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SAFETY CODES AND GUIDES - TRANSLATIONS

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Contents

Radiological Fundamentals for Decisions on Measures for the Protection of the Population against Accidental Releases of Radionuclides

of 27 October 2008

Radiologische Grundlagen für Entscheidungen über Maßnahmen zum Schutz der Bevölkerung bei unfallbedingten Freisetzungen von Radionukliden

vom 27. Oktober 2008

Bundesamt für Strahlenschutz
Salzgitter

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In case of discrepancies the German text shall prevail.

Radiological Fundamentals for Decisions on Measures for the Protection of the Population against Accidental Releases of Radionuclides

of 27 October 2008

Preface to the newly edited version

After the revision of the "Basic Recommendations for Disaster Control in the Vicinity of Nuclear Power Plants" was finished with consent of the Commission on Radiological Protection (213th meeting dated 6 December 2006 and 217th meeting dated 21 September 2007), of the Federal States Committee for Nuclear Energy (during a circulating procedure dated 29 February 2008), and of the Working Committee V of the *Innenministerkonferenz* (dated 18 and 19 October 2007) was finished, the aim – similar to the relevant precursor recommendations - was to publish the Basic Recommendations together with the "Radiological Fundamentals for Decisions on Measures for the Protection of the Population against Accidental Releases of Radionuclides". This was due to the fact that the Basic Recommendations are based on the Radiological Fundamentals.

Therefore the Radiological Fundamentals in the version of 1999 were newly edited. By doing so the amendments and corrections performed in the meantime (e.g. changing the age of children and adolescents from 12 to 18 years regarding the dose reference levels for the intake of iodine tablets as well as the new iodine instruction sheets according to the recommendations of the Committee for Radiation Protection dated 2004) were taken into account and references to the updated versions of publications were included. In addition, a new regulation of the Radiation Protection Ordinance (§ 59) and the new principles on the operation of the police and the fire brigade were incorporated in chapter 6 "Radiation protection of task personnel".

Independently thereof, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety assigned the Federal Office for Radiation Protection to check if further revision with regard to the contents was necessary due to new scientific experience and to include if necessary. Especially the recommendations of the ICRP "*Recommendations on the protection of man and the environment against ionising radiation*" dated 2007 (ICRP 103) which were recently published, the UNSCEAR-report "*Effects of ionizing radiation*" dated 2006 (publication is scheduled in 2008), and the "*Basic safety standards for protection against ionizing radiation and for the safety of radiation sources*" which are currently under revision by the IAEO, ILO, FAO, OECD-NEA and the WHO shall be taken into account. The Commission on Radiation Protection will then be asked to comment on the revised version extensively.

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1 Introduction

1.1 Fundamentals and purpose

German nuclear facilities possess safety systems and action plans that are intended to practically rule out the occurrence of a nuclear accident with relevant radiological impacts on the environment. Such a course of events could only occur if the existing severalfold graduated safety measures fail to take effect and the additional measures taken to prevent serious nuclear damage and to limit the radiological consequences thereof were unsuccessful. It is for such an event that disaster control plans are drawn up for the vicinity of nuclear power plants.

In the event of a release of radionuclides that is imminent or taking place or has already occurred following a nuclear accident, it may be necessary to take disaster control measures and radiological protection precautions. These two types of measures are subsumed under the term “Emergency Response Measures”. Their common purpose is the complete avoidance of deterministic effects and the minimization of stochastic effects on the basis of commensurability.

The basis for disaster control measures is the relevant legislation of the *Länder*; such measures are planned and implemented under the “Basic Recommendations for Disaster Control in the Vicinity of Nuclear Facilities” /RAH 99/[1]. Enforcement of the Precautionary Radiation Protection Act is carried out by the *Länder* under mandate for the federal authorities, except where federal administrative authorities are involved (e.g. in the field of large-scale monitoring of environmental radioactivity).

Regardless of competence in the individual case, the established findings of radiological protection and national, European and international experience and recommendations in the field of emergency response are an important basis for planning measures to protect the population against accidental radiation exposure in Germany. As a radiological basis the Federal States Committee for Nuclear Energy – General Committee – approved on 6 April 1999 these “Radiological Fundamentals for Decisions on Measures for the Protection of the Population against Accidental Releases of Radionuclides”, or “Radiological Fundamentals”, as they are referred as follows for short. They supersede the “Radiological Fundamentals” of 1988/89 /RAD 88/.

The Radiological Fundamentals are based on the findings of radiation biology, especially in regards to the dose/risk and dose/effect relationships for stochastic and deterministic effects, and on a comparison of the accident-induced radiation exposure with the level and range of variation of the natural radiation exposure of the population totalised over an entire lifetime. In order to take account of the principle of commensurability, the seriousness of the intervention in the life of the individual is considered for the various measures. Weighing up all the aspects mentioned results in an assignment of intervention dose reference levels for each of the measures: sheltering, intake of iodine tablets, evacuation and resettlement (measure-specific intervention reference levels). For planning purposes on a precautionary basis, this assessment and assignment can be performed for possible future events independently of the individual event.

If an incident occurs, decision-taking on measures to protect the population will be based on the Radiological Fundamentals defined here as well as on other factors. These include factors which are not known until the incident – e.g. the characteristics of the area affected and the feasibility of measures – or also include factors, which are difficult to quantify, such as public reaction or socio-psychological aspects. The intervention reference levels set out in the Radiological Fundamentals together with the event-specific factors form the basis for decisions on measures to be taken in the individual event of an incident.

1.2 Reference to international recommendations

International literature depicts a number of strategies for the planning and implementation of emergency measures. Moreover, frequently different dose levels are recommended within the same strategy. Thus there is no universally recognized strategy that the Federal Republic of Germany could adopt.

The “Radiological Fundamentals” /RAD 88/ approved on 11 May 1988 by the Federal States Committee for Nuclear Energy are based on the so-called bandwidth strategy described in 1982 by the European Community /EC 82/ and in 1984 by the International Commission on Radiological Protection (ICRP) in its publication No. 40 /ICR 84/. The figures specified in /RAD 88/ for the intervention reference levels are taken largely from /EC 82/.

In its publication No. 63 /ICR 96/, the ICRP introduced principles of justification and optimisation of measures and published a strategy based on measure-specific intervention reference levels, which when reached, means that measures are generally justified. In addition it specifies measure-specific dose ranges within which the intervention reference level to be optimized in the individual incident are presumed to lie. The dose that can be avoided as a result of the measures is a key issue in this strategy.

Both ICRP strategies /ICR 84, ICR 96/ are very flexible with regard to adaptation to the circumstances of the individual event (number of persons affected, feasibility of measures, public reaction, avoidable individual and collective doses etc.), but they have both in common that they provide inadequate assistance with respect to the practical implementation of adaption in the event of an incident. It is difficult to define intervention reference levels in the context of these strategies, because a number of the circumstances stated above are unknown until the actual incident and the optimisation called for by the ICRP cannot be undertaken until then. Moreover, the ICRP not only recommends optimising the actions, but also to take account of factors from political and social areas. Such an impact cannot be quantified *a priori* and is difficult to quantify in the actual incident. It is therefore not easy to comply with both requirements simultaneously.

On the other hand ICRP 63 explicitly demands that intervention reference levels shall be laid down during the planning for future events, which are available immediately if an incident takes place.

The International Basic Safety Standards /IAE 96/, which were published jointly by FAO, IAEA, ILO, OECD/NEA, PAHO and WHO, name specify numerical values – not ranges or bandwidths – for the measure-specific intervention reference levels. This means that on the one hand intervention reference levels are available immediately in the early phases of an incident, while on the other, the flexibility requirement is met by the fact that the intervention reference levels drawn up during emergency response planning can be adapted to the characteristics and limiting conditions of the individual incident, if there are material grounds for doing so. This strategy is referred as follows as the “initial value strategy”.

On the basis of the above-stated recommendations of the ICRP and the IAEA, and in light of findings discovered through a number of trainings that it is not sufficient in emergency response planning to only lay down bandwidths and ranges as happened in the past and refrain from specifying any intervention reference levels, Germany gives a preference to the initial value strategy.

Using an initial value strategy for emergency responseres in Germany is also in line with the approach adopted by

[1]) Updated reference, cf. annex of the bibliography: /RAH 08/

the European Commission when laying down maximum levels for contamination of foods and animal feeds /EUR 87, EUR 89a, EUR 89b, EUR 90/.

1.3 Overview

In a systematic presentation of the basis for decision-makings and measures, it is useful to distinguish between three accident phases and several exposure pathways. This is covered in Chapter 2 of these Radiological Fundamentals.

Chapter 3, "Health impacts of radiation exposure", is divided into two parts: radiation effect and dose concets. The first (3.1–3.3) discusses these radiation effects that are relevant to defining intervention reference levels. The second part explains a number of dose concepts that are used in the later chapters.

Chapter 4 is devoted to protective measures. It describes the measures and the strategy for planning them. The main focus of the chapter is on the intervention reference (dose) levels defined as initial values for individual measures. The intervention reference levels are justified, and for the individual protective measures and countermeasures, illustrated. It is made clear that from a radiological point of view there is a need to take action when dose levels reach the intervention reference levels.

The subject of Chapter 5 describes decision making in the event of an incident. It describes the main factors that are relevant to decisions on the initiation of protective measures and countermeasures. The process of decision making as an iterative process of assessing factors is illustrated, and finally the chapter draws attention to the methodological and mathematical aids available.

Chapters 6 and 7 deal with the radiological protection of task personnel and specific occupational groups.

2 Accident phases and exposure pathways

It is useful to divide the course of a nuclear accident into three phases, while at the same time taking account of aspects such as activity release status, type and urgency of measures, nature and availability of the basis for decision making and relevance of exposure pathways. These Radiological Fundamentals therefore distinguishes between the *pre-release phase* and the *release phase*, each of which may last for hours or days, and the *post-release phase*, which follows the first two and may last for weeks, months or years depending on the individual release.

The *pre-release phase* (phase when release is imminent) begins at the time when the possibility of a substantial release of radionuclides from the facility is recognized. It ends with the beginning of a substantial release or when the incident is brought under control. The pre-release phase may last hours or days. In the pre-release phase it is possible to take precautionary measures (e.g. precautionary evacuation of the immediate vicinity). If it might become necessary to take iodine tablets, this period could be used for their distribution/collection. The use of dose criteria as a basis for making decisions on precautionary measures depends on the quality of forecasts about the nature and quantity of the radioactive substances released, the start and course of the release, and the dispersion and deposition processes. If the forecast quality is poor, the focus will be on the current state of the facility as a basis for decision making. Minor releases that do not have any impact on the implementation of measures do not affect the definition of the pre-release phase.

The *release phase* follows the pre-release phase. Precautionary measures to protect the population, especially evacuation of the immediate vicinity, are preferably only possible in those areas that do not lie in the direction of dispersion or have not yet been reached by the radioactive cloud. The release phase ends when the dispersion and deposition processes in the area in question have come to an end. The release phase may last several hours or days. It is characterized by a transition from merely forecasting the radiological situation to determining the actual environmental contamination with the aid of several numerous measurements from stationary or mobile measuring devices. Unforeseeable or unexpected changes in the course of the release over time or in the atmospheric dispersion conditions may make it necessary to alter or supplement protective measures that have already been initiated. In this phase special attention must be paid to exposure pathways directly connected with the passage of the radioactive cloud and with radiological protection of task personnel, the majority of whom are not occupationally exposed persons. By the time the radioactive cloud reaches a locality, the population should have been warned and, where appropriate, any precautionary protective measures should have been taken.

