Safety Reports Series

No. 4

PLANNING THE MEDICAL RESPONSE TO RADIOLOGICAL ACCIDENTS

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SAFETY REPORTS SERIES No. 4

PLANNING THE MEDICAL RESPONSE TO RADIOLOGICAL ACCIDENTS

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FOREWORD

Radioactive substances and other sources of ionizing radiation are used to assist in diagnosing and treating diseases, improving agricultural yields, producing electricity and expanding scientific knowledge. The application of sources of radiation is growing daily, and consequently the need to plan for radiological accidents is growing. While the risk of such accidents cannot be entirely eliminated, experience shows that most of the rare cases that have occured could have been prevented, as they are often caused by human error.

Recent radiological accidents such as those at Chernobyl (Ukraine 1986), Goiânia (Brazil 1987), San Salvador (El Salvador 1989), Sor-Van (Israel 1990), Hanoi (Viet Nam 1992) and Tammiku (Estonia 1994) have demonstrated the importance of adequate preparation for dealing with such emergencies. Medical preparedness for radiological accidents must be considered an integral part of general emergency planning and preparedness and established within the national framework for radiation protection and safety.

An IAEA Technical Committee meeting held in Istanbul in 1988 produced some initial guidance on the subject, which was subsequently developed, reviewed and updated by groups of consultants in 1989, 1992 and 1996. Special comments were provided by WHO, as co-sponsor of this publication, in 1997.

This Safety Report outlines the roles and tasks of health authorities and hospital administrators in emergency preparedness for radiological accidents. Health authorities may use this document as the basis for their medical management in a radiological emergency, bearing in mind that adaptations will almost certainly be necessary to take into account the local conditions. This publication also provides information relevant to the integration of medical preparedness into emergency plans.

The major contributions of J.R. Harrison, J.C. Nenot and L.B. Sztanyik are especially acknowledged.

The Scientific Secretary responsible for the preparation of this document was I. Turai of the Division of Radiation and Waste Safety.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

A radiological accident is an unintended or unexpected event occurring with a radiation source or during a practice involving ionizing radiation, which may result in significant human exposure and/or material damage. It includes accidents with reactors, industrial sources and medicals facilities. Although radiological accidents in industry, medicine, research, teaching or agriculture are more limited in their environmental impact, they occur much more frequently than reactor accidents and can have serious health consequences [1, 2].

Not only workers but also members of the public, including children, have suffered radiation injuries as a result of radiological accidents over the past few years. These accidents not only involved external irradiation but occasionally included internal and skin contamination. Details concerning accidents which occurred from 1945 to July 1997 are contained in Annex I.

Comprehensive study of the causes and consequences of radiological accidents is a recurrent theme in several fields of IAEA and World Health Organization (WHO) activities under the programmes on radiation safety and the prevention of radiation health hazards. These include: occupational radiation protection; assessment and treatment of radiation health effects; emergency planning and preparedness; and safety of radiation sources. Each of these is concerned with a different facet of a radiological accident and approaches it from a different angle. Nevertheless, they are all important in the effort to reduce the likelihood and severity of such accidents.

Over the past few years the IAEA has issued publications [3–6] which give information on the nature of radiation health effects, and general recommendations to physicians for the diagnosis and treatment of radiation injuries resulting from a nuclear or radiological accident, as well as safety guides providing general recommendations for emergency preparedness, including some medical aspects and guidance on radiation protection criteria for reducing health consequences [7–8]. This Safety Report outlines the roles of health authorities and hospital administrators in emergency preparedness and is considered to be a logical supplement to these publications [3–8].

There is a need for great concern about the likelihood of more frequent minor radiological accidents, as there is than about the remote probability of a major radiological accident occurring rather rarely. Such more limited radiological accidents may result from:

— the use and misuse, including misadministration, of ionizing radiation or radioactive substances for diagnostic radiology, nuclear medicine and radiotherapy

(X ray generating machines and gamma ray sources, particle accelerators, and sealed or unsealed radionuclide sources);

- the use or misuse of gamma sources and X ray machines in industrial radiography and production control;
- the use or misuse of gamma sources in the sterilization and preservation of foodstuffs or for other purposes;
- the negligent or unregulated disposal of such radiation sources or of radioactive waste.

It is most important for every country in which such sources of radiation are used to have a sufficient number of medical personnel trained to take care of people involved in radiological accidents. Previous experience has shown that localized exposure, often without radioactive contamination, is the most common radiological accident. In the majority of these cases the treatment can be offered in hospital units specifically identified for this purpose as part of a medical emergency plan. Standard departments, such as haematology, burns and intensive care, are in general adequately equipped to treat such patients. In the event of radioactive contamination of people, the introduction of specific measures to prevent the spread of contamination will be necessary. Only the more seriously exposed cases may need to be transferred to hospitals with advanced facilities [9–16].

WHO co-ordinates a network of Collaborating Centres and Liaison Institutions for the provision of advice on medical preparedness and assistance for radiation emergencies (Annex II). An additional role of Collaborating Centres is to provide advice on the management of exposed individuals, which may include the transfer of severely exposed patients for specialist medical care.

