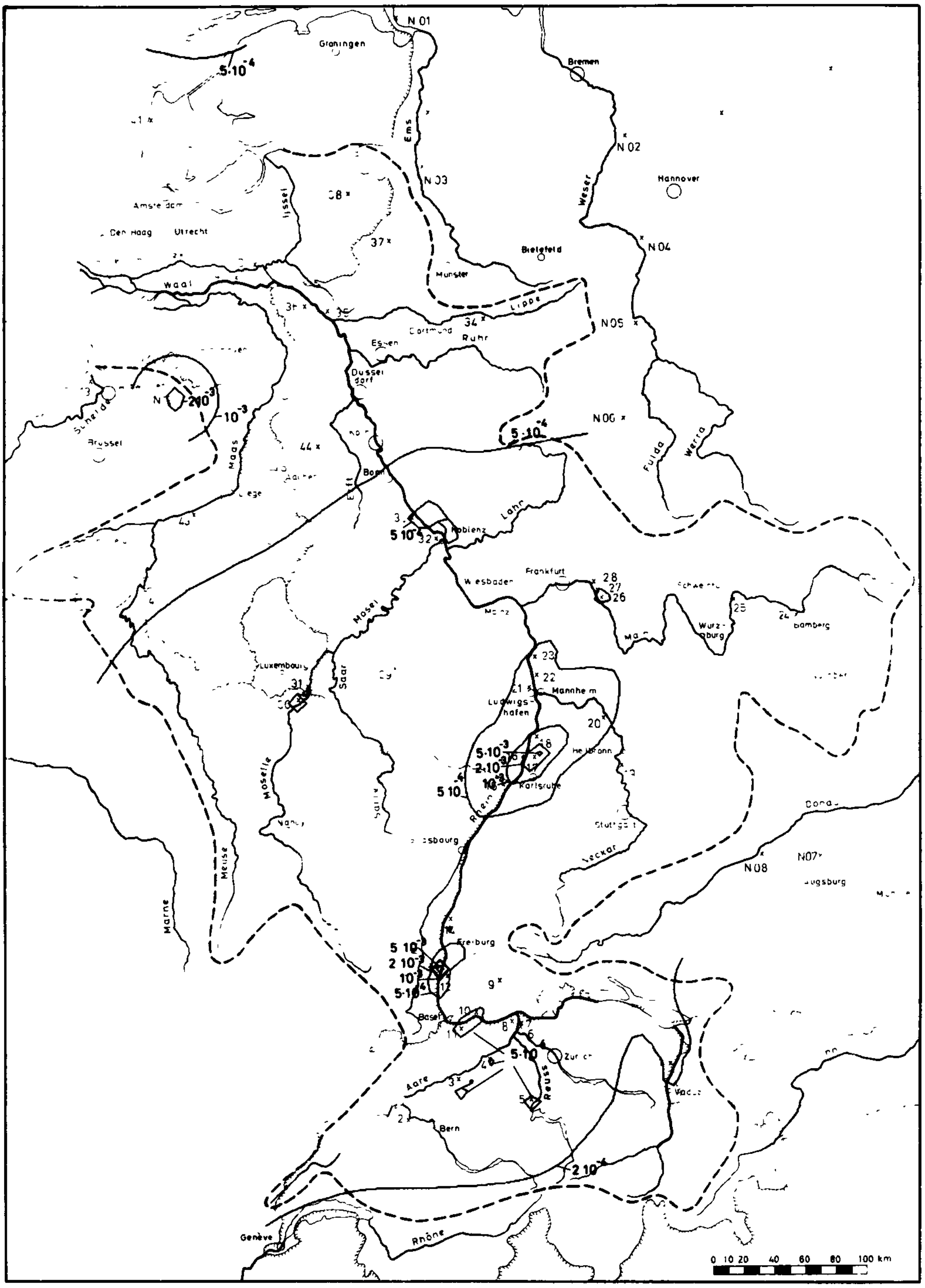



Fig. 6-1.2b: Regional Pattern of Whole Body-Dose Rates [mrem/yr] from External Ground Exposure, assuming that the Ground Concentration has achieved State of Equilibrium




<u>Fig. 6-1.3:</u> Regional Pattern of Skin-Dose Rates [mrem/yr] from External Cloud β-Exposure around the Years 1985/90




<u>Fig. 6-2.1:</u> **Regional Pattern of Whole Body-Dose Rates [mrem/yr] for the Average Person from Inhalation around the Years 1985/90**

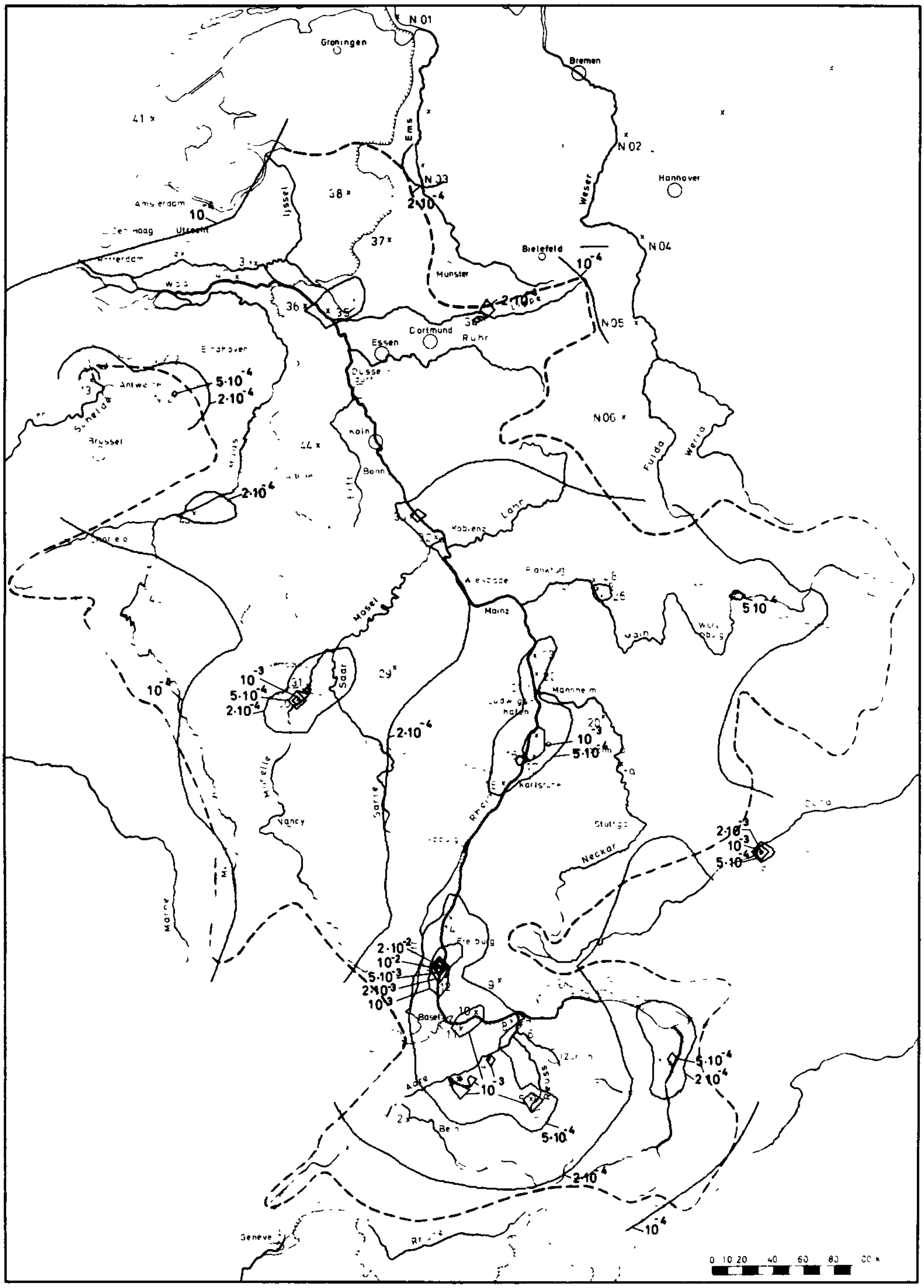



Fig. 6-2.2: Regional Pattern of Bone-Dose Rates [mrem/yr] for the Average Person from Inhalation around the Years 1985/90

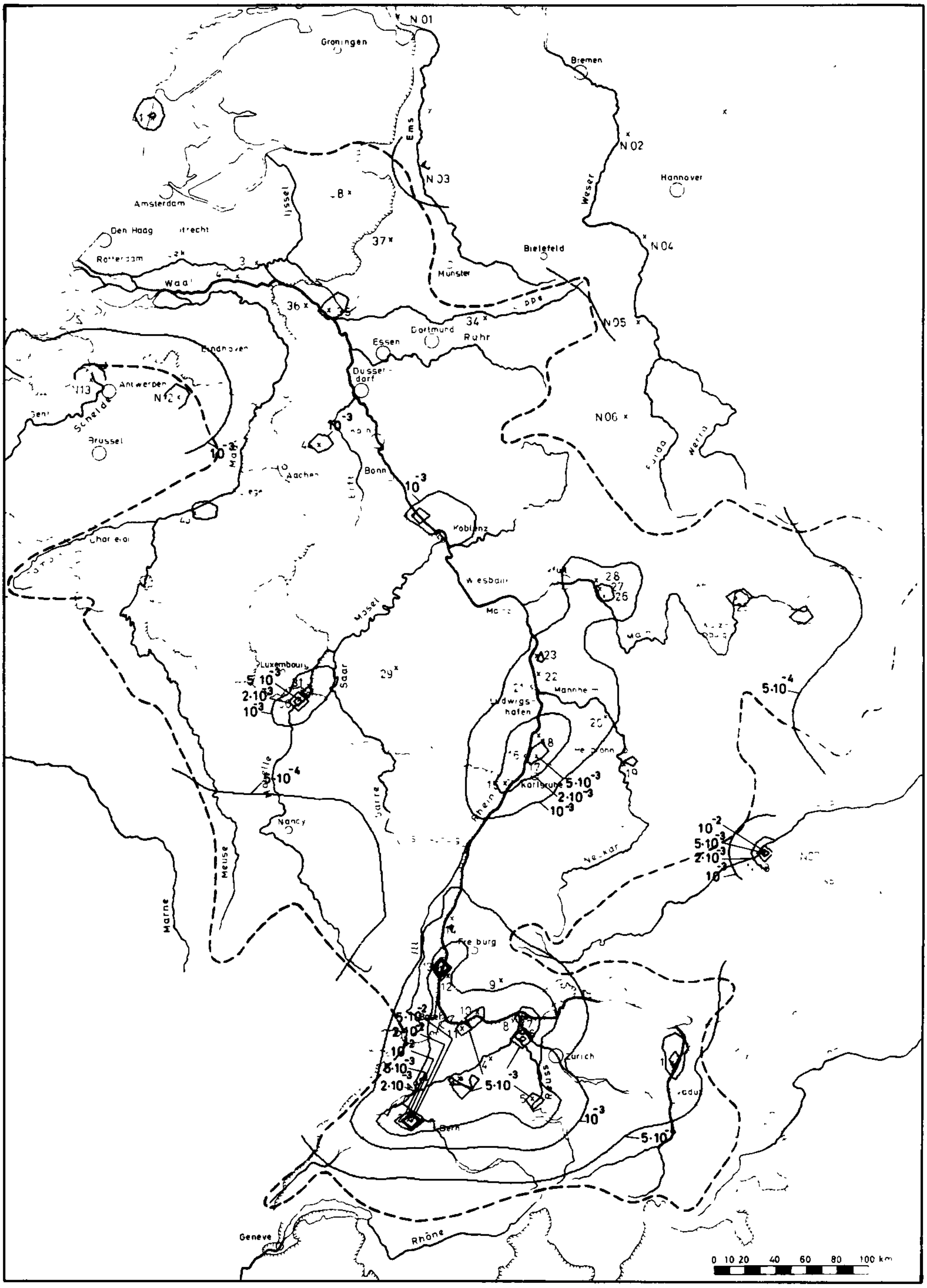
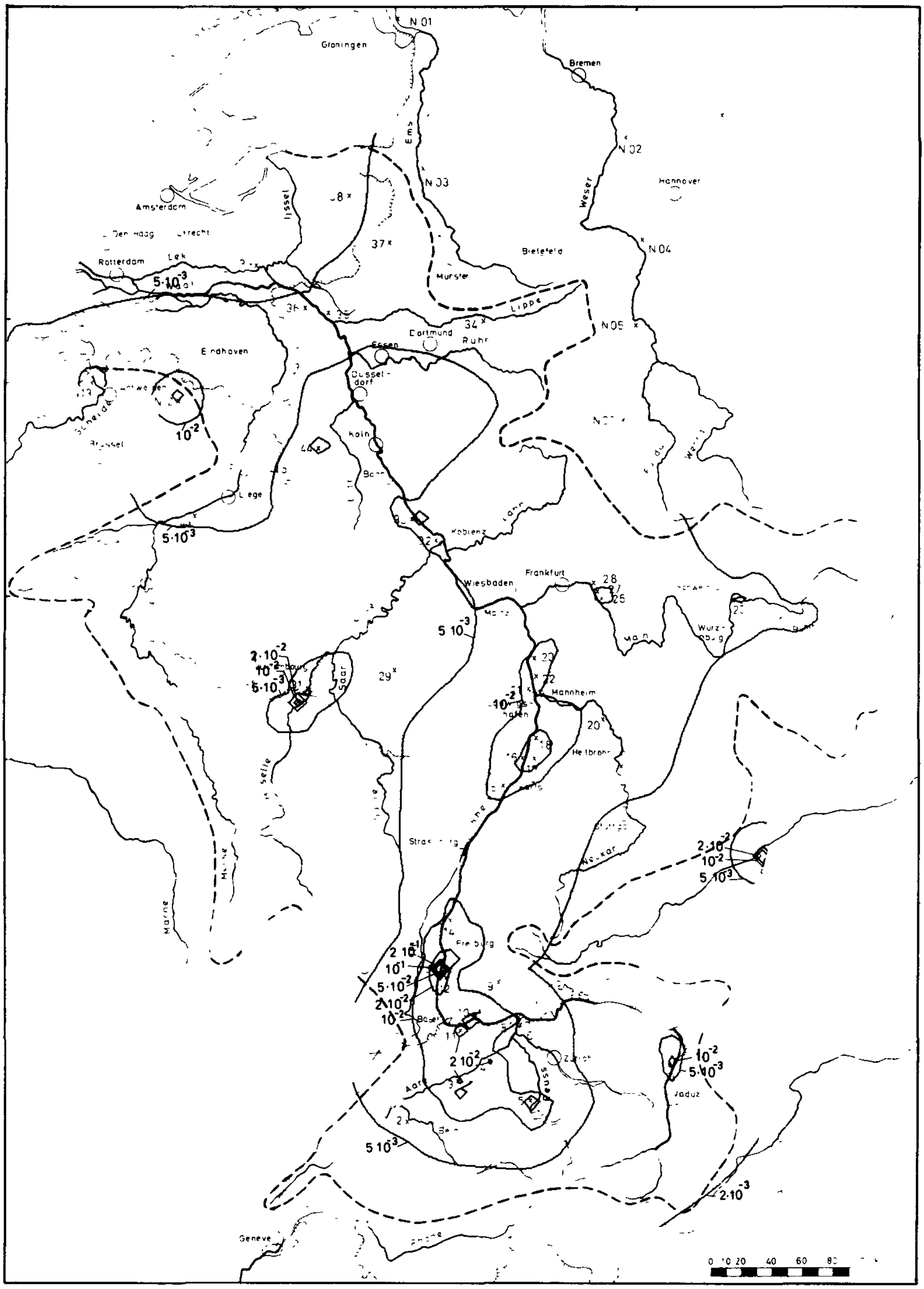



