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The Principles and General Procedures for Handling Emergency and Accidental Exposures of Workers

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RADIATION PROTECTION

ICRP PUBLICATION 28

The Principles and General Procedures for Handling Emergency and Accidental Exposures of Workers

A report of Committee 4 of the
International Commission on Radiological Protection

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A. SCOPE OF THE REPORT

(1) When a source of exposure is or has been out of control, workers may receive radiation doses greater than those corresponding to the dose-equivalent limits recommended for them for normal practice by the Commission. Such uncontrolled exposures are called abnormal exposures and they are either emergency (voluntary) or accidental (involuntary). Planned special exposures, also discussed by the Commission, are outside the scope of this report.

(2) The report is a general guide for the management of the exposed worker. It is concerned with the administrative, physical and medical aspects of the planning of actions which should be followed in emergency and accidental exposures and with the initial actions which should be taken following such exposures. It does not deal with the subsequent medical care of workers who incur abnormal exposures nor with actions which must be implemented by management to bring the source of exposure under control.

B. GENERAL CONSIDERATIONS

(3) The management in charge of an installation or an undertaking in which abnormal exposures might occur should assess the likelihood of such exposures and make the necessary plans for dealing with them. The plans should include the provision of the necessary services and the allocation of responsibilities. The effectiveness of the plans should first be tested and then maintained through appropriate exercises. The management should establish or make arrangements for a radiation protection team. This team should include the physician responsible for medical supervision of the workers. It should review in advance all situations in which abnormal exposures might occur in an installation or undertaking.

(4) Information that could be valuable in the assessment of abnormal exposures will come from the clinical course of the exposed workers, from biological and biochemical studies, from physical dosimetry and from statements made by persons actually or potentially exposed. No one member of the radiation protection team needs to have a detailed knowledge of all these aspects but there must be general understanding of them by all members of the team supported by close collaboration between those with differing responsibilities.

(5) Whether an abnormal exposure is recognized promptly, or only after a long delay, investigations should be undertaken as soon as possible to establish the sequence of events which gave rise to the exposure and the levels of doses incurred by the exposed workers. Action should be taken to prevent the recurrence of the same type of abnormal exposure in the installation or undertaking. Any significant unexpected readings on installed monitoring instruments or personal dosimeters should be immediately investigated.

C. INDICATIONS FOR ACTION

(6) It is a common characteristic of abnormal exposures that their magnitude is not immediately apparent. The severity of an abnormal exposure will then be judged on a combination of all available data and decisions will have to be made involving radiation protection (including medical) and administrative actions. It is convenient to have some classification of abnormal exposures in order to identify the priorities for various actions, but it is not practicable to lay down rigid guidelines for this purpose.

(7) Two broad categories of exposure should be considered. These are external exposure and internal contamination. Both of these may be associated with external contamination.

External exposure

(8) As soon as it becomes possible to estimate the likely dose due to external exposure, the level of action needed to deal with the abnormal situation can be roughly defined. If the external exposure is estimated to give rise to a dose greater than the relevant annual dose-equivalent limit but not exceeding twice the annual dose-equivalent limit, the action is essentially administrative. There should be an investigation into the circumstances of the abnormal exposure and any necessary confirmatory physical measurements should be undertaken.

(9) If the external exposure is estimated to give rise to a dose which exceeds twice the annual dose-equivalent limit but not exceeding five times the annual dose-equivalent limit, a more detailed administrative enquiry should be undertaken together with an assessment of possible biological consequences. The details of the abnormal exposure should be brought to the attention of the physician. The need, extent and nature of any clinical, biological or biochemical examinations will be determined by the physician and any necessary advice given by him to the exposed worker. (See paragraph 54.)

(10) If the external exposure is estimated to give rise to a dose which exceeds five times the annual dose-equivalent limit, the actions outlined in paragraph 9 should be supplemented by an examination of the exposed worker by the physician.