1.2. OBJECTIVE

The purpose of this Safety Report is to provide practical information to national and regional health authorities who have responsibility for medical planning for and medical response to a radiological accident.

1.3. SCOPE

This Safety Report provides information to health authorities on the medical and public health aspects of dealing with radiological accidents. Small scale accidents usually involve a small source term and a small number of individuals and often come to light from observations by primary care physicians. Large scale radiological accidents usually involve a large source term and large numbers of persons may be irradiated and/or contaminated, requiring specialist treatment in both primary and secondary medical facilities. Large scale accidents can also lead to widespread public health actions undertaken to mitigate the effects of radioactive contamination. This report does not discuss those actions, which include the distribution of stable iodine tablets, individual monitoring, and reassurance and counselling, as these are covered in other publications [6–9]. Nevertheless, in some small scale accidents some public health actions such as the issue and administration of stable iodine and the restriction of public access may be required.

Depending on the severity of the accident, the level of medical aid to persons irradiated or contaminated will include the following:

(a) First aid provided at the place of the accident (without a physician or nurse necessarily in attendance);
(b) Initial medical examination (triage will be required if large numbers of persons are exposed), detailed clinical and laboratory investigations and medical treatment in a general hospital;
(c) Complete examination and treatment in a specialized radiation medical centre, when there is evidence of serious irradiation or internal contamination.

This report does not deal with the technical details of (c).

In view of the infrequent occurrence of radiological accidents and the capability of existing large general centres to deal with such accidents, it is not the purpose of this report to encourage the proliferation of medical centres specifically equipped and staffed for the sole purpose of treating victims of overexposure to radiation.

1.4. STRUCTURE

Section 2 of this publication gives some idea of the different types of accidental exposure, with a description of the clinical consequences and an evaluation of the possibility of treating such cases in non-specialized hospitals.

The main part of the publication is Section 3, which is devoted to the basic medical preparedness requirements for responding to a radiological accident.

The Annexes give supplementary information including:

(1) A list of the reported accidents which have occurred over the past 50 years. This is helpful in understanding what types of accident happen most frequently and what kind of injuries can be expected;
(2) A list of WHO Collaborating Centres to which local authorities can address a request for assistance or for specialized treatment of a patient and a checklist on information to be provided when requesting assistance;

(3) A plan of a reception area which gives an idea of how the treatment of accidentally exposed individuals might be organized and the minimum equipment and materials necessary for this.

A list of related IAEA and WHO publications is given at the end of the book.

2. CLASSIFICATION OF POSSIBLE RADIOLOGICAL ACCIDENTS

Although most victims of radiological accidents receive adequate treatment in the medical facilities in their country, some more serious cases might need to be transferred to specialized centres in another country. The careful collection of the initial bioclinical and dosimetric data and details of the accident history is of vital importance for both the general hospital and the specialized centres to enable the correct diagnosis, prognosis and treatment to be established. Recording this background information should be regarded as an integral part of the initial medical handling of the patients and is very helpful for the preliminary assessment of the seriousness of the situation.

Radiation injuries may be caused by external or internal exposure, with or without contamination of the skin, and may occur either alone or in combination with other injuries, such as fractures, wounds and burns. Combinations of radiation injuries and other types of injury are referred to in this publication as 'combined injuries'.

Radiation accidents have varying clinical consequences for the exposed individuals, as shown in Table I, which also indicates the applicability of treatment at local general facilities.

TABLE I. TREATMENT OF EXPOSED PATIENTS AT GENERAL HOSPITALS

Type of exposure	Possible consequences	Treatment at a general hospital
External exposure		
Localized exposure most often to hands	Localized erythema with possible development of blisters, ulceration and necrosis	Clinical observation and treatment Securing of medical advice if necessary
Total or partial body exposure with minimal and delayed clinical signs	No clinical manifestation for 3 hours or more following exposure Not life threatening Minimal haematological changes	Clinical observation and symptomatic treatment Sequential haematological investigations

TABLE I. (cont.)

Type of exposure	Possible consequences	Treatment at a general hospital
Total or partial body exposure with early prodromal signs	Acute radiation syndrome of mild or severe degree depending on dose	Treatment as above plus securing of specialized treatment Full blood count and HLA typing before transfer to a specialized centre
Total or partial body exposure with thermal, chemical or radiation burns and/or trauma	Severe combined injuries, life threatening	Treatment of life threatening conditions Treatment as above and early transfer to a specialized centre
External contamination		
Low level contamination, intact skin which can be cleaned promptly	Unlikely Mild radiation burns	Decontamination of skin and monitoring
Low level contamination, intact skin where cleaning is delayed	Radiation burns Percutaneous intake of radionuclides	Securing of specialist advice
Low level contamination with thermal, chemical or radiation burns and/or trauma	Internal contamination	Securing of specialist advice
Extensive contamination with associated wounds	Likely internal contamination	Securing of specialist advice
Extensive contamination with thermal, chemical or radiation burns and/or trauma	Severe combined injuries and internal contamination	First aid, plus treatment of life threatening injuries; early transfer to a specialized centre
Internal contamination		
Inhalation and ingestion of radionuclides — insignificant quantity (activity)	No immediate consequences	Securing of specialist advice
Inhalation and ingestion of radionuclides — significant quantity (activity)	No immediate consequences	Nasopharyngeal lavage Early transfer to a specialized centre to enhance excretion of radionuclides

TABLE I. (cont.)