The *post-release phase* covers the period when radiation and deposition from the radioactive cloud have come to an end or are at least no longer significant, but there has not yet been a full return to completely normal living conditions. Initially it is characterized by a precise analysis of the radiological situation, for which measurements of the contamination of foodstuffs, drinking water, surfaces, soils, plants and bodies of water are now available in adequate quantity and quality. The necessary data, resources and time are now available for event-specific justification and optimisation of measures to protect the population and for justifying and optimizing the radiation exposure of task personnel and specific population groups. If the decisions are considered to alter measures decided in the preceding phases or to take supplementary measures, e.g. resettlement, it must be borne in mind that at this late point in time it is no longer possible to avoid more than a small part of the total dose that is received in the absence of measures (avoidable dose). Finally, it is necessary to take decisions on the (gradual) discontinuation of the measures.

There are various pathways via which radioactive substances released in an accident may result in radiation exposure of human beings. These are illustrated in Fig. 2.1 and summarized in Table 2.1.:

Table 2.1: Exposure pathways

External radiation exposure due to

- Radiation from the radioactive cloud
- Radiation due to soil contamination
- Radiation due to contamination of skin, clothing or objects
- Direct radiation from the facility[1])

[1]) By comparison with the other exposure pathways, direct radiation from the facility can only be of relevance in the immediate vicinity and is therefore disregarded below.

Internal radiation exposure due to

- Inhalation of airborne radioactive substances from the radioactive cloud
- Ingestion of contaminated foodstuffs
- Inhalation of stirred-up radionuclides that were previously deposited on the ground, objects or clothing.[2])

[2]) In temperate zones – such as Central Europe – the contribution of radionuclides stirred up after deposition is small in relation to the external exposure due to soil contamination, except where the release consists largely of α-emitters.

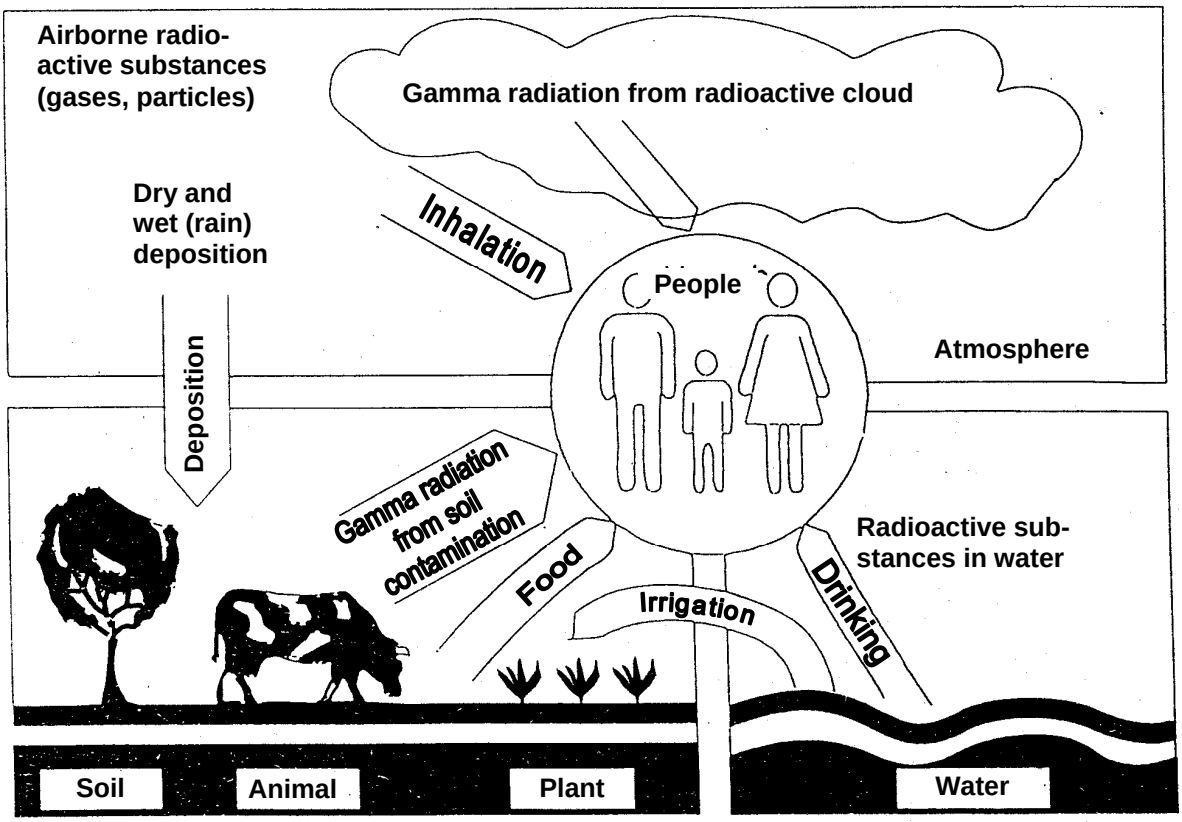

Fig. 2.1: Schematic diagram of exposure pathways that may result in external or internal radiation exposure of human beings

3 Health impacts of radiation exposure

3.1 Radiation effects: Stochastic effects

Every biological effect of ionizing radiation is caused by statistically distributed energy deposition in the cell. It leads to ionization processes in various molecules of the cell, which may undergo changes as a result. Particularly serious repercussions here are changes in the genetic information in the DNA, which may result in

- the death of the cell (immediately or after a long period) or
- mutation of the cell (permanent changes to the DNA).

Every cell has a great potential for repairing changes in the DNA. This means that most molecular changes will not have any consequences. It is however possible that a repair may fail, giving rise to a mutated cell which divides and passes on its modified genetic information. A chain of events that is not yet fully understood may result in a changed cell giving rise to the formation of a group (clone) of cells with uncontrolled growth that may develop into a carcinoma or leukaemia. This effect is known as a **somatic effect**.

If the mutation takes place in a reproductive cell, the cellular defect may be transmitted to the offspring. This is known as the **genetic effect** of radiation.

It is assumed that there is no threshold dose for such mutation effects. The consequences will only become apparent after a latency period of years. An increase in radiation dose increases the probability that the effect will occur, but not the severity of the damage (Fig. 3.1). The curve is therefore shown as starting at the origin, with a linear increase in the lower dose range, and acquires a quadratic form with higher doses and increasing probability. As the dose approaches the range of deterministic effects, the gradient of the curve becomes flatter, because the death of the cell as a result of high doses reduces the probability that a clone of malignant cells may form from surviving, but mutated cells, and thereby give rise to a cancerous tumour or leukaemia.

In this form the biological effect of the radiation is known as a **stochastic effect**.

It is difficult to quantify the biological effect, because our present knowledge does not enable us to identify whether a tumour has developed as result of ionizing radiation or for some other reason. For this reason epidemiological studies of sizeable populations that have been exposed to radiation (atomic bomb victims in Hiroshima and Nagasaki) are used to determine the number by which the deaths due to cancer exceed the number that would have occurred without radiation. This number can then be set in relationship to the dose of a prior radiation exposure. From the two sets of data it is possible to express the radiation risk in statistical form as the probability of occurrence per dose unit. The risk figures calculated in this way are not an unchangeable quantity. For example, the number of deaths due to cancer increases with the ageing process of the population studied, and the additional inclusion of cancer cases (incidence) to cancer deaths (mortality) alters the statistical basis, as do new findings about assessment of the radiation dose.

In relation to stochastic effects, the purpose of emergency response is to minimize the probability of additional cancer cases due to radiation exposure of the population by taking appropriate measures, without giving rise unacceptable disadvantages for the population as a result of the implementation of the measures.

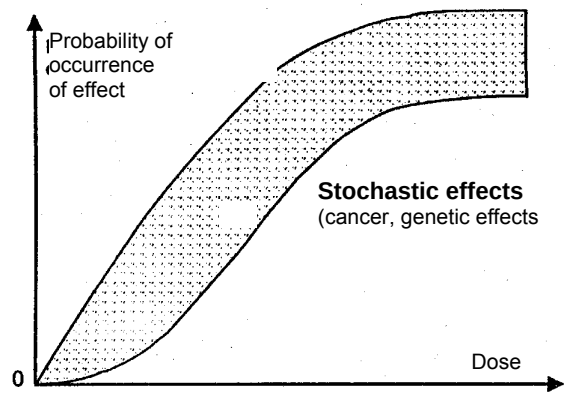

Fig. 3.1: Probability of occurrence of a stochastic effect as a function of the dose /SSK 96/[2]

3.2 Radiation effects: Deterministic effects

Whereas stochastic effects may occur without a threshold even at low radiation doses, deterministic effects occur if, as a result of the high deposition of energy, functionally significant numbers of cells are damaged or die or if regeneration is not possible or only after a considerable delay. Such effects may be temporary or permanent.

Secondary deterministic effects may become detectable if radiation changes or restricts the blood supply to organs (by damaging the blood vessels) or if functional tissue (e.g. glandular tissue) is replaced by connective tissue which cannot perform these specific functions.

Since these deterministic effects require a higher deposition of energy, they are subject to threshold doses which vary for different tissues, organs and individuals (threshold dose range, see Fig. 3.2). Above the threshold dose the extent of the damage depends on the dose, but the probability of occurrence is 100 percent.

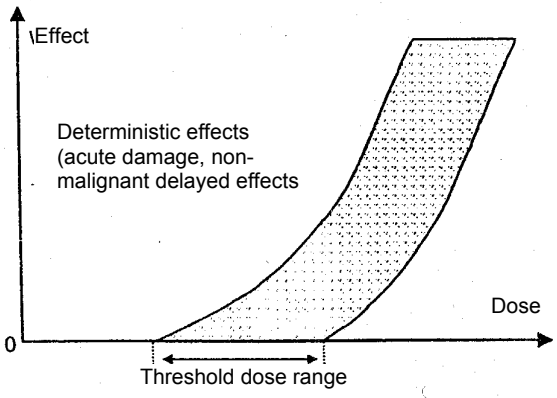

Fig. 3.2: Severity of a deterministic effect as a function of the dose /SSK 96/[3]

[2]) Updated reference, cf. Annex of the bibliography: /SSK 07a/

[3]) Updated reference, cf. Annex of the bibliography: /SSK 07a/

At a radiation exposure of less than one Sievert[4] (see section on “Dose Concepts”), most tissues do not display any evidence of clinical syndromes (ICRP publication No. 60 /ICR 93/).

The following organs are exceptions:

- *the male gonads (testes)*
  A single radiation dose of 0.15 Sv or more results in temporary sterility. Permanent sterility, however, does not occur until radiation exposures of over 3 Sv. This could for example occur in connection with an acute radiation syndrome following whole body irradiation.
- The *bone marrow* reacts with a disturbance of blood formation to acute irradiation in the dose range as low as 0.5 Sv. Complete remission of the disorder is possible.
- The *lens of the eye* displays, after a latency period of several years following a single radiation dose of more than 2 Sv, clouding that impairs sight.

The main objective of emergency responses is to prevent deterministic effects.

Depending on the dose and the amount of the body exposed (whole body or part body); it is possible to distinguish typical clinical syndromes.

The following descriptions are examples of deterministic effects in the form of clinical syndromes:

The acute radiation syndrome

The acute radiation syndrome occurs after whole body irradiation in dose ranges above 1 Sv (exposure time a few hours); such doses can only occur during a serious nuclear accident in the immediate vicinity of the facility. It displays three clinical manifestations which relate to different dose ranges /Fli 92, SSK 95b/[5]

The haematological form (primarily damage to the blood-forming bone marrow, dose range approx. 1 Sv–10 Sv) begins with fairly uncharacteristic early symptoms: nausea, vomiting and general weakness, possibly early erythema = reddening of the skin). The blood count reveals characteristic changes, the subsequent course of which depends on the dose.