(11) The higher the estimated dose, the more important becomes the need for accuracy of dose estimation through the combination of clinical, biological, biochemical and physical assessments. If clinical signs and symptoms become apparent these may be a more important guide to initial treatment than the early estimate of dose. Depending on the early estimates of the dose and their accuracy, a decision will have to be made on the possible reconstruction of the circumstances of the abnormal exposure. Such reconstructions will sometimes be simple, but, in other cases, may involve a major research effort. Each case should be considered on its merits.

Internal exposure

(12) If internal contamination greater than the annual limit of intake is suspected, the radiation protection team should immediately make the best possible evaluation of the intake, and therapy should be considered. For most types of therapy to enhance the excretion of radioactive materials taken into the body, efficacy is greatest if the therapy is applied early. In most cases of internal contamination, the initial indications for therapy are therefore almost always qualitative. They include a first assessment of the abnormal exposure, the results of simple monitoring, such as nose blows, skin contamination, contaminated wounds and, sometimes, the preliminary results for the monitoring of air

or nearby surfaces. Later assessments may provide further indications for therapy.

External contamination

(13) External contamination may, for two reasons, modify the procedures to be applied for external exposure and internal exposure. The external contamination may be sufficiently serious that it is a danger to the contaminated worker or it may indicate the need for special procedures to avoid spread of contamination through the treatment area and to those responsible for handling the patient. Unless either of these circumstances exist, the control of external contamination of the worker should be secondary to the earlier phases of examination and investigation. Any residual persistent contamination should be referred to the physician

D. PHYSICAL, CLINICAL AND BIOLOGICAL DATA FOR ASSESSING SEVERITY OF EXPOSURE

Physical dosimetry for external exposure

(14) Personal dosimeters normally provide an indication of the dose to an exposed worker only at a single part of the body. Such information may not be representative of an abnormal exposure incurred by a worker. Accordingly, the data obtained from a personal dosimeter worn by a worker incurring an abnormal exposure should be interpreted with care and in the light of information about the circumstances of exposure. If any form of reconstruction of the abnormal exposure is made, it should be directed towards providing information on the radiation fields, so that the absorbed dose and the mean quality factor in the body may be obtained. In the case of exposure to neutrons, activation products in the body or its components (e.g. blood or hair) or items carried on the body (e.g. metal objects) will be useful in supplementing the more routine forms of personal dosimetry and in identifying those who have been exposed to high levels (e.g. those referred to in paragraph 9).

(15) If preliminary assessments suggest that the dose to the exposed worker has been high, then a detailed evaluation of the dose received by the exposed worker should be treated as an urgent investigational problem with additional staff assigned to the investigation if necessary.

(16) The importance of physical dosimetry, as a contribution to the medical care of the worker incurring abnormal external exposure, will depend on the level of dose and the availability to the physician of other information. Any early indication of grossly non-uniform irradiation will be particularly valuable. The general order and priorities are indicated in Appendix 3.

Physical dosimetry for internal exposure

(17) Valuable information about the degree of internal contamination, and hence about the committed dose, may be obtained by the use of a wound probe, an external probe, an organ scanner, or of a whole body monitor. Data obtained by such direct measurement methods should be supplemented, as appropriate, by the radiochemical assay of urine and faecal samples and, in some cases, blood samples. Arrangements should be made to obtain the required samples. The frequency of subsequent sampling should be based on the results obtained in the radiochemical assays of the samples taken in the first few days.

(18) The organs and tissues exposed following the entry of a radionuclide into the body and the resulting committed dose to those organs and tissues will depend on the activity of the radionuclide entering the body, on its physico-chemical form and on its metabolism. *ICRP Publications 10* and *10a* provide useful information about the assessment of radiation doses to organs and tissues following a single short term intake of a radionuclide. However, early information about dose levels following an abnormal internal exposure will be limited, in practice, to a preliminary appreciation of the nature of the abnormal exposure supported by qualitative information about contamination of the exposed worker and measurements of air and surface contamination.

