Strahlenschutzkommission

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Medical management of radiation emergencies – Requirements and organisational matters

Recommendation by the
German Commission on Radiological Protection

Adopted at the 327th meeting of the German Commission on Radiological Protection on 11/12 September 2023

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**Medizinisches Management von Strahlennotfällen
– Voraussetzungen und Organisation**

Empfehlung der Strahlenschutzkommission

Preface

In its 2017 recommendations “Medical capacities required to care for the public in the event of a radiological or nuclear emergency” and “Medical capacities required to care for the public in the event of a radiological or nuclear emergency – training certification”, the SSK recommended establishing specifications for certified education, further and advanced training with regular exercises for medical staff required in case of a radiological and nuclear emergency, as well as details regarding their qualification. Within the scope of the recommendations, the SSK newly established qualification requirements and defined the eligible target group for the qualification as well as the curricular content of a qualification in “Radiation Emergency Management” and as “Radiation Emergency Physician”.

In an advisory mandate of 24 January 2020, the SSK was asked – as a supplement to these recommendations – to develop minimum requirements for hospitals concerning structural, staffing and technical capacities, contents for a curriculum, as well as a proposal on how to implement these recommendations in the emergency management system of the federal government and the Länder.

To fulfil this advisory mandate, the Medical Radiation Emergency Management working group of the Emergency Preparedness and Response and Radiological Protection in Medicine Committees of the German Commission on Radiological Protection was deployed, which included the following members:

- Dipl.-Phys. Franz Fehringer, Blankenheim, chair of the working group
- Prof. Dr. Wolfgang Burchert, Bad Oeynhausen
- Dr. Werner Kirchinger, Neuherberg
- Dipl.-Phys. Jürgen Kopp, Adelsried
- Prof. Dr. Matthias Port, Munich
- Prof. Dr. Christoph Reiners, Würzburg
- Dr. Rita Schneider, Würzburg
- Prof. Dr. Johann Wilhelm Weidringer, Munich

Bonn, dated 2023

Dipl.-Phys. Franz Fehringer	*Prof. Dr. Matthias Port*	*Prof. Dr. Ursula Nestle*
Chair of the Medical Radiation Emergency Management working group	Chair of the Committee on Emergency Preparedness and Response	Chair of the German Commission on Radiological Protection (SSK)

Contents

1 Introduction

In the implementation of Directive 2013/59/Euratom, Section 97 of the Federal Radiation Protection Act (StrlSchG 2017) stipulates that the federal government and the Länder shall establish coordinated emergency response plans. The response plans are intended to outline planned adequate responses to emergencies using specific reference scenarios, thus enabling the authorities and organisations involved in emergency response to make prompt coordinated decisions and take appropriate action promptly. In this context, the general emergency response plan of the federal government (ANoPl-Bund), as the overarching document, specifies fundamental protection strategies for different types of emergencies of varying severity. The general response plan shall be supplemented and substantiated by sector-specific emergency response plans of the federal government (BNoPl-Bund) and further by the general and specific emergency response plans of the Länder.

The plans and precautions for medical emergency preparedness and response are to be presented in the special Federal Emergency Plan for civil protection, general emergency response and assistance, as well as for medical treatment and precaution following radiation exposure of the public and the emergency workers (Section 99 (2) No. 1 StrlSchG).

In future, the publication “Radiation emergency medicine – Handbook for medical care and training” of the German Commission on Radiological Protection (SSK) should serve as a guideline for the medical care of radiation emergency patients (SSK 2022). The handbook describes detailed emergency response measures for scenarios affecting only a few individuals (e.g. accidents in a research laboratory or an industrial plant), but also for large-scale accidents with mass casualties (such as an accident at a nuclear power plant or a terrorist attack).

This recommendation regarding the requirements and organisation for the medical response to radiation emergencies supplements and substantiates two previous SSK recommendations published in 2017. In its recommendation “Medical capacities required to care for the public in the event of a radiological or nuclear emergency” (SSK 2017a) the SSK recommended the development of a tiered, integrated concept of precautionary measures and care which, depending on the scenarios and associated requisite capacities, includes both advice and care for individuals as well as provisions to care for vulnerable groups (e.g. the seriously ill), and of exposed or concerned people in a mass causality event. Among other things, this includes ensuring an up-to-date inventory of clinical treatment capacities and expertise by continuing regular surveys and defining the minimum requirements for hospitals in terms of structural, staffing, and equipment capacities in the sense of a mandatory requirements profile. The SSK further recommended the establishment of a central coordination unit that allocates affected persons to appropriate medical facilities throughout Germany. This coordination unit should provide information on the current treatment expertise and capacities available at the respective medical facilities, the physicians specially trained for the emergency, and the further medical staff. Finally, the SSK noted that the participation of other ministries besides the Federal Environment Ministry is necessary for implementation.

In another recommendation (SSK 2017b), the SSK described the necessary qualifications of the requisite medical staff in emergency care. Within the scope of the recommendations, the SSK newly defined qualification requirements and the eligible target group for the qualification and further presented the curricular content of a qualification in “Radiation Emergency Management” and as “Radiation Emergency Physician”.

Among other things, the SSK had already recommended establishing teams for providing emergency medical treatment on site, whose members complement one another in terms of their qualifications and, where possible, already have prior experience in handling exposure of humans to ionising radiation.

Emergency physicians, rescue services, and fire departments have only partially sufficient equipment for the primary care of radiation emergency patients at the accident site and their transportation to the hospital. Furthermore, rescue workers are only rudimentary prepared for the special challenges of medical care in radiation emergencies. The transfer of radiation emergency patients to a hospital represents an interface problem in the care chain, as the hospitals usually have neither the necessary infrastructure and equipment nor sufficiently qualified personnel at their disposal.

The reasons for this are manifold: on the one hand, the staff is not sufficiently qualified; on the other hand, the responsibilities for radiation protection, civil protection and health of the departments and authorities in the federal government and the Länder are highly complex. The system of emergency response plans of the federal government and the Länder is meant to provide more transparency here. However, fundamental questions regarding the organisation and financing of the medical care of radiation emergency patients in hospitals remain unanswered; with this recommendation, the SSK endeavours to contribute to resolving these questions.

2 Advisory mandate

In addition to the advisory mandates for medical emergency preparedness, the SSK was asked to provide a recommendation that should include the following:

- Definition of minimum requirements for hospitals concerning structural, staffing and equipment capacities through a mandatory requirements profile.
- Preparation of curricular content for the planned qualifications “Radiation Emergency Management” and “Radiation Emergency Physician”.
- Proposal on how to practically integrate the SSK recommendations into the federal government's emergency response system and the Länder.

The following recommendation is based on analyses of the status quo (early 2023) of the organisation of the medical radiation emergency response in Germany and internationally. It also takes account of general aspects to maintain competence in medical radiation protection and radiation research associated with the task at hand.

3 Recommendation

This chapter provides a summary of the main recommendations. More in-depth descriptions and suggestions are to be found in the subsequent sections.

The SSK recommends establishing a network to ensure adequate medical care of patients in the event of radiation emergencies and defining minimum requirements for the hospitals involved.

For equipping hospitals with infrastructure, devices/material and regarding staffing, the SSK further recommends

- establishing a two-tiered nationwide network of hospitals that are adequately equipped to care for radiation emergency patients (radiation emergency centres): 20 to 30 hospitals that are willing to receive radiation emergency patients (extended care) and five to seven special facilities in large hospitals (comprehensive care);

- enabling so-called extended-care hospitals to ensure primary triage and initial treatment of radiation emergency patients (e.g. with combination injuries) and to treat non-complex cases of radiation-induced health injuries;
- enabling the special comprehensive-care facilities to perform secondary triage, special decontamination and decorporation therapies as well as complex treatment of the acute radiation syndrome (ARS) following radiation emergencies with a higher exposure and an expected complex course;
- developing interdisciplinary concepts and provisions - already in the planning phase - for the care of contaminated radiation emergencies. Special medical fields to be included are, in particular, acute and emergency medicine, anaesthesia, haematology, trauma surgery, dermatology, radiotherapy and nuclear medicine;
- creating and maintaining provisions for special emergency care that are not part of the current standard equipment of hospitals (e.g. appropriate spatial planning and routing systems, decontamination facilities, special measuring instruments, sufficient stocks of medicines, equipment and medical material, personal protective equipment);
- enabling the hospital pharmacy of a radiation emergency centre to have at its immediate disposal – if indicated – medicines that are required for the treatment of ARS and radiation-induced damage to the skin and soft tissue;
- establishing teams for care of radiation emergency patients in the participating hospitals; the teams should comprise qualified physicians, medical technologists, nursing staff, rescue workers, medical physicists, technicians, radiation protection experts and crisis intervention experts; and
- forming mobile teams to support the care of radiation emergency patients, in which radiation protection experts from facilities outside of radiation emergency centres can also be involved.

For the establishment of a central coordination unit, the SSK recommends

- setting up and operating a coordination unit, e.g. based on the nationwide system for the distribution of intensive care patients according to the German cloverleaf system;
- supporting the coordination unit with an advisory panel of experts in radiation protection and the treatment of radiation emergencies;
- enabling the coordination unit to provide necessary information about available treatment capacities, the equipment and staffing resources available in the hospitals, and the current availability of mobile experts to support emergency care on-site;
- authorising the coordination unit to distribute radiation emergency patients throughout Germany based on the available daily updated treatment capacities and the currently available equipment and staffing resources in the participating hospitals;
- involving the coordination unit, with its advisory panel, in reviewing the requirements profile and the hospitals’ quality assurance system, whereby the requirements must be regulated bindingly and
- enabling the coordination unit to deploy mobile experts to assist in the care of radiation emergency patients and also for radiation emergencies even on-site.

To establish the curricula for “Radiation Emergency Management” and “Radiation Emergency Physician”, the SSK recommends

- in future, laying the foundations for a qualification (in terms of the knowledge described) already at school and study;
- developing modular curricula for further qualification of all professional groups:
  - Module 1: Basics and preclinical care
  - Module 2: Psychosocial support/crisis communication
  - Module 3: Inpatient clinical care (physicians only)
- acquiring the qualification “Radiation Emergency Management” requires successful completion of the first two modules, while the qualification “Radiation Emergency Physician” additionally requires completion of the third module. Participation in an emergency exercise is mandatory to obtain the qualification;
- updating the qualification at least every five years through participation in a course, in an exercise or through active involvement in managing a radiation emergency; and
- conducting exercises both at the level of a radiation emergency centre and at the state and federal level at regular intervals. In this regard, virtual exercises could be carried out in addition to mandatory practical exercises under realistic conditions.

