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The Agency's Statute was approved on 26 October 1956 at an international conference held at the United Nations Headquarters. The Agency came into being when the Statute entered into force on 29 July 1957. The first session of the General Conference was held in Vienna, Austria, the permanent headquarters of the Agency, in October, 1957.

The main objective of the Agency is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

One of the means towards this objective is to foster the exchange of scientific and technical information on the peaceful uses of atomic energy.

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FOREWORD

1. Under its Statute the International Atomic Energy Agency is empowered to provide for the application of standards of safety for protection against radiation to its own operations and to operations making use of assistance provided by it or with which it is otherwise directly associated. To this end authorities receiving such assistance are required to observe relevant health and safety measures prescribed by the Agency.

2. As a first step, it has been considered an urgent task to provide users of radioisotopes with a manual of practice for the safe handling of these substances. Such a manual is presented here and represents the first of a series of manuals and codes to be issued by the Agency. It has been prepared after careful consideration of existing national and international codes of radiation safety, by a group of international experts and in consultation with other international bodies.

3. At the same time it is recommended that the manual be taken into account as a basic reference document by Member States of the Agency in the preparation of national health and safety documents covering the use of radioisotopes.

4. This manual is issued by the Agency as a provisional document which will be subject to revision from time to time. Any comments submitted to the International Atomic Energy Agency's secretariat will be welcome.

5. It is intended to provide in due course technical and medical addenda to this manual to give more complete advice to the user on specialized topics.
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MAXIMUM PERMISSIBLE LEVELS FOR EXPOSURE TO EXTERNAL RADIATIONS AND FOR RADIOACTIVE CONTAMINATION OF AIR AND WATER

APPENDIX II

MAXIMUM PERMISSIBLE LEVELS FOR SURFACE CONTAMINATION
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1. INTRODUCTION

1.1. SCOPE

1.1.1. This Manual is provided as a guide to the safe handling of radioisotopes. It is hoped that it should be helpful particularly to small scale users who may not have direct access to other sources of information.

1.1.2. Large scale users and those with specialized experience may prefer to adopt other procedures which are known to provide equivalent or even superior protection. Other published guides can be recommended when appropriate to specialized fields of application. It is presumed that those using radioisotopes in the practice of their profession (radiologists etc.), will supplement the recommendations of the Manual by application of their normal professional training.

1.1.3. The Manual does, of course, not prevent the application of more stringent and more extensive instructions that may possibly be in force in some countries.

1.1.4. This Manual contains a series of recommendations which should be interpreted with scientific judgement in their application to a particular problem. The choice of wording is intentionally precise and the user must understand its implication before departing from any recommendation.

1.1.5. As most natural objects contain some radioactive material, it is clear that the provisions of the Manual are not intended to apply below a certain limiting degree of radioactivity. This lower limit can be taken as a concentration of .002 microcuries per gram of material, or a total activity in the working area less than 0.1 microcuries. These limits are based on the most dangerous radioisotopes so that the use of somewhat higher limiting levels of activity is permissible provided the isotopes present are not the most dangerous. A guide to quantities of the less toxic isotopes which may be handled without special precautions is provided in column one of Table II and the provisions of paragraphs 3.1.10 and 3.1.11. In general, the relaxation of controls must be based on an assessment of the possibi-
lity of hazard, taking into account the nature of the material, operations and working facilities.

1.1.6. Treatment of all radioisotopes as potentially dangerous, however, is recommended for its training value and the protection it offers against misidentification.

1.2. DEFINITIONS

In general, technical terms are used with their accepted scientific meanings. A few definitions of significant terms follow:

1.2.1. “Ionizing radiation”: electromagnetic or corpuscular radiation capable of producing ions directly or indirectly in its passage through matter (for instance: alpha rays, beta rays, gamma rays, X-rays, neutrons).

1.2.2. “Sealed source”: means a source of ionizing radiations that is firmly bonded within material or sealed in a cover of sufficient mechanical strength which excludes the possibility of contact with the radioisotope and the dispersion of the radioactive material into the environment under foreseeable conditions of use and wear.

1.2.3. “Unsealed source”: means any other radioactive source.

1.2.4. “External radiation”: radiation received by the body from radioactive sources external to it.