Whether the irradiated victim survives depends on the extent of the disturbance of blood formation (haematogenesis) and the treatment applied.

The gastrointestinal form (additional damage to the intestinal mucosa, following whole body exposure of about 10 Sv–30 Sv). The early symptoms are uncharacteristic here too (nausea, vomiting, weakness, always early erythema), but they begin earlier and are more pronounced. Not only haematopoiesis occurs, but the mucosa of the small intestine is also severely impaired. Up to a dose of about 20 Sv there is in some cases a chance of survival with intensive therapy, even with this syndrome.

The central nervous form (additional damage to central nervous system, follows a whole body exposure of more than 30 Sv). This most serious form of acute radiation syndrome displays immediate early symptoms with stupor and marked erythema. Owing to the extensive death of

[4]) Strictly speaking, when assessing the effects of radiation doses, the energy dose in Gray (Gy) should be used for deterministic damage and the dose equivalent in Sievert (Sv) for stochastic damage. However, since the radiation in question here is almost exclusively low-energy ionising radiation for which the numerical values of energy dose and dose equivalent are the same, the following discussion uses the dose equivalent in accordance with the Radiological Protection Ordinance in the interests of simplifying the explanation. /SSK 95b/

[5]) Updated reference, cf. Annex to the bibliography: /SSK 07b/

cells and/or the massive disturbance of their function, this condition is always fatal.

The clinical symptoms listed here are the central aspects of the pathological development of the syndrome. Other organs are always affected as well: the mucous membrane of the mouth and the salivary glands, the thyroid gland and especially the lungs, the radiation-induced inflammation of which (radiation pneumonitis) is a considerable complication.

The cutaneous syndrome (radiation effects on the skin)

In principle, this radiation effect belongs to the acute radiation syndrome, because higher doses (approx. 3 Sv–5 Sv /ICR 93/) are necessary to cause skin damage by external radiation.

In cases of partial exposure of the body, this may occur even without the clinical manifestations of the acute radiation syndrome, and it may also be caused by heavy contamination of the skin with beta emitters.

The early symptom is an early erythema that occurs after 0.5 to 36 hours. After a latency period of up to 28 days this is followed by a second erythema (main erythema) which gives way to blistering and ulceration. The ensuing chronic phase lasts for months or years.

3.3 Effects of irradiation during prenatal development

This effect of radiation must be considered separately, because life at this stage of development reacts particularly sensitively to ionizing radiation. Deterministic and stochastic effects are discussed here together. The following effects have been observed – some only in animal tests:

- Death of unborn or new-born child
- Visible physical malformations
- Growth disorders
  these may affect brain development in particular and give rise to functional disorders (e.g. brain dysfunction).
- Fertility disorders (sterility)
- Malignant diseases (cancer or leukaemia)
- Hereditary defects (only observed in animal experiments)

These effects depend on the prenatal development phase during which the exposure occurred:

- In the *pre-implantation period*, i.e. the period when the egg is fertilized but not yet implanted in the endometrium, the most likely consequence of irradiation is the death of the embryo. The period ranges from conception to about the tenth day. At this point the woman is not aware that she is pregnant.
- In the *organ formation period*, which lasts from about the tenth day to the sixth week after conception, either the death of the embryo or a pronounced malformation is possible. In this period too, many women are still unaware of their pregnancy.
- In the following *foetal period*, which lasts until birth, growth disorders may occur which affect brain development in particular and which may result in mental retardation after birth. (Increased risks especially in the eighth to 15th week of pregnancy given high dose and dose rate).

For almost all these effects there are threshold levels below which the effect is no longer detectable. The threshold levels are however different depending on the radiation effect and the prenatal stage during which exposure took place.

ICRP publication No. 60 /ICR 93/ quotes 100 mSv as the lowest threshold level. This value is an estimate based on animal experiments involving short-term radiation exposure.

The possibility that malignant diseases (cancer or leukaemia) may develop after birth in cases where the embryo or foetus was exposed to radiation in the uterus cannot be ruled out on the basis of epidemiological studies. The increase in the leukaemia and cancer rate reported for the range 10 mSv–50 mSv is however not undisputed, as it conflicts with other findings. Today it is assumed that embryos during prenatal development and infants suffer from a greater radiation sensitivity than adults, which means that that the same dose is 2 to 3 times more likely to result in a malignant disease. /SSK 89, ICR 93/.

3.4 Dose concepts

Every biological effect of radiation is caused by energy deposition in the cell. Its quantity is specified by the **energy dose**, i.e. by the energy that is input into a volume element divided by the mass of this volume. The unit of energy is the joule, the unit of mass the kilogram. In the context of radiological protection the energy doses of interest are usually averaged over biological tissues or an organ. The unit of the **energy dose** is the **gray** (Gy). 1 Gy = 1 J/kg.

The biological effect depends not only on the energy, but also on the type of radiation. Alpha particles and neutrons have a different biological effectiveness than X-ray, beta or gamma radiation. In order to obtain a measure of radiation effect that is valid for all radiation types, the energy dose is multiplied by a weighting factor which is defined for each radiation type and which characterizes the biological effectiveness relative to that of photons. The mean energy dose for a tissue or organ multiplied by the radiation weighting factor is known as the **dose equivalent** in a tissue or organ. It is expressed in Sievert (Sv). 1 Sv = 1 J/kg. In practice the millisievert (mSv) is often used (1 Sv = 1 000 mSv).

The biological effect of ionizing radiation also differs in various tissues and organs of the human body. These differences must be assessed separately with regard to stochastic effects. The probability of cancer developing is different in the different tissues and organs of the body. In order to give quantitative expression to these differences in sensitivity in the dose, tissue weighting factors have been introduced. The sum of the tissue and organ doses weighted in this way is known as the **effective dose**. It too is given in sievert (Sv). For emergency respomse purposes it is common to work with the effective dose, because measures are initiated at doses, which only lead to stochastic effects. They are too low for deterministic effects.[6]

Also significance for the biological effect is the period of time for which ionizing radiation acts upon a biological tissue, i.e. whether a dose of 1 Sv is received over a period of an hour or a year, for example. The ratio of the dose and the relevant time interval is known as the dose rate. It is specified in Sv/h. In emergency response the time interval to which a dose value relates is known as the **dose integration time**.

The **collective dose** is the sum of all effective doses in an affected population.

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[6]) Nevertheless, the possibility of higher doses occurring for example in the immediate vicinity of an affected nuclear facility cannot be discarded. For such doses it would no longer be possible to use the model of the effective dose, which relates to stochastic damage.

Ionizing radiation may impact the body in various ways. Gamma rays, X-rays and neutrons are hardly diminished by the skin. They are absorbed by body tissue to varying extents. Such external irradiation, impinged on the entire body, leads to **whole-body exposure**, if only parts of the body are affected, to **partial body exposure**.
The deposition of radionuclides on the uncovered skin is known as **skin contamination**. Especially beta emitters (e.g. strontium 90, iodine 131) with a relatively small depth of penetration result in energy absorption in the skin, in other words they essentially create a **skin dose**.

Owing to the much greater penetration depth of gamma radiation, the skin dose it causes is negligible compared with the effective dose. Alpha particles have such a small penetration depth that in the event of contamination no relevant dose occurs in the radiation-sensitive renewal layer of the skin, since the radiation does not penetrate this far.

There are also various possible ways of direct incorporation of radioactive substances in the body:

- Airborne radioactive substances may be breathed in through mouth and nose and result in an **inhalation dose**.
- Radionuclides (e.g. iodine 131, caesium 137) may be taken in with contaminated foodstuffs (**ingestion dose**).

If radioactive substances have entered the body, they are partly excreted from it again (breath, faeces, urine), and partly accumulated in organs for varying periods of time. This residence in the body is characterized by the "biological half-life", i.e. the time that elapses until half the radionuclides have been excreted from the body. This half-life may differ greatly from the "physical half-life" of a radionuclide, which is determined by radioactive decay. As long as radionuclides remain in the body, they generate a dose that is known as the **dose commitment**. Depending on whether it is an effective dose or an organ dose, they are either known as an effective dose commitment or a dose equivalent commitment. Both types of dose commitment are determined for an integration time of 50 years for adults and 70 years for children.

Right from birth, every human being is exposed to ionizing radiation that originates from the natural environment and can hardly be influenced. This natural radiation varies in the different parts of the earth. From this permanent exposure to **natural radioactivity** it is possible to estimate a **lifetime dose**. In Germany, for a life expectancy of 70 years, this averages 170 mSv, varying from 100 mSv–400 mSv. No correlation between the variations in natural radiation exposure and health consequences has been found to exist in Germany.

4 Measures to protect the population

4.1 Measures and their effect

Measures to protect the population are initiated by decisions taken by the task managements of the disaster control authority or the precautionary radiological protection authority based on the knowledge of the condition of the facility and after an assessment of the radiological situation and the current situation in the areas affected. An overview of the main measures suitableto avoid or at least reduce radiation exposure is given in Table 4.1 together with the exposure pathways that can be affected by such measures.

Table 4.1: Measures and exposure pathways that can be influenced by the measures

Measures	Exposure pathways that the measures are suitable for influencing
Sheltering	All exposure pathways except ingestion
Precautionary evacuation in the pre-release phase	All exposure pathways except ingestion
Intake of iodine tablets	Inhalation of radioactive iodine
Evacuation in the release phase	All exposure pathways except ingestion
Restrictions on access, closing off areas	All exposure pathways except ingestion
Decontamination of individuals	External exposure due to radionuclides deposited on skin and hair
Intervention in supplies of foodstuff and feeding stuff	Ingestion of contaminated foods
Temporary resettlement, long-term resettlement	External exposure due to deposited radionuclides, inhalation due to resuspension
Decontamination of objects, buildings and sites	External exposure due to deposited radionuclides and incorporation

Sheltering means that the population is called upon to enter buildings which offer protection and to stay there for the recommended period. Protective rooms should be chosen such that incorporation of radionuclides with the air breathed and the external radiation are minimized by shielding. The shielding effect that can be achieved with respect to external radiation is vastly dependent on the type of building, the building materials and the surrounding buildings; the range of variation may be several powers of ten (see Table 4.2).

Special attention should be paid to settlement areas with timber houses or timber-frame structures, since only a low level of screening is possible there.

Sheltering not only serves to provide protection against radiation exposure, but also makes it easier for the authorities to inform the population by radio and television.

The term *evacuation* characterizes rapid clearance of an area in the pre-release phase and the release phase, either organized or at least assisted by emergency personnel: there is no implication as to whether or not the population will be able to return to their homes in the near future. If undertaken in time, this measure achieves the greatest protective effect, namely the avoidance of external and internal exposure via the exposure pathways stated in Table 4.1. If the residential area is too highly contaminated, it may be necessary to turn the evacuation into resettlement.