Fig. 6-2.3: Regional Pattern of Thyroid-Dose Rates [mrem/yr] for the Average Person from Inhalation around the Years 1985/90




<u>Fig. 6-3.1:</u> Regional Pattern of Whole Body-Dose Rates [mrem/yr] for the Average Person from Ingestion around the Years 1985/90

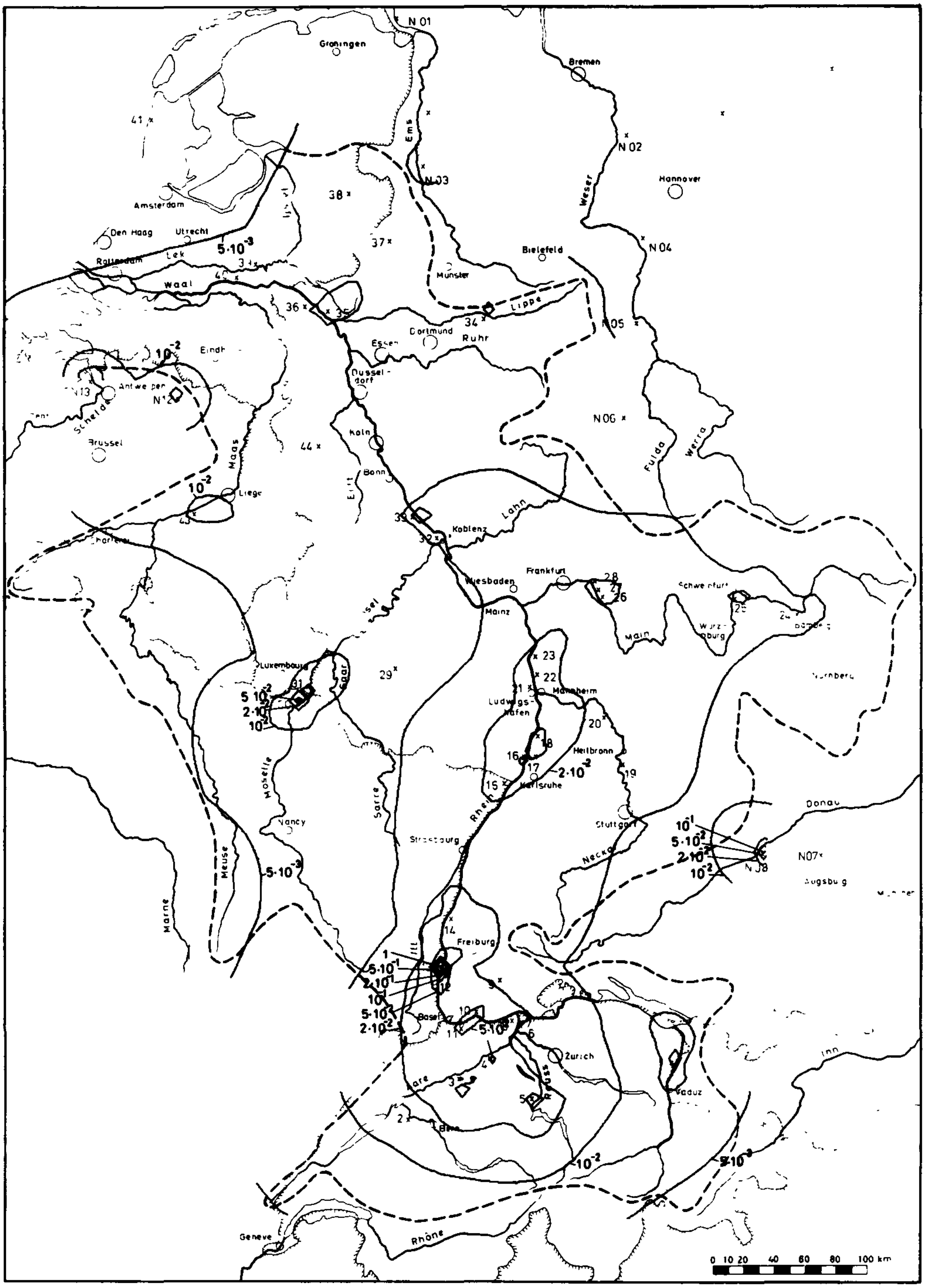



Fig. 6-3.2: Regional Pattern of Bone-Dose Rates [mrem/yr] for the Average Person from Ingestion around the Years 1985/90

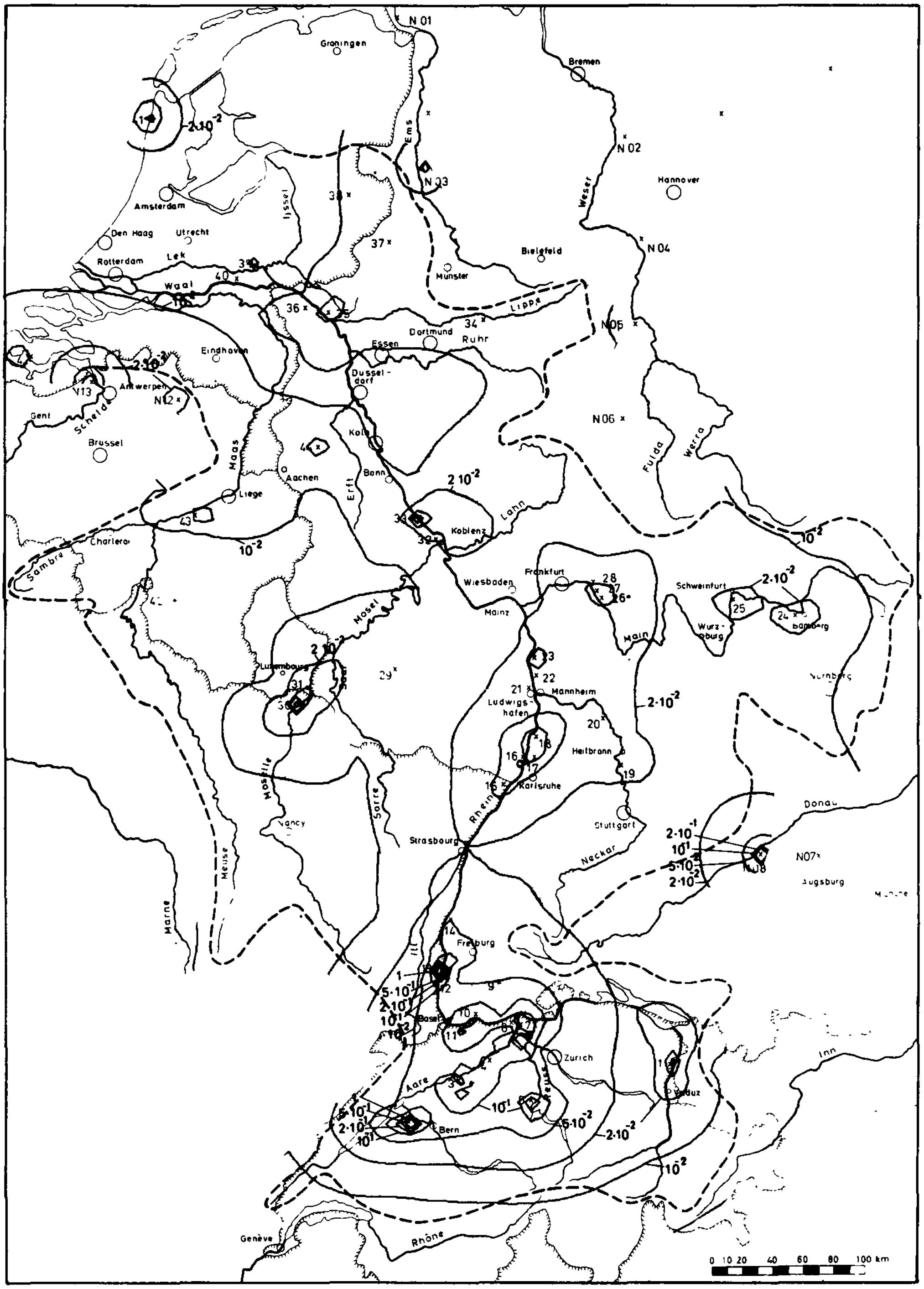



Fig. 6-3.3: Regional Pattern of Thyroid-Dose Rates [mrem/yr] for the Average Person from Ingestion around the Years 1985/90

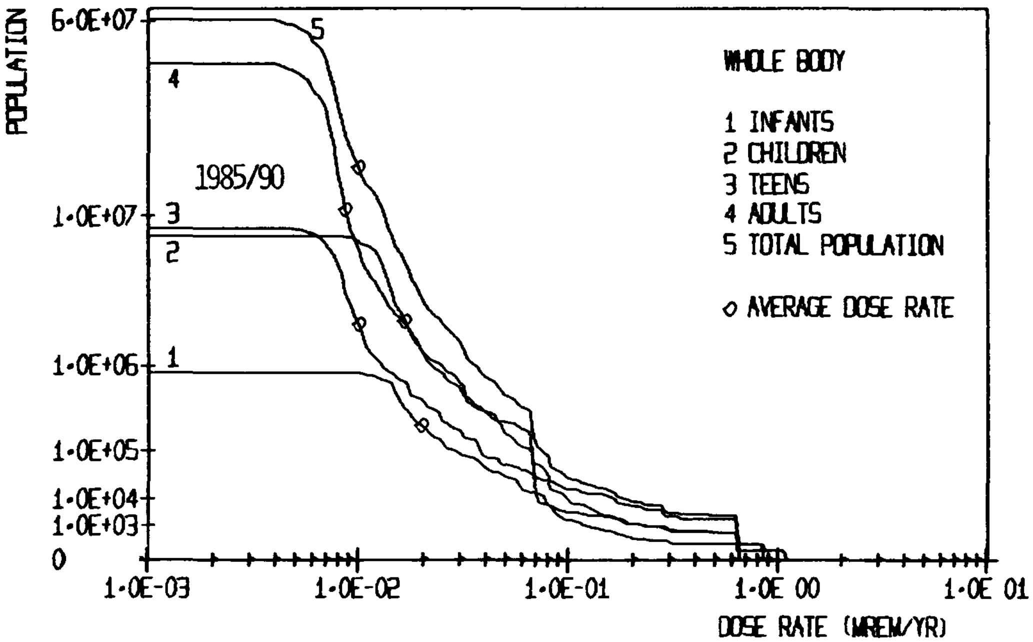



Fig. 6-4.1a: Distribution of Whole Body-Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

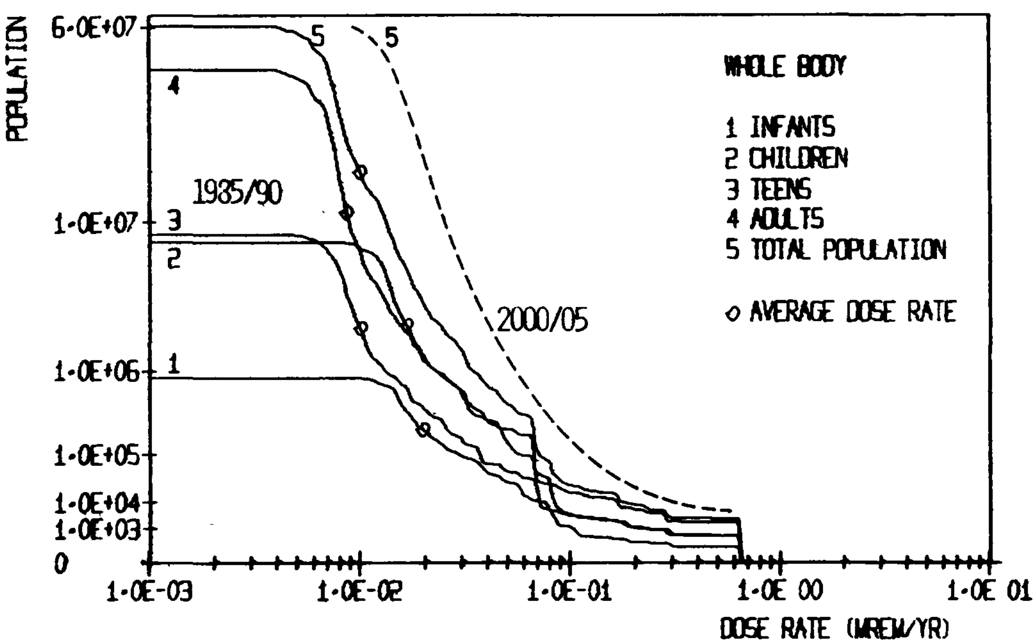



Fig. 6-4.1b: Distribution of Whole Body-Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contribution from Ingestion: dependent on averaged District Values

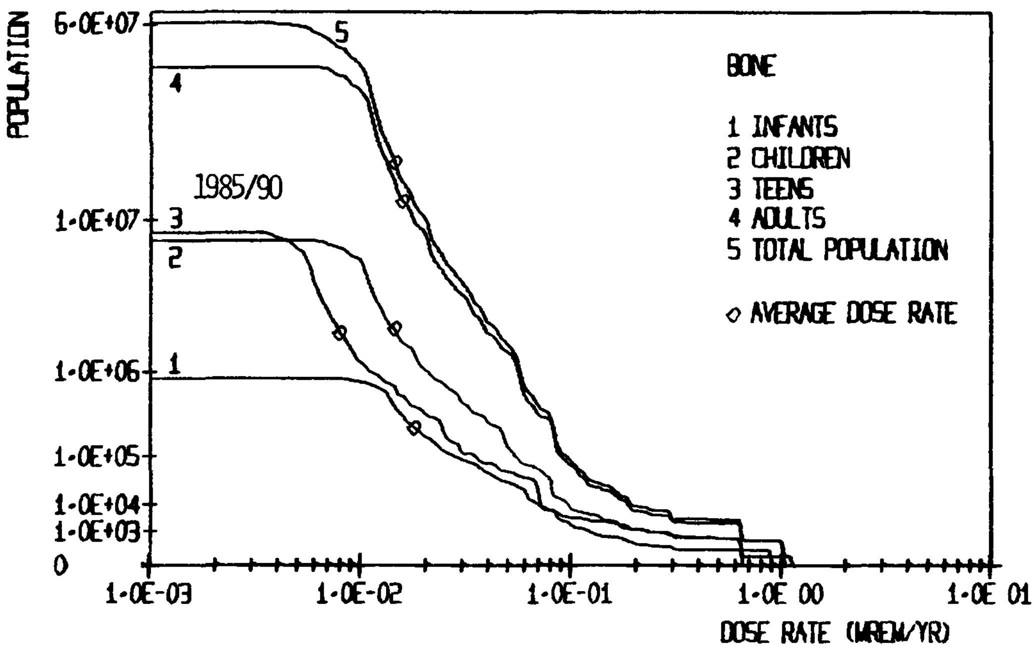



Fig. 6-4.2a: Distribution of Bone-Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