Regarding the integration into the emergency response system of the federal government and the Länder, the SSK recommends

- implementing the present SSK recommendations in the relevant regulations of the federal government and the Länder applicable to the respective subject area within the scope of the interlinked structure (cf. in particular Section 92 (1) and Section 109 StrlSchG);
- fostering close collaboration among the BMUV, BMG, BMI, BfS, BBK and the Länder, especially to establish the network for the care of radiation emergency patients in Germany recommended by the SSK; and
- ensuring the flow of communication from the coordination unit into the emergency management system of the federal government and the Länder.

Financing of the necessary expenditures for implementing these SSK recommendations should be provided jointly by the federal and state ministries for the environment, health and internal affairs. The SSK recommends

- financing the facilities, the operation and the maintenance of the hospital network (infrastructure, equipment and material, staff) with specific means;
- ensuring the installation and operation of the central coordination unit (digital infrastructure, personnel); and
- covering the costs due to the release of staff from work, the participation in qualification measures, trainings and exercises, and the costs of developing virtual training and decision-making systems.

4 Care of radiation emergency patients

4.1 Situation in Germany

4.1.1 Overview of available clinical capacities and expertise for caring for radiation emergency patients

Since 2007, a nationwide overview of clinical capacities and expertise for caring for radiation emergency patients in Germany has been compiled within the scope of a research project commissioned by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The project was first conducted under the auspices of the Federal Office for Radiation Protection (BfS) and later by the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) (SSK 2017a).

Annual surveys among (non-representatively) selected hospitals collect information about available capacities (general hospital information, specific structural and performance data and staffing resources), identify the subjective self-assessment of the treatment expertise for radiation emergency patients and ascertain the hospitals' willingness to receive and treat such patients. A database-driven web application, updated annually, serves to facilitate the identification of hospitals for patient allocation (Schneider and Reiners 2010).

Since 2007, a core group of approximately 35 hospitals has consistently expressed its willingness to receive and treat radiation emergency patients and to take part in the voluntary allocation procedure. This means that, in an emergency, only a few clinical care facilities would be available throughout Germany. Access to the list of participating facilities is granted by the BMUV (SSK 2017a).

The current concept of the hospital survey has some weaknesses outlined below; these concern the survey instrument itself, the performance of the survey and the interpretation of the results. Shortcomings also exist concerning the further development, financing and availability of and access to the hospital database.

Since the information provided in the questionnaire represents a self-assessment, it remains unclear whether the results can be considered a reliable indicator of a hospital's qualification in the event of an actual radiation emergency. Furthermore, the questionnaire lacks some relevant questions, such as the stockpiling of special decorporation agents or the technical equipment available in the hospitals. The reliability of the survey results is further limited due to incomplete or missing data.

Since the data are collected with a delay of at least one year, the lack of actuality of the data also poses a problem.

Information relating to technical expertise, available staffing and structural capacities is based on a hospital's subjective self-assessment, which is neither reviewed nor externally verified. Since objective external verification is lacking thus far, the survey results do not allow reliable conclusions about the hospitals' available treatment capacities. In addition, the results depend on the responding hospitals' knowledge, accuracy and motivation. Therefore, a responder bias, as well as an over- or underestimation of the capacities and expertise, cannot be ruled out.

Other open questions concern the verification of the expertise, for example, through participation in seminars, training courses and exercises, as well as the certification of the hospitals.

Questions related to the continuation of the project, the financing of the survey, and the access rights to the database also remain unresolved.

4.1.2 System of the Regional Centres for Radiation Protection of the Professional Associations (RCRP)

Already towards the end of the 1970s, the employers' liability insurance associations, following a change in radiation protection legislation with a resulting increase in occupationally exposed persons, recognised the need to make provisions to establish special facilities capable of receiving and caring for persons exposed to ionising radiation in work-related accidents. Here, the focus was not on emergencies affecting a large number of individuals but rather on "small radiation accidents" that can occur within the scope of occupational activities and involve only a few individuals. Furthermore, according to observations of the employers' liability insurance associations, problems (e.g. delay or refusal to receive patients) also emerged among medical staff due to personal fears and because of the increasing politicisation of the topic of ionising radiation when dealing with exposed individuals.

In the following years, collaboration on a contractual basis was established in medical facilities at university hospitals and research centres, at times with up to eleven of these facilities and centres. These are referred to as Regional Centres for Radiation Protection of the Professional Associations (RCRP)[1]. Over the years, the number of RCRP decreased to currently seven, mostly for economic reasons and due to a shift in the institutions' priorities.

The system of the RCRP is meant to ensure that, if the need arises, those affected can be treated with the resources available on-site. In addition to diagnostic examination procedures, this also includes admitting these individuals to the hospital where necessary and possible. In the event of a radiation emergency, the RCRP can take on an advisory role for the facility, occupational radiation protection, the radiation protection physician (authorised physician or radiation emergency physician), the emergency physician and, if necessary, also for the hospitals involved. To ensure this, staff members of the RCRP are available around the clock.

To support the RCRP, the BG Clinic in Ludwigshafen-Oggersheim is also integrated into the care system. A special hospital ward for radiation emergency patients with a reception area for decontamination and a special operating theatre was established at this clinic in the 1990s. The clinic is designed especially for exposed persons with conventional injuries due to accidents. For special treatments, contracts have been signed with external facilities.

To organise and coordinate collaboration among the RCRP and with the German Social Accident Insurance Institution, the Institute for Radiation Protection (IfS) was founded in 1982 by the German Social Accident Insurance Institution for Precision Mechanics and Electrical Engineering and the German Social Accident Insurance Institution for the Chemical Industry. The German Social Accident Insurances that resulted from several mergers, namely the German Social Accident Insurance Institution for the energy, textile, electrical and media products sectors (BG ETEM) and the German Social Accident Insurance Institution for the raw materials and chemical industry (BG RCI), also recognise the need to continue the institute and the system of the RCRP.

Particularly worthy of mention is that the IfS offers interesting further training for the RCRP and BG Clinic staff members. The annual additional training courses also serve to establish the network between the RCRP staff members and the radiation protection experts involved in a radiation emergency. Further, the institute organises and supports radiation emergency exercises.

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[1] https://www.bgetem.de/arbeitssicherheit-gesundheitsschutz/institute/institut-fuer-strahlenschutz-1/regionale-strahlenschutzzentren, last accessed on 20.07.2023

4.1.3 Special diagnostic facilities

Diagnosing radiation emergency patients requires technical expertise that is not widely available in either outpatient or inpatient settings in conventional medical care. Given the rarity of radiation incidents, this kind of expertise is not expected to be widely available in the future either.

The following special diagnostic facilities are required for medical questions following exposure to ionising radiation and radioactive substances: approved laboratories for incorporation monitoring, retrospective dosimetry laboratories, simulation system to estimate the isodoses of deterministic effects (tissue reactions) and wound monitors.

Neither classic dosimetry applications nor contamination detection devices will be explicitly discussed here.

4.1.3.1 Incorporation Monitoring

Incorporation measurements can be performed by officially designated laboratories for incorporation monitoring[2]. About half of these approved laboratories use in-vitro methods to measure activity concentrations in excretions; three-quarters use in-vivo methods (whole-body and partial-body counters). Besides the approved laboratories for incorporation monitoring, additional facilities and laboratories also offer in-vitro or in-vivo measurements. A mobile whole-body counter is also available in Germany. The BfS currently carries out regular interlaboratory trials for quality assurance purposes.

The integration of all mentioned monitoring stations into concepts for emergency care is currently not regulated. In future, these monitoring stations are to be included in the special emergency plans of the Federation and the Länder for the care of the public in radiation emergencies.

4.1.3.2 Wound monitors

There are currently no wound monitors available in Germany that meet all the requirements for use in a radiation emergency. Therefore, the BfS is developing a system ensuring quality through participation in international interlaboratory trials.

Therefore, using the sentinel lymph node scintigraphy devices available in many hospitals for radiation emergencies would be conceivable. This applies in particular when the nuclides in question are gamma emitters. However, suitable devices and the necessary settings would still have to be determined and/or defined along with the quality assurance requirements for this application.

4.1.3.3 Retrospective dosimetry

Both retrospective physical and biological dosimetry methods can be used for retrospective dosimetry. It is planned to establish facilities for retrospective physical dosimetry (optically stimulated luminescence (OSL) and electron paramagnetic resonance (EPR)) at the BfS. Provisions should be made to enable access to these procedures in Germany.

Biological dosimetry is currently offered by the BfS and the Institute of Radiobiology of the Bundeswehr (InstRadBioBw) for classical cytogenetic analysis. Other methods for which the evidence base remains presently a little scarce with regard to biological dosimetry are also available, such as analyses of gene expression or gamma-H2AX foci. Besides the institutions mentioned above, individual working groups engage in biological dosimetry. The European

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[2] https://www.bfs.de/DE/themen/ion/service/inkorporation/messstellen/messstellen.html, last accessed on 20.07.2023

Network of Biological and Retrospective Physical Dosimetry (RENEB) offers regular interlaboratory trials for its members. It maintains an informal European network with connections to institutions and individual members from other continents. Access to the global laboratories of retrospective physical and biological dosimetry is possible via the RENEB network.

In the event of an unclear, not further specified exposure to ionising radiation, experts from the networks for physical or biological dosimetry should be contacted short term. For sensitive and rapid analysis, suitable methods of both types of dosimetry should be selected and partly combined in the case of incorporation. In the event of possible contamination, appropriate safety precautions should be taken. If only external exposure is suspected, sensitive biological dosimetry methods can be considered for a very early diagnosis. In the long term, analysis of clinical findings (including differential blood counts) with the help of artificial intelligence would also be conceivable to confirm exposure even without a precise cause and to enable further analyses. There is a definite need for research and further development in this field.