Type of exposure	Possible consequences	Treatment at a general hospital
Absorption through damaged skin (see under external contamination)	No immediate consequences	Securing of specialist advice
Major incorporation with or without external total, or partial body or localized irradiation, serious wounds and/or burns	Severe combined radiation injury	Treatment of life threatening conditions and transfer to a specialized centre

3. BASIC MEDICAL RESPONSE TO RADIOLOGICAL ACCIDENTS

To cope with radiation casualties medical planning is essential. The emergency arrangements described in this section are intended to make it possible to deal with the medical needs of persons affected by a radiological accident.

3.1. EVALUATION OF THE POSSIBILITIES FOR AND TYPES OF ACCIDENTS

An important part of medical preparedness is the evaluation of the accidents that may occur. This will vary from country to country, but in any particular region there should be an authority familiar with the types and locations of the various radiation sources. This will enable the appropriate medical planning to be incorporated into the emergency plans to deal with any radiological accident.

Health authorities and hospital managements have to be informed of the probabilities of radiological accidents with or without radionuclide contamination. Accidents with the various kinds of X ray machines or with most accelerators cannot lead to radioactive contamination. Poor control or misuse of gamma sources have been the most common cause of external exposures leading to significant clinical consequences, including death. Manipulation of unsealed sources can lead to external or internal contamination which is unlikely to result in severe clinical consequences. The types of accidents, the numbers of persons who may be affected, the places where radiation sources are handled and the methods of transportation have to be taken into account by the responsible health authorities and organizations.

A list of major radiological accidents between 1945 and 1997 in the nuclear industry, non-nuclear industries, research and medicine, involving workers as well as members of the public, is presented in Annex I. It gives a general idea of the frequency of accidents with different radiation sources.

3.2. MEDICAL CARE AT THE ACCIDENT SITE AND IN HOSPITALS

3.2.1. Initial treatment

Trained first aid workers may be called upon to conduct resuscitation. Paramedical or ambulance personnel are required to transport the patient to a reception area, which may be a local clinic or a general hospital. Specific training of such personnel should be organized, and, as part of the emergency plan, rehearsals held. In enterprises where a nuclear accident might occur, regular training of an on-site emergency team to provide the initial treatment is necessary.

3.2.2. Treatment in the reception area

Once the patient arrives at the pre-planned reception area, the trained staff establishes the general condition of the patient and the severity of any associated injury.

Decisions on whether the subsequent therapy should be undertaken at a general hospital or at a specialized medical centre can be determined from the suggested categories in Table I. The medical team members dealing with the reception of casualties of a radiological accident must be capable of carrying out a preliminary assessment, conducting a careful interview and performing triage and any necessary treatment of the exposed persons. This team should include physicians, surgeons, nurses, and a physicist or technician competent in the monitoring and assessment of radiation exposure and radionuclide contamination. A full haematological, pathological and biochemical laboratory service is necessary.

All persons involved in a radiological accident should be carefully interviewed; a full, detailed description of the radiation situation should be made as soon as possible. For purposes of dose assessment it is often useful to show by means of a diagram the position of each person present at the accident site.

(1) *The first priority* is the treatment of life threatening injuries (shock, bleeding, thermal burns, fractures, etc.) by whichever type of specialist is appropriate for the condition.

(2) *The second priority* is the assessment of the extent and magnitude of contamination, and decontamination as necessary. Any person with external contamination requires a special and separate (isolated) treatment. The most effective decontamination procedure is washing, subject to control by monitoring.

(3) *The third priority* is that if there is suspected internal contamination, a quick assessment of its nature and degree should be made so that appropriate measures to reduce the contamination may be started as soon as possible. In handling internally contaminated persons the following procedures are essential:

— collection of appropriate samples, such as nasopharyngeal swabs, for clinical evaluation (a scheme of preliminary investigation is shown in Table II). It may be important to continue collecting samples of urine and faeces for further analyses;
— continuation of external decontamination, if necessary;
— special tests such as whole body monitoring and/or direct thyroid counting depending on the radionuclides involved;
— decontamination therapy, including excision of contaminated wounds.

Medical team members who deal with contaminated persons are to be monitored for contamination. Provision should be made for changing clothes and for washing and showering. The number of individuals dealing with decontamination should be kept to a minimum.

Only those patients with combined injuries and/or a severe prodromal syndrome will require treatment in the reception area.