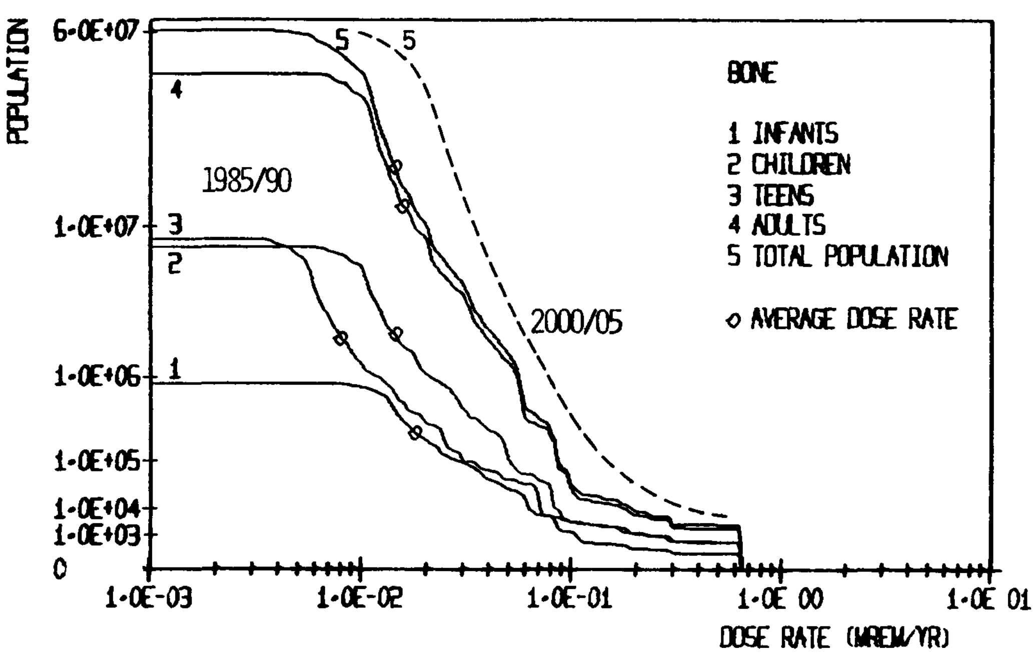



Fig. 6-4.2b: Distribution of Bone-Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contribution from Ingestion: dependent on averaged District Values

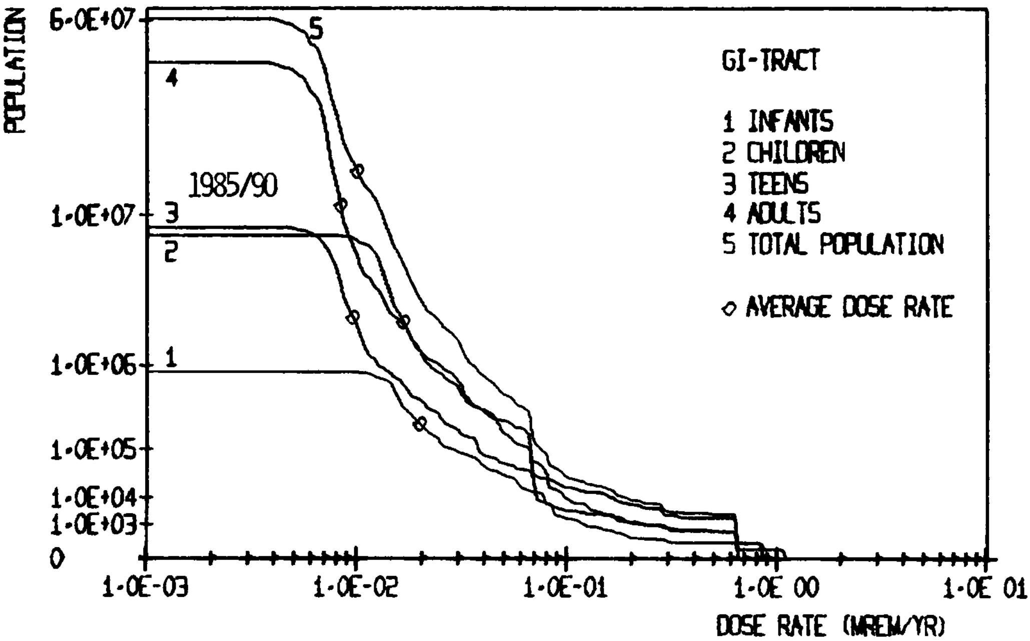



Fig. 6-4.3a: Distribution of GI-Tract-Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

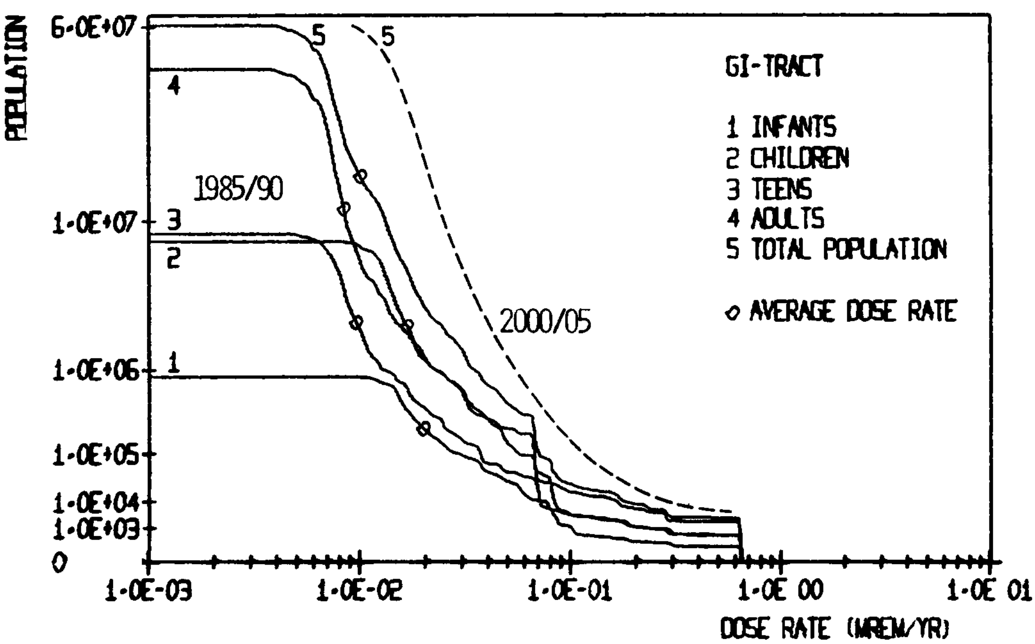



Fig. 6-4.3b: Distribution of GI-Tract-Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contribution from Ingestion: dependent on averaged District Values

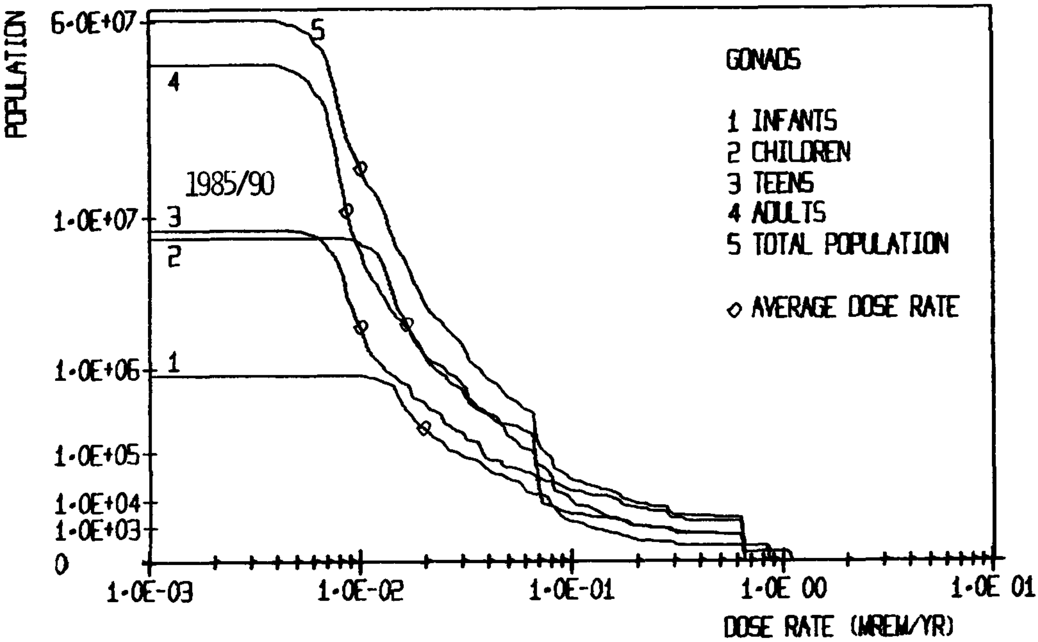



Fig. 6-4.4a: Distribution of Gonad - Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

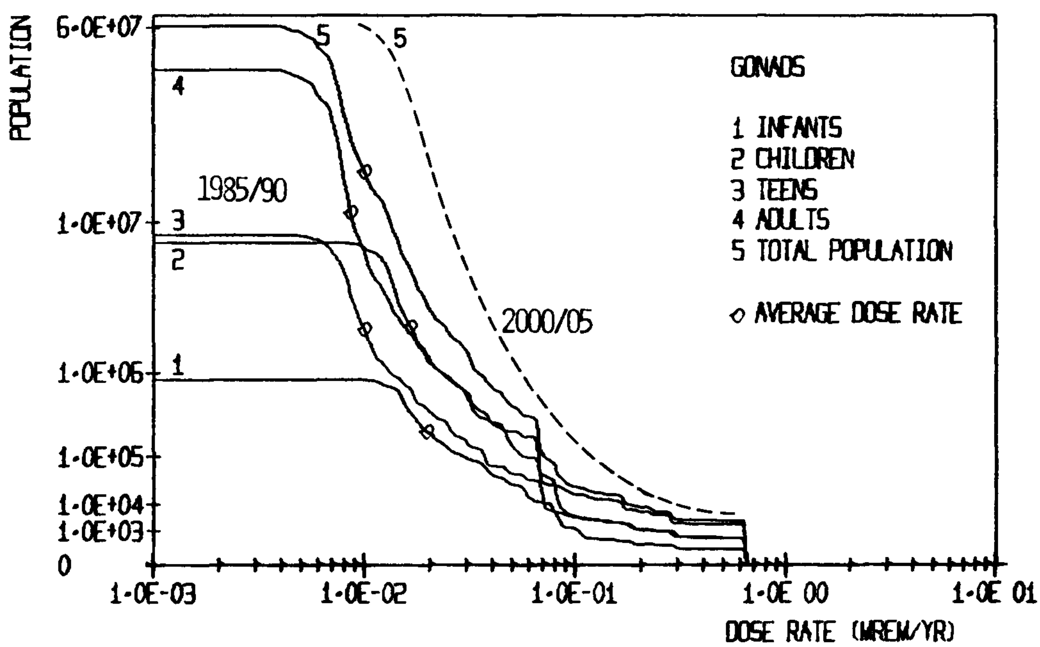



Fig. 6-4.4b: Distribution of Gonad - Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contribution from Ingestion: dependent on averaged District Values

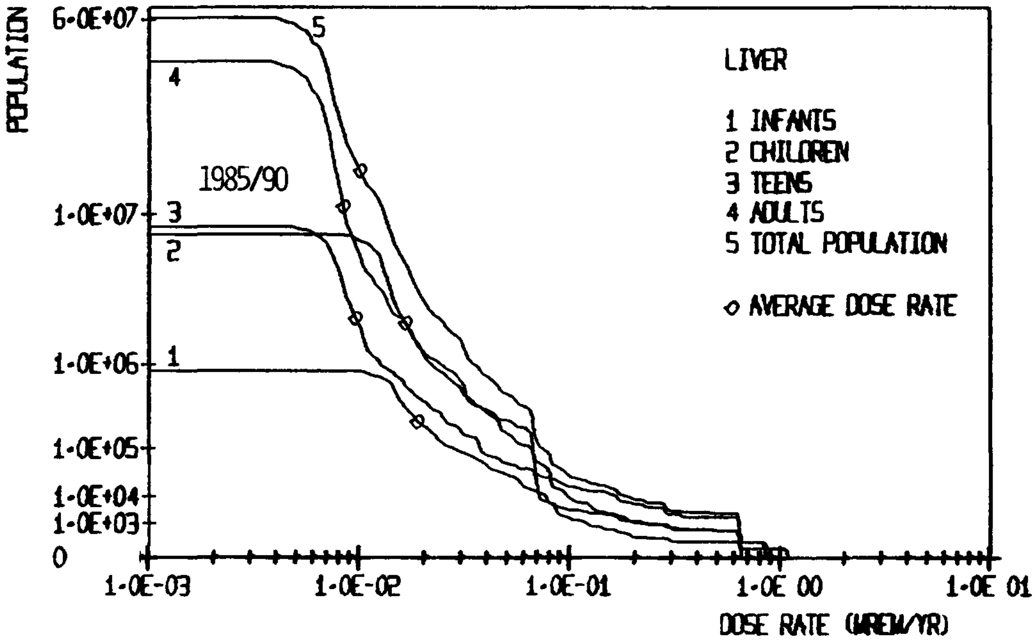



Fig. 6-4.5a: Distribution of Liver-Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