1.2.5. “Internal radiation”: radiation received by the body from radioactive sources within it.

1.2.6. “Dose”: a measure of the quantity of radiation delivered to a specified absorber.

1.2.7. “Radioactive contamination”: the undesired presence of radioactive substances in or on any material.

1.2.8. “Adequate protection”: protection against external radiations and against intake of radioactive material such that the radiation dose received by any person from sources external and/or internal to the body does not exceed the maximum permissible levels set for exposure by the competent authority.

1.2.9. “Installation”: any accommodation or facility where radioactive substances are produced, processed, used or stored.

12 1.2.6. “Curie”: the unit of quantity of radioactive material evaluated according to its radioactivity. One curie is a quantity of a radioactive nuclide in which the number of disintegrations per second is \(3.7 \times 10^{10}\)
1.2.10. "Enclosed installation": an installation in which the radiation source and all objects exposed thereto are within a permanent enclosure:
(a) to which no person has access, or within which no person (except those undergoing treatment) is permitted to remain during irradiation: and
(b) which affords under all practical operating conditions adequate protection for all persons outside the enclosure.

1.2.11. "Open installation": an installation which, due to operational requirements, e.g. the use of mobile equipment, does not meet the conditions specified for "enclosed installation".

1.2.12. "Competent authority": a national or international authority whose jurisdiction in the field of problems concerned applies to the activities of the installation considered.

1.2.13. "Controlled area": area in which exposures may exceed the permissible levels for non-occupationally exposed persons and therefore requires the supervision of a radiological officer.

1.2.14. The terms "Workers" or "Personnel" are used in the sense of including all persons potentially exposed to radiation or radioactive substances as a result of their occupation.

1.3. **MAXIMUM PERMISSIBLE LEVELS FOR EXPOSURE TO EXTERNAL RADIATION AND TO RADIOACTIVE CONTAMINATION**

1.3.1. Pending the issuing by the International Atomic Energy Agency of regulations on maximum permissible levels for exposure to external radiation and to radioactive contamination, it will be generally acceptable to this Agency if all work performed in installations using radioactive isotopes obtained through the International Atomic Energy Agency is in conformity with maximum permissible levels fixed by the competent authority.
1.3.2. As in most countries the setting of maximum permissible levels has been done on the basis of recommendations of the International Commission for Radiological Protection, for countries where such maximum permissible levels have not been fixed the recommendations of the International Commission for Radiological Protection of 1954 as subsequently amended in 1956 and 1958 are recommended as a common basis until such time as the regulations of the International Atomic Energy Agency may be issued.

1.3.3. A generally accepted maximum permissible level is often not available with respect to certain specific problems, particularly for surface contamination or waste disposal. The problem involved and useful working guides are given in the applicable sections of the Manual.

1.4. ORGANIZATION

1.4.1. Principles. Good radiation safety practice depends on an effective health and safety organization. Experience shows that even the most competent worker cannot be relied upon to keep in mind all health and safety requirements while preoccupied with the successful prosecution of his work. Responsibilities and duties must be set out clearly to assure safety.

1.4.2. Responsibility of the authority in charge of the installation
The authority in charge of the installation is customarily held responsible for the radiological safety of both the workers and the general public. To meet those responsibilities it should ensure that the following actions are taken:

1.4.2.1. Health and safety rules (in conformity with this Manual) should be prepared for the areas in which radioactive material is to be handled.

1.4.2.2. All necessary operating instructions should be provided.

1.4.2.3. Suitable installation and equipment should be provided.

1.4.2.4. Provisions should be made for necessary medical supervision of the workers and for suitable medical casualty service.
1.4.2.5. Only persons medically suitable and adequately trained or experienced should be allowed to work with radioactive material.

1.4.2.6. All workers liable to exposure to ionizing radiation in the course of their work should be instructed about the health hazards involved in their duties. Suitable training with reference to health and safety should be provided for all staff.

1.4.2.7. A person technically qualified to advise on all points of radiation safety should be employed or otherwise provided. In this Manual he will be referred to as the "radiological health and safety officer" although various titles are customary in different countries. The authority in charge of the installation should consult this person on all points of radiation safety. Appropriate means should be taken to ensure that all persons who may be exposed to radiation hazards know his name and how to get in touch with him. Any necessary alternates should be provided.