In the reception area specific substances may be required for the treatment of internally contaminated patients. Many of these substances are available com-

TABLE II. IMPORTANT LABORATORY SAMPLES TO BE TAKEN IN THE RECEPTION AREA/HOSPITAL FOR SUBSEQUENT ANALYSIS

Blood, approximately 20–30 mL for the following analyses:	
(1)	Full blood count
(2)	Cytogenetic analysis (24 h after exposure is the optimum time)
(3)	Biochemical analysis (serum amylase)
(4)	Analysis for radionuclide content
Urine	
(1)	Routine analysis
(2)	Biochemical (creatinuria)
(3)	Analysis for radionuclide content
Stools (for estimation of radionuclide content)	

TABLE III. EXAMPLES OF SUBSTANCES WHICH SPEED UP THE ELIMINATION OF RADIONUCLIDES FROM THE HUMAN BODY

Substance	Target radionuclides
Prussian blue	Caesium
Alginate	Strontium
Aluminium phosphate	Radium
Isotonic sodium bicarbonate	Uranium
CaDTPA	Plutonium and in general the transuranics, lanthanides, manganese, iron, cobalt, zirconium, ruthenium
Calcium glauconite	Calcium, strontium, barium, radium
Cobalt glauconite	Cobalt
Strontium glauconite or lactate	Strontium
Potassium iodide	Iodine
Aluminium phosphate	Strontium, radium
Barium sulphate	Strontium, radium
Magnesium sulphate	Strontium, radium

mercially under various names in different countries and they may be available in general hospitals. The most common substances and principal target radionuclides are presented in Table III.

In addition, medicaments of the following groups may be needed in the reception area: anti-emetic agents; analgesics; cardiac stimulants; anti-intoxicant agents; antiviotics; haemostatics; and desensitizers.

3.2.3. Treatment in the hospital

The medical staff dealing with patients transferred from the reception area will complete the diagnostic investigation and will plan the appropriate treatment. Specialists appropriate for the particular type of syndrome of the radiation illness (bone marrow, gastrointestinal, central nervous system or radiation burns) may be required. For example, medical specialists experienced in treating patients with leukaemia by chemotherapy or total body irradiation are well qualified to deal with patients who have radiation induced bone marrow aplasia.

Additional specialists may be needed for the treatment of exposed individuals. Surgeons, especially burns specialists, should be available to deal with radiation burns and contaminated wounds, both of which should be treated as soon as possible [17].

A clinical laboratory should be available to carry out appropriate daily routine investigations for each patient.

3.3. DOSIMETRY SERVICES

In any accident in which people have been irradiated or contaminated, it will be important to assess the absorbed dose [18–20].

In cases of external contamination it is necessary to measure its level and extent with appropriate instrumentation. Trained staff will be needed to make such assessments.

The evaluation of a high absorbed dose received from external irradiation in an accident can be an extremely complex matter, and must be undertaken by dosimetric specialists. If the irradiation was by neutrons, gamma rays or X rays, and if the irradiated person was not wearing a personal dosimeter at the time of exposure, the assessment of absorbed dose will require a reconstruction of the accident. For this purpose a detailed interview with the persons involved is necessary. Means of estimating dose without dosimeters have been developed, such as electron spin resonance analysis of exposed clothes, cotton fibres, dental enamel or other substances. These techniques can augment the well established cytogenetic dosimetry assays. The clothes of exposed but non-contaminated persons should be kept for this purpose.

In the event of neutron irradiation, it may be important to analyse blood, hair and nails for induced radioactivity. Samples of such materials should be taken as soon as possible and kept for subsequent analysis by a competent laboratory. Time is an important factor for this. The earlier the analysis is performed, the higher its sensitivity. In addition, items such as jewellery, coins, metal rims of spectacles, wrist watches and belt buckles should also be retained for activation analysis.

3.4. SPECIALIZED EQUIPMENT AND MATERIAL

In addition to the type of equipment normally available in a hospital, certain special items will be needed for dealing with victims of radiological accidents.

3.4.1. Equipment for the detection of radionuclide contamination

To deal with an accident involving radionuclide contamination, it is essential to make effective measurements. These will normally be undertaken by the Radiation Protection Officer or Health Physicist. Staff who do not regularly use radiation measuring instruments should receive special training.

Appropriate instruments are used to measure the relevant contamination. Specialized radiation monitoring instruments are needed to enable the extent of external contamination and the subsequent efficacy of decontamination to be evaluated. Suitable instruments may well be available in the nuclear medicine department of the hospital. Alternatively, a designated reception area may need to have its own equipment. If significant amounts of internal contamination are found or suspected, a patient may need to be transferred to a centre with a whole body counter (WBC). In some cases it might be better if a mobile WBC is moved to the hospital from a specialist centre. Personal dosimeters are necessary for staff who handle contaminated casualties.

Regular checking and periodic calibration of instruments, to ensure that they are in good working order, is an essential part of good operational practice.

3.4.2. Measures for minimizing the spread of contamination

When contaminated patients are brought to a hospital some simple preventive measures will minimize the possibility of spread of radionuclide contamination. Such spreading is unlikely to cause significant doses to hospital personnel but could be difficult to rectify.

It will be useful to have the following items in stock to reduce the spread of contamination:

— large plastic sheets or heavy duty paper for placing under contaminated patients;
— protective clothing (overalls, masks, rubber or plastic gloves and overshoes) for staff;
— plastic bags for collecting all items that have been in contact with the patient (e.g. clothing, swabs, dressings, instruments, gloves and overalls);
— large containers for storing fluids used in decontaminating the patient;
— special containers for samples of tissue, urine and faeces.