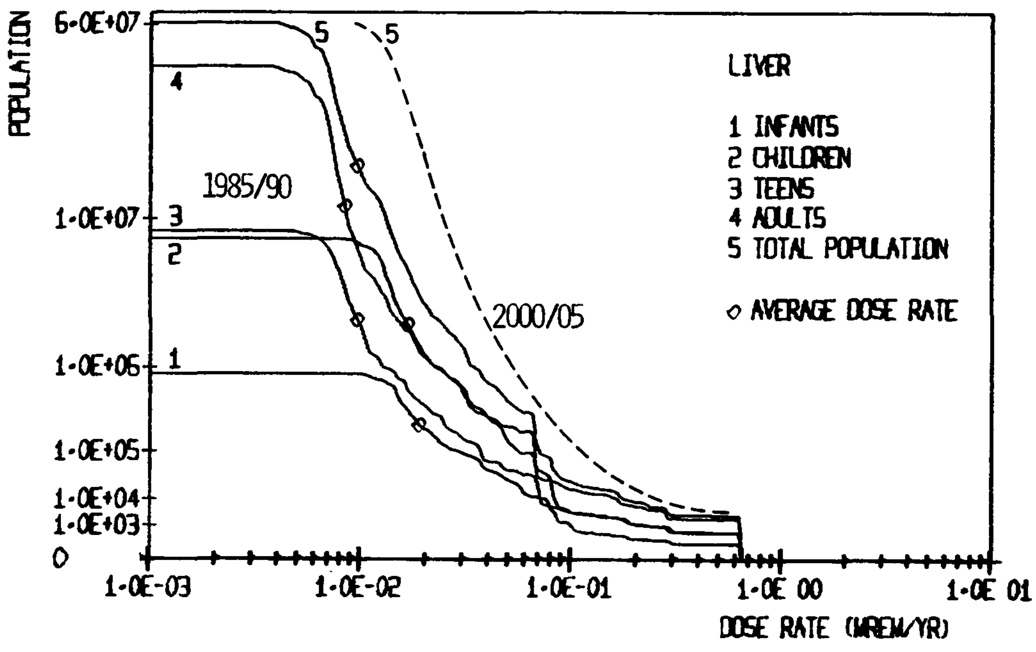



Fig. 6-4.5b: Distribution of Liver-Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contributions from Ingestion: dependent on averaged District Values

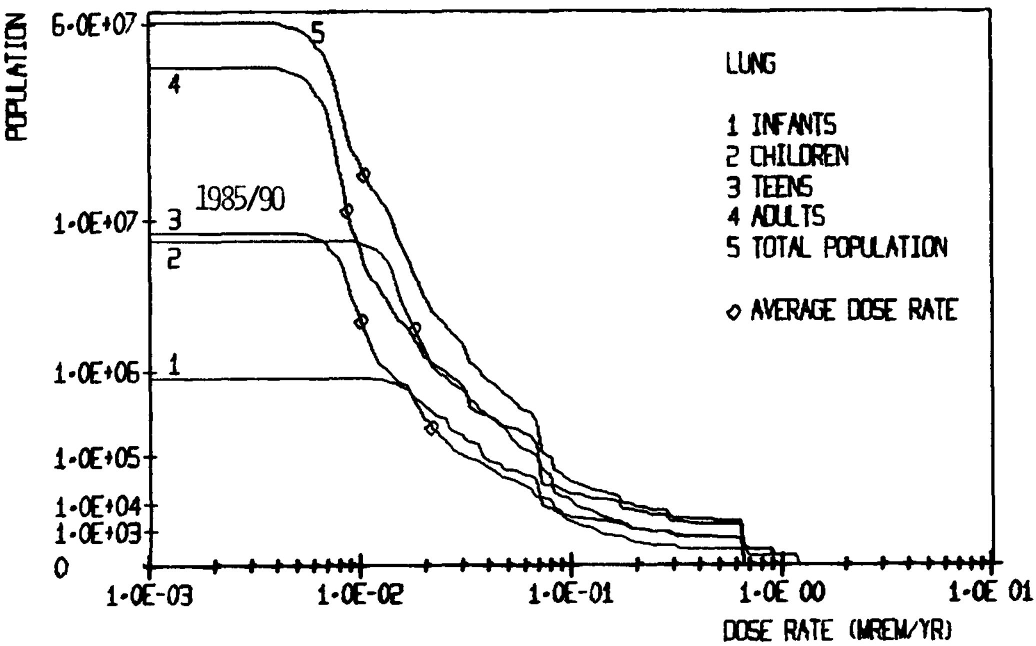



Fig. 6-4.6a: Distribution of Lung-Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

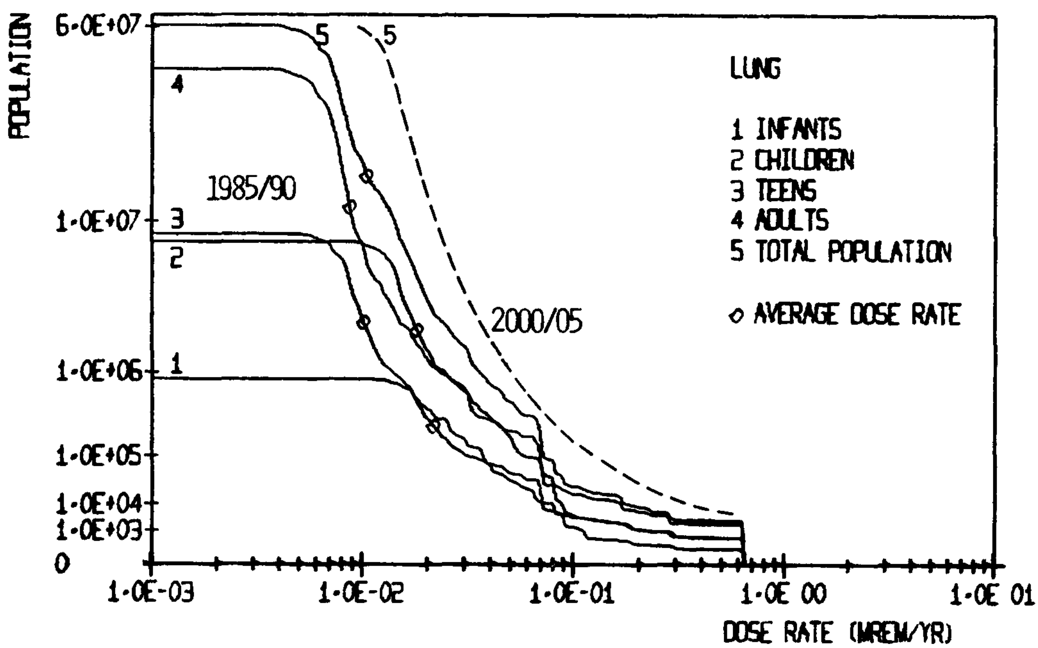



Fig. 6-4.6b: Distribution of Lung-Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contribution from Ingestion: dependent on averaged District Values

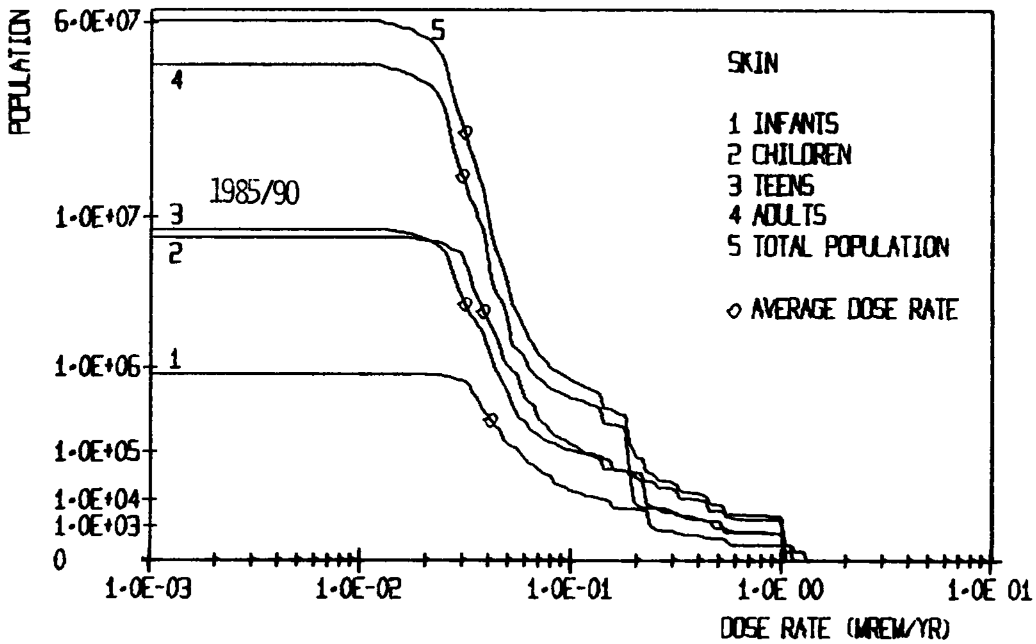



Fig. 6-4.7a: Distribution of Skin-Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

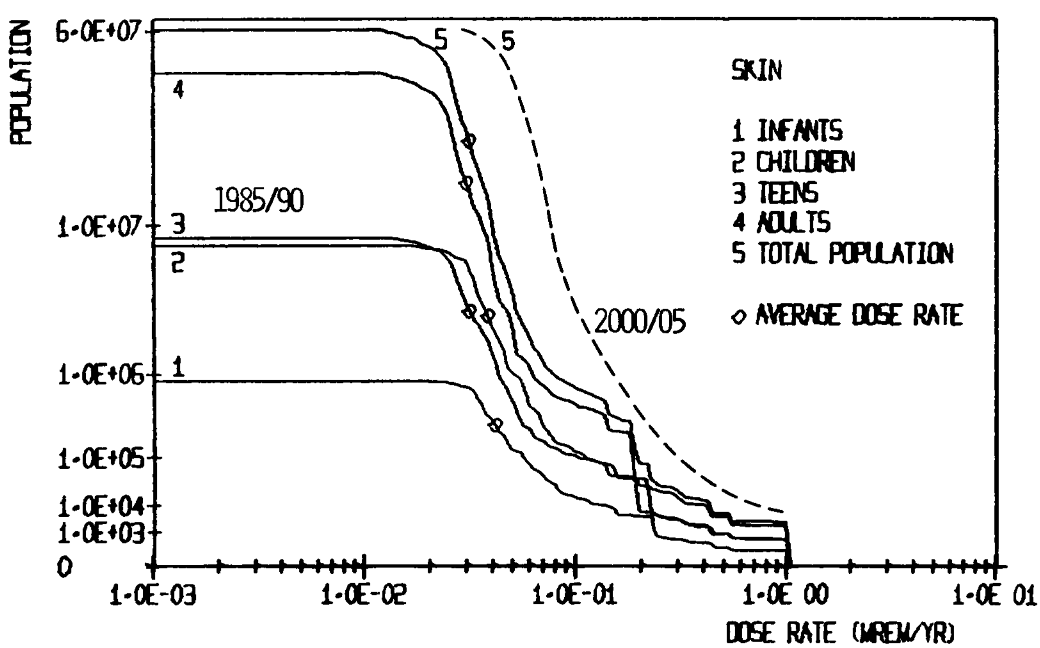



Fig. 6-4.7b: Distribution of Skin-Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contribution from Ingestion: dependent on averaged District Values

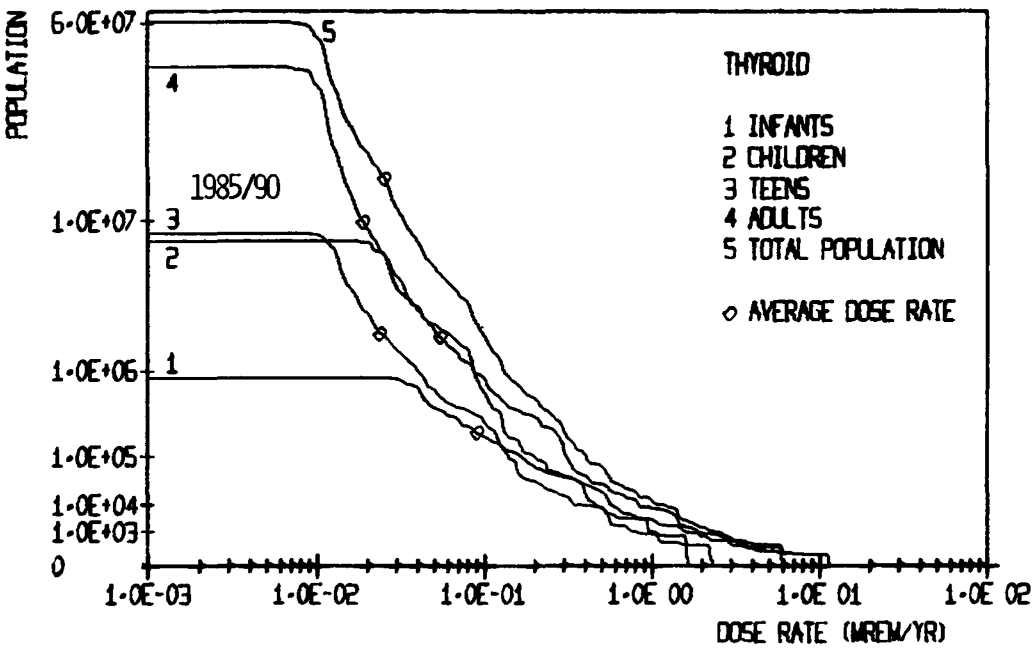



Fig. 6-4.8a: Distribution of Thyroid-Dose Rates from Gaseous Releases around the Years 1985/90
Contribution from Ingestion: dependent on local Community Values

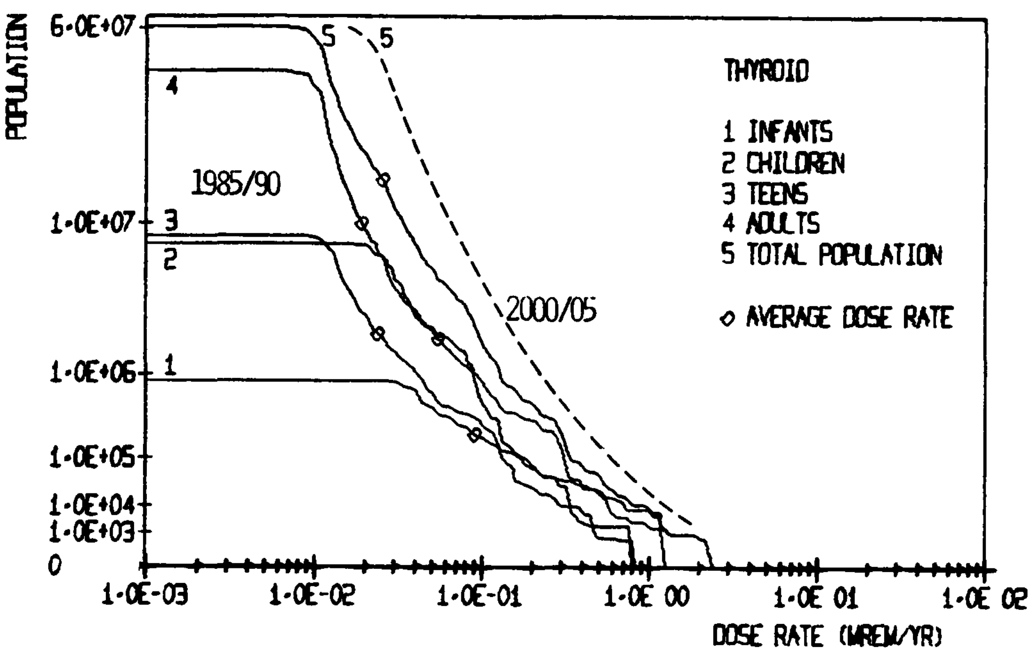



Fig. 6-4.8b: Distribution of Thyroid-Dose Rates from Gaseous Releases around the Years 1985/90 and Extrapolation to the Years 2000/05
Contribution from Ingestion: dependent on averaged District Values