1.4.3. *Duties of the "radiological health and safety officer"* The radiological health and safety officer's duties will vary somewhat according to the organizational structure of the group with which he is working and the degree of the hazard of the class of work undertaken. In general he will assist the authority in charge to carry out the latter's responsibilities for radiation protection. In the accomplishment of his duties, the "radiological health and safety officer" should call for advice or help upon professionally competent persons whenever necessary. His work will usually include the following duties:

1.4.3.1. Any necessary administrative, technical and medical instructions concerning the radiation hazards and safe working practices relevant to the nature of the installation and work should be provided to all employees whose duties involve the handling of radioactive material and to all other employees who are not regularly employed in such work but who may occasionally be exposed to radiation and radioactive material. These instructions should be written, understandable, practicable and, whenever possible, posted.
1.4.3.2. All persons working with radioactive materials should be instructed in the use of all necessary safeguards and procedures and all visitors should be informed of pertinent precautions to be taken. They should be supplied with such auxiliary devices as may be necessary for protection. The "radiological health and safety officer" should ensure that every visitor has a proper authorization and should recommend that no unnecessary visit is made.

1.4.3.3. Radioactive material (including that in patients, animals and equipment) should be prevented from leaving the jurisdiction of the authority in charge under circumstances that may subject other persons to radiation in excess of the limits prescribed by the competent authority. The "radiological health and safety officer" should ensure that the proper arrangements for safe waste disposal are made.

1.4.3.4. Any area, inside or outside the installation should be ensured against subjection to radiation levels or concentrations of radioactive material exceeding the maximum permissible levels indicated by the competent authority for such a type of area.

1.4.3.5. The appropriate authorities (for instance the Fire Department) should be notified of the existence of any conditions or situations that, while not normally considered a radiation hazard, may become a hazard under special or unusual circumstances.

1.4.3.6. Measures should be taken to ensure that no modification of equipment or installations which might lead to unforeseen radiation hazards is made without provision of appropriate safeguards.

1.4.3.7. Measures should be taken to ensure that no radioactive material is dealt with by unauthorized people in the installation.

1.4.3.8. Suitable alternates or other means should be provided to ensure that necessary advice is available at all times in case of an emergency and the particular safety measures to be taken in such cases are provided for.

1.4.3.9. It should be established that suitable records are kept.

1.4.3.10. It should be established that the necessary tasks of monitoring, medical supervision and protection measures are carried out and properly co-ordinated.
1.4.4. **Duties of the worker**

1.4.4.1. The operating instructions provided should be known.

1.4.4.2. Health and safety rules for his area should be known and followed.

1.4.4.3. The safety equipment provided should be used properly.

1.4.4.4. He should protect both himself and others by acting carefully and working safely.

1.4.4.5. Any accident or unusual incident or any personal injury, however slight, should be reported.

1.4.4.6. Workers exposed to radiation hazards should immediately report any significant ailment and any suspected over-exposure to external radiation, or any suspected introduction of radioactive material into their systems.

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1.5. **MEDICAL SUPERVISION OF WORKERS**

1.5.1. **General Considerations**

1.5.1.1. Medical supervision of persons employed in radiation work should be based on the experience that in any properly run radiation laboratory radiation accidents will be secondary to normal industrial accidents. Pre-employment and routine medical examinations should be primarily those desirable in good industrial medical practice but certain medical requirements are specific to radiation work and should supplement regular industrial medical practice. Opportunities for observation of genuine symptoms of radiation injuries will be extremely rare unless very bad working conditions prevail. Undesirable working conditions may be present to a considerable degree before any clinical symptoms of radiation damage appear.

1.5.1.2. Young persons should not be occupationally exposed to radiation. In many countries the minimum age is taken as eighteen years.

1.5.1.3. Special attention should be directed toward protecting women of reproductive age.

1.5.1.4. If X-ray examinations are carried out, care should be given to keep to a minimum the exposure involved.
1.5.2. **Medical Examinations before Employment**

1.5.2.1. No persons should be employed in work involving a possible radiation hazard unless within the period of 2 months preceding his first employment in that work he has undergone a medical examination.