There is currently no known facility in Germany that could use simulation to determine – in a quality-assured manner – isodoses following exposure for the appropriate surgical treatment of tissue damages (formerly deterministic soft tissue reactions).

4.1.4 Provision of protective agents

Protective agents refer to medicines used to treat internal contamination with radionuclides, for example, after ingestion or inhalation.

Unspecific medicines are used to facilitate the elimination of radionuclides from the body as fast as possible, delay their absorption from the gastrointestinal tract into the body, and accelerate their elimination via the kidneys. These medicines include, for example, laxatives or fluids to flush the digestive tract. These substances are well established in the acute treatment of poisoning and usually are also widely available following incidents affecting a larger number of patients.

Specific decorporation agents, on the other hand, are used to minimise the committed effective dose as far as possible if incorporation cannot be prevented or has already begun despite the above measures. These medicines are nuclide-specific therapeutic agents that are also used in facilities that provide acute medical care. At best, the stockpiles are currently aligned to decorporate individual patients in specialised facilities. Among the decorporation agents, potassium iodide is a special active substance as it can be administered broadly and outside of medical facilities as an early precautionary measure following exposure of the population to radioactive iodine isotopes.

According to Section 192 (1), in conjunction with Section 104 StrlSchG, the BfS is responsible for procuring protective agents to care for the public in the federal republic in the event of radiological emergencies. The protective agents are provided to the Länder for stockpiling, pre-distribution and distribution to the public.

Consequently, in 2019, the BfS newly purchased 189.5 million potassium iodide tablets of 65 mg. Long-term storage and distribution by non-medical personnel to the end user is regulated by relevant exemptions from the German Medicinal Products Act (AMG) in the Potassium Iodide Regulation (KIV). The regulations governing stockpiling and distributing potassium iodide tablets in the event of an emergency vary between the Länder; corresponding exercises are only conducted irregularly.

A plan is currently being developed detailing the strategic procurement and stockpiling of nuclide-specific decorporation agents. The aim is to promptly ensure the capacity for decorporation treatment to at least 100 patients. With a view to rapid availability, decorporation agents should also be stored in decentralised depots to ensure short-term transportation to an acute medical facility (see section 5.5.4).

4.1.5 Care structures for conventional injuries and illnesses in Germany

There are several networks in Germany whose primary objective is allocating and transferring seriously ill patients to facilities with currently vacant hospital beds. The expertise for treating the corresponding illnesses and the infrastructure needed are provided according to a phased model. For the care concept for radiation emergency patients outlined in this SSK recommendation, the necessary infrastructure must be supplemented, established and integrated into corresponding structures.

4.1.5.1 Burns units and central point of contact for severe burn victims

According to its statute, the German Burn Association (DGV) supports measures to ensure and improve the treatment quality of burn victims. In this regard, the DGV’s recommendations regarding burns units' structure and staffing resources play a major role. Based on the specific severity defined in these recommendations, burn victims should be treated in certified burns units with more structural, technical, and staffing resources than conventional intensive care units. It is required that the burns units are affiliated to hospitals authorised by the German Social Accident Insurance (DGUV) for inpatient and outpatient care of occupational, school and commuting accidents.

For the allocation of hospital beds to severe burn victims, there is a **central point of contact (ZA Schwerbrandverletzte)** available in operation since 1999 by the rescue coordination centre of the fire department in Hamburg (https://verbrennungsmedizin.de/ brandverletztenzentrenThe task of the ZA-Schwerbrandverletzte is to refer callers to a suitable facility with free capacities nearest to the accident site and to identify the contact persons there. The hospitals participating in this allocation system must promptly report all occupancy rate changes to the ZA-Schwerbrandverletzte. Almost 40 burn units with approximately 150 special beds (a quarter designated for children) currently participate in this system.

4.1.5.2 Supraregional trauma centres and trauma networks

A **supraregional trauma centre** is a hospital certified by the German Trauma Society (DGU) to provide the maximum level of care to seriously injured patients. Since launching the initiative in 2008, the trauma centres are connected in three stages within the **trauma network**, ensuring that patients can be transferred from a local or regional trauma centre to a national trauma centre[3]. Reasons that necessitate treatment in a national trauma centre may be diagnoses such as severe bleeding as well as therapies, e.g. treatment of complex soft tissue injuries, as well as concomitant circumstances such as complex treatment to prevent blood coagulation. In Germany, just under 600 trauma centres of various care levels (including some 120 national centres) currently cooperate with one another in around 50 trauma networks. A central point of contact, such as the one for severe burn victims, is not provided.

4.1.5.3 System for the strategic transfer of (intensive care) patients

In 2021, a system for the strategic distribution of COVID-19 patients requiring intensive care was developed under the term *Kleeblattkonzept* (cloverleaf system). The fundamental idea of the system is to ensure that appropriate treatment and transport resources are available if a strategic transfer is necessary. To this end, Germany was divided into five regions (*“cloverleafs”*). In each cloverleaf, designated single points of contact are responsible for

[3] https://www.traumanetzwerk-dgu.de, last accessed on 20.07.2023

coordinating patient transfers. The Expert Group on Intensive Care, Infectious Diseases and Emergency Medicine (COVRIIN), located at the Robert Koch Institute, is responsible for providing specialist medical advice to the cloverleaf partners (Gräsner et al. 2021).

Since 2022, the cloverleaf system has been successfully used to accept and distribute Ukrainian patients needing (acute) inpatient hospital care (BBK 2023[4]). For this purpose, other specialist medical fields were added to the expert group to become COVRIIN + (Gräsner et al. 2022). In addition, the Joint Information Centre of the Federal Government and the Länder (GMLZ), as part of the Federal Office of Civil Protection and Disaster Assistance (BBK), was added as the sixth cloverleaf. It networks information within the cloverleaf system and coordinates, moderates and arranges necessary transports and transport resources (BBK 2023[3]). Depending on the situation and if applicable, the GMLZ coordinates efforts with foreign countries and integrates requests for assistance made to Germany into the national process. Together with the cloverleaf partners, it is also responsible for ensuring the provision of treatment and transport resources along with the necessary coordination and harmonisation.

4.2 International situation

4.2.1 WHO REMPAN network

After the Chornobyl reactor accident in 1986, a system to manage radiation emergencies at the international level was established with two international conventions on early notification and assistance under the auspices of the International Atomic Energy Agency (IAEA). In 1987, the World Health Organization (WHO) became a party to both conventions and subsequently established the REMPAN network (Radiation Emergency Medical Preparedness and Assistance Network). The network's activities include the procurement of radiation emergency patients, the research and development of medical countermeasures to manage radiation emergencies, as well as the areas of radiation dosimetry and radiation epidemiology.

The network has three levels of membership:

1) WHO Collaborating Centres (WHO CC) are formally designated as WHO CC by the WHO in agreement with the national health authorities for a term of four years. Generally, the WHO CC are government institutions but also partly include research centres or university hospitals. The number of designated CC within the REMPAN network is dynamic; approximately 20 WHO CC are currently from about 15 nations[5]. About half of them have their own medical capacities (beds) for treating radiation emergency patients.

   In Germany, the Department of Nuclear Medicine of Würzburg University has been a designated WHO CC since 2005. 2018 the Federal Office for Radiation Protection was designated as a further German WHO CC.

2) Liaison institutions (LI) have an informal relationship with the WHO. A "letter of intent" forms the framework for cooperation in specific subject areas. With 33 institutions from 25 countries, there are more LIs than WHO CCs. On the German side, the following institutions have the status of an LI: Institute of Radiobiology of the Bundeswehr (InstRadBioBw), Munich; Institute for Radiation Protection of the employers' liability insurance associations (IfS), Cologne.

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[4] https://www.bbk.bund.de/DE/Infothek/Fokusthemen/Corona-Pandemie/Kleeblattkonzept/Was-ist-Kleeblattkonzept/was-ist-kleeblattkonzept_node.html#vt-sprg-5, last accessed on 20.07.2023

[5] https://apps.who.int/whocc/Default.aspx, last accessed on 20.7.2023

3) Observers are individual experts with specialist knowledge in the field of medical radiation emergency management. The number of observers is currently just over 30.

Within the scope of designation, the WHO CCs and the WHO mutually determine specific tasks as “terms of reference” (TOR).

The TOR of the Department of Nuclear Medicine of Würzburg University Hospital include assisting WHO in radiation emergency preparedness and response of the public health system, in training and dissemination of information in the field of radiation protection and radiation emergency management and, in the field of medical radiation protection in patient care with a focus on "best practice" in clinical nuclear medicine. .

The TOR of the BfS are much broader. They cover preparedness and response of the public health system to radiation emergencies (including REMPAN and activities of the Global Biodosimetry Network for Radiation Emergencies of the WHO (BioDoseNet)). Tasks related to non-ionising radiation, medical application of radiation, and the existing natural radiation exposure are added.

4.2.2 IAEA Response and Assistance Network (RANET)

The IAEA Response and Assistance Network (RANET) was founded in 2000 and is part of the implementation of the Convention on Assistance. Countries that require support in the event of a radiation emergency can request assistance from a member state registered in RANET, either through the IAEA or directly bilaterally. The network standardises and harmonises the assistance process and is designed to provide rapid international assistance to protect human life, health, property and the environment.

The RANET mechanism has already been activated multiple times. The capabilities and capacities provided by the member state registered in RANET are organised into eight categories (functional areas), including, for example, medical support. Expertise (including deploying teams of experts) for the medical care of affected persons, both in individual cases and in emergencies, can also be requested through RANET. This also includes triage support and psychological support for the patients themselves, their families, first responders and medical personnel. Germany joined RANET in August 2013; the BMUV is the German coordination unit. Both the BfS and the InstRadBioBw currently report their capabilities and capacities.

4.2.3 Examples of care structures abroad

The care concept of the **Russian Federation** serves as an example of a strongly centralised care structure. Already in 1948, Clinic No. 6, with 200 beds in Moscow, was commissioned by the Russian Ministry of Health to provide care to radiation emergency patients. The Institute of Biophysics was established on the clinic's premises. The clinic became renowned for treating survivors of the Chornobyl reactor accident suffering from acute radiation syndrome. 2007 the clinic and institute were renamed Burnasyan Federal Medical Biophysical Center. Hospital bed capacities for radiation emergency patients in the Russian Federation are also provided by the Nikiforov Center of Emergency Medicine in St. Petersburg, the A. Tsyb Medical Radiological Research Center in Obninsk and the Urals Research Center for Radiation Medicine in Chelyabinsk. All of the above facilities are research centres with affiliated clinics registered in the REMPAN network.