3.5. PREPARATION OF THE RECEPTION AREA

The following preparations are necessary before exposed and/or contaminated patients arrive at the reception area:

(1) An area outside the building should be designated to receive the vehicles bringing patients; in this area the vehicles can be checked for contamination and, if necessary, decontaminated.
(2) A special reception area should be established; an example is given in Annex III. It is advisable to ensure the separate handling of contaminated and non-

contaminated persons. Most floors in hospitals are easily cleaned; however, if the floor is not easily cleanable, it should be covered with thick paper. Experience has shown that the use of polythene, particularly when wet, is a hazard to personnel. Newspaper can be used if nothing else is available. Such coverings should be taped to the floor. It may be necessary to control the ventilation of this area to prevent the spread of contamination.

(3) The reception area should be supplied with a decontamination table covered with waterproof sheets. Arrangements should be made to collect contaminated fluids resulting from the decontamination process.

(4) To prevent the possible spread of contamination, only a limited number of trained staff should be allowed to handle the patients and monitoring arrangements should be made to control the movements of any staff leaving the contaminated area. The staff and any equipment leaving the contaminated area should be monitored. In the event of radionuclide contamination there should be provision for decontaminating the staff and the equipment before they leave the area.

(5) If other parts of the hospital are likely to become involved in the handling of any of the contaminated patients (e.g. an operating theatre or an intensive care unit), appropriate isolation should be arranged to prevent or minimize contamination.

(6) All staff who will handle the patients should be supplied with protective clothing (waterproof apron, gown, cap, mask, gloves and covering for footwear).

(7) Large waterproof bags should be made available for contaminated articles such as clothing.

(8) Plentiful supplies of paper towels and tissues should be made available for decontamination.

(9) Radiation warning signs should be posted to prevent unauthorized entry.

3.6. FIRST AID PROCEDURES

Details of the medical procedures to be followed in the event of a radiological accident are given elsewhere [5, 6, 9, 21, 22]. However, there are a few simple procedures that can be undertaken by non-medical staff, pending the arrival of medical specialists in the reception area:

— Normal first aid measures should be taken to deal with life threatening conditions such as asphyxiation and haemorrhage, irrespective of contamination levels.
— Surface contamination on undamaged skin can usually be removed by washing with soap and water. Stronger agents or scrubbing should not be used at this stage.

3.7. TRAINING

Arrangements should be made for all medical and paramedical staff to be trained in the principles of radiation protection [1], including the health effects of radiation and the methods for dealing with patients who have been accidentally irradiated or contaminated, with or without complications.

This training should be both theoretical and practical. Practical skills are to be taught by exercises in contamination monitoring and decontamination procedures.

Physicians and/or health physicists with specialized training in assistance in a radiological emergency are usually responsible for organizing regular emergency exercises for their local colleagues.

3.8. RESPONSIBILITY OF THE HOSPITAL ADMINISTRATION

Overall, the administration is responsible to ensure that:

- detailed emergency plans are drawn up and regularly exercised;
- appropriate staff are designated and given specific training;
- space is allocated for reception and treatment as well as for vehicle parking;
- special equipment and materials are provided and properly maintained;
- someone in authority is designated to deal with enquiries and with representatives of the media.

When accident cases are received, the hospital administration will be responsible for ensuring that the emergency plan is put into effect, and that employers and relatives of the accident victims are informed.

If medical assistance is needed from the WHO, the request should be sent through national health authorities to WHO Headquarters directly or via a relevant WHO Regional Office or Collaborating Centres within REMPAN (Radiation Emergency Medical Preparedness and Assistance Network) (see Annex II).

Annex I

MAJOR RADIATION ACCIDENTS (1945–1997) IN NUCLEAR INDUSTRY, NON-NUCLEAR INDUSTRY, RESEARCH AND MEDICINE INVOLVING WORKERS AS WELL AS MEMBERS OF THE PUBLIC

Year	Place	Source	Dose (or activity intake)	Significant exposures[a]	Deaths
1945–1946	Los Alamos, USA	Criticality	Up to 13 Gy (mixed[b] radiation)	10	2
1952	Argonne, USA	Criticality	0.1–1.6 Gy (mixed[b] radiation)	3	—
1953	USSR	Experimental reactor	3.0–4.5 Gy (mixed[b] radiation)	2	—
1955	Melbourne, Australia	Co-60	Unknown	1	—
1955	Hanford, USA	Pu-239	Unknown	1	—
1958	Oak Ridge, USA	Criticality (Y-12 plant)	0.7–3.7 Gy (mixed[b] radiation)	7	—
1958	Vinča, Yugoslavia	Experimental reactor	2.1–4.4 Gy (mixed[b] radiation)	8	1
1958	Los Alamos, USA	Criticality	0.35–45 Gy (mixed[b] radiation)	3	1
1959	Johannesburg, South Africa	Co-60	Unknown	1	—
1960	USA	Electron beam	7.5 Gy (local)	1	—
1960	Madison, USA	Co-60	2.5–3 Gy	1	—
1960	Lockport, USA	X rays	<12 Gy, non-uniform	6	—
1960	USSR	Cs-137 (suicide)	~15 Gy	1	1
1960	USSR	Radium bromide (ingestion)	74 MBq	1	1 (after four years)