1.5.2.2. It is recommended that this medical examination on recruitment includes the following:

1.5.2.3. a complete medical examination, as given normally in pre-employment examinations, including a personal history covering family, medical and occupational background, as well as the usual clinical tests;

1.5.2.4. special investigations of those organs and functions which are considered as particularly vulnerable to radiation hazards according to the class of work undertaken, e.g. by:

- hematological examinations
- dermatological examinations
- ophthalmological examinations
- pulmonary examinations
- gynaecological examinations
- neurological examinations
- etc.,

1.5.3. **Medical Examinations during Employment**

1.5.3.1. All persons employed in work involving radiation hazard should undergo medical examinations.

1.5.3.2. The routine examinations should be carried out every twelve months, or such other periods as the competent authority may require. They should include the general examinations practised in industrial medicine and also special examinations desirable because of the hazards of external radiation and contamination in each particular case. The special examinations as given in 1.5.2.4. should be carried out at appropriate intervals. In the case of suspected over-exposure or internal contamination, the physician should specify any required programme of examinations.

1.5.3.3. In case of internal radioactive contamination, the radiotoxicological examinations yield information on the nature and extent of such contamination, by means of measurements and analyses carried out directly on the organism.
and indirectly on the excreta (urine, faeces, exhaled air). In addition, in cases of inhalation of aerosols or radioactive dust or gases, the examination of the lungs should include the investigation of combined mechanical, chemical or radioactive effects.

1.5.3.4. In the case of workers handling unsealed radioactive isotopes, tests are useful from time to time to determine the total body burden; in many cases monitoring of the excreta (more particularly of the urine, or in case of radium of the radon in the breath) will permit an assessment of the body burden.

In certain circumstances, a more elaborate test can be adopted to determine the body burden, by measuring the gamma-radiation (or Bremsstrahlung) emitted by the body. If it is possible to measure such a body burden the dose of radiation received should be estimated and noted on the personnel record and taken into consideration by the physician.

1.5.4. Medical casualty service

1.5.4.1. The form of medical casualty service provided will depend on the availability of medical staff within the establishment.

1.5.4.2. First aid advice and equipment should be immediately available throughout the working area. The scope of first aid treatment attempted should be based on medical advice.

1.5.4.3. Arrangements for referring casualties and personnel contamination problems to medical services at an appropriate stage should be clearly defined and known.

1.6. DETERMINATION OF RADIATION EXPOSURE OF PERSONNEL

1.6.1. General Considerations

The essential aim of radiological protection is to prevent injury from ionizing radiations. Its basis is respect for the recommended maximum permissible doses, but it also calls
for systematic observation, to detect any irradiation or irradiation effect. This observation must include both physical and medical control.

Symptoms following irradiation are at present detectable only for relatively high doses. This lack of sensitivity in the clinical examination is aggravated by the lack of specificity of the injuries observed, and the often considerable latent time between irradiation and the manifestation of its effects. This in no way reduces the necessity for systematic medical examinations to detect any radiation-induced effects but makes it essential to complement them by rigorous control of the doses received.

Present physical or radiochemical techniques allow the measurement of very low radiation doses and quantities of radioelements. This sensitivity is very helpful, as it permits the detection of irradiations considerably lower than those considered permissible. The methodical application of these techniques should therefore be regarded as essential. These techniques may be classified as follows:

1.6.1.1. Personnel Monitoring
   (a) External Radiation Monitoring in which radiation measuring devices are worn by the worker;
   (b) Internal Contamination Monitoring in which suitable instruments may be used or the body wastes may be sampled and analyzed, to determine the presence and quantity of radioactive material within the body.

1.6.1.2. Area Monitoring
   The determination of radiation levels and air contamination in the working area.
   (a) Measurement by the use of radiation measuring instruments and devices;
   (b) Calculation based on the amount of radioactive material present, its form and the nature of the processes in which the workers will be exposed.

1.6.2. Determination by Personnel Monitoring
1.6.2.1. Monitoring for External Radiation Exposure with Personnel Dosimeters
This simple and convenient method should be used for the measurement of external radiation exposure of all workers in the controlled area.