Clinical observations and biological investigations for external exposure

(19) Since reliable dosimetric data may be difficult to ascertain quickly after an external exposure and are often very incomplete at this stage, early assessment of the severity of the exposure must, in most cases, be largely based on clinical signs and symptoms, haematological data and chromosome analysis. Early clinical observations and biological investigations are thus of primary importance to make a prognosis and to plan the medical care of the patient and should be made as soon as possible. A rough appraisal of the severity of the prognosis should be given, if only for psychological reasons, to the patient and his family as early as possible.

Clinical observations

(20) The clinical picture following whole body acute exposure is well documented and is summarized in Appendix 2. Initial symptoms may serve as a reasonable guide for the assessment of the exposure severity. At doses below or near those corresponding to the median lethal range, the main symptoms are anorexia, nausea and vomiting. The shorter the interval between exposure and the onset of nausea and vomiting, the more severe these symptoms and the longer their continuance, the more serious the prognosis is. However, psychosomatic symptoms produced by fear, or from witnessing the distress of heavily exposed persons, may complicate this picture. Early neurological symptoms such as apathy, ataxia or convulsions indicate a very high dose to the whole body or to the central nervous system.

(21) Early erythema and conjunctivitis are useful indicators of the spatial distribution of the dose and its magnitude. The latent period of erythema and the magnitude of the dose vary inversely and the skin should be therefore frequently examined. Colour photographs of the development of skin changes should be obtained in order to follow up their evolution.

(22) If the dose received by the whole body is assessed as being very high or if the irradiation was directed mainly towards the head, a neurological examination should be made and, if possible, an electroencephalogram arranged. In the case of possible high dose to the thorax, a cardiovascular examination, including an electrocardiogram, may be indicated.

Haematological, biological and biochemical investigations

(23) Haematological data are of importance in assessing the severity of exposure, and the most useful for an early assessment are the granulocyte and lymphocyte counts.

(24) The number of granulocytes in the blood increases sharply in the first day, then falls back rapidly to the previous value in 1 or 2 days and thereafter drops progressively. In order to observe the initial peak, the amplitude of which is roughly related to the severity of the exposure, blood counts should be made several times during the first 2 days.

(25) The number of lymphocytes decreases rapidly after the exposure and reaches a minimum in 2 or 3 days. The sharper the

slope of the fall and the lower the value of the minimum, the more severe the exposure is.

(26) Within a few hours of the accident a special blood sample should be taken for chromosome aberration studies, as this investigation could give a quick assessment of the absorbed dose to the whole body.

(27) Blood and urine samples taken immediately after the abnormal exposure will often provide a useful baseline for subsequent biological examinations. Blood and urine samples should be taken at later times as determined by the physician. Blood examinations should include standard haematological cell counts and may include biochemical assays for plasma electrolytes and blood sugar. Urine samples may be used for biochemical assays of urinary sugar levels, creatine and urinary amino acids. If there is any suspicion of internal contamination, it is important that a bulk initial urine sample, and possibly later samples, should be collected for radiochemical assay for excreted radionuclides.

(28) Sperm counts showing a diminution or disappearance of spermatozoa some days after exposure indicate a gonadal absorbed dose of several hundred rad. Bone marrow examination may also be useful, especially for evaluating partial irradiation at high doses. These procedures must, however, be carried out in specialized hospital departments and will not be considered further in this report.

E. PRINCIPLES OF URGENT MEDICAL CARE OF ABNORMAL EXPOSURES

Aspects of initial medical care

(29) The care of the injured patient is paramount. Initially, any severe physical injuries (e.g. trauma and burns) are likely to be more important than possible radiation injuries. Treatment priorities are indicated in the action sheets in Appendix 3.