Table 4.2: Protection factors for external exposure in residential areas /Jac 89, Jac 98, Mec 88/

Whereabouts	Protection factors for external exposure in residential areas	
	from radioactive cloud[b])	shortly after deposition
Outdoors		
Areas with vegetation (trees)	1.0 – 1.4	0.6[c]) –2.0
Urban environments with neighbouring buildings, without vegetation (trees)	1.2 – 3.3	3.3 – 10
In living rooms of [a])		
Prefabricated houses	1.2 – 10	1.2 – 2.5
Semidetached houses and detached terraced houses	1.2 – 10	3.3 – 50
Multi-family buildings and blocks	10 – 200	25 – 1000
In basement rooms [a])		
With windows above ground level	10 – 1000	20 – 100
Without windows, semi-detached house	10 – 1000	330 – 5000
With light wells and windows, in blocks	500 – 10000	1000 – 20000

[a]) The protection factors are calculated without any contamination of interiors. If the surface contamination of floors, walls and ceilings is approximately 1 percent of the contamination of fields, the actual protection factor is reduced to about 100 and is thus much lower than shown in the table for well screened rooms.
[b]) Estimate based on homogeneous distribution of radioactivity in the atmosphere.
[c]) Protection factors less than 1 are due to the increased deposition on trees under dry deposition conditions.

Resettlement means clearing an area in the post-release phase; this means it is only effective against the external irradiation from the soil and the inhalation of radioactive substances resuspended in the air. It is generally ordered after comprehensive measurements are available. With regard to implementation and duration a distinction has to be made between temporary and longer-term resettlement.

Temporary resettlement is limited to a period of a few weeks to several months; the affected population can then return to their homes; decontamination measures in residential areas and on land areas may shorten the duration of temporary resettlement. The infrastructure and all production and supply facilities in the affected area can be used again after this measure. The social and economic consequences are thus less pronounced compared to long-term resettlement.

Long-term resettlement for an indefinite period is necessary in cases where a high dose rate in the affected area is slow to decline as a result of contamination with long-lived radionuclides. As a consequence the affected population has to be resettled and integrated in the social and economic life in other areas. This means not only the construction of new housing with the necessary infrastructure and the creation of new jobs, but also dealing with social problems due to – at least temporary – loss of income and the psychological burdens of the individuals affected.

A timely intake *of iodine tablets* protects the thyroid gland from radioactive iodine incorporated in the body. This is important for those groups of the population who inhale radioactive iodine with the air they breathe during the passage of the radioactive cloud. Intake of radioactive iodine in contaminated foodstuffs is prevented by providing supplies of non-contaminated foodstuffs.

With regards to *intervention in supplies* for the population, a distinction is made between (precautionary) warning of the population against eating freshly harvested foods and fresh milk on the one hand, and intervention in supplies of foodstuffs and feeding stuff on the basis of maximum contamination levels on the other. The warning to the population is issued in the area surrounding an emission source not later than the beginning of a hazardous release or in unclear radiological situation, or in more distant areas in the event of substantial radionuclide concentrations in the air. The maximum radioactivity levels in foodstuffs and animal feeds in the event of a nuclear accident are laid down in EU regulations /EUR 87, EUR 89a, EUR 89b, EUR 90/ and in the catalogue of measures /MNK 98/[7].

The most important requirement for achieving the best possible protective effect of measures in response to a nuclear accident is full and appropriate information of the population.

4.2 Principles for initiating measures in the event of an incident

The object of these Radiological Fundamentals is to justify protective measures and countermeasures from a radiological point of view. On radiological grounds there is a need for action when the intervention reference levels are reached.

Optimisation takes account of the conditions of the individual case. It cannot take place until an event occurs, and in these Radiological Fundamentals it is therefore dealt with solely in Chapter 5 in the context of decision making in the event of an incident.

The following principles are assumed from the “Radiological Fundamentals” of 1988/89 /RAD 88/:

- Serious deterministic effects should be avoided by means of measures to limit the individual radiation dose to levels below the threshold dose for such effects (principle of avoiding deterministic effects).
- The risk of stochastic effects should be reduced for individuals by taking measures, if such measures do more good than harm to the persons affected (principle of commensurability).

[7]) Updated reference, cf. Annex of the bibliography: /MNK 08/

The principle of avoiding deterministic effects and high risks of stochastic effects is the basis for the work of the emergency control authority in the vicinity of nuclear facilities. The importance attached to deterministic effects is so great that the call for optimizing measures is synonymous with the call for minimizing cases of damage.

The principle of commensurability means that measures which involve a lesser degree of intervention in the lives of individuals (e.g. sheltering, and intervention in trade in foodstuffs and feedstuffs) are implemented at lower radiation doses than measures that have a substantial impact on living circumstances (e.g. evacuation and resettlement).

The importance of the collective dose as a basis for decisions can only be judged in the actual event of an incident. If the largest contribution to the collective dose comes from large numbers of small individual radiation doses, which are received by large numbers of individuals and which can only be reduced with great difficulty, the collective dose is not a suitable basis for decision making.

4.3 Strategy for defining intervention reference levels

These Radiological Fundamentals make a distinction between intervention reference levels and intervention levels. Intervention reference levels are planning values, intervention levels are the values that apply in case of an event. Departures from the intervention reference levels should only be made in case of an incident if there are strong reasons for doing so.

When drawing up the strategy for defining intervention reference values, it was necessary to take account of the following:

- There are bases for decision making that are independent of the nature of a nuclear accident. These include
  - the dose-risk relationship for stochastic effects,
  - the dose-effect relationship for deterministic effects,
  - the seriousness of the intervention in personal life involved in the various measures,
  - the principle of commensurability, and
  - the range of variation of natural radiation exposure.
- There are also bases for decision making that depend on the nature and extent of an accident. These include amongst others the characteristics determined by the location and size of the affected area, aspects of the feasibility of measures, the economic and ecological impact of the accident and the actions taken, and the individual and collective doses that can be avoided by each measure.
- There are effects on decisions which are difficult to quantify in advance, especially in view of the political and social area, including the reaction of the population in the event of an incident

These Radiological Fundamentals are a planning instrument that is based entirely on the above mentioned bases for decision making that are independent from the nature and extent of a nuclear accident. The intervention reference levels derived here are therefore universally applicable values. In case of an incident they serve as an intervention level (initial value) which should be modified if there are strong reasons for doing so, e.g. if the assignment of measures and areas defined in this way conflicts with serious influencing factors (see Chapter 5).

Intervention levels that are higher than the intervention reference levels may be justified in cases where the implementation of measures has serious drawbacks or the avoidable dose is small.

Intervention levels that are lower than the intervention reference levels are not justified on radiological grounds.

If radiation doses are below the intervention levels, the population must be informed about the radiation risk and provided with appropriate comparative figures.

It shall be avoided to use different intervention levels in different regions.

On the basis of the considerations outlined above, intervention reference levels have been defined which, with the exception of the value for evacuation, lie between the reference levels of the existing bandwidth strategy, in other words they are not identical to either the upper or the lower value of the reference level hitherto recommended.

In publications by the International Commission on Radiological Protection and the European Commission, strategies are put forward that also seek to take account of factors and bases for decision-making that are difficult to quantify and which depend on the nature and extent of the accident (see Introduction). In any comparison of these Radiological Fundamentals with the international and European publications stated, it is therefore important to make a clear distinction between the generally valid Radiological Fundamentals and comprehensive bases for decision-making that, for example, take account of event-specific – and possibly extreme – conditions, non-quantifiable factors, or examination of the feasibility of measures.

4.4 Intervention reference levels for initiating measures

4.4.1 General considerations

When defining intervention reference levels for initiating measures, the dose limits set out in the Radiological Protection Ordinance are not applicable, because the latter were arrived at in accordance with the principles of justification and optimization of predictable and controllable radiation exposure. Furthermore, the Radiological Protection Ordinance in general regulates activities that can be carried on continuously (e.g. operation of nuclear power plants, use of radionuclides in medicine, research and technology).

By contrast, a nuclear accident is an event that is singular in time and space. The range of variation of the lifetime dose due to natural radiation exposure can therefore be used as a suitable comparative quantity for assessing the additional radiation exposure caused by the accident. In Germany the effective lifetime dose is around
$70\ a \cdot 2.4\ mSv/a \approx 170\ mSv$, with a fluctuation range between about 100 mSv and 400 mSv, i.e. a fluctuation range of about 300 mSv.

If it is assumed that

1. measures that represent a serious intervention in the life of the population, such as evacuation or resettlement, are only justified when they allow to avoid accident-induced dose levels of at least the same magnitude as the radiation doses accumulated during an entire lifetime as a result of natural radiation exposure, and

2. easily implemented measures, e.g. sheltering, intake of iodine tablets, or restrictions on eating foodstuffs, should be initiated at considerably lower dose levels,

intervention reference dose level in the range of 300 mSv should be used.

No connection between natural radiation exposure and health effects has been found in Germany. For highly unlikely occurrences there is therefore no reason to set intervention reference levels of less than 300 mSv per lifetime for such far-reaching measures as evacuation or resettlement. The fact that an intervention reference level of 100 mSv per year for long-term resettlement is nevertheless laid down below, takes account of the fact that

- for practical reasons an integration time of one year was chosen for external radiation exposure, and
- the radiation exposure after a nuclear accident is not homogeneously distributed over time, but is considerably elevated during the release period itself and up to a few weeks or months thereafter. This means that those members of the population who are very young at the time of release receive a disproportionately large part of the radiation exposure during childhood.

If the dose of 100 mSv set for serious interventions (evacuation, resettlement) is reached in a period of less than one year, it is necessary to examine whether, in addition to resettlement, the intervention reference level for the short-term measure of evacuation (dose integration time = 7 days) is reached.

On the other hand, intervention reference levels for the less far-reaching emergency measures should also be well above the bandwidth of annual natural radiation exposure in Germany. This consideration is independent from the current assessment of the radiation risk. For this reason an effective dose of 10 mSv is set as the lowest intervention reference level for the relatively easily implemented measure of staying indoors.

The values 10 mSv and 100 mSv also give expression to the fact that in the context of the strategy adopted here; intervention reference levels cannot be derived from mathematical formulae, but are the result of a qualitative judgement.

The range of intervention reference levels justified by these general considerations must further be defined for practical application with regard to the dose integration time, i.e. the time on which the calculation of radiation doses is to be based, the exposure pathways to be taken into account, and the type of dose. Information on these aspects is to be found under the intervention reference dose levels for the individual measures (see Sections 4.4.2 to 4.4.6).

The objective of the disaster control and precautionary radiological protection measures is to avoid deterministic effects and to reduce accident-induced stochastic effects. In line with intervention reference levels specified above, the measures sheltering, intake of iodine tablets, intervention in trade in foodstuffs, and resettlement serve to minimize stochastic effects, while evacuation is also calculated to avoid high short-term doses ranging up to the deterministic range. For this reason the appropriate integration time for the dose that represents the intervention reference level for evacuation is the exposure time relevant for deterministic effects. Protection from stochastic effects is achieved by means of longer integration times and/or lower intervention reference levels for the other measures. The intervention reference levels for the other measures are reached before the level for evacuation.

The dose to be compared with the intervention reference levels is basically the total dose from all exposure pathways against which the measure is effective. It must be possible to calculate it from the basic information available at the time the decision is taken: measurements and/or calculated spatial and temporal distributions of radiation doses/dose equivalents or activity concentrations (possibly calculated on the basis of such measurements). These are basically “potential” radiological quantities that do not take account of any possible measures.

Theoretically it would be possible to take account of individual living habits. However, in view of vast differences in individual living habits –long or short time spent outdoors, living in houses with a low or high screening effect – and therefore in order to simplify and standardize the calculation procedure it is practical to assume a permanent outdoor presence.