The preferred device is the film dosimeter which permits measurement of the accumulated radiation dose over a period. This film also provides a permanent means of checking the accumulated external radiation exposure record which should be kept for each individual. Similar film dosimeters should be used on the hands, wrists or other extremities when these are exposed to higher radiation fields than is the trunk of the body.

Pocket ionization chambers, luminescent individual radiation detectors and thimble chambers supplement the above film dosimeters and are particularly useful where an immediate and sensitive measurement is needed in connexion with a specific task.

In the use of both film dosimeters and ionization chambers for personnel monitoring, serious errors may occur unless standard procedures are adopted.

1.6.2.2. Monitoring for Internal Contamination

The difficulties of this monitoring are very real due to the complicated and specialized nature of the techniques involved. In the case of monitoring of body wastes by radiochemical analysis, there are further difficulties in interpreting results.

(a) Monitoring by Instruments

Whole body or gamma spectrometry radiation detectors may be used to determine the presence and quantity of radioactive material in the body. However these instruments are expensive and their operation and the interpretation of results is very specialized. It is unlikely that the small users would have such instruments though in special cases their use could be arranged through other institutions.

(b) Monitoring by Analysis of Body Wastes

A routine programme of urine analysis should be drawn up for workers exposed to the possibility of significant internal contamination. The frequency of urine sampling should be evaluated on the basis of an appraisal of the nature and quantity of the isotopes
involved and the operations necessary in the particular process.
In the event of suspected internal contamination, if appropriate, a special series of samples should be collected and analyzed. The biological half life and the period of body retention should be borne in mind in scheduling these samples.
Where appropriate, urine analysis should be supplemented by faecal analysis, nose swabbing, examination of stomach washings and radon breath tests.

1.6.3. Determination by area monitoring

1.6.3.1. Monitoring by Instruments

The use of ionization chambers, pocket ionization chambers and film dosimeters exposed under conditions similar to those in which the workers will be exposed, enable the dose to an individual over any particular time to be inferred.
Measurements of contamination present in the air or drinking water can be used to estimate possible body uptake. However considerable errors will occur, especially if the measurements are not representative due to the presence of particles of high specific activity.

1.6.3.2. Monitoring by Calculation

Knowledge of the total radioactive material present, its nature, the processes and the working conditions in a laboratory enable the estimation of possible exposure of personnel. However, considerable experience and technical skill are demanded for such estimates.

1.7. Monitoring

In addition to personnel monitoring to determine the exposure history of individuals, general area monitoring is carried out to determine the need for protective action. Monitoring should be done periodically or continuously with due regard to the external and internal radiation hazards for the purpose of determining the possibility of exposure of persons, workplaces and articles.
1.7.1. Monitoring of radiation from external sources

1.7.1.1. All places around radioactive sources emitting penetrating radiation where persons can be exposed to radiation, not neglecting adjoining rooms or places outside the building, should be monitored for radiation. This should be done before starting a project, after any significant modification of the set-up and also periodically during work.

1.7.1.2. Portable ionization chambers, pocket ionization chambers, GM-counters, scintillation counters (in some cases also film dosimeters) may be used. All instruments used for monitoring should be calibrated and checked regularly, for which a radiation standard should be available. Duplication of instruments is desirable in some cases.

1.7.2. Monitoring of contamination on surfaces of rooms and equipment

1.7.2.1. Everything used for work with radioactive materials may be subject to wide-spread contamination. This includes surfaces or working places, walls of fume hoods or glove boxes, floor or walls of working rooms, clothing, equipment, etc.

Contamination by radioactive substances of working surfaces, clothing and equipment can be a hazard to health and also may interfere with the work being carried out.

1.7.2.2. It is not yet possible to recommend definite permissible levels for surface contamination and contamination of clothing and equipment. However, the inexperienced user may adopt any one of a number of proposed levels accepted in certain countries. A number of such presently used standards are given in the Appendix II.

If it is known that contamination is permanently fixed monitoring can be based on the consideration of permissible external radiation levels.

1.7.2.3. It is necessary to carry out a systematic monitoring of contamination of all places and equipment that have been in contact with radioactive materials. Such monitoring must be performed at least when work has been completed but, if necessary, also several times during work.