Medical care of workers subject to whole body abnormal exposures

(30) For workers who, in an abnormal exposure, are believed to have received absorbed doses to the whole body less than 10 rad, there is no special medical care as the action to be taken is essentially administrative (see paragraph 8).

(31) Those exposed workers who show minimal evidence of physical injury and are believed to have received, in an abnormal exposure, whole body absorbed doses of less than 100 rad are almost certain to recover. Mild sedation may be given. There will often be doubt in the early stages as to the exact degree of the exposure. Those suspected of having been exposed need not necessarily be transferred immediately to a hospital and the decision on whether to transfer the exposed workers to a specialized hospital may be made within a few days. However, in the meantime, they should be kept under clinical surveillance until there is confirmation of the level of the absorbed dose. If the exposed workers are hospitalized, they must not be subject to undue stress and will require consultation with the physician at least weekly.

(32) Workers who, it is believed, have received whole body absorbed doses greater than 100 rad should be transferred to a specialized hospital. Prior to their transfer such patients may require sedation and symptomatic treatment. Special measures should be observed to keep the skin and mucous membrane clean.

(33) The medical care of patients with

obviously lethal exposures involves symptomatic treatment and sedation as needed. If practicable, such patients should be transferred to a specialized hospital. This may be impracticable with patients in circulatory or nervous shock.

Medical care of workers subject to partial body abnormal exposure

(34) There is no specific early treatment for the affected areas. The injury may often prove to be more serious than the initial assessments of dose suggest and the damage may progress for many months. Any prognosis given to the patient or his family at this stage should therefore be guarded. It is of prime importance that infection should be avoided in exposed areas. Should infection occur, local and systemic therapy is indicated. Appendix 3 provides guidance on the medical care of workers who have incurred abnormal exposure to superficial tissue.

Medical care of workers contaminated in an abnormal exposure

Immediate emergency procedures

(35) In any abnormal exposure in which contamination, either external or internal, of a worker by a radionuclide is suspected, it is essential to give immediate first aid, to check the nature and degree of contamination and to proceed without delay with the first decontamination measures and with the appropriate emergency therapy for internal contamination. Decontamination of the exposed worker should be as effective as possible before he is taken to hospital for further treatment. If the presence of residual contamination is confirmed by monitoring, it should be noted so that the necessary precautions can be taken by ambulance and hospital staff.

Decontamination of intact skin

(36) When skin contamination exists, immediate decontamination must be performed. The basic and most important procedure is simply to wash with soap and copious quantities of water. This procedure can, in most instances, be carried out by the worker himself. As decontamination proceeds, records should be made of all residual contamination. Care must be taken not to abrade the skin, and decontamination by this procedure must stop before the appearance of skin abrasions.

(37) If contamination persists, the worker should be transferred to the care of the physician who should supervise, or carry out, any further decontamination which may be appropriate. With such patients, the decontamination must be as thorough as possible, but the integrity of the skin should be respected. The methods of decontamination instituted by the physician will vary with the nature and degree of the residual contamination and will also depend on the radiotoxicity of the contaminant.

(38) Decontamination of the eyes, nose and mouth should be carried out as soon as possible by washing with copious quantities of water. Isotonic irrigants may be used instead of water.

(39) In all the above decontamination procedures, care should be taken to prevent the transfer of the contamination into the body of the exposed person. Those assisting in the decontamination procedures should take appropriate measures to prevent themselves becoming contaminated.

Treatment of contaminated wounds

(40) First aid procedures at the site of the abnormal exposure should begin, without delay, by washing with copious quantities of water any wound suspected of being contaminated. Bleeding of the wound should be promoted. In some cases, and especially those involving lanthanides or actinides, therapy to the wound with the chelating agent, DTPA, in an appropriate form, is recommended. Such therapy should be

carried out as soon as possible and preferably in the first few minutes following injury.