In **Japan**, based on the experience of the nuclear accident in Fukushima, a two-tiered system was established that involves a larger number of peripheral hospitals for providing care to radiation emergency patients (Tatsuzaki 2022). A distinction is made between “high-level” medical radiation emergency centres (nuclear emergency medical support centres) and peripheral hospitals (nuclear emergency core hospitals) involved in providing medical care in radiation emergencies. The four high-level” centres are facilities located across Japan at the universities of Hirosaki, Fukushima, Hiroshima and Nagasaki. The University of Hirosaki is responsible for managing the network; it is supported by the Core Advanced Radiation Emergency Medical Support Center at the National Institutes for Quantum Sciences and Technology (QST) in Chiba. The peripheral hospitals involved in medical care in case of radiation emergencies are facilities located in the vicinity of Japanese nuclear power plants; 41 such facilities were designated by 2019 (Ogasawara 2019). The QST deploys mobile expert teams to support all hospitals involved in providing care.

In the **United Kingdom (UK),** the UK Health Security Agency (UKHSA) is the competent body for advice and support in the event of radiation emergencies. Regular facilities of the UK’s National Health Service (NHS) are responsible for providing inpatient care to radiation emergency patients. In the case of acute radiation syndrome with the development of an acute haematopoietic syndrome, reference is made to hospitals registered with the European Society for Blood and Marrow Transplantation (EBMT) and their expertise. UKHSA operates its own laboratories for special diagnostics.

In the event of radiation emergencies in **France**, military hospitals (Hôpital d'Instruction des Armées, HIA) are explicitly designated for the reception of radiation emergency patients, as well as a number of civilian hospitals. Here, the HIA Percy in Clamart (near Paris) plays a key role, as it can care for contaminated patients and operates specialist departments for treating radiation emergency patients (haematology, burns unit). The HIA Percy is part of international assistance networks for radiation emergencies (e.g., RANET) and has also provided international assistance on multiple occasions.

In the **United States of America (USA)**, two institutions in particular must be mentioned for their commitment to caring for suspected radiation emergency patients:

The REAC/TS (Radiation Emergency Assistance Center/Training Site) is an institution within the US Department of Energy (DOE) and is leading in terms of know-how in medical treatment of radiation emergencies. It serves as a key partner for the IAEA and the WHO. It provides subject matter expertise on counterterrorism and counterproliferation to the National Nuclear Security Administration (NNSA) and plays a crucial role in medical training for radiation emergencies. In the past, REAC/TS has repeatedly deployed multidisciplinary teams to support patient care. REAC/TS does not operate its own inpatient treatment facilities.

The RITN (Radiation Injury Treatment Network) is a cooperative effort of the National Marrow Donor Program and the American Society for Transplantation and Cellular Therapy. RITN aims to inform haematologists, oncologists and stem cell transplantation experts about their potential involvement in the response to a radiation emergency and to provide treatment expertise. This also includes exercises. Every two years, interdisciplinary meetings take place where clinicians, physicists and radiobiologists exchange information and their experience. However, the network does not have designated care facilities available for combination injuries.

5 Establishment of a network and minimum requirements for the care of radiation emergency patients in hospitals

According to the SSK, the definition of minimum requirements for hospitals in terms of structural, staffing and equipment capacities and networking of these hospitals via a coordination unit is the prerequisite for developing an integrated clinical care concept for radiation emergency patients in Germany. The aim is to ensure treatment of radiation emergency patients in hospitals specialised for this purpose on a uniform and high standard. The resulting requirements profile and the verification of its implementation form the basis for providing adequate care to radiation emergency patients (SSK 2017a).

An adequate care concept includes clinical care, case-related care, and follow-up care for organic, social and psychological problems of those affected. The requirements for clinics, their leaderships and employees are thus manifold. They are determined, among others, by the nature of the radiation emergency, the number of persons affected, and the type and scope of injuries to the patients. For this reason, different scenarios will be considered in this care concept for radiation emergencies. Given the current political and social situation, it is expected that nuclear accidents will be regarded less relevant in Germany in the future. However, the risk of a severe nuclear accident in bordering countries remains present. In Germany, accidents in industrial and medical settings, as well as terrorist attacks in which ionising radiation or radioactive substances are used with criminal intent, can become a risk factor. Besides terrorism, the use of nuclear weapons cannot be ruled out.

As a result, combination injuries (accidental or burn injury plus radiation exposure) will be of greater importance than in the past. For this reason, training of the staff involved in the treatment of accidental or burn injuries must also be given a higher priority in radiation emergency management.

The necessary provisions – which are also described internationally – are presented below, particularly for serious nuclear power plant accidents. The SSK considers these provisions exemplary for the medical care of radiation emergency patients in Germany but also for other emergency scenarios, such as the use of nuclear weapons.

5.1 Establishment and tasks of a central coordination unit

Establishing a central coordination unit is mandatory for inpatient care of radiation emergency patients within a network of hospitals that meet the requirements described in the following sections.

This coordination unit should provide information on the current treatment expertise and capacities present at the medical facilities, on the physicians specially trained for the emergency and the further medical staff. Therefore, the coordination unit requires, in a timely manner, a daily updated list of vacant beds for the care of radiation emergency patients and an existing stock of special medicines for radiation emergencies.

When allocating vacant hospital beds, the coordination unit could draw on the experience with the system for the strategic transfer and allocation of intensive care patients according to the cloverleaf system (cf. section 4.1.5). Involving experts with specific medical know-how in radiation emergencies is indispensable when allocating patients.

Additional tasks of the coordination unit include involving radiation emergency experts in reviewing the requirements profile, ensuring quality assurance of the participating hospitals, and deploying mobile experts to provide on-site support in patient care (cf. section 5.6.2).

5.2 Current general regulations for inpatient emergency care

According to the regulations of the Federal Joint Committee (G-BA), emergency care centres, as per Section 136c German Social Code Book V (SGB V), are generally subdivided into centres for basic emergency care, extended emergency care and comprehensive emergency care (GBA 2020).

Hospitals providing basic emergency care operate specialist departments of internal medicine, surgery and anaesthesiology, as well as an intensive care unit with at least six beds, at least three of which are equipped for ventilated patients (GBA 2020).

For hospitals participating in extended emergency care departments of haematology and oncology, as well as trauma surgery, are additionally required. Extended-care hospitals operate an intensive care unit with at least ten intensive care beds, which are also equipped for ventilated patients.

Centres providing comprehensive emergency care have additional special resources at their disposal, such as departments for bone marrow transplantation and for severe burn victims. The central emergency department has an observation ward with at least six beds, which is organisationally connected to the emergency department; emergency patients should generally remain under surveillance for no more than 24 hours until further treatment has been clarified medically and organisationally.

However, these regulations do not account for the specific requirements associated with care in case of a radiation emergency. The subdivision into three levels of care is currently the subject of political discussion. The specific requirements for care in the event of a radiation emergency have not yet been and will probably not be considered by the G-BA in the future; for this reason, they will be described in detail in the following sections (see section 8 on financing).

5.3 Necessary hospital infrastructure

5.3.1 Specialist medical fields and special inpatient facilities

Centres providing extended and comprehensive care (e.g. maximum-care hospitals and university hospitals) are primarily suitable for the care of radiation emergency patients in radiation emergency centres. In emergencies that involve contamination and incorporation, several hundred persons may be affected (SSK 2017a). Based on this, there is a need for at least 20 to 30 facilities spread across the Federal Republic of Germany that are both qualified and willing to provide adequate care to those affected.

5.3.1.1 Extended-care centres

In principle, for the screening and the primarily outpatient initial treatment of these persons, extended emergency care centres are suitable that provide specialist departments of nuclear medicine (supported by medical physicists), a central emergency reception, anaesthesiology, internal medicine, surgery and dermatology and are supported, in case of emergency, by crisis intervention teams specially trained for radiation emergencies.

5.3.1.2 Comprehensive-care centres

The treatment of acute radiation syndrome (ARS) in reverse isolation, as is common in, e.g. stem cell transplantation, represents the most significant challenge in caring for radiation emergency patients on the wards that are explicitly provided for this purpose. Acute radiation syndrome is a disease that often leads to multiple organ failure and, therefore, requires the provision of an emergency centre that provides comprehensive care (with special equipment). For this reason, experts from the field of intensive medicine, specifically for severe burn victims and for haematology, transfusion medicine, gastroenterology, neurology, immunology, infectiology and psychiatry, should also be available.

To ensure that acute clinical care can be provided in a centre for comprehensive care (with special equipment), capacities for second triage and extended decontamination (wound decontamination, among others) for up to ten exposed persons should be provided in addition to the infrastructure for extended-care centres described above. In the event of accidents in industrial and medical settings, and in the case of terrorist attacks, the number of persons that require special treatment for local radiation injury is expected to be less than ten; the maximum number of persons requiring treatment due to ARS is likely to be in the same order of magnitude (SSK 2017a). Except for mass casualty scenarios, only two to no more than three patients should be treated per radiation emergency centre providing comprehensive care due to the effort of the intensive treatment of ARS. If treatment is to be provided to approximately ten ARS patients, this means that five to seven comprehensive-care centres (with special equipment) would have to be available across Germany. In the event of a nuclear attack on European countries, international precautions should be put in place.

5.3.2 Structural and space requirements

Minimum requirements for care and radiation protection relate to the structural prerequisites, an efficient layout of rooms and anticipatory pathways, which must be established in advance (BBK 2020) to prevent or minimise the uncontrolled spread of radioactive substances within the hospital and to lower the risk of secondary contamination (spread of contamination) (BBK 2020).

The layout of rooms and the pathways should be designed according to the unclean-to-clean principle (black/white) and function as a one-way street system (Cwojdzinski 2008a).

Layout planning must consider areas for patient registration, triage, emergency and standard admission, decontamination room, treatment areas and staff changing rooms, among others. The hospital alarm and response plan (KAEP) must describe the pathways. Here, emergency response plans can be developed for different types of emergencies.