4.4.2 Sheltering

Compared with evacuation or resettlement, staying in protective rooms away from doors and windows or in basement rooms is a comparatively minor intervention in the life of the population. An intervention reference level of 10 mSv effective dose is therefore justified as an initial value. Relevant exposure pathways (see Table 2.1) are external irradiation from the radioactive cloud and from radionuclides deposited on surfaces, and internal irradiation due to inhalation. A period of seven days is set as the integration time for the dose. In laying down this period, it is assumed that it will not be possible to keep up the initially strict and subsequently predominant practice of staying indoors for a longer period. The majority of the population would probably leave the affected area in such a case without being requested to do so. This applies even in the case of releases lasting longer than a few days. If the intervention reference level for temporary resettlement (see 4.4.6) is not reached, the population must be informed about the radiation risk with details of suitable comparative values. Since the intervention reference level is well below the dose threshold for deterministic effects, the effective dose is an appropriate parameter:

Intervention reference level for the measure sheltering:

10 mSv as the sum of effective dose from external exposure in seven days and effective dose commitment resulting from radionuclides inhaled during this period

4.4.3 Intake of iodine tablets

Taking iodine tablets in good time protects the thyroid gland from incorporating radioactive iodine. Radioactive iodine may find its way into the human body (incorporation) via the respiratory tract (inhalation) or as a result of eating contaminated food (ingestion). In the absence of protective measures, the ingestion dose due to consumption of locally produced foodstuffs may, during the vegetation period, be considerably greater than the inhalation dose. When taking decisions on the intake of iodine tablets, however, it must be borne in mind that providing supplies of uncontaminated foodstuffs does more to avoid ingestion of radioactive iodine than administering iodine tablets.

Taking iodine tablets is a minor intervention in the life of the population. When setting the intervention reference level, however, it is important to take account of possible side effects. After weighing up the benefits and risks, an intervention reference level of 50 mSv thyroid dose for children and adolescents aged below 18 years and pregnant women and 250 mSv for persons aged 18 to 45 years was considered appropriate /SSK 04a/. Information on the type and dosage of the tablets can be found in the Appendix.

Persons aged over 45 years are advised not to take the tablets, because for this age group the risk of side effects is greater than the protection from possible radiation damage. They are adequately protected by the measures scheduled for all age groups, namely staying indoors, intervention in trade in foodstuffs and fedding stuff, and evacuation.

Intervention reference level for the intake of iodine tablets:

50 mSv thyroid dose (organ dose commitment) for children and adolescents aged below 18 years and pregnant women, and 250 mSv for persons aged 18 to 45 years resulting from the radioactive iodine inhaled during the period of seven days

provided that supplies of uncontaminated food are ensured.

4.4.4 Evacuation

In view of the seriousness of the intervention in individual lives, an intervention reference level of 100 mSv effective dose is appropriate. Relevant exposure pathways (see Table 2.1) are external irradiation from the radioactive cloud and radionuclides deposited on surfaces and internal irradiation following inhalation. A period of 7 days is set as the integration time for the dose. This integration time represents a conservative estimate of the contribution to the short-term dose that is relevant for deterministic effects. It also takes adequate account of the contribution of short-lived fission products ($T_{1/2}$ < 1 day). In cases of predominantly external radiation exposure due to longer-lived deposited radionuclides, the intervention reference levels for temporary or longer-term resettlement are reached first. Since the intervention reference level is well below the dose thresholds for deterministic effects, the effective dose is the appropriate parameter:

Intervention reference level for evacuation:

100 mSv as the sum of the effective dose resulting from external exposure in seven days and effective dose commitment due to the radionuclides inhaled during this period

4.4.5 Long-term resettlement

Resettlement for a long period or for the rest of a lifetime must be regarded as a severe intervention in the living circumstances of the individual. Therefore, as for evacuation, an intervention reference level of 100 mSv is appropriate. Since resettlement is an effective measure against longer-term external exposure, it is necessary to consider a longer period, but one that is amenable to the dose forecast. A period of one year is therefore set as the dose integration time. Because the intervention reference level is well below the dose threshold for deterministic effects, the effective dose is the appropriate parameter:

Intervention reference level for long-term resettlement:

100 mSv effective dose due to external exposure in one year from radionuclides deposited on the ground and on other surfaces

In temperate zones – such as Central Europe – the inhalation dose due to resuspension of deposited radionuclides is small compared with external exposure due to deposited radionuclides, and can therefore be disregarded when calculating the intervention doses. There is no need to take account of the ingestion pathway, as it may be assumed that sufficient uncontaminated food will be available.

4.4.6 Temporary resettlement

If it is to be expected that the dose rate due to external exposure from the ground surface will subside relatively rapidly in the weeks and months following the accident as a result of radioactive decay or natural decontamination processes, temporary resettlement for a period ranging from a few weeks to several months may be sufficient. The dose integration time must be longer than the duration of the temporary resettlement, but should be considerably shorter than the integration time for long-term resettlement, in order to make the possibility of a return after a few weeks clear. A period of one month is therefore set as the dose integration time for temporary resettlement. Since temporary resettlement as a measure in itself has less impact on the personal and social living circumstances of the affected population, the intervention reference level must lie below the level for long-term resettlement. It is therefore set to 30 mSv. Since the intervention reference level is well below the dose threshold for deterministic effects, the effective dose is the appropriate parameter:

Intervention reference level for temporary resettlement:

30 mSv effective dose due to external exposure in one month

If the soil and other surfaces are contaminated with radionuclides with very long half-lives, a dose of 100 mSv per year is roughly equivalent to a dose of 10 mSv per month, i.e. the intervention reference level for long-term resettlement is reached before the value for temporary resettlement. Conversely, where contamination is largely by short-lived radionuclides (e.g. radioactive iodine), the greater part of the dose is received within one month. This means that depending on the size of the dose rate and its distribution over time, the intervention reference levels for sheltering, temporary resettlement or evacuation will be exceeded, but the intervention reference level for long-term resettlement will not.

The following table 4.3 provides a summary of the intervention reference levels for the measures specified.

In the event of longer-lasting releases, the time taken for the passage of the radioactive cloud in individual areas is greater than seven days; the integration time must be extended accordingly.

More time is available for decisions on the measures temporary and long-term resettlement than for decisions on the disaster control measures sheltering, intake of iodine tablets and evacuation.

Under the overall system of intervention reference levels as set out in Table 4.3, the countermeasures are taken as follows:

- against the total radiation exposure associated with the passage of the radioactive cloud including inhalation and dose commitment: at a level of not more than 10 mSv effective dose in seven days (sheltering/ intake of iodine tablets)[8],
- against the total external radiation exposure due to deposited short-lived radionuclides: at a level of approximately 30 mSv effective dose in one month (temporary resettlement), and
- against external exposure to deposited caesium isotopes at 100 mSv effective dose in the first year (long-term resettlement).

In order to be independent from local variations in protection factors, an uninterrupted outdoor presence of 24 hours per day is assumed in the application of the intervention reference levels specified. Thus the measures associated with the intervention reference levels commence at real radiation exposure levels that are considerably lower. Real radiation exposure levels are understood to mean exposure occurring during normal living habits, i.e. predominantly staying indoors.

[8]) 50 mSv of organ dose commitment (thyroid gland) corresponds to 2.5 mSv effective dose.

Table 4.3: Intervention reference levels for the measures: staying indoors, intake of iodine tablets, evacuation, long-term resettlement and temporary resettlement

Measure	Intervention reference levels		
	Organ dose (thyroid)	**Effective dose**	**Integration times and exposure pathways**
Sheltering		**10 mSv**	External exposure in **7 days** and effective dose commitment due to radionuclides inhaled during this period
Intake of iodine tablets	**50 mSv** for children and adolescents aged below 18 years and pregnant women, **250 mSv** for persons aged 18 to 45 years		Dose commitment on the thyroid gland by radioactive iodine inhaled over a period of **7 days**
Evacuation		**100 mSv**	External exposure in **7 days** and effective dose commitment due to radionuclides inhaled during this period
Long-term resettlement		**100 mSv**	External exposure in **1 year** due to deposited radionuclides
Temporary resettlement		**30 mSv**	External exposure in **1 month**.

The overall system of intervention reference levels therefore ensures that the maximum accidental radiation exposure received by children, as a group worthy of special protection, during their childhood is in the same range as their natural radiation exposure during the rest of their life.

Furthermore, the intervention reference levels set out in Table 4.3 are at the lower end of the interval specified in ICRP 63 for the optimized intervention levels. When considering this fact it should be remembered that the ICRP interval referred to relates to the dose that can be avoided by taking the measures, i.e. not to the dose for uninterrupted presence outdoors.

4.4.7 Intervention in supplies of foodstuffs for the population

With regards to intervention in supplies for the population, a distinction is made between (precautionary) warning of the population against eating freshly harvested foods and fresh milk on the one hand, and intervention in supplies of foodstuffs and feeding stuff on the basis of maximum contamination levels on the other. The warning to the population is issued in the area surrounding an emission source no later than the beginning of a hazardous release or in unclear radiological situations, or in more distant areas in the event of substantial radionuclide concentrations in the air. The maximum radioactivity levels in foodstuffs and feeding stuff in the event of a nuclear accident are laid down in EU regulations /EUR 87, EUR 89a, EUR 89b, EUR 90/ and listed in detail in the catalogue of measures /MNK 98/[9].

[9]) Updated reference, cf. Annex of the bibliography: /MNK 08/

4.5 Derived reference levels

Considerable difficulties arise when considering the question of whether certain body doses may occur in a given situation. These difficulties are due to the extremely complex processes which determine the way radioactivity is transported to human beings within the ecosphere following an accidental release. Depending on the nature of the accident, the release conditions, local conditions, time aspects, and ultimately the individual behaviour of the persons affected, there are a large number of different exposure possibilities and hence body doses for individual persons.

It must also be borne in mind that as a rule body doses are calculated figures, and not values that can be directly determined by measurement. The defined reference dose levels must therefore be expressed in terms of measurable quantities that can be used in decisions on the initiation of measures. Such figures are known as “derived reference levels”.

Suitable quantities are:

- local dose rate
- activity concentration in the air
- surface contamination (skin, ground, objects)
- specific activity, e.g. in foodstuffs and drinking water, in surface waters and feeding stuff.

To make it possible to convert measurements of the above-stated parameters into body doses, it is usually necessary to make further assumptions; in case of local dose rate, for example, these relate to past and future changes and the exposure time. In general, determination of the derived reference levels is based on the following requirements:

- A measurement method for determining the derived parameter has been laid down.
- Between the derived parameter and the body dose there is a correlation defined by model assumptions that reflects the exposure conditions.
- In order to comply with the principle of limiting the individual dose, the models take account of the characteristics of particularly sensitive groups of people and dominant exposure pathways.

Derived reference levels, like dose reference levels, always relate to specific measures. The fact that the correlation between measured value and dose may be measure-specific also plays a role here.

Derived reference levels can be obtained for a wide variety of contaminated environmental materials, exposure pathways and radionuclides. As a general rule derived reference levels used will be limited to those that are relevant to the radiation exposure for large population groups and which can be easily determined by measurement with sufficient accuracy. These must therefore be made available in advance as a basis for decision making. A comprehensive collection of derived reference levels can be found in the catalogue of measures /MNK 98/[10].

5 Decision making in the event of an incident

The intervention reference levels described in Section 4.4 are principally to be used for *assessing the necessity for protective measures and countermeasures*: the isodose contours defined on the basis of intervention reference levels are used to designate areas in which a need for

[10]) The reference was updated, cf. Annex of the bibliography: /MNK 08/

action regarding the relevant protective measures and countermeasures exists.

Nevertheless, it is possible that in the pre-release phase and the release phase knowledge deficits may render it impossible to make sufficiently accurate dose estimates. In that case the disaster control management – possibly with the aid of information from the facility or from expert institutions – will have to discuss the question of ordering precautionary measures. As a starting point for these deliberations it is also necessary to designate areas in which such measures must be considered.