(41) For definitive wound care, the usual surgical procedures apply, with some modifications to aseptic and debridement procedures. For certain radionuclides, for example plutonium, it may be desirable to give intravenous DTPA, in an appropriate form, prior to surgery, to minimize the deposit of any radioactive contaminant which enters the circulation during surgery. Care must be taken not to introduce radioactive contamination from the skin to the wound in the course of aseptic cleansing. Accordingly it is desirable to isolate the wound, particularly initially, with suitable barriers or drapes. Repeated irrigation of the wound, followed by monitoring of it, are needed to effect its decontamination and to check for residual contamination. The tissue removed during debridement should be set aside in suitably labelled containers for radioactivity assay. When monitoring of the wound indicates that it is free of radioactive contamination, gloves and surgical instruments used in the debridement should not be used for the completion of surgical treatment but put aside for monitoring and decontamination.

(42) Special wound probe counters and detectors are required for the monitoring of wounds.

Treatment of internal contamination

(43) If radioactivity measurements of urine, faeces, swabs from the nose or mouth, or from detectors external to the body, suggest a significant residual body burden of a radionuclide in an exposed worker, treatment with various agents may be undertaken in an attempt to minimize deposit in internal organs and tissues and to enhance the excretion of the radionuclide.

(44) In a few cases, isotopic dilution of the ingested radioactive substance by the administration of a stable isotope is recommended, provided the stable substance is not toxic. To prevent the deposit of radioiodine in the thyroid gland, the early oral administration of stable iodine as sodium or potassium iodide or iodate is extremely effective.

(45) To minimize respiratory absorption, irritants and expectorants may be used. Pulmonary lavage is under current investigation. For lanthanides and actinides, DTPA may be administered as aerosol mist in order to prevent the deposition of that fraction which is transferred to blood. It may also be given intravenously.

(46) To minimize gastrointestinal absorption, the simplest treatment is to accelerate excretion with a laxative such as magnesium sulphate. In some cases of internal contamination with radionuclides of strontium, sodium alginate has been used in an attempt to prevent uptake from the gut. Orally administered Prussian Blue has been used to limit the uptake of ingested radionuclides of caesium from the gut and to enhance caesium excretion.

(47) To achieve blood clearance, and to reduce deposit in bone of radionuclides entering the body, a variety of agents are available. For lanthanides and actinides chelating agents are useful, with DTPA in an appropriate form being the most effective known. For internal contamination with soluble uranium compounds, an alkaline diet, the infusion of sodium bicarbonate, and the use of diuretics such as acetoazolamide have been advocated.

F. ADMINISTRATIVE ACTION FOLLOWING AN ABNORMAL EXPOSURE

(48) It is not possible to make general recommendations, which will be valid for all cases, concerning the attitude to be adopted on the subsequent employment in radiation work of a worker who incurred an abnormal exposure. Generalizations are precluded by the individual nature of the decisions to be made concerning the worker, his general health, his expertise, his prospective period of employment and the nature of the doctor–patient relationship. Specific recommendations would be arbitrary and might not be acceptable either to the physician or to the exposed worker.

(49) The physician should have considerable latitude when making recommendations with respect to the future employment of a worker who has incurred an abnormal exposure. He should take into account all the personal circumstances which relate to the worker as these may be known only to him. However, guiding principles are desirable, if only to ensure that administrative actions in cases of similar abnormal exposures are not widely different. The following comments are in the nature of a statement of principles rather than action guides for the physician.

(50) Abnormal exposures are generally rare and the possibility of further abnormal exposure to a given worker is not usually a major factor in deciding his future employment. Nevertheless, if the worker by his own actions contributed to his accidental exposure, his suitability for the type of work involved should be considered.

(51) After each abnormal exposure, a general review of the circumstances relating to the exposure should be made by the radiation protection team (including the physician), in collaboration with the supervisor of the area in which the abnormal exposure occurred, to determine the likelihood of similar abnormal exposures arising in the future in that area.