1.7.2.4. Monitoring should be performed both with the help of dosimetric instruments and by smear tests. Thin windowed GM-counters are suited for examining the smear samples
taken; the presence of alpha emitters may make an alpha scintillation monitor or equivalent device desirable.

1.7.2.5. When alpha or soft beta emitters are used, the walls of beakers, bottles, pipettes, etc., may absorb most of the radiation so that monitoring from outside of these containers might be insufficient.

1.7.2.6. Experimental animals, their excreta and the premises, cages, etc., where they are kept should be monitored.

1.7.3. Monitoring of contamination of the air

1.7.3.1. In cases where radioactive aerosols, gases or powders (dust) are handled or produced the air must be monitored for contamination.

1.7.3.2. A reliable system of monitoring of the air after filtering, before releasing it into the open, should be carried out in cases when the activity released could exceed levels set for such outside places by the competent authority.

1.7.3.3. For monitoring aerosols the airborne substances are either deposited by electrostatic precipitation, impactors or by filtration.

1.7.3.4. Some radioactive gases can only be monitored after collection by chemical or other means.

1.7.3.5. It will often be desirable to identify the radioactive contamination by radiochemical analysis or physical means.

1.7.4. Monitoring of contamination of water

1.7.4.1. A simple monitoring method (e.g. dipping a GM-counter or scintillation counter into the water) in many cases will prove to be unsatisfactory and a more elaborate procedure for monitoring must be effected.

1.7.4.2. A reliable assessment of the contamination of waters to be released to public drains or sewers in accordance with 8.3.2. is necessary. Sampling may prove necessary, in which case the radioactive substances dissolved may require concentrating (for instance by ion exchange or evaporation) before activity measurements can be carried out.

1.7.5. Monitoring of skin and clothing

1.7.5.1. Monitoring of hands, clothing and particularly shoes should always be carried out when working with unsealed
sources. No person should leave the working place (room) without checking for contamination.

1.7.5.2. Monitoring for contamination of the skin and clothing should be performed by appropriate means. A thin window GM-counter may be sufficient in many cases. When alpha contamination may occur independently of beta and gamma radiation an alpha-selective monitor should also be provided.

1.7.5.3. A number of presently used standards for permissible levels of skin and clothing contamination are given in Appendix II.

1.8. RECORDS

1.8.1. Personal history

1.8.1.1. A health record, in a form to be approved by the competent authority, should be kept for every worker exposed to ionizing radiations. Such records should contain relevant data and information on:
(a) the nature of the work involving radiation and the type of radiation involved;
(b) the extent to which the individual has been or may have been exposed to radiation, as obtained by various individual or collective monitoring methods. In particular the accumulated dose of radiation received should be regularly computed;
(c) any results available from medical examinations.

1.8.1.2. These records should be in a form such that they can be used for statistics on an internal, national or international basis.

1.8.2. Area monitoring results

1.8.2.1. Permanent records should be kept of the results of all area monitoring and of significant happenings affecting radiation protection. Maintenance of a working area log book is suggested. Necessary data for investigations will normally only be available by consulting such records.
2. SEALED SOURCES

2.1. CHOICE AND DESIGN OF SEALED SOURCES

2.1.1. A source used to produce radiation field should be sealed in a suitable container or prepared in a form providing equivalent protection from mechanical disruption. The following characteristics are desirable consistent with the work being carried out:

2.1.1.1. The activity of the source used should be a minimum.

2.1.1.2. The energy or penetrating power of the emitted radiation should not be greater than that necessary to accomplish the task with a minimum total exposure.

2.1.1.3. If possible, the radioactive material in the source should be of low toxicity and in such a chemical and physical form as to minimise dispersion and ingestion in case the container should be broken.

2.1.2. Sealed sources should be permanently marked to permit individual identification and facilitate determination of nature and quantity of radioactivity without undue exposure of the worker.

2.1.3. Sealed sources or appropriate containers should be regularly examined for contamination or leakage (smear tests, and/or electrostatic collection may be used). The interval between examinations should be determined by the nature of the source in question.

2.1.4. Mechanically damaged or corroded sources should not be used and should immediately be placed in sealed containers. They should be repaired only by a technically skilled person, using suitable facilities.