When taking *decisions on the implementation of protective measures and countermeasures*, the opinions of the expert advisors from all sectoral authorities and institutions concerned should be heard and weighed up, provided time permitting. The result of this decision making process will be the ordering of disaster control measures and/or radiological protection precautions, specified as to time and place. If measures have already been taken, it will subsequently be necessary to decide whether and to what extent supplementary measures are necessary or whether measures can be discontinued.

5.1 Influencing factors

The purpose of assessing and weighing up all relevant influencing factors is to identify the strategy that achieves the best possible protection of the population under the prevailing limiting conditions. The expert advisors play a significant role here, because thanks to their expert knowledge they are in a position to provide qualitative and quantitative information about the relevant factors. The relevance of the factors in turn depends on the time after release and the location in view; the list below summarizes the main influencing factors without ranking them in order of importance:

- Potential individual dose:
  Avoiding serious deterministic effects and high risks of stochastic effects,

- Effectiveness and feasibility of measures:
  This includes in particular: feasibility aspects (availability of technical resources or administrative/ personnel support; state of transport routes, traffic conditions etc.), specific infrastructural limiting conditions (special facilities such as supply utilities, airports, old people's homes, hospitals, schools, prisons etc.), the commencement and progress of measures and their protective effect and the time until the radioactive cloud arrives, and the size of the avoidable body doses and/or health damage and risks,

- Negative impact of measures:
  Body dose of auxiliary personnel, exposure of population to risks, economic and social consequences of the measures.

- Subjective factors:
  Situation-specific assessments and judgements by the groups of people involved in the decision making process, such as acceptance by the public, equal treatment of the public and flexibility with regard to future decisions, and also socio-psychological or political aspects,

- Allowance for uncertainties:
  Inaccuracies in assessments of meteorological or radiological situation (weather development, source term etc.),

- Planning requirements (sectors):
  Representation of areas defined by isodose contours on the emergency control planning sectors.

5.2 Decision Making

The necessity to take a decision only arises when a variety of possible strategies for taking measures are conceivable. However, variations of the course of measures in time and space mean that one is very quickly confronted with a wide variety of action options. The real decision process then consists in identifying among these action options, in what is generally an iterative process, the most suitable procedure for taking measures as individual actions or combinations of actions (see Fig. 5.1).

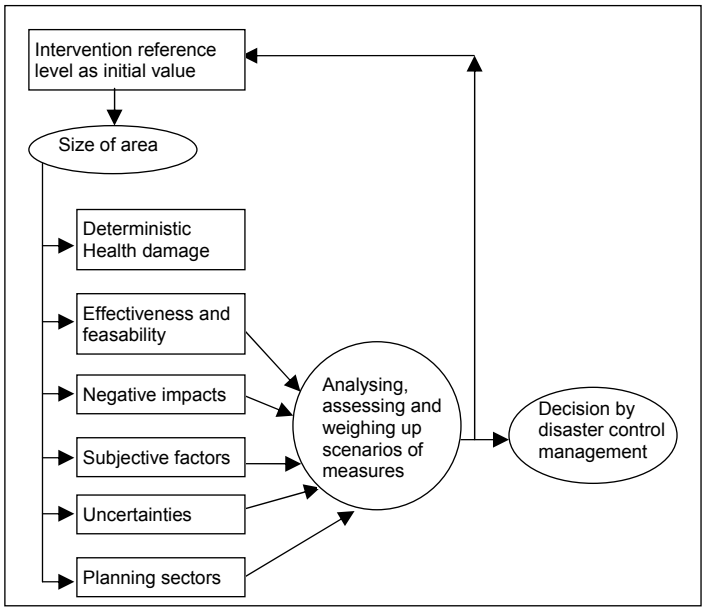

Fig. 5.1: Influencing factors and decision making as an iterative process

The process of assessing and weighing up is usually an intuitive one without any fixed structures or rules. It is therefore sensitive to variations in the availability of reliable information on the individual factors and in the decision makers' awareness of their relevance.

The extent to which such information is taken into account will also depend on the time available for decision making and the extent to which the relevant technical support is available. It is thus possible that objective factors may receive less attention if a very quick decision is required, if relevant technical arguments are not put forward, or if such aspects have not previously been addressed in trainings.

5.3 Methodological tools

From a scientific and technical point of view there are a number of tools available that may assist the emergency management under the conditions described. These include:

- Manual methods in which radiological parameters are estimated in manual calculations with the aid of tables, nomograms and calculation rules (Guidelines for the Technical Advisor on Radiological Protection to the Emergency Control Management in the event of Nuclear Accidents /SSK 95a/[11]; catalogue of measures /MNK 98/[11], mainly for decisions in the context of precautionary radiological protection).

- PC-based tools which essentially replace the manual calculations of the manual methods and thus reduce the possibility of calculation errors while increasing

[11]) Updated references, cf. Annex to the bibliography: /SSK 04b/, /MNK 08/, /PLU 07/, SAF 06/

computation speed (PLUTO /PLU 97/[11], SAFER /SAF 97/[11]).

- Computerized decision making support systems; these make it possible to create sound knowledge bases at various levels of information processing which can then serve as a basis for efficient decision making.

Decision making support systems for disaster control cover the distance range up to several (ten) kilometers within which (rapid) disaster control measures may be necessary. Such systems usually have access to facility-specific emission and immission data from a local monitoring network. They can also process measurement data from special measuring systems or mobile task squads (remote monitoring (KFÜ) systems in the *Länder* /Ebe 93/, CAIRE /CAI 92/, RODOS/RESY /ROD 97b/).

Decision making support systems for precautionary radiological protection cover an entire *Land* right up to its borders; they automatically evaluate and assess all the data from a full-coverage network of local dose rate measuring stations. In the event of radioactive contamination, additional data from special measuring systems or mobile task squads on nuclide-specific contamination of water, soil and foodstuffs is also fed into these systems (IMIS /IMI 93/[12], PARK [PAR 91], RODOS [ROD 97b]).

6 Radiological protection of task personnel

Task personnel within the meaning of the explanations below mean persons who are deployed in the event of a nuclear accident to deal with the consequences of the accident. In addition to the personnel of the nuclear facility this includes persons who are deployed due to their general occupational qualification for certain tasks (e.g. measurements, transport, repairs, construction work) and security and rescue personnel (e.g. the police, the fire brigade, ambulance personnel, doctors). There are considerable differences between the groups with regard to their knowledge of radiological protection and hence their ability to assess the extent to which they are at risk and to take effective independent action to minimize it.

Task personnel differ from the general public in that their additional radiation exposure results from the decision to deploy them to deal with the impact of the accident. The radiation exposure of the public can be avoided or reduced by measures taken by the task personnel. There must therefore be a difference between the radiological protection principles for the public and those for the task personnel.

The tasks to be undertaken by the task personnel differ depending on the phase of the accident, and consequently on the scope for steering radiation exposure in a planned way. The justification for the additional radiation exposure of task personnel is determined by the importance of their tasks.

The tasks can be divided into:

- Lifesaving measures
- Measures to avert a danger to persons or to prevent substantial expansion of the damage
- Early measures to protect the public
- Longer-term relief measures
- Measuring tasks

Before discussing the conclusions to be drawn from this, it is worth taking a brief look at the existing regulations in the Federal Republic of Germany. In § 59 of the Radiation Protection Ordinance the following are determined on "radiation exposure with personal hazard and assistance" /STR 01/:

(1) With measures for the fighting of dangers on behalf of persons, the aim shall be for an effective dose of more than 100 mSv to occur only once during any one calendar year and an effective dose of more than 250 mSv only once a lifetime.

(2) The rescue measures may only be conducted by volunteers over the age of 18 years who have first been instructed on the dangers of these measures.

For police and fire brigade assignments the *Länder* Ministers of the Interior have issued the service regulations for the fire brigade 500 "Units in NBC-operation" (FwDv 500) /FEU 04/ and the police guideline 450 "Dangers by chemical, radioactive and biological substances". In these dose reference levels of 15 mSv per person and year (fire brigade) and of 6 mSv per person and year (police), respectively, are determined for operations to protect material assets, in addition to the regulations according to § 59 of the Radiation Protection Ordinance .

In connection with these regulations and the dose limits laid down in them, it should be noted that they are intended for application to events of a different quality (e.g. accidents in radionuclide laboratories, transport accidents etc.) in which there is generally no justification for higher radiation exposure of task personnel who are not occupationally exposed persons. Their application in the event of a nuclear accident should, if appropriate with reference to the possibility of exceeding the limit, be handled such that a conflict with the intervention levels used for the general public is avoided in a particular case. It may also be borne in mind here that police and fire brigade task personnel are adults and usually in good health.

Lifesaving measures

The regulations referred to above provide for higher dose reference levels only in the exceptional case of an assignment to save human life, and are below the threshold for deterministic effects. In this dose range, the risk of delayed damage (stochastic effects) that is associated with every exposure to radiation is justifiable for saving human lives and does not exceed the usual extent of health risks otherwise involved in accident and disaster control assignments.

The Commission on Radiological Protection therefore recommends in Volume 4 of its publications "Medical Measures in Connection with Nuclear Power Plant Accidents" dated1995 /SSK 95b/[13] that a dose of 1 Sv should not be exceeded. However, in case of a nuclear accident, it must be ensured that dose limits for task personnel do not make it impossible to save lives.

Personal protective equipment must be used during the assignment. Radiation exposure must be monitored and recorded, insofar as is possible in the prevailing circumstances.

Measures to prevent escalation of damage

The tasks to be undertaken are characterized by

- Measures, which must not be delayed to restore the controllability of a radiation source that has got out of control,
- Implementation of measures to prevent or limit substantial releases of radioactivity into the surrounding area.

[12]) Updated reference, cf. Annex of the bibliography: /IMI 06/

[13]) Updated reference, cf. annex of the bibliography: /SSK 07b/

Releases are substantial if, for example, they are capable of resulting in deterministic effects in the population or if they make it necessary to evacuate a very large number of people. The tasks may, for instance, include switching operations and urgent repairs to restore coolability, and sealing and extinguishing work.

It may be assumed that as a rule such tasks will be performed by facility personnel with training in radiological protection and knowledge of how to apply radiological protection measures such as reducing exposure time, shielding, and protection against contamination and incorporation. The group of persons entrusted with such tasks also includes the facility's fire brigade.

However, it cannot be ruled out that members of the public fire brigades, the police and medical rescue services also take part in such assignments. Generally speaking, members of these groups know little about radiological protection and must therefore be advised by personnel with knowledge of the locality and of radiological protection.

It is typical for such tasks that they have to be carried out quickly and without delay. In such situations it is unlikely that there will be sufficient time for optimization.

As a rule, measures to prevent a substantial release are justified. Nevertheless, task personnel should not receive doses in excess of the threshold levels for deterministic effects (approx. 1 Sv effective dose or 5 Sv skin dose).

In the context of emergency response planning, steps must be taken to ensure that the protective equipment necessary for such tasks (breathing equipment, contamination protection, iodine tablets) is available.

Radiation exposure must be monitored and recorded. The exposure and the potential health consequences resulting from it must be notified and explained to the task personnel.

Early measures to protect the population

Typical assignments are in connection with traffic control measures or the transportation of persons, e.g. in an evacuation. Performing such tasks is the responsibility of members of the police, fire brigade, rescue services and additional helpers (e.g. drivers of vehicles).

Such assignments are generally justified if certain body doses are not exceeded. It may be possible to carry out a rough optimization. Every reasonable effort should be made to keep the body dose of the above-mentioned task personnel below 100 mSv a year.