(52) If the exposed worker shows clinically observable injuries as a result of the abnormal exposure, his duties may have to be modified to ensure that those injuries are not aggravated by his employment. It is not, however, always necessary to remove a worker from radiation work until all those injuries or clinical signs have disappeared. Thus, for example, a local radiation injury to superficial tissue does not necessarily preclude some degree of more general exposure to radiation in future employment.

(53) The decision whether or not to remove a person from radiation work should take into account his social, occupational and economic responsibilities. An established specialist may find it difficult to change his specific occupation. In a younger man, less specialized and therefore more flexible, a change of specific occupation may be easier. It is also necessary to consider the influence that a senior staff member or an advanced specialist may have on the work carried out by a large group of persons and on the completion of a socially or scientifically significant project. Such considerations as these could justify a person with considerable responsibility being retained in his position even though he had incurred an abnormal exposure. In such circumstances, close medical surveillance of the individual is necessary.

(54) The physician should explain to the exposed worker any limitations which are advisable on his normal activities. In particular, following irradiation of the male gonads in an abnormal exposure, advice should be given on the possible risks of procreation within a few months. After irradiation of a pregnant worker advice should be given on the risk of abnormal foetal development.

(55) It is essential to establish and maintain, with respect to each worker incurring an abnormal exposure, a record of all results of health physics measurements and of the medical histories including long term follow-up histories. When it is recommended that a worker who has incurred an abnormal exposure be permitted to return to radiation work, the detailed reasons for that recommendation should be recorded in the medical history of that worker. Periodic medical observation, with medical histories being maintained, is important even with respect to those workers who showed no signs or symptoms of radiation injury immediately after an abnormal exposure.

G. ORGANIZATION OF MEDICAL SERVICES IN ANTICIPATION OF ABNORMAL EXPOSURES

(56) Because of the different potential causes of abnormal exposure of workers which exist in the variety of installations and undertakings using sources of radiation and because of the differences in the staff organizations and in the arrangements for the medical care of workers in such installations and undertakings, it is not practicable to provide in this report a detailed plan for the organization of medical services in anticipation of abnormal exposure of workers. It is desirable, however, to outline here the type of planning which the management of such installations and undertakings should initiate. For each installation or undertaking, such planning should be based on a thorough evaluation, by the radiation protection team (including the physician responsible for the medical care of the workers) of the risks of different types of abnormal exposure which exist therein.

(57) As a general principle, planning of medical services in anticipation of abnormal exposures should provide for three functional levels: immediate first aid to deal with all urgent non-radiation injuries; treatment by "local" medical services; and treatment at a specialized facility.

First aid at the site of the abnormal exposure

(58) In any installation, specified workers should be trained to ensure that, immediately following a suspected abnormal exposure, persons will be available with appropriate knowledge to render first aid. These trained persons should be provided with detailed directives of the actions to be taken by them in rendering first aid. First aid equipment should be subject to frequent and regular inspection.

(59) Lines of communication should be established between the first aid services and the radiation protection services so that specialized equipment and expertise are available for radiation or radioactivity monitoring.

Treatment in "local" medical services

(60) "Local" medical services may be either those established within the installation or undertaking or existing medical facilities (e.g. a hospital or medical clinic) in the general neighbourhood of the installation or undertaking. With respect to the latter medical facilities, appropriate arrangements should be made in advance by the management of the installation or undertaking for the provision of treatment for a worker who has incurred an abnormal exposure.

(61) Appropriate facilities, staff, equipment and ancillary items should be readily available at "local" medical services and arrangements should be made to ensure that the radiation protection services of the

installation or undertaking will be available and equipped to collaborate with the "local" medical services.

(62) With respect to each of the risks of abnormal exposure in an installation or undertaking for which the physician has responsibility for the medical care of the workers, he should prepare and document a well-defined plan of action for the medical care of a worker who has incurred an abnormal exposure including the criteria upon which transfer of the worker should be made to the "local" medical services after first aid. Such a plan should also provide for the communication to him of information on all first aid rendered at the site of an abnormal exposure.