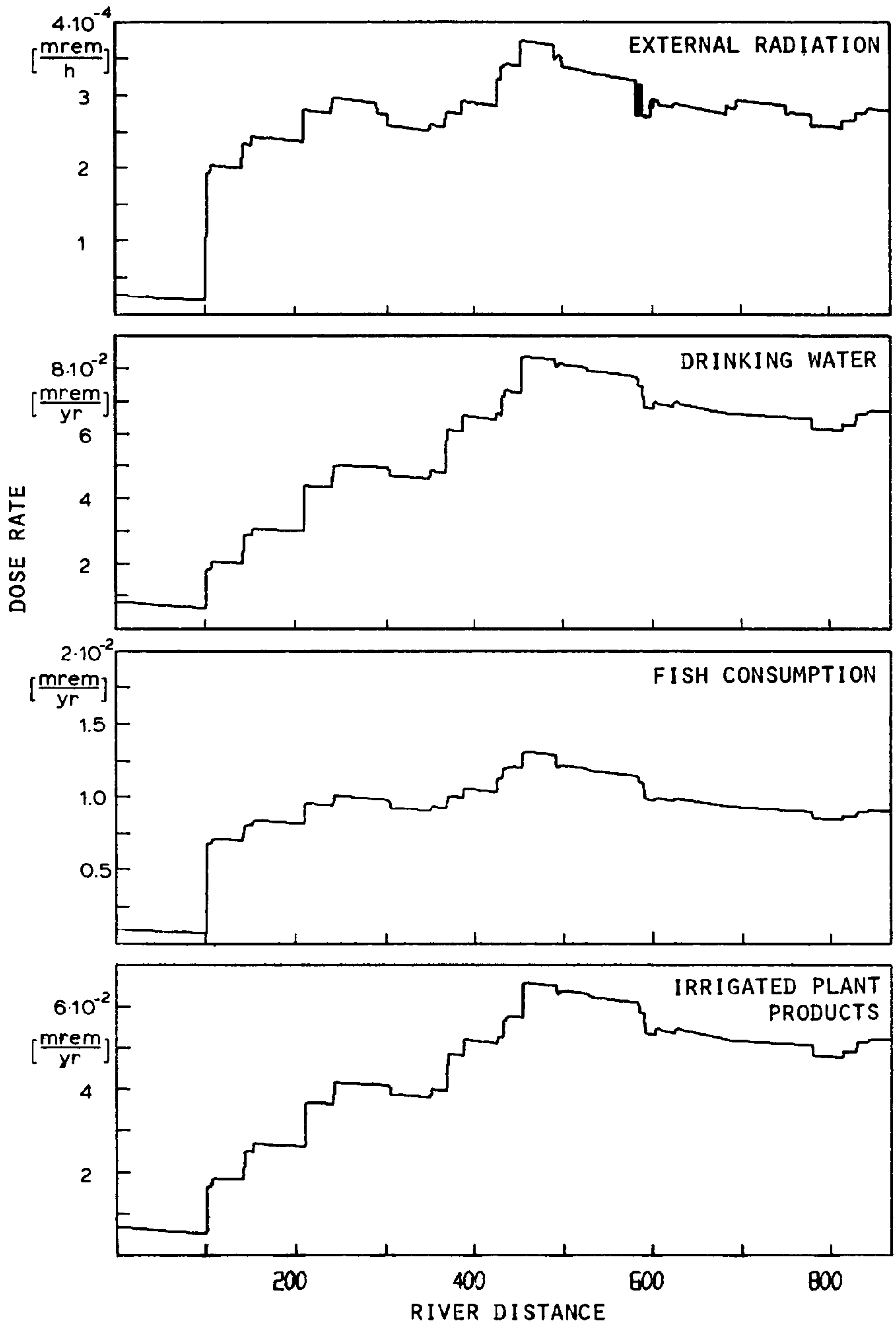
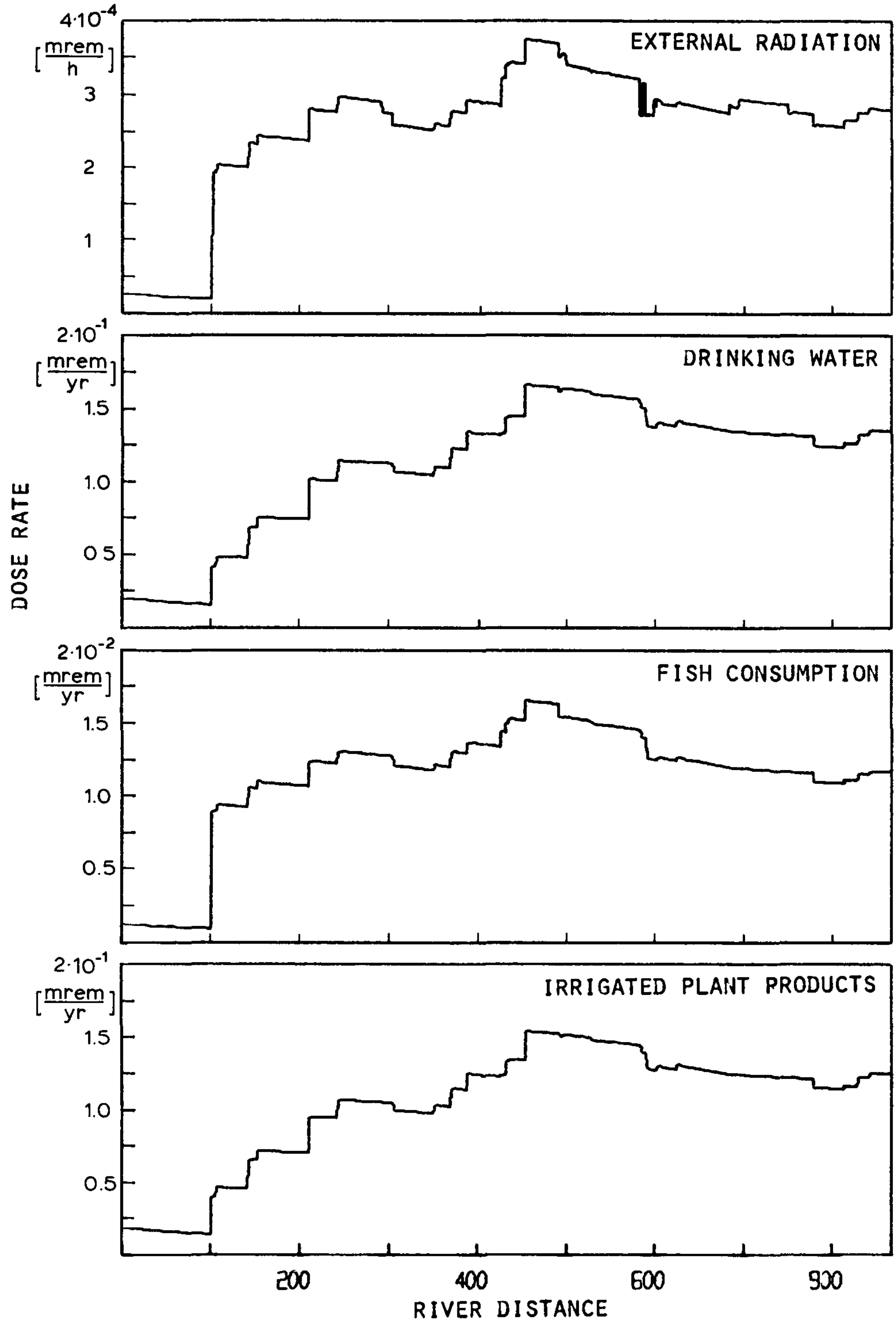



Fig. 6-5.1: **Fluvial Pattern of Whole Body-Dose Rates along the River Rhein via Various Exposure Pathways around the Years 1985/90**




<u>Fig. 6-5.2:</u> **Fluvial Pattern of Bone-Dose Rates along the River Rhein via Various Exposure Pathways around the Years 1985/90**

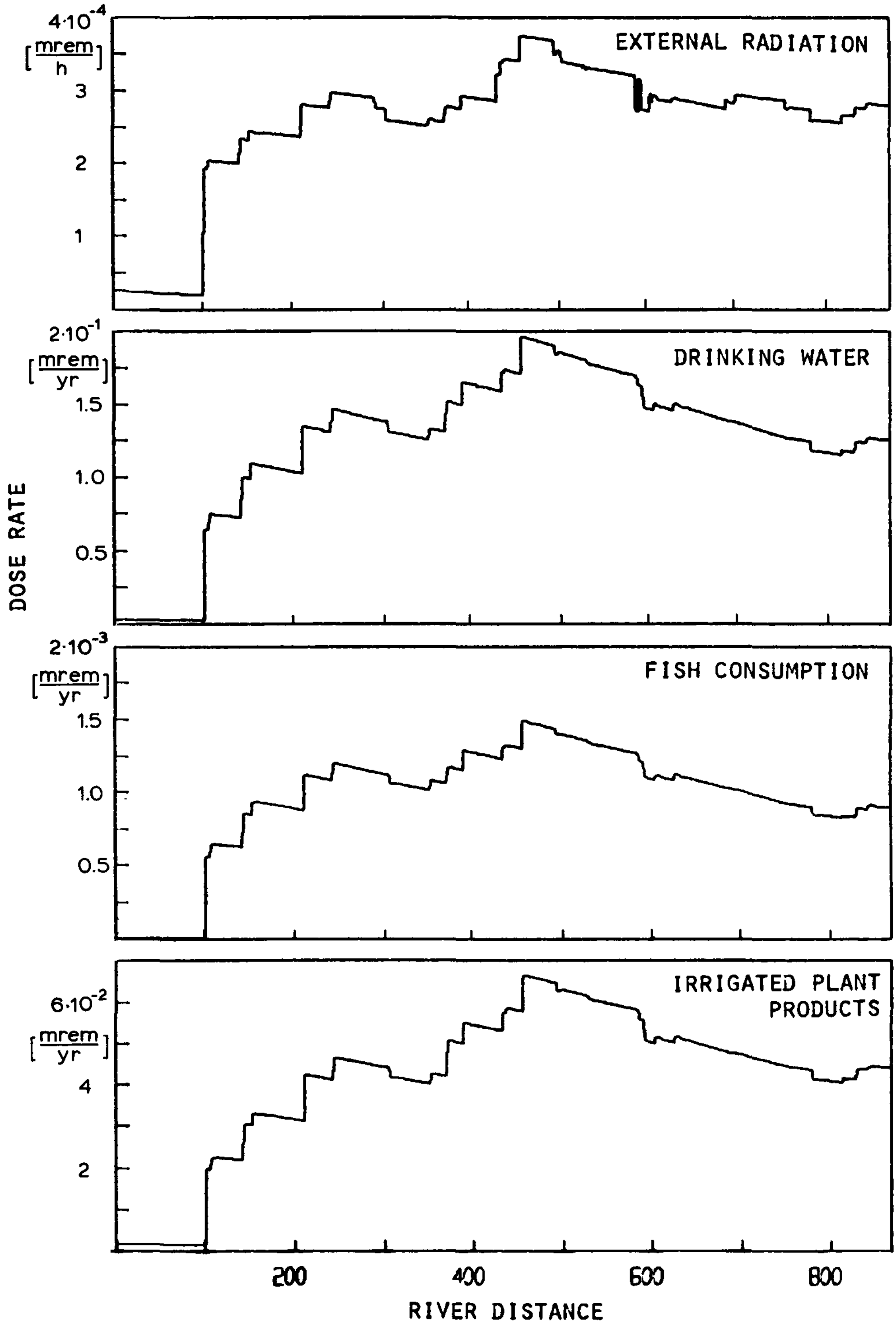



**Fig. 6-5.3:** **Fluvial Pattern of Thyroid-Dose Rates along the River Rhein via Various Exposure Pathways around the Years 1985/90**

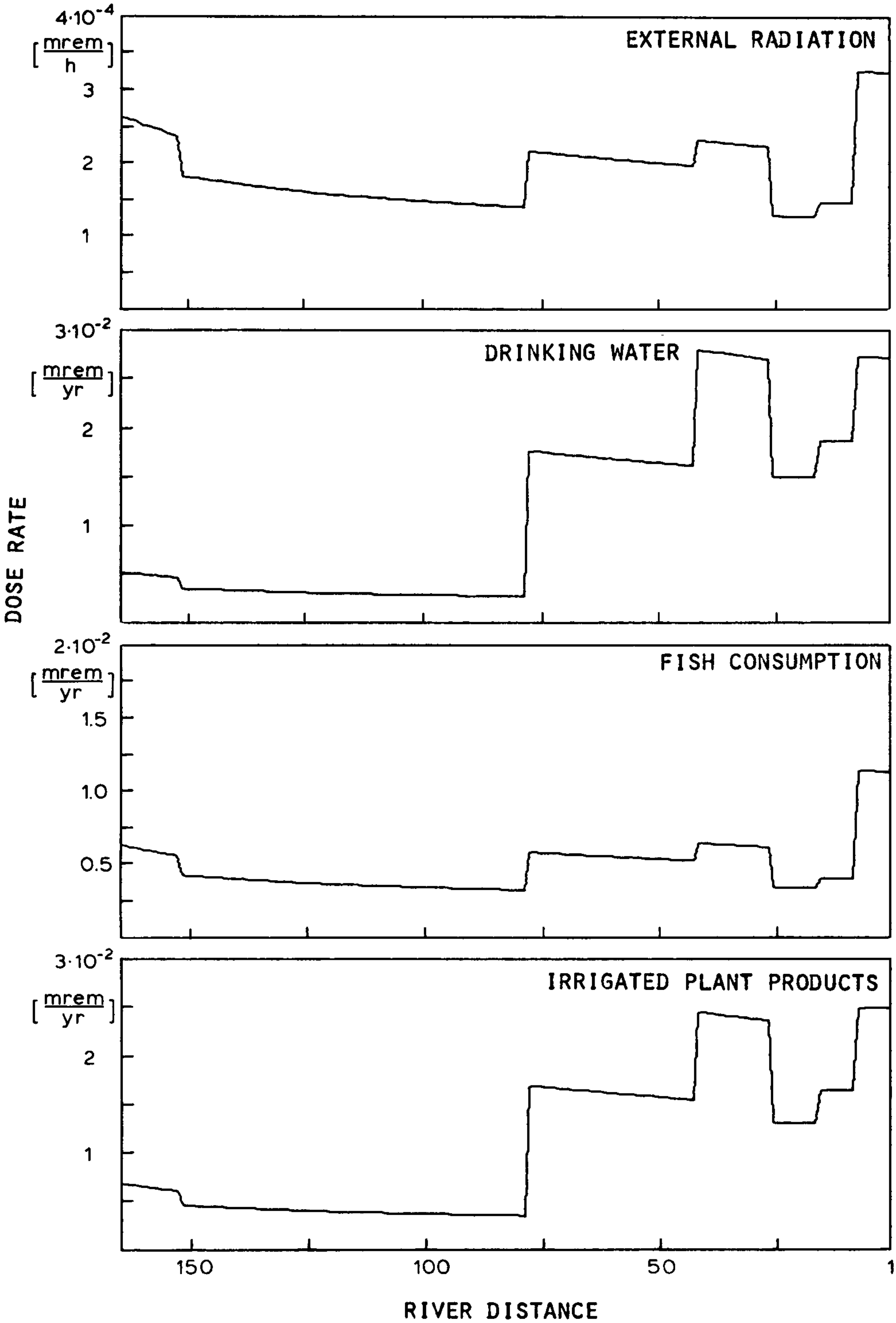



Fig. 6-6.1: Fluvial Pattern of Whole Body-Dose Rates along the River Aare from Various Exposure Pathways around the Years 1985/90