Year	Place	Source	Dose (or activity intake)	Significant exposures[a]	Deaths
1961	USSR	Submarine accident	10–50.0 Gy	>30	8
1961	Miamisburg, USA	Pu-238	Unknown	2	—
1961	Miamisburg, USA	Pu-210	Unknown	4	—
1961	Switzerland	H-3	3 Gy	3	1
1961	Idaho Falls, USA	Explosion in reactor	Up to 3.5 Gy	7	3
1961	Plymouth, UK	X rays	Local overdose	11	—
1961	Fontenay-aux-Roses, France	Pu-239	Unknown	1	—
1962	Richland, USA	Criticality	Unknown	2	—
1962	Hanford, USA	Criticality	0.2–1.1 Gy (mixed[b] radiation)	3	—
1962	Mexico City, Mexico	Co-60 capsule	9.9–52 Sv	5	4
1962	Moscow, USSR	Co-60	3.8 Gy (non-uniform)	1	—
1963	China	Co-60	0.2–80 Gy	6	2
1963	Saclay, France	Electron beam	Unknown (local)	2	—
1964	Germany, Fed. Rep.	H-3	10 Gy	4	1
1964	Rhode Island, USA	Criticality	0.3–46 Gy (mixed[b] radiation, etc.)	4	1
1964	New York, USA	Am-241	Unknown	2	—
1965	Rockford, USA	Accelerator	>3 Gy (local)	1	—
1965	USA	Diffractometer	Unknown (local)	1	—
1965	USA	Spectrometer	Unknown (local)	1	—
1965	Mol, Belgium	Experimental reactor	5 Gy (total)	1	—
1966	Portland, USA	P-32	Unknown	4	—

Year	Place	Source	Dose (or activity intake)	Significant exposures[a]	Deaths
1966	Leechburg, USA	Pu-235	Unknown	1	—
1966	Pennsylvania, USA	Au-198	Unknown	1	1
1966	China	"Contaminated zone"	2–3 Gy	2	—
1966	USSR	Experimental reactor	3.0–7.0 Gy (total)	5	—
1967	USA	Ir-192	0.2 Gy 50 Gy (local)	1	—
1967	Bloomsburg, USA	Am-241	Unknown	1	—
1967	Pittsburgh, USA	Accelerator	1–6 Gy	3	—
1967	India	Co-60	80 Gy (local)	1	—
1967	USSR	X ray medical diagnostic facility	50.0 Gy (head, local)	1	1 (after seven years)
1968	Burbank, USA	Pu-239	Unknown	2	—
1968	Wisconsin, USA	Au-198	Unknown	1	1
1968	Germany, Fed. Rep.	Ir-192	1 Gy	1	—
1968	La Plata, Argentina	Cs-137	Local, 0.5 Gy (WB)	1	—
1968	Chicago, USA	Au-198	4–5 Gy (bone marrow)	1	1
1968	India	Ir-192	130 Gy (local)	1	—
1968	USSR	Experimental reactor	1.0–1.5 Gy	4	—
1968	USSR	Co-60 irradiation facility	1.5 Gy (local, head)	1	—
1969	Wisconsin, USA	Sr-85	Unknown	1	—
1969	USSR	Experimental reactor	5.0 Sv (total) non-uniform	1	—
1969	Glasgow, UK	Ir-192	0.6 Gy	1	—

Year	Place	Source	Dose (or activity intake)	Significant exposures[a]	Deaths
1970	Australia	X rays	4–45 Gy (local)	2	—
1970	Des Moines, USA	P-32	Unknown	1	—
1970	USA	Spectrometer	Unknown (local)	1	—
1970	Erwin, USA	U-235	Unknown	1	—
1971	Newport, USA	Co-60	30 Gy (local)	1	—
1971	UK	Ir-192	30 Gy (local)	1	—
1971	Japan	Ir-192	0.2–1.5 Gy	4	—
1971	Oak Ridge, USA	Co-60	1.3 Gy	1	—
1971	USSR	Experimental reactor	7.8; 8.1 Sv	2	—
1971	USSR	Experimental reactor	3.0 Gy (total)	3	—
1972	Chicago, USA	Ir-192	100 Gy (local)	1	—
1972	Peach Bottom, USA	Ir-192	300 Gy (local)	1	—
1972	Germany, Fed. Rep.	Ir-192	0.3 Gy	1	—
1972	China	Co-60	0.4–5.0 Gy	20	—
1972	Bulgaria	Cs-137 capsules (suicide)	>200 Gy (local, chest)	1	1
1973	USA	Ir-192	0.3 Gy	1	—
1973	UK	Ru-106	Unknown	1	—
1973	Czechoslovakia	Co-60	1.6 Gy	1	—
1974	Illinois, USA	Spectrometer	2.4–48 Gy (local)	3	—
1974	Parsippany, USA	Co-60	1.7–4 Gy	1	—
1974	Middle East	Ir-192	0.3 Gy	1	—
1975	Brescia, Italy	Co-60	10 Gy	1	1
1975	USA	Ir-192	10 Gy (local)	1	—