2.2. METHODS OF USE OF SOURCES

2.2.1. Sources should always be handled in such a way that proper location is possible at all times. Inventories should be kept.
2.2.2. If any person has reasons for believing that a source has been lost or mislaid, he should notify the "radiological health and safety officer" immediately. If the loss is confirmed, the competent authority should be notified without delay.

2.2.3. Sources should be handled in such a way that the radiation dose to personnel is reduced to a minimum by such methods as shielding, distance and limited working time.

2.2.4. Sources should be handled in such a way as to avoid hazards to all personnel including those not involved in the operations. Attention should be paid to people in adjacent areas including rooms above and below. Areas subject to high radiation levels should be clearly marked and, if necessary, roped off.

2.2.5. Beams of radiation arising from a partially shielded source should be clearly indicated. Care should be taken to insure that such a beam is stopped at the minimum practical distance by suitable absorbing material. Monitoring procedures should be planned to take into account the sharp collimation of radiation fields which may occur.

2.2.6. When practical, sealed sources should be used in enclosed installations from which all persons are excluded during irradiation.

2.2.7. Sources should not be touched by hands. Appropriate tools should be used, for instance, long handled, lightweight forceps with a firm grip. If needed, even more elaborate means of protection have to be considered, such as master slave manipulation, etc.

2.2.8. Work with radioactive materials should be planned to permit as short an exposure as possible. The extent of protection provided by limiting working time can easily be lost if unexpected difficulties occur in the work, so that dummy runs should preferably be performed whenever it is possible.

2.2.9. Although work should be planned to limit exposure time to a safe figure, if sufficient shielding cannot be provided and time of exposure must be controlled, this should be carried out in a systematic way, preferably with time keeping and warning services outside the responsibility of the actual worker.
2.3. **SHIELDING**

2.3.1. Adequate shielding should be provided.

2.3.2. For beta rays the protection of eyes, face and body can be accomplished, by transparent plates of moderate thickness.

2.3.3. For gamma rays the protection of head and body may be effected by screens of adequate shielding effect for the source in question.

2.3.4. In addition to shielding for direct radiation, shielding may be necessary to give adequate protection against the back-scattering from the floor and ceiling (proper care should be taken against direct radiation through the supporting structure).

2.3.5. Bricks used for shielding sources should overlap to prevent penetration of the radiation at the joints:

2.3.6. Shielding should, as far as possible, be near the source.

2.3.7. As there are many possibilities for error in shielding calculation the adequacy of shielding should always be tested by direct measurements.

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2.4. **SPECIAL USES OF SEALED SOURCES**

2.4.1. *Large sources and teletherapy installations in medical departments*

2.4.1.1. As far as practicable, high intensity ionizing radiations should be used only within enclosures set apart for the purpose and which provide adequate protection under all operating conditions against the useful beam, leakage and scattered radiations for all persons outside the enclosures.

2.4.1.2. Shielding should be adequate to protect persons in neighbouring rooms and on adjacent floors. The shielding material should not lose its effectiveness through creeping or sagging.

2.4.1.3. In case of installations for teletherapy, the controls should be in a separate room or behind permanent structures.

2.4.1.4. Effective interlocks should be provided to prevent any person from entering a radiation room during irradiation.
2.4.1.5. Suitable means of exit should be provided so that any person who might be shut in by accident can leave the enclosure without delay.

2.4.1.6. Teletherapy apparatus should be constructed on the "fail safe" principle, that is to automatically cut off the beam in case of any irregularity, for instance, the opening of doors during irradiation; the activating force should only be initiated again from the control panel.

2.4.1.7. Light or audible signals, or both, are recommended inside and outside enclosures, and also in the vicinity of installations, to provide warning before and during irradiation.

2.4.1.8. A radiation monitor should be provided in the teletherapy room, giving a warning signal if the dose rate exceeds a pre-set level, to be sure that the apparatus is in the "off" position.

2.4.2. Small sources for contact and interstitial therapy in medical departments

2.4.2.1. A special room should be provided for the "make up" of sources or applicators with access to this room restricted to authorized personnel.