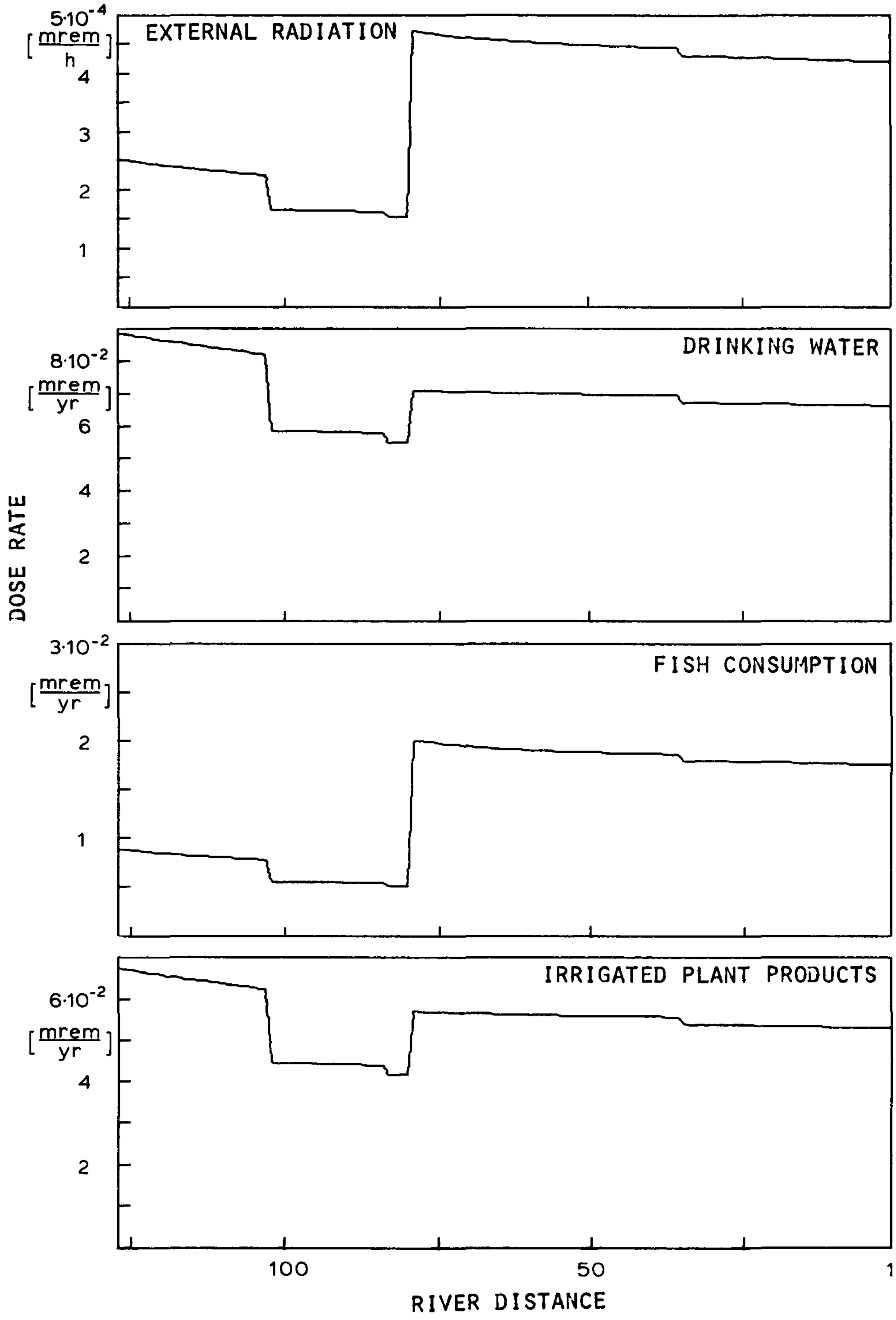



Fig. 6-6.2: Fluvial Pattern of Whole Body-Dose Rates along the River Neckar from Various Exposure Pathways around the Years 1985/9o

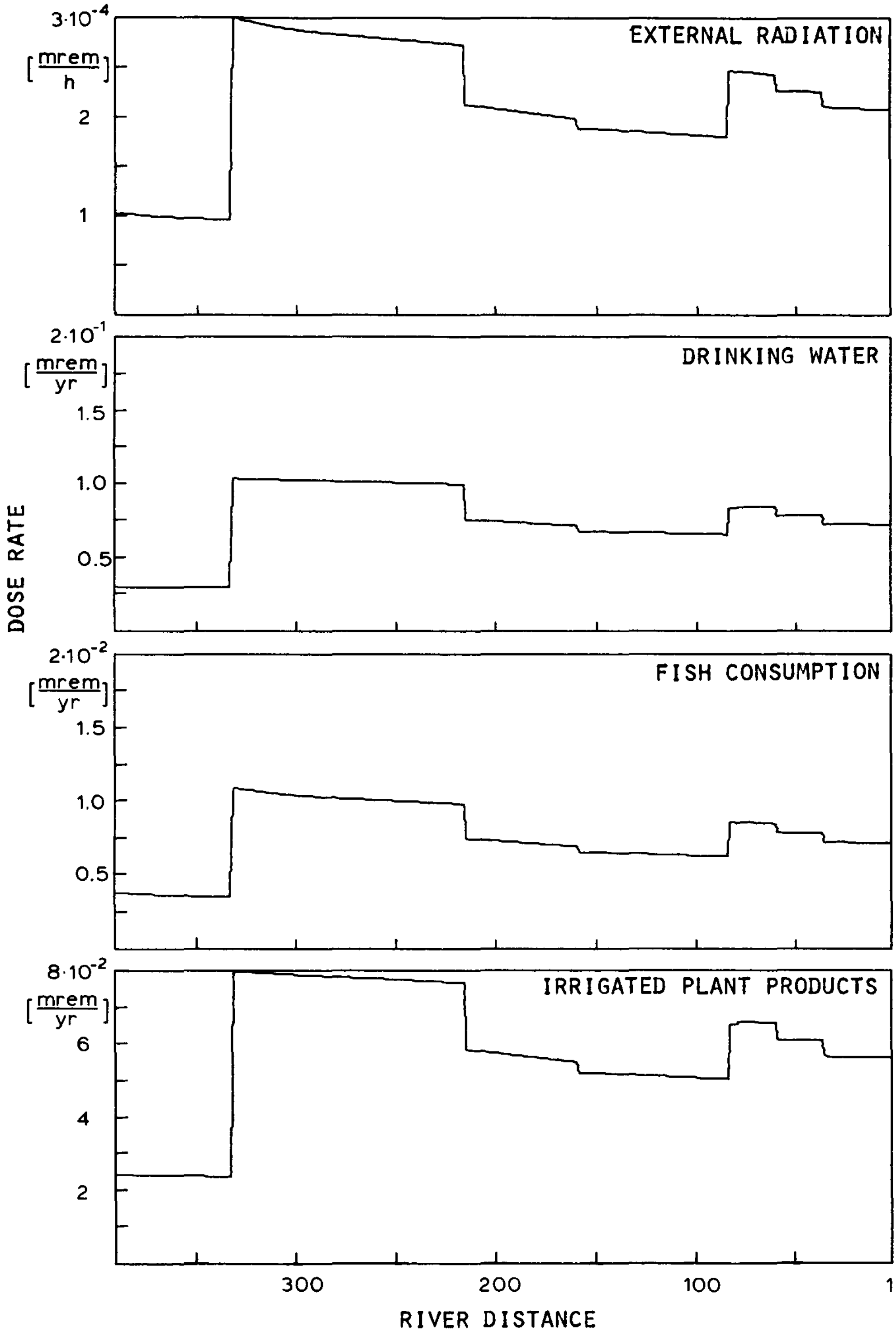
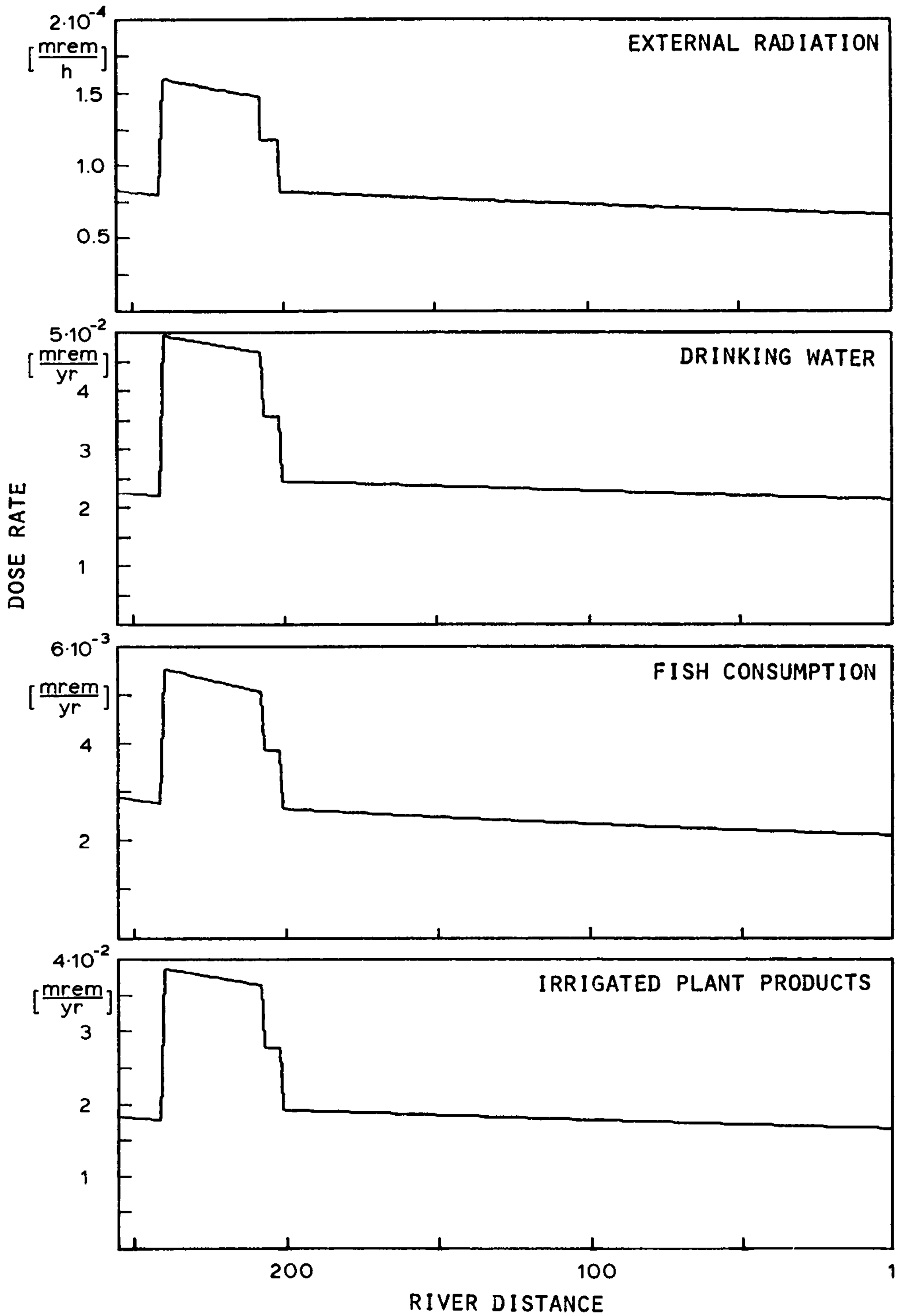



**Fig. 6-6.3:** Fluvial Pattern of Whole Body-Dose Rates along the River Main from Various Exposure Pathways around the Years 1985/90




<u>Fig. 6-6.4:</u> **Fluvial Pattern of Whole Body-Dose Rates along the River Mosel from Various Exposure Pathways around the Years 1985/90**

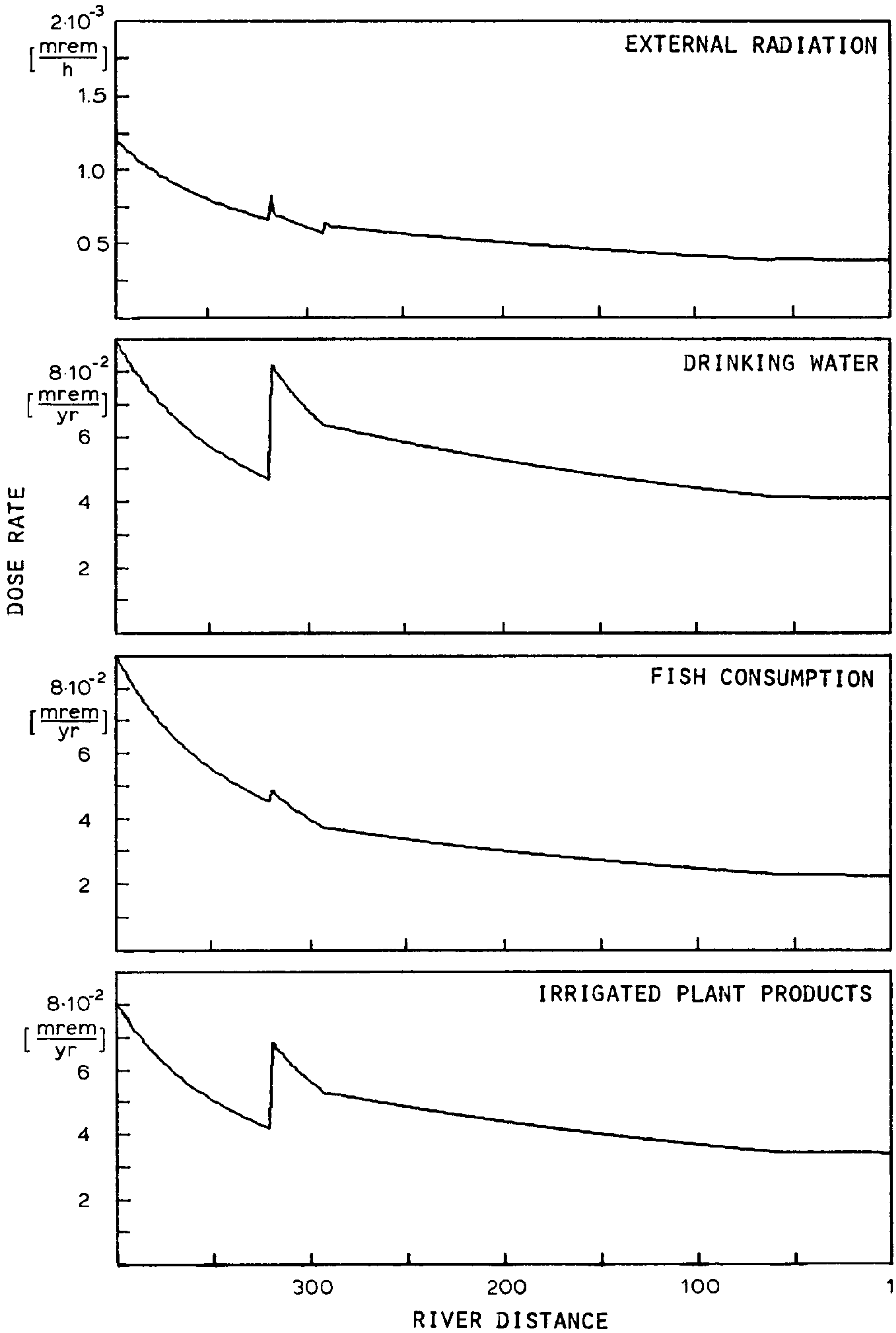



**Fig. 6-6.5: Fluvial Pattern of Whole Body-Dose Rates along the River Maas from Various Exposure Pathways around the Years 1985/90**