Year	Place	Source	Dose (or activity intake)	Significant exposures[a]	Deaths
1975	Columbus, USA	Co-60	11–14 Gy (local)	6	—
1975	Iraq	Ir-192	0.3 Gy	1	—
1975	USSR	Cs-137 irradiation facility	3–5 Gy (total) + >30 Gy (hands)	1	—
1975	German Democratic Rep.	Research reactor	20–30 Gy (local)	1	—
1975	Germany, Fed. Rep.	X ray	30 Gy (hand)	1	—
1975	Germany, Fed. Rep.	X ray	1 Gy (total)	1	—
1976	Hanford, USA	Am-241 intake	>37 MBq	1	—
1976	USA	Ir-192	37.2 Gy (local)	1	—
1976	Pittsburgh, USA	Co-60	15 Gy (local)	1	—
1976	Rockaway, USA	Co-60	2 Gy	1	—
1977	Pretoria, South Africa	Ir-192	1.2 Gy	1	—
1977	Denver, USA	P-32	Unknown	1	—
1977	USSR	Co-60 irradiation facility	4 Gy (total)	1	—
1977	USSR	Proton accelerator	10.0–30.0 Gy (hands)	1	—
1977	UK	Ir-192	0.1 Gy + local	1	—
1977	Peru	Ir-192	0.9–2.0 (total) ~160 (hand)	3	—
1978	Argentina	Ir-192	12–16 Gy (local)	1	—
1978	Algeria	Ir-192	Up to 13 Gy (for max. exposed person)	7	1
1978	UK	—	—	1	—
1978	USSR	Electron accelerator	20 Gy (local)	1	—
1979	California, USA	Ir-192	Up to 1 Gy	5	—

Year	Place	Source	Dose (or activity intake)	Significant exposures[a]	Deaths
1980	USSR	Co-60 irradiation facility	50.0 Gy (local, legs)	1	—
1980	German Democratic Rep.	X rays	15–30 Gy (hand)	1	—
1980	Germany, Fed. Rep.	Radiography unit	23 Gy (hand)	1	—
1980	China	Co-60	5 Gy (local)	1	—
1981	Saintes, France	Co-60 medical facility	>25 Gy	3	—
1981	Oklahoma, USA	Ir-192	Unknown	1	—
1982	Norway	Co-60	22 Gy	1	1
1982	India	Ir-192	35 Gy local	1	—
1983	Constitu, Argentina	Criticality	43 Gy (mixed[b] radiation)	1	1
1983	Mexico	Co-60	0.25–5.0 Sv protracted exposure	10	—
1983	Islamic Republic of Iran	Ir-192	20 Gy (hand)	1	—
1984	Morocco	Ir-192	Unknown	11	8
1984	Peru	X rays	5–40 Gy (local)	6	—
1985	China	Electron accelerator	Unknown (local)	2	—
1985	China	Au-198 (mistake in treatment)	Unknown, internal	2	1
1985	China	Cs-137	8–10 Sv (subacute)	3	—
1985	Brazil	Radiography source	410 Sv (local)	1	—
1985	Brazil	Radiography source	160 Sv (local)	2	—
1985–1986	USA	Accelerator	Unknown	3	2
1986	China	Co-60	2–3 Gy	2	—
1986	Chernobyl, USSR	Nuclear power plant	1–16 Gy (mixed[b] radiation)	134	28 (+ 2 non-radiation deaths)

Year	Place	Source	Dose (or activity intake)	Significant exposures[a]	Deaths
1987	Goiânia, Brazil	Cs-137	Up to 7 Gy (mixed[b] radiation)	(50)[c]	4
1987	China	Co-60	1.0 Gy	1	—
1989	El Salvador	Co-60 irradiation facility	3–8 Gy	3	1
1990	Israel	Co-60 irradiation facility	>12 Gy	1	1
1990	Spain	Radiotherapy accelerator	Unknown	27	11 ?[d]
1991	Nesvizh, Belarus	Co-60 irradiation facility	10 Gy	1	1
1991	USA	Accelerator	>30 Gy (hands and legs)	1	—
1992	Viet Nam	Accelerator	20–50 Gy (hands)	1	—
1992	China	Co-60	>0.25–10 Gy	8	3
1992	USA	Ir-192 brachytherapy	>1000 Gy (local)	1	1
1994	Tammiku, Estonia	Cs-137 source from waste rep.	1830 Gy (thigh) + 4 Gy (whole body)	3	1
1996	Costa Rica	Radiotherapy	Unknown	110	40 ?[d]
1996	Gilan, Islamic Republic of Iran	Ir-192 radiography	3 Gy? (whole body) + 50 Gy? (chest)	1	—
1997	Tbilisi, Georgia	Cs-137 source at a military training site	10–30 Gy to different small parts of the body	11	—
1997	Kremlev, Sarov Russian Federation	Criticality experiment	5–10 Gy (whole body) + 200–250 Gy (to hands)	1	1

[a] ≥0.25 Sv to the whole body, blood forming organs or other critical organs; ≥6 Gy to the skin locally; ≥0.75 Gy to other tissues or organs from an external source, or exceeding half of the annual limit on intake (ALI).

[b] Mixed radiation is a mixture of various types of radiation with different LET values, such as neutrons and gamma rays, or gamma and beta rays.