(63) The physician should establish means by which comprehensive medical histories with respect to the exposed worker are maintained and medical follow-up of the exposed worker is effected.

Treatment at a specialized facility

(64) It may be necessary to transfer workers who have incurred more severe abnormal exposures, involving external exposure and/or external or internal contamination, to a specialized medical facility. Such a facility would be expected to have available to it the resources of a major medical centre together with the specialist personnel, equipment and services to undertake the medical care of a patient who has incurred a severe abnormal radiation exposure. With the help of rapid transport, one such specialized facility could serve a large area. For this reason, only one or two such specialized facilities are likely to be required in any wide geographical region.

(65) It is essential that well-defined arrangements be made in advance to facilitate the transfer of an exposed worker to such a specialized facility. These arrangements should include transport, the establishment, by the physician responsible for the medical care of the workers at a particular installation or undertaking, of the necessary liaison with the specialized facility and, through his consultation with that facility, the drawing up of the criteria to be used in determining whether to transfer an exposed worker to the specialized facility.

APPENDIX 1

PRELIMINARY SCREENING OF WORKERS WHO MAY HAVE INCURRED AN ABNORMAL EXPOSURE

1.1. After any radiation accident it may be difficult to identify those who have incurred an abnormal exposure. Reliance must be placed on information obtained from the workers involved and from their colleagues, from the onset of clinical symptoms (see Appendix 2) and on information obtained by radiation and radioactivity measurements.

Information from workers

1.2. It is important that all information on the event, which may have resulted in workers incurring abnormal exposures, be collected and collated carefully and quickly. In some instances, the information would allow a positive conclusion that an abnormal exposure of some workers did occur. The assessment of the level of the abnormal exposure and the identification of the workers who incurred the exposure would be improved by the collection of the most complete information such as the location of the workers in relation to the source of exposure, the train of events which led up to alleged exposure and the duration of the exposure. Experience shows that some workers are more reliable than others in providing factual information on abnormal situations and, therefore, an attempt should be made to identify, as quickly as possible, corroborative evidence. In many circumstances it may be best to assume that all workers in the relevant area have incurred abnormal exposure and to rely on other methods to make positive identification at a later stage.

Contamination

1.3. Where the abnormal exposure potentially involves external contamination, monitoring instruments of suitable characteristics provide a ready means of identifying workers with external contamination. In circumstances where significant internal contamination may have occurred, direct monitoring of the body surfaces of the workers, and of the clothing they are wearing, may give an ambiguous answer (see paragraph 1.4). In these circumstances, an unequivocal answer with respect to external contamination may be obtained by the measurement of "smear samples" made on the worker and his clothing.

1.4. When internal contamination is suspected, the identification of the exposed worker involves, in most circumstances, more elaborate assessments although positive results of monitoring of air and nearby surfaces for radioactivity may, *prima facie,* warrant a preliminary assumption of internal contamination of all workers in the area. Measurements on the workers with external probes, gamma cameras, scanners or whole body monitors may give positive findings through photon emission from radionuclides taken into the body or from the Bremsstrahlung as a consequence of the intake of a beta-ray emitter. However, these measurements may be equivocal if external contamination is present on the worker or if the worker has been exposed to neutron or high energy photon irradiation (see paragraphs 1.10–1.11).

1.5. A more reliable indication of internal contamination may be obtained by the radiochemical assay of samples of urine or faeces taken after the suspected abnormal exposure. Such assays may be time consuming. If suitable measuring equipment is available and high levels of internal contamination exist, positive indications of internal con-

tamination may be obtained by the measurement of samples of urine and faeces without prior chemical analysis.