Generally, task personnel will come from the local area. As part of emergency response planning for the facility, the group of persons likely to be involved should be provided with basic instruction on the risks arising from ionizing radiation, radiological practices (limitation of exposure time, contamination protection etc.) and the use of simple measuring instruments (dose meters, dose rate meters, dose warning devices). The task leader is to be advised by radiological protection experts. The emergency task management has to ensure that task personnel do not receive any unjustified radiation exposure.

The radiation exposure of task personnel is to be monitored and recorded; simplified methods are permissible (e.g. dose meter measurement of body dose on only one member of a group, estimate on the basis of the measured local dose rate and the relevant exposure times). After the assignment, the individuals concerned are to be told about the estimated body doses and the associated health risks must be and explained to them.

Longer-term remedial measures

Once the facility in question has been brought under control again, there is usually time available for tasks such as

- decontamination of the facility and the vicinity
- repairs to facility and buildings
- treatment and storage of waste

In such a situation it is possible to control the radiation exposure of task personnel assigned to such work. The persons so employed are to be classified as occupationally exposed persons in compliance with the relevant provisions of the Radiological Protection Ordinance.

Measuring tasks

To determine the radiological situation following a nuclear accident, it is necessary to undertake measurements both in the affected facility and in the vicinityt. This may result in radiation exposure of the measuring service personnel.

The justification for such radiation exposure must be based on the context in which the results of the measurement task are required. For example, radiation exposure of individual persons in connection with the measurements necessary for preparing lifesaving measures may be higher than the relevant radiation exposure for measurements obtained for decisions on longer-term remedial measures. Such considerations should take account of the fact that the radiation exposure resulting from performing a measurement task must be considerably lower than the radiation exposure that could be expected in other persons if the measurement were not carried out. For this reason the upper limits specified for the various task purposes stated above also always apply to the measurement tasks that are necessary for the decisions on such purposes.

Optimization aspects must be examined as early as the planning stage. Here it is necessary to consider whether the measurements necessary for determining the radiological situation can be obtained by means which eliminate or at least reduce exposure of the measuring services to radiation. Examples of potential options are stationary measuring points and probes with remote data communication links that can be deployed if needed, remote-controlled measuring vehicles, aerometry (= measurements from helicopter/aircraft). For cases where it is not possible to manage without measuring personnel, it is necessary to draw up deployment strategies that help to determine the radiological situation with a minimum of radiation exposure (deployment in specially protected measuring vehicles [with shieldings and air filters], equipping with dose meters and dose warning devices for self-monitoring, time limits for assignments, situation-dependent planning of measurement sorties, specification of return doses).

7 Radiological protection of specific occupational groups

If an accident has resulted in contamination of the surrounding area, all persons living there will be exposed to increased radiation. Decisions on whether people can stay in such an environment are to be taken in accordance with the radiological protection principles for the population. However, the increase in ambient radiation will not be uniformly distributed: there will be local concentrations and activity-specific concentrations. This could for example be the case for the following occupations:

- Sewage sludge processing,
- Work on industrial filter systems (presence close to such systems, changing or cleaning filters, waste treatment).

The programme of measurements for monitoring environmental radioactivity will provide indications as to whether such activities may result in elevated radiation exposure, which may create a need for specific monitoring programmes and also radiological protection measures for the persons employed there.

In view of the large number of possible situations, it is not possible to define any requirements in advance; decisions on the justification and optimization of such activities must be taken in the light of the circumstances actually prevailing.

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List of abbreviations used

CAIRE	Computer Aided Response to Emergencies
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILO	International Labor Office
IMIS	Integrated Measurement and Information System
OECD/NEA	Organization for Economic Cooperation and Development / Nuclear Energy Agency
PAHO	Pan American Health Organization
PARK	Programmsystem zur Abschätzung und Begrenzung Radiologischer Konsequenzen (Programme to estimate and limit the radiological impact)
PLUTO	**P**rogrammsystem nach dem **L**eitfaden für den Fachberater Katastrophenschutz bei kerntechnischen **U**nfällen für den Fachberater Strahlenschutz und **T**echnik vor **O**rt (Programme in accordance with the guideline for the expert consultant on emergency management in the event of radiological accidents and for the expert consultants on radiation protection and technican on site)
RODOS/RESY	**R**ealtime **O**nline **D**ecisi**o**n **S**upport System/ rechnergestütztes Entscheidungshilfe-System
SAFER	Strahlenexposition als Folge eines Reaktorunfalls (radiation exposure due to an accident at a nuclear power plant)
WHO	World Health Organization

Appendix

Iodine Saturation of Thyroid Gland in the Event of Nuclear Accidents

Recommendation by the Commission on Radiological Protection

Table of contents

1 Instruction sheet for physicians

1.1 Preliminary remarks

The authorities responsible for disaster control keep stocks of potassium iodine tablets (called iodine tablets in the following) to issue them to the population if the need arises, except where they have already been distributed to households meeting certain criteria. One tablet contains 65 mg potassium iodide (KI), corresponding to 50 mg iodide. This instruction sheet is intended to inform the physician about the main questions associated with iodine saturation of the thyroid gland. In this connection, attention is also drawn to the instruction sheet for the population.

1.2 Why saturate the thyroid gland?

Among the fission products created during the operation of nuclear reactors are the various radioactive isotopes of iodine. Because of the special biological feature of iodine, namely its incorporation in the thyroid hormones, these isotopes are of special importance. Since the temperatures in nuclear reactors are such that the iodine is present in gaseous form, it is possible that in the event of an accident, radioactive iodine may in unfavorable circumstances be released into the air. The greater part of this radioactive iodine will be deposited on the ground and on plants. From here it may be absorbed by humans by way of foodstuffs, and in particular through milk. In case of a nuclear accident, radioactive iodine may also be inhaled with the air and absorbed by the lungs.

After absorption, the radioactive iodine behaves in exactly the same way as stable iodine. Dispersion in the extravascular area is followed by a temporary concentration in the salivary glands and the mucous membrane of the stomach and, in particular, by a long-lasting accumulation in the thyroid gland. The extent of the accumulation in the thyroid gland depends on the functional state of that organ and, in the case of euthyroidism, especially on iodine supply in nutrition. The lower the amount of iodine in nutrition, the higher the percentage accumulated in the thyroid gland. In Germany, which is an iodine-deficient region, the intake of iodine from foodstuffs is generally less than 100 µg per day, and in case of euthyroidism more than 50 % of the radioactive iodine absorbed is accumulated in the thyroid gland. In countries with adequate supplies of iodine the absorption of radioactive iodine is lower by a factor of 2 to 3.

The purpose of iodine prophylaxis is to prevent radiation-induced thyroid carcinomas. Children are especially at risk.

1.3 When is iodine prophylaxis indicated?

Iodine propyhlaxis of the thyroid gland shall only be considered if the assessment of the situation indicates that there is a genuine risk of a substantial release of radioactive iodine. High thyroid doses via incorporation of iodine may especially affect children younger than 4 years. Therefore; the main focus when implementing iodine prophylaxis should be on the protection of children and pregnant women.

A release of radioactive iodine on a scale suggesting a need for iodine prophylaxis for the population will usually be identified in good time. A warning period ranging from hours to days can therefore be expected, during which the authorities can issue the necessary instructions based on the information available to them and their judgement of the situation.

It is necessary to point out to the population that it would be useless and even harmful to undertake iodine prophylaxis on their own, i.e. without being requested to so by the authorities. This would merely expose them unnecessarily to the risk of side effects.

1.4 Is thyroid prophylaxis permissible for pregnant women and breastfeeding mothers?

The recommended iodine prophylaxis shall also be carried out by pregnant women independent of their age.

Fetuses, start taking up iodine through the thyroid gland from about the 12th week of pregnancy. From sixth to ninth month, iodine storage in the foetal thyroid gland is considerable. There is thus a need for saturation of the thyroid gland in older foetuses, and this takes place through the administration of iodine to the pregnant woman without the need for any special dose adjustment.

Occasionally, the sensitive foetal thyroid gland may develop a goitre with hypothyroidism. This hypothyroidism is identified by the routine TSH screening on the fifth day after birth and treated accordingly.

During lactation, iodine is present in the mother's milk in individually varying quantities. Since this does not guarantee adequate iodine prophylaxis for breast-fed babies, iodine tablets should also be given to neonates and breast-fed babies (see dosage scale).

Women who have been treated with large doses of iodine during pregnancy and lactation should be urged to point this out to the obstetrician and paediatrician so a particularly careful check for any functional disorders of the thyroid gland can be carried out in the newborn baby.

1.5 How is the thyroid blocked against radioactive iodine?

Accumulation of radioactive iodine in the thyroid gland can be prevented by administering a considerable quantity of stable (non-radioactive) iodide in large individual doses (ranging from 12.5 to 100 mg depending on age) before the intake of radioactive iodine takes place. As a result of this increased supply of stable iodine in conjunction with the limited uptake capacity of the thyroid gland, only a small fraction of radioactive iodine absorbed by the body is stored in the thyroid gland. The iodine not stored is excreted from the body with a biological half-life of approximately six hours.

Since the accumulation curve of the thyroid gland is initially very steep, iodine prophylaxis is most effective if the stable iodine is already present in the organism shortly before the radioactive iodine is absorbed. However, a reduction in the amount accumulated is still achieved in the first few hours after intake of radioactive iodine (iodine taken two hours later – reduction by about 80 percent; iodine taken eight hours later – reduction by about 40 percent). By contrast, administering stable iodine later than 24 hours after inhalation or ingestion of radioactive iodine no longer has any appreciable influence on this accumulation nor, consequently, on the radiation exposure of the thyroid gland due to radioactive iodine. If large doses of stable iodine are given much later than 24 hours after incorporation, this actually increases the time the radioactive iodine is retained in the body. Iodine tablets should therefore not be taken after this point in time.

1.6 What should be the dose of potassium iodide?

Not only the timing of administration, but also the quantity of stable iodine is of crucial importance in reducing the accumulation of radioactive iodine. Since it is important that the blockage is is as complete as possible, a high plasma concentration of stable iodine must be achieved initially. In adults this is achieved with a dose of 130 mg potassium iodide; this dose does not generally involve any risk of an intolerant response by the stomach, provided the intake does not occur on an empty stomach.

Reducing the dose does not reduce possible side effects; increasing it would not be harmful, but does not result in any appreciable reduction in radiation exposure.

1.7 The following doses are recommended

These doses apply only to the tablets of 65 mg potassium iodide stored at emergency storage.

Group of persons	Daily dose in mg iodide	Daily dose in mg potassium iodide	Tablets of 65 mg potassium iodide
< 1 month	12.5	16.25	¼
1 – 36 months	25	32.5	½
3 – 12 years	50	65	1
13 – 45 years	100	130	2
> 45 years	0	0	0

(When tablets with other potassium iodide concentrations are used please observe the relevant dosages.)

Iodine tablets are only to be taken on request by the competent authority. Pregnant women and breast-feeding mothers receive the same iodine dose as the group aged 13 to 45 years. As a rule it is sufficient to take a single dose of iodine tablets. In exceptional cases, however, the competent authority may recommend taking an additional dose. For new-born children younger than one month and for pregnant or breast-feeding women the intake should however be limited to one day and two days, respectively.

Iodine tablets should preferably not be taken on an empty stomach. The tablets can be swallowed or ingested after been solved in liquid. The intake can be made easier – especially for children – by dissolving the tablet in a drink, e.g. water or tea. The solution does not keep, however, and must be drunk immediately.