Separate access, waiting, admission and treatment areas for radiation emergency patients must be determined and kept available (Haeseler et al. 2008). Provisions must be made for cordoned-off areas, airlock chamber, access controls and pathways to prevent unauthorised persons from entering the decontamination area.

Areas for material disposal in unclean areas and material storage in clean areas must be provided (SSK 2022).

Planning must include cordoning off access routes and controlling patient access to the hospital building to safeguard the hospital as a critical infrastructure (Haeseler et al. 2008). This requires detailed coordination with the law enforcement agents, such as the police, already in the planning phase.

In a mass casualty event, options for decontamination outside the hospital building (e.g. in tents) or in rooms inside the hospital customarily used for other purposes should be planned and provided (Martens 2008). Provisions for traffic planning (parking spaces for vehicles, routing of persons to the admission areas, etc.) are to be made in the hospital emergency response plan.

All rooms in the decontamination area, as well as patient rooms, toilets and operating rooms, must be connected to special collection tanks in the sewage system for radioactive wastewater; provisions must be made at least for the collection of wastewater in special collection tanks.

Decontamination rooms must be equipped with a ceiling-mounted shower, a basin for washing hair, an eye shower, a water basin for the local decontamination of extremities and a full-body shower.

Provisions for intensive care and reverse isolation of radiation emergency patients in the controlled area of the nuclear medicine department are desirable, such as the dual use of the treatment ward for regular patient care and radiation emergencies, as is the case, for example, at Würzburg University Hospital. However, the rapid availability of dual-use care structures should be ensured. For these wards, particularly with regard to the preceding decontamination, comprehensive solutions for other rare events resulting from CBRN[6] hazards must be considered in the future, also for economic reasons.

5.3.3 Management organisation and tasks

The management structure of the hospital should be described in the KAEP for radiation emergencies.

All workflows and processes, from triggering the alert to ending the emergency, must be defined and practised beforehand; this includes, for example, reporting channels, alert cascades, formation of a hospital response control unit (KEL) and a medical response control unit (MEL), staff planning and control, material and resource management and debriefing of the operation.

The clinical care of radiation emergency patients should be integrated into the specific concepts of civil protection of the Länder, considering the specific emergency response plans of the federal government and the Länder.

5.4 Staffing capacities, teams

The experiences of previous radiation emergencies have shown that teams of experts from different health professions are needed for the care of radiation emergency patients; the teams should comprise physicians, medical technologists, nursing staff, rescue workers, medical physicists, technicians and radiation protection experts who are qualified to care for radiation emergency patients (IAEA 2020a, IAEA 2020b). The collaboration among the individual actors of the **hospital teams** and their roles are to be defined in the hospital emergency response plan, and their tasks are to be specified in worksheets with instructions.

Additional staff members are required for logistics, safety (restricted areas, traffic control, etc.), and the decontamination area's setup and operation (Martens 2008). An overview of staff available for current deployment must be provided in the hospital emergency response plan beforehand (BBK 2020). For reasons of personal protection, only staff members who are absolutely needed and adequately trained and protected should be deployed (Adams et al. 2012).

In a radiation emergency, at least two treatment teams are required for triage and treatment. If contamination is suspected, one treatment team is assigned to the clean (non-contaminated) area and the other to the unclean (contaminated) area. In the unclean area, patients are treated by a decontamination team consisting of staff members with special training and experience in using personal protective equipment (PPE) and the care of contaminated patients (Haeseler et al. 2008). Furthermore, when caring for radiation emergency patients, staff trained in psychosocial crisis management are needed to support patients, relatives and staff members (see above).

To support, in particular, the extended-care centres outlined in section 5.3.1.1, **mobile teams** should be formed and managed by the coordination unit according to section 5.1. Radiation protection experts from facilities outside of radiation emergency centres can also be integrated into the teams. Tasks of these mobile teams are to provide support with specific expertise on-site, including, for example, diagnostics, initiation of therapy, sample collection and consultation.

The mobile teams should at least be allowed to use the official digital radio, transport patients in emergency vehicles, and use special signalling equipment similar to senior emergency

[6] CBRN: Chemical, biological, radiological and nuclear

physicians. In the event of an emergency, communication with all functional units should be ensured.

An officially recognised qualification based on the curricula (section 6.2, Annex A2) with regular exercises for the staff needed to care for radiation emergency patients is required. This supplementary qualification is a key component of a tiered, integrated precautionary and care concept for affected persons (exposed and concerned persons) in a radiation emergency (SSK 2017b).

To ensure psychosocial support of affected persons and response personnel, crisis intervention workers, pastoral workers, psychologists, psychotherapists and psychiatrists should be trained and qualified in radiation protection basics and the principles of emergency care, and should also be considered when forming teams.

The staff members' basic and further training needs is to be determined by the hospital management regularly. A structured continued training concept should be available. Verification of qualification of the staff members is to be provided in the form of appropriate further training courses.

Also, persons of different professional groups with a management role should undergo further training in radiation emergency management.

5.5 Material and equipment capacities

The general provisions for centres providing comprehensive emergency care for conventional emergencies must be supplemented by additional resources intended explicitly for radiation emergencies as part of preparedness and emergency alert planning. Some of these, such as contamination monitors, are used daily in nuclear medicine departments. PPE, decontamination facilities, decontaminants, and the necessary decorporation agents are also required. Depots to be set up should provide supplementary equipment, particularly the medicines listed in section 5.5.4.

Depot sites in hospitals should ensure recording, maintenance, quality control and – if necessary – expert testing and documentation to ensure that the material is usable at any given time (Bail et al. 2009).

5.5.1 Measurement technology

The technical resources for radiation protection measurements include instruments to measure contamination, dose rates, etc. All radiation protection centres should at least have the following readily available:

- two contamination monitors,
- two dose rate meters,

Access to radiation spectroscopy for nuclide identification should be available.

Optional technical equipment, particularly in special facilities providing comprehensive care, may include a whole-body counter, thyroid monitor, semiconductor detector and hand-operated probes for wound monitoring and/or intraoperative measurements.

The minimum equipment for all radiation protection centres includes six electronic personal dosimeters that can be read immediately, with adjustable alert thresholds assigned to specific persons or groups of persons. They should be earmarked as group dosimeters for those individuals who are not considered occupationally exposed persons.

5.5.2 Personal protective equipment (PPE)

For the rescue teams (planned to be working in three-shift operation plus standby[7]) the hospital should make provisions to have at least PPE available for 100 persons, to be used according to the existing risk and practicability (Annex A3).

5.5.3 Decontamination equipment

For staff working in decontamination, water-resistant materials should be used for protection in addition to PPE, such as waterproof overshoes, plastic aprons, plastic visors, etc.

The materials needed for the decontamination itself, disposal, cordoning, as well as the collection and preservation of samples are detailed in the SSK publication “Radiation emergency medicine – Handbook for medical care and training” (SSK 2022) and in part in Annexes A2 and A3.

5.5.4 Protective agents

Most hospitals are currently unprepared to use nuclide-specific decorporation agents, as this class of substances is not commonly used in everyday acute medical care. Particular attention should therefore be paid to close cooperation, for example, with facilities that can carry out measurements of radioactivity in body fluids and tissue to manage therapy (see section 5.5.5) and to managing the disposal of nuclide-contaminated excretions (e.g. facilities with nuclear medicine therapy wards).

In addition to decontamination agents or decorporation drugs, pharmaceuticals suitable for treating other radiation effects such as acute radiation syndrome (ARS) or cutaneous damage should be mentioned. The hospital pharmacy of a radiation emergency centre should be in able to access the protective agents (Annex A1) immediately and based on the indication.

Cytokines and cytokine-like substances play a prominent role in treating ARS. However, these substances are not protective agents but therapeutic agents used regularly in haemato-oncology. The pharmaceuticals that are discussed worldwide and that have thus far been authorised for use in the USA by the Food and Drug Administration (FDA) are

- Granulocyte Colony Stimulating Factor (G-CSF),
- Granulocyte-Macrophage Colony Stimulating Factor (GM-CSF), and
- Romiplostim (see Annex A1.2).

Pharmaceutical agents supplement these for the cutaneous manifestation of acute radiation syndrome and severe local radiation cutaneous injuries and the underlying tissue (local radiation Injury – LRI). These mainly include stem cell products (mesenchymal stem cells (MSM), among others), which, as cell products, are currently not considered pharmaceuticals in the conventional sense. Provisions for the strategic procurement and stockpiling of these pharmaceuticals, their manufacture, quality assurance and marketing authorisation for use in humans in the context of radiation emergencies must be made in the future.

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[7] Two teams work in parallel and in multiple shift operations, contaminated PPE must be exchanged:

Team size approx. ten people, two teams in parallel = 20 people

Three shift operation = 60 people, + reserve for contamination etc. = 100 people

It should be noted that no substance has proved an isolated success in the treatment or ARS or LRI thus far. As a general rule, the pharmaceuticals should be integrated into a complex clinical care concept, which requires further therapeutic agents, e.g. from the field of antibiotics, antifungals, virostatics, blood products, antiemetics or other symptom-based drugs, to optimise the therapy.

Details on protective agents and pharmaceuticals can also be found in the WHO guideline on developing stockpiles[8].

5.5.5 Sample collection for incorporation measurements as well as biological and retrospective physical dosimetry

Urine and stool samples are generally suitable for measuring incorporated radioactivity. The respective sample should be collected over a period of 24 hours. In the event of an emergency, suitable containers or the appropriate instructions can be provided, for example, by the approved laboratories for incorporation monitoring. If collection begins immediately after incorporation, at least three 24-hour samples should be provided over the first three days after intake of the substances.

Different body tissues can be used for biological and retrospective physical dosimetry. While blood samples are usually processed within the scope of biological dosimetry, teeth (also in vivo) and finger or toenails can be used for retrospective physical dosimetry. However, biopsies from other tissues are also conceivable for special medical questions.

Lithium heparin is suitable as a blood collection system for cytogenetic testing. A sample of 5 ml to 10 ml of venous whole blood must be delivered to the specialist laboratory at room temperature in a timely manner. Other procedures (gene expression, gH2AX) require other blood collection systems.