1.6. Swabs of the nasal passages and of the mouth may be taken quickly after the suspected abnormal exposure and checked for radioactivity by suitable monitors. If these swabs give positive evidence of radioactivity, internal contamination should be assumed until the results of more sophisticated assays (e.g. of urine are available).

External exposure

1.7. Preliminary identification of external exposure may be made by the results obtained from personal and area dosimeters. However, narrow beams or limited fields of irradiation may give no indication of exposure on these dosimeters even though the worker actually received a partial body exposure.

1.8. In contrast to beta rays and low medium energy photons, exposure to neutron and high-energy photon irradiations may result in the production of detectable amounts of induced radioactivity in the worker, in objects worn or carried by him and in materials in the area. Recourse should be made to these potential sources of information in an attempt to identify the workers who have incurred abnormal exposures.

1.9. Where the personal dosimeters of workers include an indium foil, this should be used as a means of identifying exposure to neutrons. A preliminary assay of the indium foil may be made with a portable radiation monitor. However, the radioactivity induced by neutrons in the indium foil in personal dosimeters will be influenced considerably by the degree to which the foil is shielded from neutron irradiation by the body of the worker. More sophisticated assays of indium foils should be carried out as quickly as possible because of the short-half life of the induced radioactivity. In the presence of other confirmatory evidence of neutron irradiation, (see paragraphs 1.10–1.11), data obtained from the assays of indium foils may provide useful information on the orientation of the exposed worker with respect to the neutron beam.

1.10. More reliable information on neutron irradiation of a worker may be obtained from the assay of blood samples for induced radioactivity due to sodium-24 and chlorine-38. These assays should be made as early as possible if advantage is to be taken of the induced activity of chlorine-38 which has a half-life of 37 min. However if the assay is to rely on the activity of sodium-24 alone, it may be delayed for some hours because of the longer half-life (15 h) of that radionuclide.

1.11. Supplementary information with respect to neutron irradiation may be obtained from the assay of metal objects carried by the worker, of hair or finger nail samples, of samples taken from woollen clothing and of objects in the area. Information obtained may be valuable in determining the spatial distribution of the neutron irradiation.

APPENDIX 2

SYMPTOMS AND CLINICAL SIGNS OF RADIATION SICKNESS

Prodromal Manifestations

Anorexia
Nausea
Vomiting
Diarrhoea
Fatigue

Apathy
Prostration
Perspiration
Erythema
Conjunctivitis

Fever
Respiratory distress
Hyperexcitability
Ataxia

Main Illness

Fever
Anorexia
Lassitude
Fatigue
Weakness
Weight loss
Diarrhoea

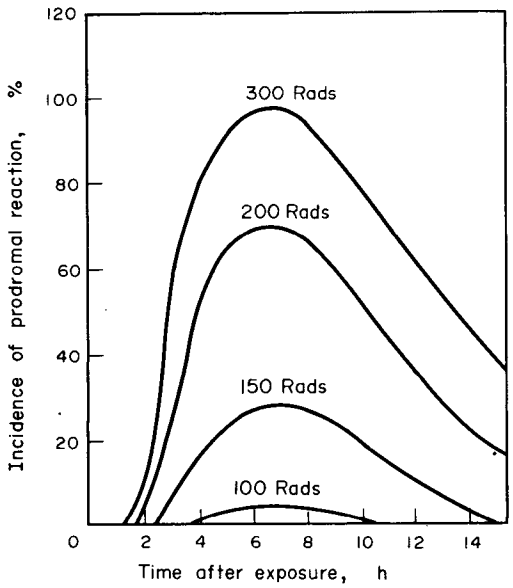
Infection
Haemorrhage
Erythema
Tanning
Epilation
Aspermia
Ileus

Shock
Ataxia
Agitation
Disorientation
Convulsions
Coma

Latent period

No Symptoms

Estimated incidence and timing of prodromal symptoms in man in relation to absorbed doses received at low LET



(From "Radiation Injury" by A.C. Upton, Chicago 1969)