1.8 What health risks are involved in iodine prophylaxis of the thyroid gland?

Persons with a known hypersensitivity to iodine (very rare disorders such as genuine iodine allergy, dermatitis herpetiformes Duhring, iododerma tuberosum, hypocomplementaemic vasculitis, myotonia congenita) must not take iodine tablets. In rare cases iodine tablets may also lead to skin rashes, oedema, sore throat, watering eyes, nasal catarrh, swelling of the salivary glands and elevated temperature.

In very rare cases, signs of hypersensitivity to iodine (genuine iodine allergy), e.g. iodic rhinorrhea or iodic rash, may be observed. The possibility of intolerance to iodine should not be overrated. Absorption of iodine by the body can be inhibited by gastric irrigation with starch solution (30 g to 1 litre until blue colour disappears) or with a 1–3 % solution of sodium thiosulphate. Administration of Glauber's salts and forced diuresis are recommended to speed up excretion. Any shock and any water and electrolyte disorders are to be treated in the usual way.

In cases of a previous history of thyroid disorder, even if its course has so far been asymptomatic (especially in cases of nodular goitre with functional autonomy), hyperthyroidism may be triggered within weeks or months after administration of iodine.

Conversely, neonates and infants are especially susceptible to hypothyroidism if iodine is administered for longer periods of time.

Owing to the low risk of carcinoma induction by radioactive iodine in older individuals and the rising incidence of pathological functional autonomy with increasing age, iodine prophylaxis should not be given to persons over 45 years of age.

1.9 Induction of hyperthyroidism

A healthy thyroid gland has several regulatory mechanisms that enable it to tolerate an excess supply of iodine without any harmful increase in production of thyroid hormones. The pathological mechanism by which an elevated supply of iodine results in clinically manifest thyroidism is not yet fully understood. It is however known that this transition to hyperthyroidism occurs mainly in areas where goitre is endemic with a high prevalence of functional autonomy.

This possibility of triggering hyperthyroidism therefore has to be expected in the Federal Republic of Germany if the intake of iodine is high.

The following are possible bases for the development of hyperthyroidism:

1. Autoimmune hyperthyroidism (Basedow's disease),

2. Functional autonomy
   - unifocal/multifocal ("autonomous adenoma"),
   - disseminated.

All three disorders of the thyroid gland may also exist as latent disorders without displaying any clinical symptoms of hyperthyroidism.

1.10 Contra-indications for iodine prophylaxis of the thyroid gland

Unfounded contra-indications occasionally found in literature are cardiac insufficiency and the various forms of tuberculosis. Pregnancy and lactation, as well as hypothyroidism and thyroiditis, are also mentioned but are not contra-indications.

Iodine must not be administered if there is a known iodine allergy. This should not be confused with an intolerant response or allergy to X-ray contrast agents, which in most cases is not due to the iodine they contain.

Patients suffering from certain very rare diseases – genuine iodine allergy, dermatitis herpetiformes Duhring, iododerma tuberosum, hypocomplementaemic vasculitis, myotonia congenita – must not take iodine under any circumstances.

Patients undergoing treatment for hyperthyroidism must continue their treatment alongside the intake of iodine. All patients suffering from hyperthyroidism – whether or not undergoing treatment – must be monitored by a doctor with hormone analyses at frequent intervals after the end of an emergency involving iodine prophylaxis.

1.11 Other medication that can be used to block the thyroid gland

Since the aim of iodine prophylaxis is to prevent the accumulation of radioactive iodine in the thyroid gland as much as possible, the most suitable medication apart from iodine is perchlorate, which competitively inhibits the uptake of iodine, e.g. potassium perchlorate as Irenat®.

The following dosage is recommended for adults:

Sodium perchlorate as Irenat®:
- on first day 60 drops,
- there after 15 drops every six hours for seven days.

Contra-indications such as hypersensitive reactions (agranulocytosis) and serious liver damage must be observed.

As iodine prophylaxis using iodide is more effective than using perchlorate, perchlorate shall only be used if high iodide dosages are contraindicated.

2 Instruction sheet for the population

2.1 Radiation accidents with release of radioactive iodine

In case of accidents at nuclear facilities, especially at nuclear power plants, there may in unfavorable circumstances be a release of radioactive substances – including radioactive iodine – that makes it necessary to take countermeasures. Radioactive iodine has the same chemical and biological properties as natural iodine contained in our food, and it is therefore stored in the thyroid gland in the same way as normal, non-radioactive iodine. This concentrated storage in the thyroid gland makes iodine different from other substances.
As countermeasure the intake of iodine tablets (iodine prophylaxis of the thyroid gland) can inhibit this storage.

2.2 How does radioactive iodine enter the body?

Like other substances from the environment, radioactive iodine can enter the human body (incorporation) in three ways:

1. with air via the respiratory tract (inhalation),
2. with food and drink via stomach and intestines (ingestion), and
3. via the skin following contamination.

Uptake via the skin is usually so minimal that it can be disregarded. Intake with water or food may be considerable, e.g. if milk is drunk that comes from cows that have been grazing on grass contaminated with radioactive iodine. This intake, however, is very easy to prevent following a nuclear accident: such milk, or vegetables from areas on which radioactive iodine has been deposited, are withheld from immediate consumption.

The intake of radioactive iodine with the air we breathe can only be reduced insignificantly by staying indoors. Taking iodine tablets reduces the effect of radioactive iodine in the body by ensuring that it is excreted as quickly as possible.

2.3 How do iodine tablets work?

In order to function properly, the thyroid gland needs small quantities of iodine, which are normally present in the food we eat. Since Germany is an iodine-deficient region, adequate supplies cannot be guaranteed from our normal food intake. For this reason it is generally recommended that iodine-deficiency diseases be prevented by using iodine-enriched salt or taking tablets with a low iodine concentration (0.1 to 0.2 mg); these tablets, however, are not suitable for iodine prophylaxis of the thyroid gland.

Only iodine tablets with a significantly higher iodine concentration are suitable for saturation purposes, since they prevent the uptake of radioactive iodine by the thyroid gland. The surplus iodine is quickly excreted from the body.

2.4 Why take iodine tablets as a preventive measure?

It must be pointed out that taking iodine tablets provides protection against the effects of radioactive iodine only, and not against the effects of other radioactive substances. This protection is most effective if the tablets are taken shortly before or practically at the same time as the radioactive iodine is inhaled. A certain protection is nevertheless achieved even a few hours after inhaling radioactive iodine. More than a day after the intake of radioactive iodine, taking iodine tablets no longer provides any protection; indeed, it is more likely to be harmful. The same applies to taking iodine tablets too early.

2.5 Where and when are iodine tablets obtainable if needed?

The competent authorities have built up adequate stocks of iodine tablets and have stored them so that if required they can be distributed without delay to the affected population, except where they have already been distributed beforehand to households meeting certain criteria. “If required” means that – depending on how an accident situation develops – it might become advisable to take iodine tablets. The distribution of iodine tablets is a precautionary measure and does not mean that the tablets should be taken immediately. If the intake should in fact become necessary, the disaster control authority will expressly request the affected population to do so with announcements over the radio or public address system.

Since only the authorities, in light of their assessment of the accident situation, can decide whether the intake of iodine tablets is necessary, the tablets should never be taken on own initiative or as a result of anxiety.

2.6 Composition of tablets for iodine prophylaxis

One tablet of the emergency storage in Germany contains 65 mg potassium iodide, corresponding to 50 mg iodide.

At the pharmacies also iodine tablets with 130 mg potassium iodide, corresponding to 100 mg iodide, are obtainable.

2.7 Effects and reason for use

In the specified doses and taken at the specified time, iodine tablets saturate the thyroid gland with iodine and thereby prevent it from storing radioactive iodine (iodine prophylaxis). Iodine tablets of this kind are not suitable for compensating the iodine deficiency prevailing in Germany.

2.8 Dosage

This dosage only applies to the 65 mg potassium iodide tablets of the emergency storage.

Individuals aged 13 to 45 years take a single dose of two tablets. Children aged three to twelve years take a single dose of one tablet. Infants aged one to 36 months take a single dose of a half of a tablet. Neonates up to one month take a single dose of a quarter of a tablet.

(When tablets with a different concentration of potassium iodide are used, please follow the dosage as prescribed in the corresponding instruction sheet.)

The iodine tablets should preferably not be taken on an empty stomach. The tablets can be swallowed or ingested after been solved in liquid. Taking them can be made easier – especially for children – by dissolving the tablet in a drink, e.g. water or tea. The solution however does not keep and should be drunk immediately.

Iodine tablets are only to be taken when so directed by the competent authority. Pregnant women and breastfeeding mothers receive the same iodine dose as the

group aged 13 to 45 years. Adults aged over 45 years should not take any iodine tablets, as the health risk of serious thyroid disorders (e.g. iodine-induced hyperthyroidism) as a result of taking the tablets is greater than the radiation risk from breathing radioactive iodine.

As a rule, a single dose of the iodine tablets is sufficient. In exceptional cases the competent authority may recommend taking additional tablets. The number of tablets issued is adequate for this purpose. For neonates younger than one month the administration of iodine must be limited to one day and for pregnant women to two days.

2.9 Iodine tablets during pregnancy

As the intake of iodine tablets protects both mother and the unborn child, the recommended iodine prophylaxis should be carried out during pregnancy as well independent of the age of the pregnant woman. The pregnant woman should however inform her physician that she has taken iodine tablets, as the physician will then pay special attention during the routine thyroid check on the new-born child.

2.10 Incompatibility and risks:

Iodine tablets must not be taken at:

- known hypersensitivity to iodine (this is very rare and must not be confused with an intolerant response or allergy to X-ray contrast agents),
- dermatitis herpetiformes Duhring,
- hypocomplementaemic vasculitis (inflammation of the blood vessel wall due to allergy)

In rare cases iodine tablets may also lead to allergic reactions such as skin rashes, oedema, sore throat, watering eyes, nasal catarrh, swelling of the salivary glands, elevated temperature and other similar symptoms

Individuals who are or were suffering on hyperthyroidism shall take iodine tablets while continuing their treatment, after the emergency situation finishes, however, they shall consult their physician.

Individuals suffering on hyperthyroidism or a giotry are at a higher risk that their situation worsens or of triggering a hyperthyroidism. Therefore, it is necessary that they consult their physician at the earliest possibility after the intake.

Individuals developing complaints during one week and up to three months after the intake of the tablets that are symptoms for an over activity of the thyroid gland, such as agitation, heart palpitation, weight loss or diarhoea, must also consult their physician.

2.11 Persons aged over 45 years

The performance of iodine prophylaxis in persons aged over 45 years is not recommended due to the following reasons:

1. As iodine-deficient country, in Germany dysfunctional metabolisms of the thyroid gland occur with increasing age. Such a so-called functional autonomy increases the risk of side effects during iodine prophylaxis.
2. With increasing age the risk of a thyroid carcinoma induced by radiation significantly decreases.

2.12 Concomitant phenomena

Taking iodine tablets may cause temporary stomach problems, especially when iodine tablets are taken on an empty stomach. If the symptoms last for any length of time, a physician should be consulted.

2.13 What do iodine tablets not protect against?

Iodine tablets do not provide protection against radiation from outside the body, nor against radioactive substances other than iodine that have been absorbed by the body.

2.14 Urgent request

In your own interests you should therefore follow the instructions given by the authorities, since they are able to judge the overall situation and will order further appropriate protective measures.

2.15 Note

The tablets – like other pharmaceutical products – shall be protected from light and moisture and be kept out of children's reach

In view of the possible side effects, iodine tablets should only be taken by persons aged below 45 years (except for pregnant women) and only after specific request by the competent authorities.