To ensure that the monitoring stations and laboratories can perform their measurement tasks appropriately, the respective facility should already be contacted before the sample collection to ensure an optimal process chain right from the beginning.

5.6 Requirements profile, quality assurance

5.6.1 Verification and implementation of the requirements profile

Section 4.2.3 described the Japanese care system that was newly established based on the experience of the Fukushima nuclear accident. Transferring this system to Germany, a similar two-tiered structure with five to seven medical radiation emergency centres that provide comprehensive care (see section 5.3.1.2) could be established at university or maximum-care hospitals. Special facilities that are particularly well equipped for caring for radiation emergency patients but who themselves cannot treat patients with acute radiation syndrome should ensure patient care in neighbouring hospitals through cooperation agreements.

In addition, provisions should be made to establish at least one to two extended-care centres (see section 5.3.1.1) at participating hospitals in each federal state.

When developing this two-tiered system, already existing facilities of the established network of the RCRP and designated facilities of the German Armed Forces could be used.

According to the SSK, the requirements for hospitals and care structures should be regulated bindingly. Verifying the fulfilment of minimum requirements requires a quality assurance

8 https://www.who.int/publications-detail-redirect/9789240067875, last accessed on 20.07.2023

process that should be carried out under the responsibility of the central coordination unit as outlined in section 5.1 with the participation of a committee of medical experts in radiation emergencies.

5.6.2 Quality assurance

According to Section 136c (5) SGB V, the Federal Joint Committee (G-BA) defines the tasks of centres and critical areas with special tasks and the quality requirements to be met. These could be correspondingly cited as follows:

> The special tasks can arise from: 1) a supra-regional fulfilment of tasks, 2) the need for special provisions at the individual locations (particularly at centres for rare diseases), 3) the need for care at individual locations due to exceptional technical and staffing requirements. Insofar as this is needed to fulfil the special tasks, quality requirements must be defined, in particular specifications regarding the type and number of specialist departments.

Points 1) to 3) of the above list apply to centres providing care to emergency radiation patients. The quality assurance procedure for the medical treatment and care after exposure should be defined bindingly. The SSK recommends involving the planned coordination unit in the quality assurance process, along with the radiation emergency experts supporting this facility (cf. section 5.1).

6 Qualification and skills acquisition of the staff

In the future, the foundations for a qualification within the meaning of this section should, on a much broader scale than before, already be laid at school and study programs.

At the school level, starting from secondary level 1, the subjects biology and physics are suitable for this purpose. During medical studies, aspects of radiation protection are only insufficiently covered by the German National Competence-Based Learning Objectives Catalogue (NKLM) 2.0. Future physicians are expected to be able to provide professional answers to patients’ questions. This includes knowledge of radiation protection and medical characteristics of protective measures. The curriculum is to include at least one hour per week in semesters 5 or 6.

6.1 Target groups for the qualification

The terms “radiation protection physician” and “authorised physician” are presently found in current language. According to the StrlSchV, the “authorised physician” is often used as a synonym for the non-defined term “radiation protection physician”. With the increasing withdrawal from nuclear energy, the proportion of authorised physicians with extensive experience in dealing with unsealed radioactive substances in routine practice or emergency became increasingly smaller as compared to authorised physicians specialising in occupational medicine, so that in 2017 the SSK (2017a) recommended, in addition to the “authorised doctor” described in radiation protection law (Section 175 StrlSchV), defining the “radiation emergency physician” who should be actively involved in the care and treatment of radiation emergency patients.

The qualification **“radiation emergency physician”** can be acquired through modular training. Physicians who have experience with ionising radiation or unsealed radionuclides due to their occupational activities (for example, from the fields of nuclear medicine, radiology and radiotherapy) are primarily suitable for this qualification. Professional groups whose members have experience in dealing with the diseases and complications of exposure are also possible candidates. Besides authorised physicians, these physicians can be recruited from different medical disciplines, such as emergency medicine, intensive medicine, surgery, haematology and dermatology (SSK 2017).

A supplementary qualification, **“radiation emergency management”,** that contains modules of the qualification “radiation emergency physician” should be introduced for non-medical staff involved in the care of radiation emergency patients (see section 6.2).

6.2 Curricula for “radiation emergency physician” and “radiation emergency management”

The legal basis for the qualifications “radiation emergency physician” and “radiation emergency management” should be created rapidly. To obtain the qualifications, the SSK recommends a modular curriculum (SSK 2017b). The curriculum consists of three consecutive modules covering basics and preclinical care, psychosocial support and crisis communication, and aspects relating to inpatient clinical care.

The “radiation emergency management” qualification requires participants to complete the first two modules. The qualification “radiation emergency physician” also requires the third module's completion. The qualification is obtained through successfully completing the required modules and participating in an emergency exercise. The three modules are taught over six days as follows:

- Module 1: Basics and preclinical care 2.5 days[9]
- Module 2: Psychosocial support/crisis communication 1 day
- Module 3: Inpatient clinical care 2.5 days.

Successful participation in the modules can be ascertained through a technical discussion or a test. Proof of qualification is issued after participating in an exercise. The two or three modules should be completed within one year.

Just like the expertise in radiation protection, these qualifications should be updated at least every five years. Participation in a course, an exercise or active involvement in the medical management of a radiation emergency within the mentioned period could be considered actualisation.

Appropriate rules must be defined for the certification of qualifications, exercises and updates, as well as for the recognition of the training centres.

Didactic methods used for the qualification of a radiation emergency physician are appropriate to the topic, for example, face-to-face teaching formats (e.g. problem-oriented learning, optional operational exercises), e-learning (also preparatory), in particular competency-oriented training/qualification, hybrid/online teaching and virtual reality training.

A proposal on how to design course units for the three modules in question can be found in the annex (Annex A2).

6.3 Maintaining the competence of the training centres

In its 2021 statement, “Long-term assurance of competence in the field of radiation protection research in Germany” (SSK 2021), the SSK concluded that qualified personnel to ensure the complex, interdisciplinary care of radiation emergency patients will only be available to a

9 One day should correspond to eight teaching units of 45 minutes each.

sufficient extent if academic research and educational establishments are in a position to provide adequate training capacities and concepts over a long period of time. The capacity required by such academic institutions, which is currently declining, should not merely be maintained but instead strengthened.

6.4 Creation of incentive systems

The staffing situation at hospitals barely leaves staff members enough time to pursue the supplementary qualifications outlined in this recommendation, in addition to the further and continuous training courses required by their employers. Furthermore, as radiation emergencies are generally rare in Germany, many individuals who in principle are suitable candidates for one of the supplementary qualifications will question whether it is worth their time. Regarding the training, the SSK proposes sharing the costs: The federal government and the Länder should take over the costs for suitable courses, thus enabling individuals to attend them free of charge. By analogy with Section 3 of the Act on the German Federal Agency for Technical Relief (THW-Gesetz), fire protection acts, and other legal provisions, employers should release employees from work to acquire this qualification. However, this means that additional staffing capacities must be financed to replace the employees released from work.

It is further recommended to designate the “radiation emergency physician” within the meaning of the SSK recommendation (SSK 2017) for performing the follow-up examinations of occupationally exposed persons (Section 78 StrlSchV) in addition to the authorised physicians. The follow-up examinations enable the early diagnosis of illnesses that may be associated with previous occupational radiation exposure. This requires an in-depth understanding of radiation biology and radiation risks. These are precisely the skills that will be taught in the qualification “radiation emergency physician”. The SSK, therefore, recommends amending Section 78 and Section 125 StrlSchV accordingly.

7 Training and exercises

7.1 Training

In the hospitals taking part in the care of radiation emergency patients, radiation emergencies should be included in the hospital alert and response plan (KAEP). To ensure a high level of penetration of the specialised knowledge, as many staff members as possible from different areas should be trained. Most likely, this would be achieved by conducting regular training courses at the hospitals participating in radiation emergency protection, analogous to fire protection training. The training courses should be kept short and concise. They should focus - concerning a radiation emergency - on the role of the hospital response control unit, the emergency room, the nuclear medicine department and other involved clinical disciplines, and special tasks related to hospital logistics.

7.2 Exercises

Because an emergency event differs from hospital routine, the processes of the hospital alert and response plan (KAEP) must be established, taught and trained. Since the KAEP represents a cycle, it should be regularly taken up, reviewed and adjusted where necessary, at least in stages (BBK 2020). Staff, tabletop, virtual and particularly real exercises that validate the respective KAEP also with regard to radiation emergencies appear advisable.

Even if exercises in hospitals require a considerable amount of work and can give rise to significant costs, especially in the case of full-scale exercises, they are the only way to optimise the preparedness for radiation emergencies and train the staff accordingly. It is recommended to establish and further develop a culture of exercise that ensures a high degree of preparedness for radiation emergencies through realistic and regular exercises (Miska 2010).

Based on relevant exercises, such as those conducted by the Department of Nuclear Medicine of Würzburg University Hospital, the BG Hospital in Ludwigshafen and the Armed Forces Hospital in Ulm, experiences concerning the organisation and performance of exercises are available.

Exercises at the level of a radiation emergency centre and the state and federal levels should be held at regular intervals. In addition to indispensable practical exercises under realistic conditions, virtual exercises using augmented reality methods[10] can increasingly offer effective ways of preparing for a real emergency, especially for complex scenarios like radiation emergencies.

The evaluation of an exercise is just as important as the exercise itself. Debriefing with the participants immediately after the exercise serves to obtain first impressions. A detailed analysis of the knowledge gained and a broad discussion forms the basis for improving the concepts and measures (IAEA 2005).

As scenarios arising from radiation emergencies are generally considered unlikely, hospitals' motivation to conduct exercises is neither constant nor a priority. The motivation to conduct exercises is usually only increased if there is a “comprehensible threat” due to acute globally relevant incidents. Generally, emergency exercises for all staff members should be performed at least annually.

When it comes to the medical care of contaminated radiation emergency patients, whether in the preclinical or clinical setting, measurable activities should be practised to simulate realistic situations and increase the motivation and learning effect of the trainees involved. This requires an additional logistical effort, including radiation protection specialists and possibly requesting corresponding radiation protection approvals.