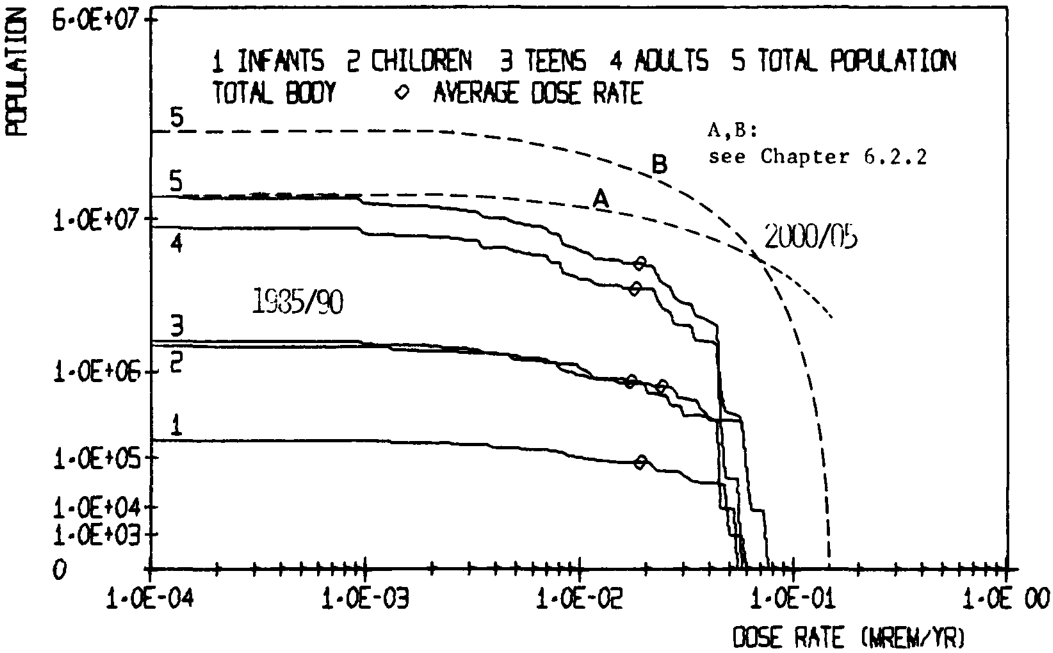



Fig. 6-7.1: Distribution of Whole Body-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

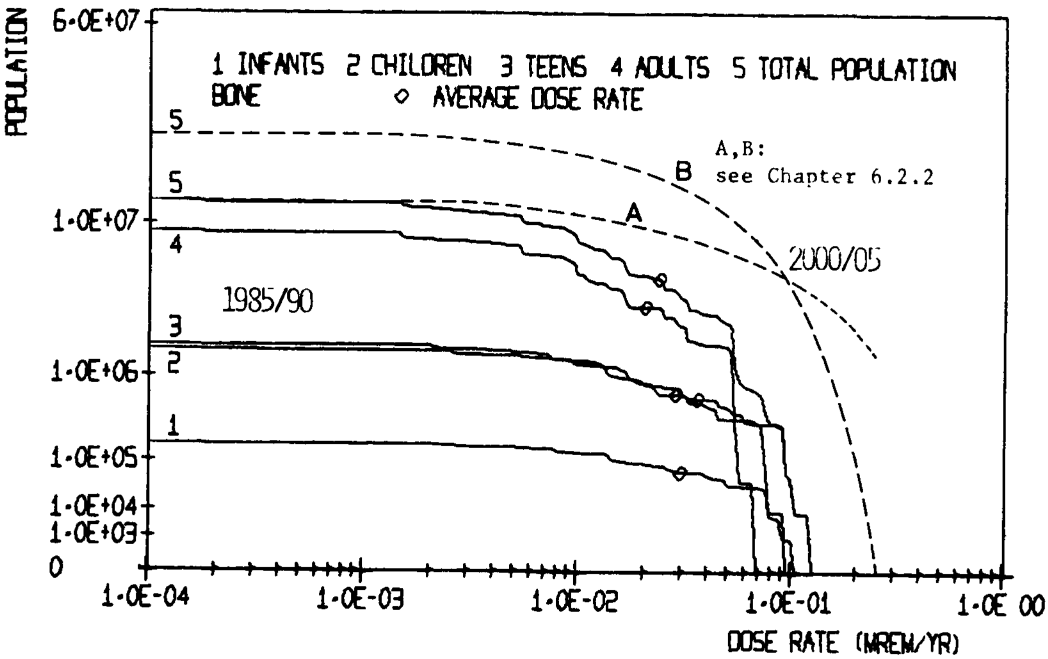



Fig. 6-7.2: Distribution of Bone-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

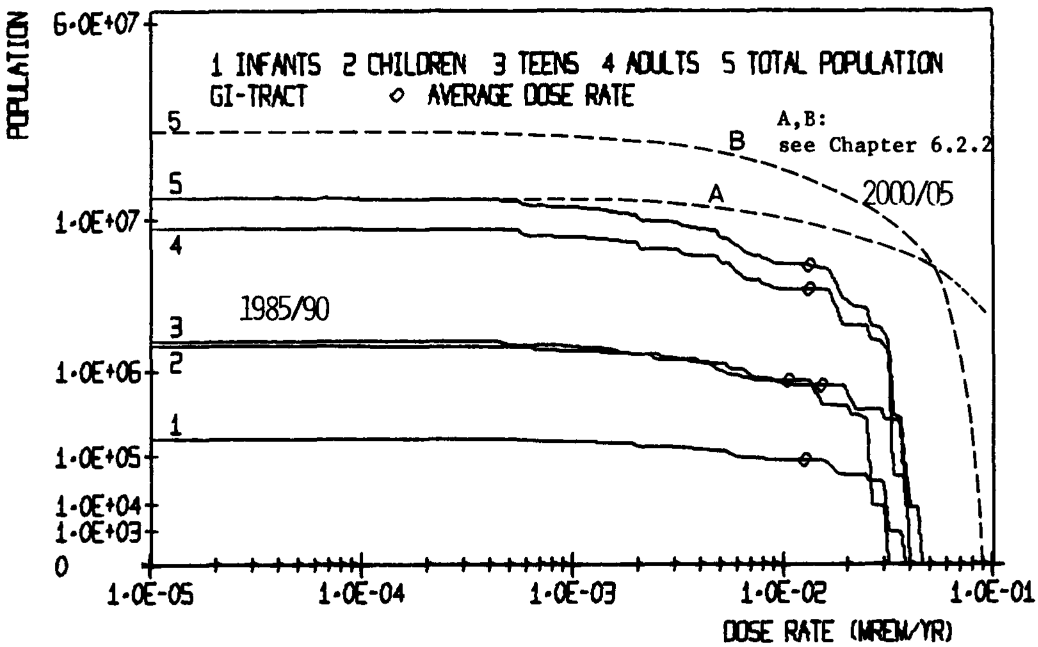



Fig. 6-7.3: Distribution of GI-Tract-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

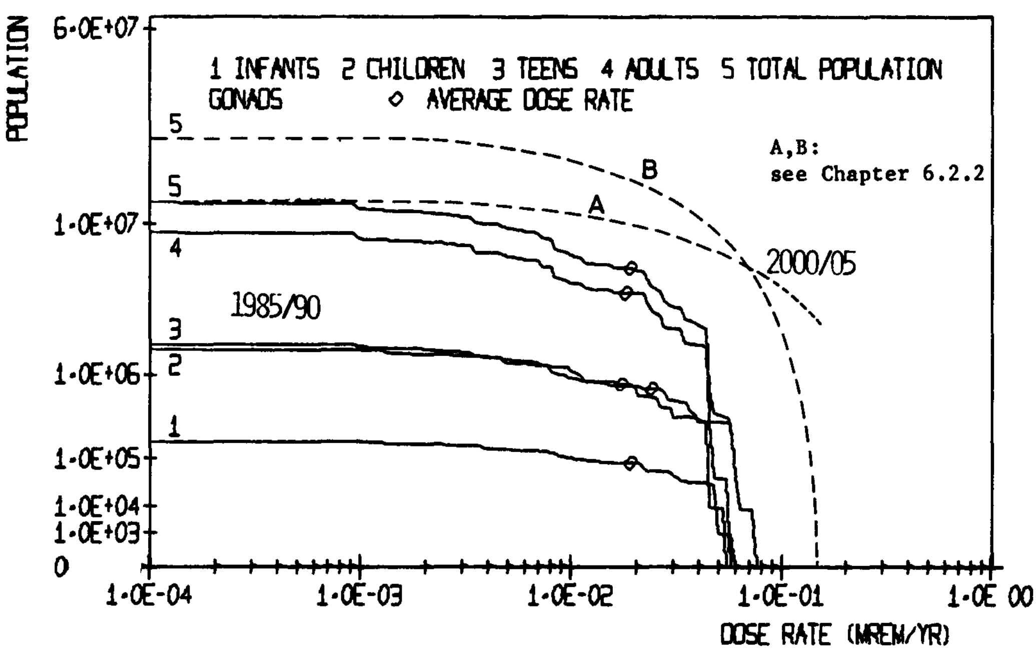



Fig. 6-7.4: Distribution of Gonads-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

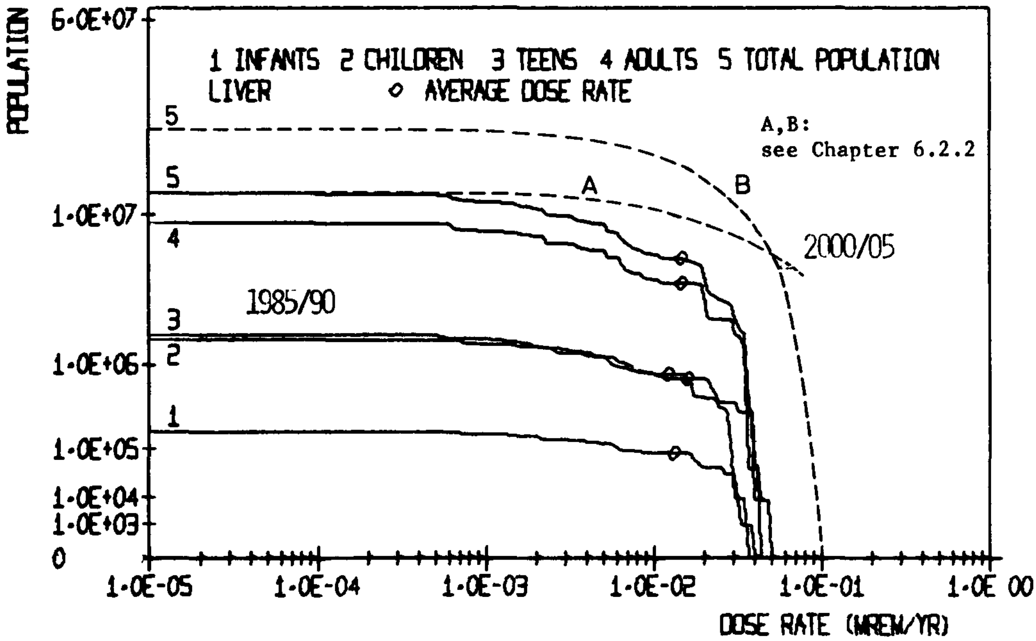



Fig. 6-7.5: Distribution of Liver-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

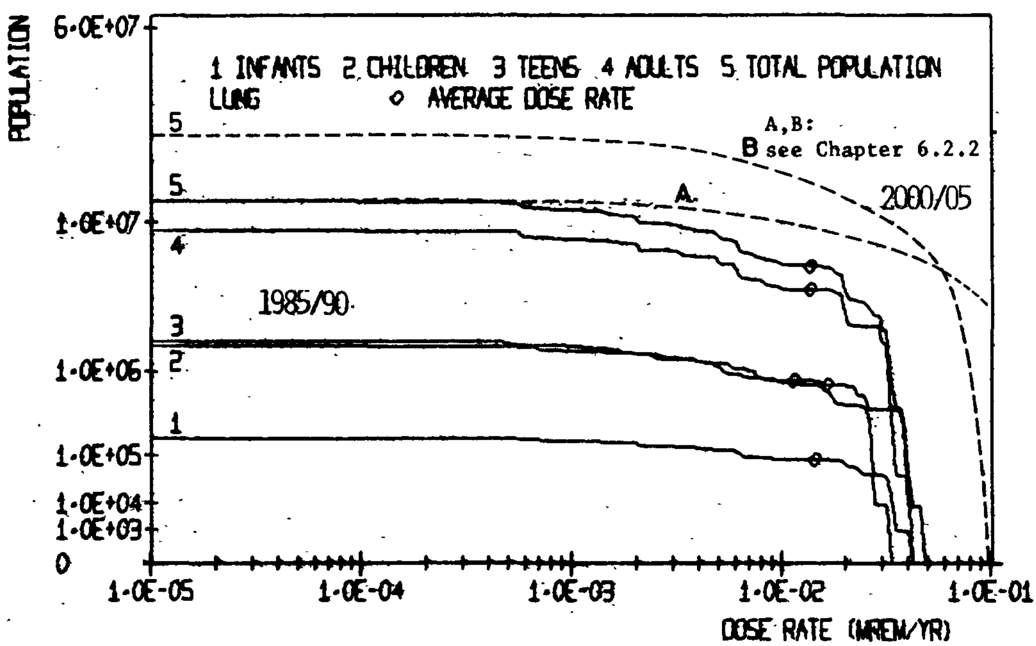



Fig. 6-7.6: Distribution of Lung-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