[c] The number of persons who received significant overexposures is probably lower (some of the 50 contaminated persons received doses of less than 0.25 Sv).

[d] The number of deaths due directly to radiation is under investigation; it is most probably under 10.

Annex II

LIST OF INTERNATIONAL CONSULTING CENTRES

In a particular radiological accident involving injuries to persons, there may be a need, often urgent, for expert medical consultation and help. If this is not available nationally, WHO has designated a number of Collaborating Centres and Liaison Institutions around the world from which help can be obtained. These are listed below. General advice and assistance can also be obtained from IAEA and WHO Headquarters.

Argentina	Department of Health Physics, POB 3268, Buenos Aires Fax: +541 382 5680 or +541 381 0971 Tel: +541 382 5680
Armenia	Research Centre of Radiation Medicine and Burns, 375078 Davidasben, Yerevan Fax: +3742 340 800 Tel: +3742 341 144
Australia	Radiation Protection and Radiation Emergency, Yallambia, Victoria 3093 Fax: +613 9432 1835 Tel: +613 9433 2211
Brazil	Radiation Protection and Medical Preparedness for Radiological Accidents, Avenida Salvador Allende (vio9), Jocorepogu, CP 37750, CEP 22780, Rio de Janeiro Fax: +5521 442 2539 or +5521 442 1950 Tel: +5521 442 1927 or +5521 442 9614
China	Institute of Radiation Medicine, 27, Tai Ping Road, 100850 Beijing Fax: +8610 821 4653 Tel: +8610 821 3044 or 821 4653
France	Centre International de Radiopathologie, BP No. 34, Bâtiment 01, F-92269 Fontenay-aux-Roses Fax: +331 4638 2445 Tel: +331 4554 7266
Germany Ulm	Institute for Occupational Health, University of Ulm, Pf. 2060, D-89069 Fax: +49 731 502 3415

	Tel: +49 731 502 3400
India	Bhabha Atomic Research Centre, 400085 Mumbai Fax: +9122 556 0750 Tel: +9122 551 1677
Japan	Radiation Effects Research Foundation, 5-2 Hijiyama Park, Minami-Ku, J-732, Hiroshima Fax: +11 8182 263 7279 Tel: +11 8182 261 3131
Russian Federation	State Research Centre, Institute of Biophysics, 46, Zhivopisnaya, 123182 Moscow Fax: +7095 190 3590 Tel: +7095 190 5156
	Central Research Institute of Roentgenology and Radiology, Pesochnij 2, 189646 St. Petersburg Fax: +7812 437 8787 Tel: +7812 437 8781
	All-Russian Centre on Ecological Medicine, 17, Botkinskaya, 194175 St. Petersburg Fax: +7812 541 8805 Tel: +7812 248 3419
	Medical Radiological Research Centre, 4, Koroliev, 249020 Obninsk Fax:+7095 956 1440 Tel:+7095 956 1439
	Urals Research Centre for Radiation Medicine, Medgorodok, F1B, 454076 Chelyabinsk Fax: +73512 344 321
United Kingdom	National Radiological Protection Board, NRPB, Chilton Didcot, Oxfordshire OX11 0RQ Fax: +441235 822 630 Tel: +441235 822 612
USA	Radiation Emergency Assistance, REAC/TS, Oak Ridge, TN 37831-0117 Fax: 001 615 576 9522

Tel: 001 615 576 3450

WHO

Headquarters
CH-1211 Geneva 27, Switzerland
Fax: 0041 22 791 0746
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IAEA

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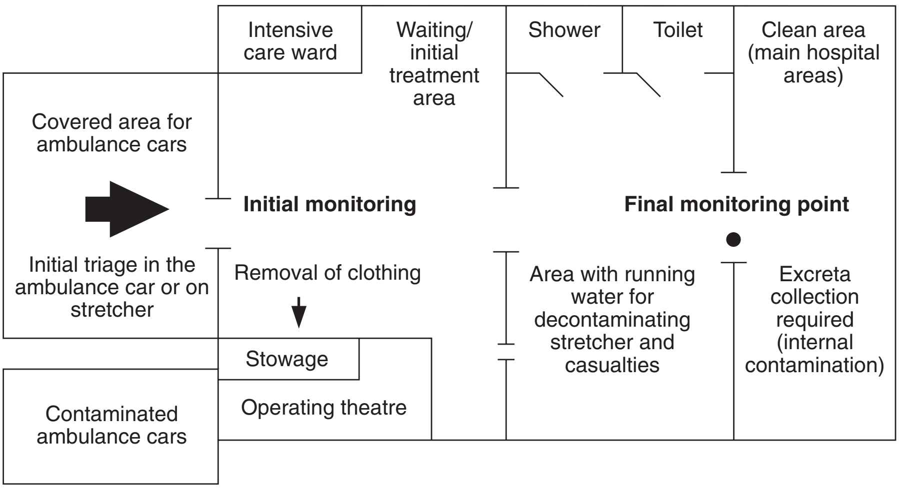
Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria
Fax: 431 20607
431 2060 29309 (for emergency service during office hours)
431 239270 (for emergency service 24 hours)

Annex III

PLAN OF A RECEPTION CENTRE FOR RADIATION CASUALTIES



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