As ensuring general health care is the top priority in hospitals, this means that exercises can usually not be conducted with all staff members or in the real infrastructure. Exercises that represent the entire care chain (preclinical ⇨ emergency room ⇨ surgery/internal medicine/nuclear medicine) and involve the competent authorities are desirable. However, due to the complexity of the matter, it shows that exercises can only represent partial care processes in reality.

Even in the context of exercises, risk communication in connection with ionising radiation always represents a challenge (dealing with fears) and should be addressed appropriately. This may also include the unjustified concern of hospital decision-makers of becoming a centre that will have to deal with a large number of radiation emergencies in the future due to their participation in these exercises.

8 Financing the network for the care of radiation emergency patients

In its regulations for specifying the special tasks of centres and priorities according to Section 136b SGB V (GBA 2020), the Federal Joint Committee has generally defined the basics

10 https://okat-sim.geo.uni-potsdam.de/, last accessed on 20.07.2023

for the agreement on surcharges for such facilities in accordance with Section 5 of the German Hospital Financing Act (KHG) with regard to quality requirements and special tasks.

These requirements are specified for a number of such facilities, e.g. centres for rare diseases or oncology centres, trauma centres, rheumatism centres, heart centres, stroke centres and several other organ centres; the basis is given for claims of hospitals for reimbursement of these surcharges after designation of the centres in the hospital plan of the federal state. However, special infrastructural costs, which are incurred by radiation emergency centres, are not taken into account.

There is thus an urgent need for regulation concerning financing of the infrastructure, of specific provisions and qualified staff for the network of radiation emergency centres outlined in section 5 to enable the authorities and organisations of the federal government and the Länder involved in the emergency response to make coordinated decisions without delay and implement the appropriate measures in a timely manner in the event of an emergency (Section 97 (1b) StrlSchG of 2017).

The coordination unit to be established plays a key role in this (see section 5.1). The logistics of this institution could be set up similarly to the concept for the strategic distribution of intensive care patients according to the cloverleaf system; under certain circumstances, it may also be possible to use existing structures. However, It must be emphasised that the above-mentioned strategic distribution concept does not include expertise for radiation emergencies and must be developed first. Expertise in radiation emergencies is indispensable for a regular review of the qualification of hospitals participating in the care, the decision on transfers and the further development of the radiation emergency medical care system.

In the hospital setting, in case of contamination or incorporation with radionuclides, it is important to place contaminated patients in specially dedicated areas in addition to maintaining clinical treatment expertise. Such provisions for emergency care (e.g. with separate capabilities for decontamination and wastewater disposal – cf. section 5.3.2) are not part of the standard of general care in nuclear medicine and must, therefore, be established. Nuclear medicine departments also usually meet the structural requirements for radiation protection and have measuring devices available. Personal protective equipment, personal dosimeters, decontamination procedures and preparations, and the necessary decorporation agents are also required (see section 5.5.4).

Reliable and diversified clinical care for diagnostics and intensive medical treatment of organ and haematological damages also plays an important role in the treatment of patients with acute radiation syndrome. To this end, a sufficient number of centres of comprehensive emergency care (see 5.2.1) should reliably provide the infrastructure for such intensive medical treatment under radiation protection conditions. This, however, makes sufficient financing of all of the provisions mentioned in this recommendation indispensable.

The costs for the training of radiation emergency physicians and acquisition of the qualification of non-medical staff in "radiation emergency management" (see section 6) as well as the education and training (see section 7) of cross-functional groups of hospital staff are not included in hospital financing and should therefore also be financed.

9 Integration of the recommendations into the emergency management system of the federal government and the Länder

9.1 Legal framework – implementation of the interlinked structure

In implementing the provisions of Directive 2013/59/Euratom, the Federal Radiation Protection Act integrates the federal government's legal and technical provisions for radiological emergency preparedness and response into the complex federal civil protection system (Sections 92 to 96, 99, 109 to 111 StrlSchG, among others).

According to Section 97 of the Federal Radiation Protection Act, the federal government and the Länder shall prepare emergency response plans that describe the appropriate response to possible emergencies. These also include measures to provide medical treatment or preventive care following radiation exposure.

The special emergency response plan (BNoPl) of the federal government shall present planning and precautionary measures for medical emergency care and response, in particular for civil protection, general emergency response and assistance, as well as for the medical treatment and precaution of the public and rescue workers after radiation exposure (Section 99 (2) No. 1 StrlSchG). The specific planning and precautionary measures for setting up a network for the medical care of radiation emergency patients should be integrated into this BNoPl, as proposed by the SSK in this recommendation.

In connection with this SSK recommendation on the medical management of radiation emergencies, the implementation of Section 110 StrlSchG is of utmost significance. This section regulates the cooperation and coordination in radiation emergencies in general and stipulates that authorities and organisations should work together in accordance with the emergency response plans. At the federal level, the planning of the hospital network for the care of radiation emergency patients in Germany recommended by the SSK requires close coordination of the competent federal and state ministries of radiation protection, health and internal affairs, the Federal Office for Radiation Protection (BfS) and the Federal Office of Civil Protection and Disaster Assistance (BBK). As the Länder are responsible not only for disaster response but also for the planning and particularly the financing of the hospital infrastructure, the responsible state ministries should be closely involved in preparing the special emergency response plans of the federal government.

9.2 Involvement of the coordination unit, radiation emergency physicians and staff qualified in radiation emergency management

The federal government's system for managing radiation emergencies currently does not provide up-to-date information about available capacities in medical care (such as the number of vacant special hospital beds). It should be a top priority to establish such an information tool at the planned coordination unit (cf. section 5.1). Furthermore, additional decision support systems may be helpful, for example, in the distribution logistics of decorporation agents and medicines to treat ARS or in evacuating hospital patients.

Individuals who hold the qualification "radiation emergency physician" or "radiation emergency management" should be listed in a central file at the central coordination unit according to section 5.1 for a case of emergency. This would ensure that the Länder or specific institutions can request assistance, if necessary, as is also envisaged, for determining the whole-body dose due to incorporation and for biological dosimetry.

Appropriately qualified persons could, for example, provide expert advice and support to determine the dose in the event of exposure to external radiation and contamination.

As medical consultants, radiation emergency physicians listed in the file could be assigned to work in the emergency care centre or, in the event of radiation emergencies with only a small number of affected persons, act as a point of contact for the emergency physician on site or the senior emergency physician. This group of individuals should be able to get to the location with emergency vehicle equipment and the public safety radio system (BOS-Funk[11]).

9.3 Communication

According to Section 106 StrlSchG it is the task of the Radiological Situation Centre (RLZ) of the BMUV to coordinate the protective measures and the measures for informing the public and for assistance across departments and with the Länder, as well as at the international level. The BMUV is supported here by the Federal Office for Radiation Protection (BfS), the Federal Office for the Safety of Nuclear Waste Management (BASE), the German Organisation for Reactor Safety (GRS) and the Federal Office of Civil Protection and Disaster Assistance (BBK).

Crisis and risk communication are discussed in detail in section 15 of the SSK recommendation "Radiation emergency medicine – Handbook for medical care and training" (SSK 2022).

Under crisis communication to convey information, this section discusses the nature and scope of the emergency as well as the cooperation between the authorities and organisations involved. Crisis communication also includes informing affected persons about necessary protection measures.

Risk communication refers to the risk to an individual in a specific emergency. Risk communication aims to enable affected persons to make an assessment of their own situation as realistically as possible, considering health risks. The risk analysis results should be incorporated into the crisis communication to increase the understanding of necessary protective measures.

In particular the possibility of very rapid dissemination of information via social media requires those responsible to provide crisis and risk communication that is quick, correct in terms of content and, above all, understandable. This can only be achieved if roles and tasks are specified for individuals in advance, not only when an emergency occurs. Roles and tasks should be trained regularly, where possible, within the scope of realistic emergency scenarios.

The flow of information to authorities, staff members, the media and the population should be prepared and background material should be readily available. It must be noted that, in the event of a radiation emergency, the medical staff themselves often do not have sufficient knowledge of radiation risks. The SSK believes that special training is urgently needed here.

Up-to-date information on civil protection should be compiled and made available on an integrated, government-authorised internet platform (e.g. BfS, BBK).

The internet platform should provide information on the following topics in a clear manner:

- General radiation protection
- Radiation risk
- Practical radiation protection

[11] BOS radio is a non-public mobile VHF land radio service in Germany and Austria that is used by authorities and organizations with security tasks (BOS) and the German Federal Armed Forces.

- as well as up-to-date information on the population's existing or expected exceptional exposures.

The information can be provided in the form of texts, graphics or video recordings.

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Annex

Annex A 1 Protective agents and medicines

A 1-1 Protective agents for decorporation (for more information see SSK 2022)

1) Prussian blue (iron(III) hexacyanoferrate(II)) effective against caesium incorporation (also thallium, indium or a mixture of fission products (off-label)).

2) Ca(DTPA) (pentetate calcium trisodium) effective against incorporation of americium, plutonium, curium, californium, berkelium (probably also effective to varying degrees against several other bivalent to pentavalent cations).

3) Zn(DTPA) (pentetate zinc trisodium) effective against incorporation of americium, plutonium, curium, californium, berkelium (alternative to Ca(DTPA))

4) DMPS (dimercaptopropane sulfonic acid), off-label against incorporation of polonium in individual healing attempts (licensed only for mercury poisoning).

5) KI (potassium iodide) for iodide blocking of the thyroid gland.

A 1-2 Additional medicines

1) G-CSF/PEG-G-CSF (granulocyte colony-stimulating factor) effective against radiation exposure that may induce ARS (indication in the USA > 2 Gy).
2) GM-CSF (granulocyte macrophage colony-stimulating factor) effective against radiation exposure that may induce ARS (indication in the USA > 2 Gy).
3) Romiplostim effective against radiation exposure that may induce ARS (indication in the USA > 2 Gy).

While the marketing authorisations of G-CSF and romiplostim cover a different indication in Europe and are authorised for off-label use, GM-CSF can hitherto only be requested within the scope of named patient programs.