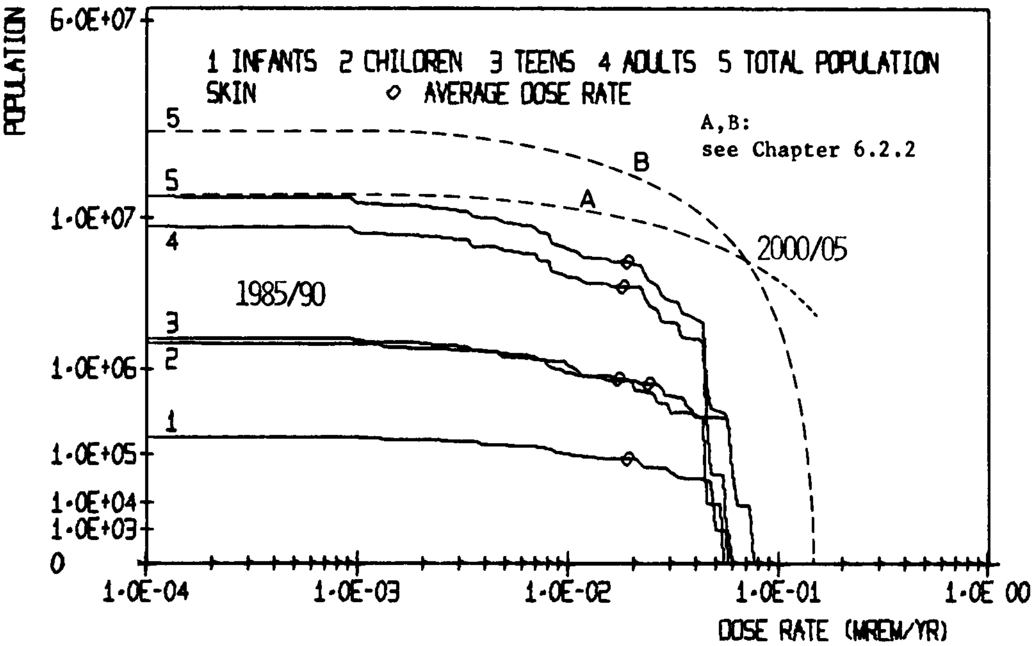



Fig. 6-7.7: Distribution of Skin-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

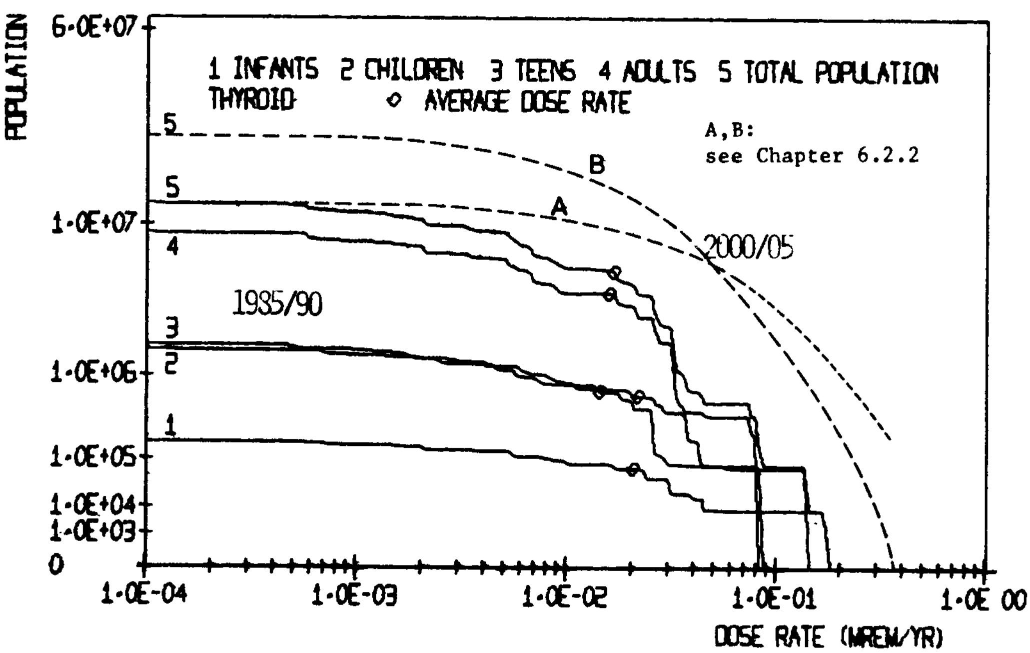



Fig. 6-7.8: Distribution of Thyroid-Dose Rates from Liquid Releases via the Drinking Water Pathway around the Years 1985/90 and Extrapolation to the Years 2000/05

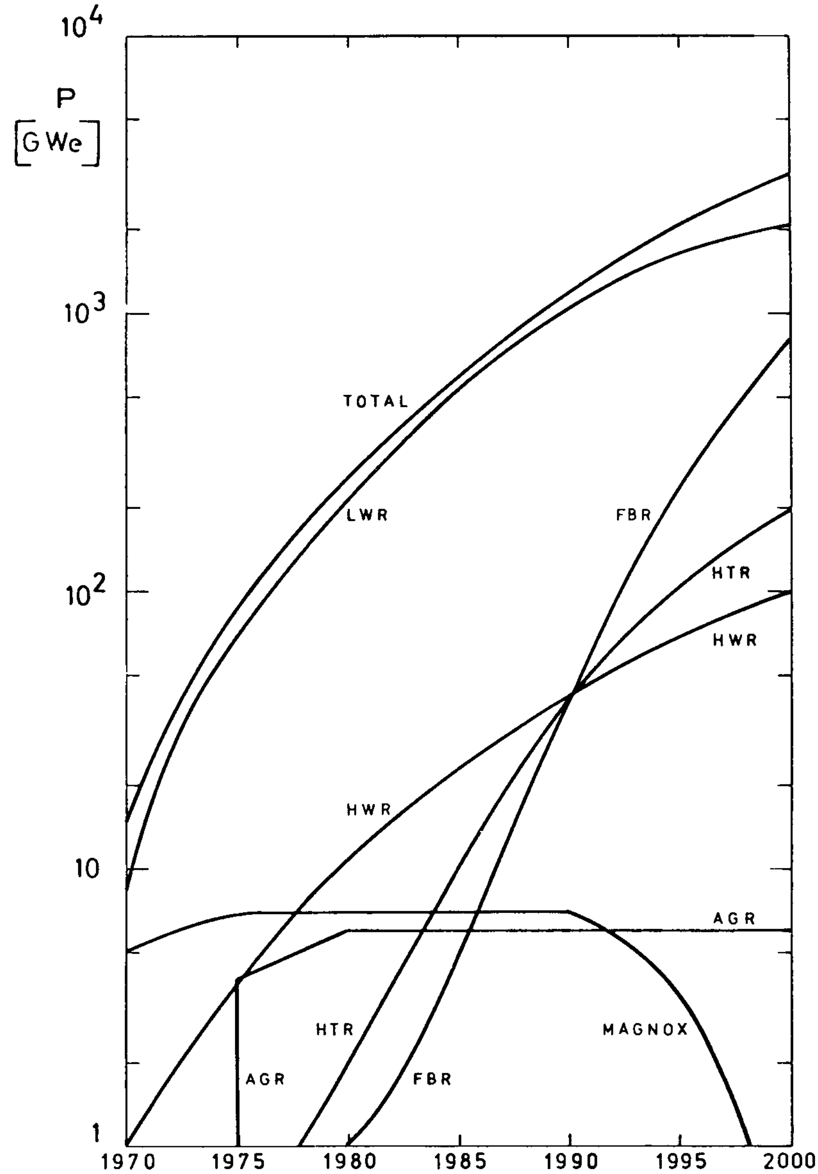



Fig. 8-1: Forecasted Global Installed Electric Power on a Nuclear Basis contributed by the Various Reactor Types (from UK-NRPB [83])

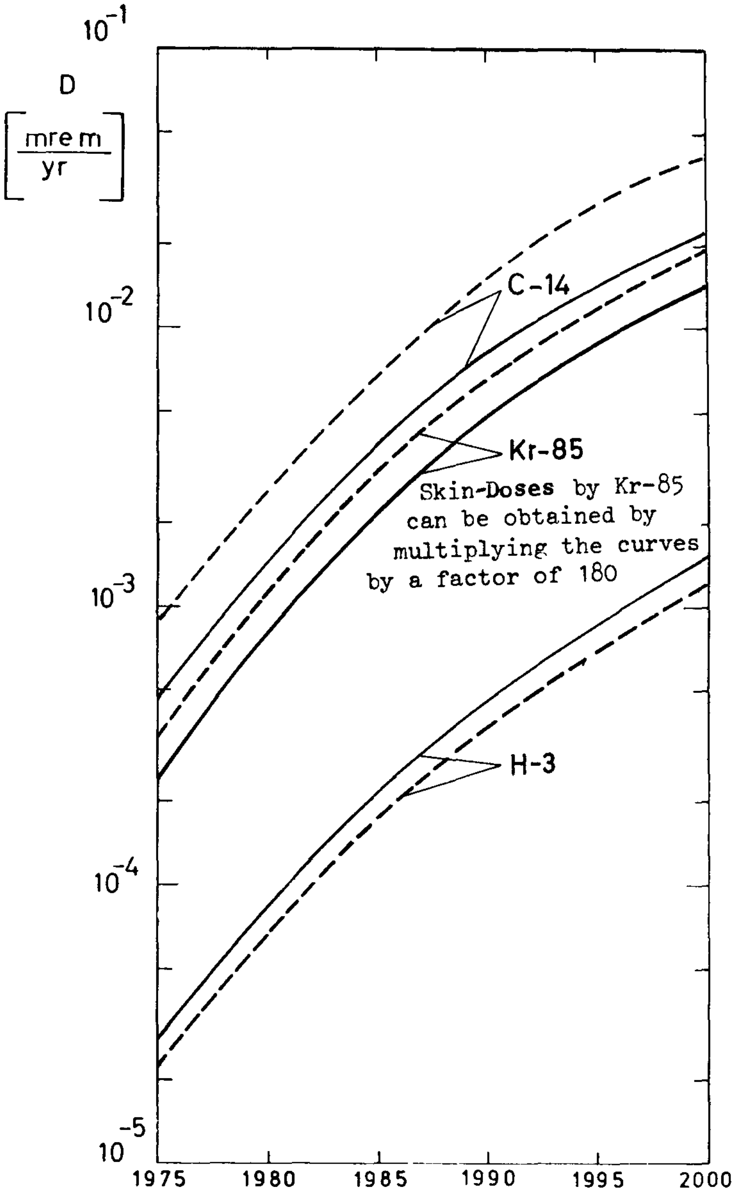



Fig. 8-2: Gonad-Dose Rates from the Global Circulation of H-3, C-14 and Kr-85
full line: from UK-NRPB [83]
dashed line: according to the source strengths in this study

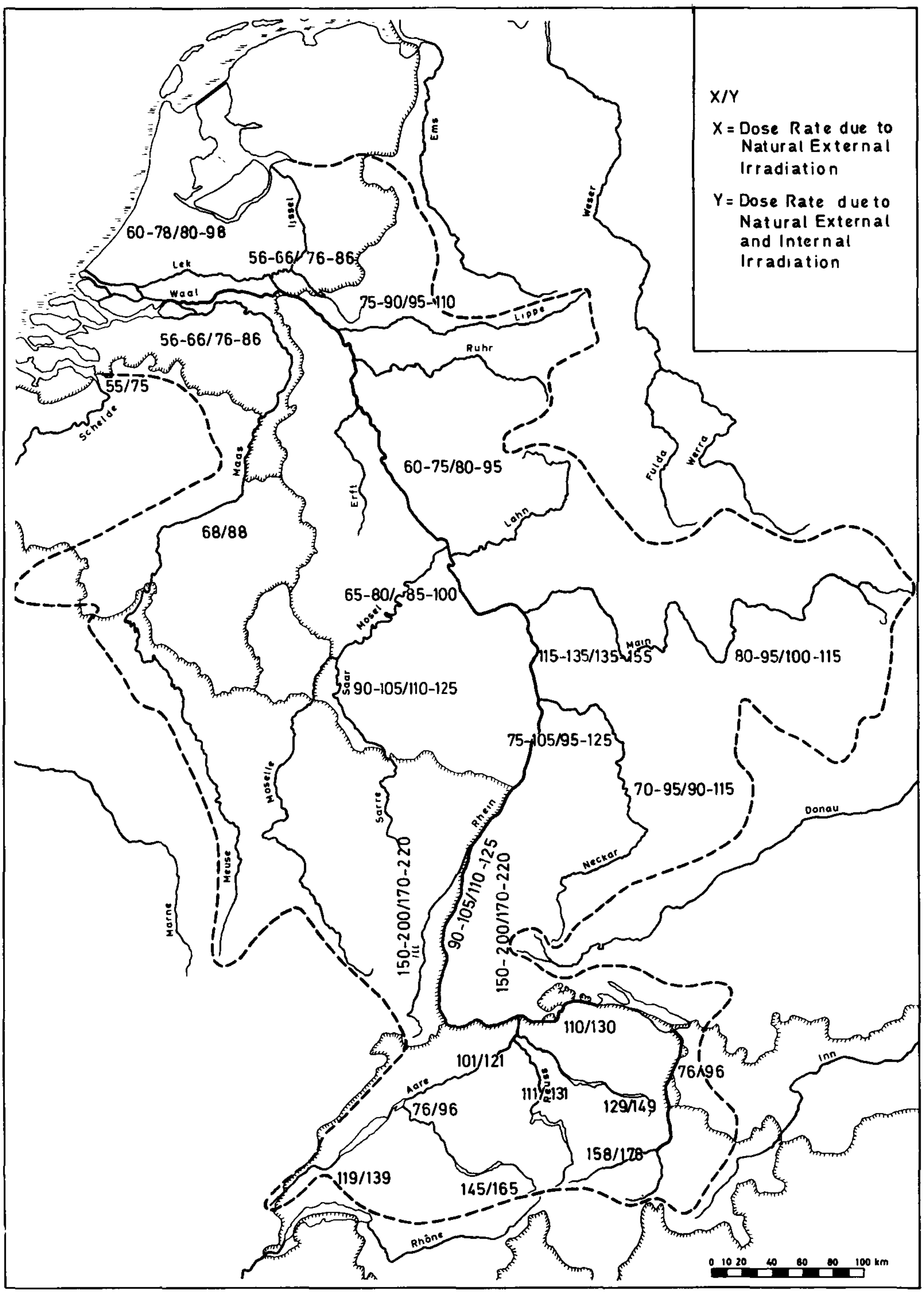



Fig. 9-1: Whole Body-Dose Rates [mrem/yr] due to Natural External Irradiation and due to Natural External plus Internal Irradiation