Other medicines include antiemetics, antidiarrheals, antibiotics, antifungal drugs, and mesenchymal stem cells. For an overview of the current (2022) state of knowledge, see (WHO 2023 https://apps.who.int/iris/rest/bitstreams/1488994/retrieve)

Annex A 2: Educational contents of the three modules of the qualifications "Radiation Emergency Management" and "Radiation Emergency Physician"

Overlapping in time with this recommendation, the handbook "Radiation Emergency Medicine – Handbook for Medical Care and Training" was compiled by a working group of the SSK. The contents of the three modules to be taught are described in detail in the handbook. Below, reference is made to the corresponding section of the handbook.

Table A2-1: Contents and competences of Module 1

Module 1 Basics and preclinical care 22 course units				
Subject	Duration (course units)	Competences	Section (SSK 2022)	Content of section
Radiation emergency-related radiation physics, radiobiology and radiation risk, dosimetry	4	Basic knowledge of radiation emergency-related radiation physics, radiobiology and radiation risks	4	Types of radiation, radioactivity, dose values, the three principles of radiation protection (time, distance, shielding), biological effects of radiation, deterministic and stochastic effects, LNT hypothesis, basic knowledge of physical and biological dosimetry
Operation of radiation measurement technique	2	Knowledge of and practical training in operating radiation measurement technique	10	Different measurement devices and their possible applications
Emergency scenarios	2	Knowledge of emergency scenarios concerning ionising radiation and unsealed radioactive substances	3	Different emergency scenarios with regard to external and internal exposure, possible risks and the number of people affected
Different forms of radiation damages	2	Knowledge of the different forms of radiation damages	8	Characteristics of acute and chronic radiation damage and their diagnosis
Self-protection and personal protective equipment	2	Knowledge of and practical training in using personal protective equipment	12, Annex 2	Potential hazards, risk-adapted personal protective equipment
Pre-clinical emergency measures, provision of first aid to injured persons	3	Knowledge of pre-clinical emergency measures, including first aid for injured persons	5	Procedure in emergencies and disasters taking into account self-protection, the c-ABCDE rule, the current recommendations of the German Federal First Aid Association (BAGEH), the

Module 1 Basics and preclinical care 22 course units				
Subject	Duration (course units)	Competences	Section (SSK 2022)	Content of section
				German Social Accident Insurance and the current resuscitation standards
Radiological triage and decontamination, where necessary	2	Knowledge of the contamination or incorporation pathways and detection thereof, Knowledge of and practical training in radiological triage and decontamination	5.1, 6	Triage categories and tagging, monitoring of contamination, systematic personal decontamination, and decontamination procedures
Transport and logistics of radiation emergency patients	3	Knowledge of and practical training in transporting radiation emergency patients	13, 14	Measures of protecting transport vehicles and personnel; preventive measures in the hospital, personnel and material resources, required infrastructure and logistics, working in teams
Clinical care of radiation emergency patients	1	Knowledge of clinical care of radiation emergency patients	8	Interface to basic knowledge, Module 3
Emergency organisation, e.g. including national and international resources and networks	1	Knowledge of emergency organisation (including national and international networks and resources)	16, 17	Emergency management system of the federal government and the Länder, general and specific emergency response plans, involvement of civil protection, emergency care centres, international networks

Table A2-2: Contents and competences of Module 2

Module 2 Psychosocial support and crisis communication 8 course units				
Subject	Duration (course units)	Competences	Section (SSK 2022)	Content of section
Psychosocial care in radiation emergencies	3	Knowledge of psychosocial care in radiation emergencies	9	Psychosocial care for affected persons and response personnel, psychological first aid, further acute psychological aid, early identification of post-traumatic stress syndromes
Risk and crisis communication strategies with affected persons and response personnel	3	Knowledge of and training in risk and crisis communication with affected persons and response personnel	9	Allocation of roles in risk and crisis communication, communication strategies, special tasks for medical personnel
Examination and follow-up programs after radiation emergencies	2	Knowledge of examination and follow-up programs for radiation emergencies	9	Medium- and long-term psychosocial follow-up, vulnerable groups, dealing with concerned persons, usefulness of mass screening for stochastic radiation effects, treatment of post-traumatic stress syndromes

Table A2-3: Contents and competences of Module 3

Module 3 Clinical care 20 course units				
Subject	Duration (course units)	Competences	Section (SSK 2022)	Content of section
Different forms of acute and chronic radiation injuries and their categorisation, acute radiation syndrome (ARS)	2	In-depth knowledge of the different forms of acute and chronic radiation injuries and their categorisation, symptoms and courses	8	Presentation of the pathophysiology of different radiation syndromes (cutaneous, haematopoietic, gastrointestinal, cerebrovascular), combined injuries, treatment principles of ARS
Local radiation injury of the skin (LRI)	1	In-depth knowledge of aspects of LRI	8	Presentation of the pathophysiology of the cutaneous manifestation of ARS, treatment principles of LRI
Necessary infrastructure and logistics in the hospital	1	Knowledge of the hospital infrastructure needed for care of emergency patients	13, 14	Contents of the alert and deployment plans for radiation emergency scenarios, provisions for infrastructure and staff deployment planning Transport of contaminated patients inside the hospital Possible preparatory measures (e.g. decontamination) for hospital admission
Phase-related clinical care of radiation emergency patients	3	In-depth knowledge of emergency scenarios and estimation of the number of persons affected and the treatment capacities required Knowledge of the treatment of the different forms of acute and chronic radiation injuries (acute radiation	5, 6, 8	Radiological triage and scoring systems, Priority life-saving emergency immediate actions, first aid of wounds Early symptoms of acute radiation syndrome, severity levels, response categories Early/late manifestation of LRI and their treatment

Module 3 Clinical care 20 course units				
Subject	Duration (course units)	Competences	Section (SSK 2022)	Content of section
		syndrome, local radiation injuries)		
Decontamination and decorporation	4	Specialised knowledge of decontamination and exercises Knowledge of unspecific and specific decorporation measures and their performance (including iodide blocking)	6, 7, 11	Decontamination of contaminated wounds, prevention of secondary incorporation, operational intervention levels for decontamination measures Inhibition of absorption or acceleration of elimination through unspecific measures Possible applications, side effects and contraindications of specific decorporation agents Measuring radioactive iodine uptake by the thyroid gland, principles of iodide blocking of the thyroid gland. Sources of information for the population (SSK, www.iodblockade.de)
Psychological support and treatment	2	In-depth knowledge of psychosocial support in radiation emergencies (with a focus on post-traumatic stress disorder)	9	Psychological support and treatment, particularly Prevention, diagnosis and therapy of post-traumatic stress disorder
Exercise: sequential care of radiation emergency patients from the gateway/pre-clinical area to the clinic all the way to (inter)national transfer and rehabilitation (presentation or better virtual reality)	4	In-depth practical skills for the sequential care of a radiation emergency patient in the pre-clinical area and clinic		Working in teams teaching the skills of leadership, processing of scenarios under time pressure

Module 3 Clinical care 20 course units				
Subject	Duration (course units)	Competences	Section (SSK 2022)	Content of section
Management of treatment strategies beyond the hospital Management of regional, national, international transfer of radiation emergency patients	1	In-depth knowledge of network structures in the clinical treatment of radiation emergency patients	16, 3.3	Imparting specialist units and official representatives possibly involved in radiation emergencies, of dosimetry facilities, approved laboratories for incorporation monitoring, contact persons of the Regional Radiation Protection Centres, of the international REMPAN network of the WHO, etc.
Applications of dosimetry in the clinical treatment of radiation emergency patients	1	In-depth knowledge of dosimetry methods and results	10, 11	Types of biological dosimetry, incorporation detection methods, staff dosimetry
Follow-up care of exposed patients	1	Knowledge of late effects of radiation injuries (cancer, cardiovascular diseases, etc.) and corresponding follow-up care programs	8.2	Experience with follow-up care programs after the atomic bomb tests and bombings of Hiroshima and Nagasaki and after the NPP accidents in Chornobyl and Fukushima
Follow-up care of exposed personnel	1	Assessment of the need for a follow-up examination (medical examination after terminating the task as an occupationally exposed person) and authorisation to perform the corresponding examination (Section 78 StrlSchV)	see also Section 78 StrlSchV	Aims and contents of a follow-up examination of exposed personnel

Annex A 3 Equipment including decontaminants

In hospitals, provisions should be make available among others the following materials and equipment as minimum requirements. Adequate stockpiling, circulation and, if necessary, disposal of the material must be taken into account:

Material checklists

Personal protective equipment (PPE)

Amount required	PPE items	Available?
10	Powered air purifying respirators, liquid-tight protective clothing plus communication equipment	
200	Respiratory protection masks (FFP 3)	
100	Waterproof overalls – synthetic fleece	
10 packs/size	Single-use nitrile gloves (double, if possible) All sizes (usual hospital stocks)	
100 pairs	Solid shoe covers	
100	Plastic aprons	
100	Safety goggles	
100	Surgical caps	
20	Electronic dosimeters in addition to officially approved personal dosimeters	

Decontamination

Decontamination products	Available?
Decontamination solutions	
Topographically and physiologically suitable decontaminants as are common in nuclear medicine and in research laboratories	
Citric acid solution	
Na-EDTA/DTPA solution	
Physiological saline	
Decontamination material	
Moist wipes	
Dry wipes	
Disposable razors	
Brush, sponge	
Nail brush, nail clippers, nail file	
Scissors, bandage scissors	
Hair dryer	
Towels	
Replacement clothing	
Blankets	
Sample collections	
Standard sample containers (at least 20 per decontamination)	
Sample containers for biological dosimetry and special investigations	
Cotton wool, cotton swabs	
Cups	
Adhesive strips	
Permanent markers	
Materials to prevent the spread of contamination	**Available?**
Solid plastic sheets to cover the floor and inventory	
Tape with radiation warning sign to cordon off areas	

Containers for collecting contaminated waste, such as used decontamination agents and wastewater, for personalised and safe storage of contaminated clothing or other personal possessions	
Single-use drapes	
Ionizing radiation symbol	
Adhesive tape to attach foil	

Monitoring devices

Amount required	**Monitoring devices**	**Available/access to**
2	Portable contamination monitor	
2	Dose/dose rate meters	
1 or access to	Mobile dose rate meter for gamma spectroscopy	
1 or access to	Semiconductor measuring station	
1 or access to	Whole-body counter	