2.4.2.2. Handling of sources in this room should not inadvertently expose people in adjacent rooms or in rooms above or below to radiation.

2.4.2.3. Adequate shielding and handling equipment should be used in the "make up" of sources or applicators in order to minimize the radiation exposure to the personnel.

2.4.2.4. Periodic inventories should be carried out and proper records kept including a record of the inserted and removed sources for each applicator.

2.4.2.5. When sources or applicators are used on a patient, sufficient protection measures should be taken to minimize the radiation hazards to other patients or personnel in adjacent areas or in rooms above or below. In such instances movable screens could be used.

2.4.2.6. The fact that a patient is undergoing treatment by radioactive substances, and the precautions required, should be clearly indicated to all concerned in a manner approved by the responsible authority.
2.4.2.7. The movements of the patient undergoing treatment should be restricted according to the sources used.

2.4.2.8. After treatment the patient and the equipment should, preferably, be monitored to detect any possible contamination caused by an undetected breakage in any of the sources or of the applicators used.

2.4.3. *Industrial Gamma Radiography*

2.4.3.1. The controlled area should be clearly marked with easily recognizable signs. Such area should be made inaccessible to unauthorized personnel.

2.4.3.2. Light or audible signals, or both, should be provided to give adequate warning before and during irradiation.

2.4.3.3. The radiographic set-up should be completed before starting the irradiation.

2.4.3.4. For radiography which requires the removal of the sealed source from its shielding container a clearly identifiable dummy capsule should be used during any preliminary adjustments that may be necessary.

2.4.3.5. If the sealed source must be handled outside the container, this should be done automatically or by remote means, so as to give adequate protection to all personnel concerned with the operation.

2.4.3.6. A radiation detection instrument should be used to verify that the radiographic source has been correctly returned to its shielding container at the end of radiographic exposure.

2.4.3.7. When an industrial gamma radiography source is used away from the premises of normal use notices consisting of diagrams and/or photographs with dimensions and identifying features of the radioactive source and the steps to be taken by any person finding such a source should be prepared. These notices should be displayed at the area where the source is being used until removal of it from the area has been verified.

2.4.4. *Thickness gauges, static eliminators and similar devices using sealed sources*
2.4.4.1. Radioactive materials used for thickness gauges, static eliminators and similar devices should be in the form of sealed sources conforming to the general provisions for sealed sources.

2.4.4.2. Whenever practicable, the normally unshielded portion of the sealed source should be protected against mechanical damage, and be provided with a cover plate, shutter or shield that can be readily secured so as to effectively intercept the useful beam.

2.4.4.3. Wherever possible, such devices should be installed or shielded so as to ensure that the levels of irradiation of all persons, including those installing or maintaining the sealed source or any machinery or plant in close proximity to it, should be in conformity with the allowed doses to the general public put up by competent authority (so avoiding the need for personnel monitoring procedures and special medical examinations).

2.4.4.4. Such devices should be conspicuously and permanently marked so as to warn personnel of the presence of radioactive material and the need to avoid unnecessary exposure.

2.4.4.5. In case of a breakage of the source, the "radiological health and safety officer" or other designated persons should be notified at once.
3. UNSEALED SOURCES

3.1. GENERAL OPERATIONS WITH UNSEALED SOURCES

3.1.1. The provisions of sections 2.2. and 2.3. with respect to protection from external radiation also apply to unsealed sources. In respect to marking, the corresponding indications should be put on the associated container of the unsealed source.

3.1.2. All operations should be planned to limit spread or dispersal of radioactive material. To this end all unnecessary movement of persons or materials should be avoided.

3.1.3. Areas in which radioactive work is carried out should be designated, marked and monitored. At the boundaries of such areas monitoring and control measures should be set up if so required by the levels present. In larger establishments such check points should be established not only between areas subject to radioactive contamination and those not, but also between active areas subject to different usage. In this way an accidental escape of radioactive material is limited to a restricted local area and one may avoid difficult and expensive decontamination.

3.1.4. Equipment, glassware, tools and cleaning equipment for use in any particular active area should not be used for work in inactive areas and should be suitably marked. Special consideration should be given to avoiding contamination of major items of equipment which might need to be transferred for economic reasons.

3.1.5. Equipment should not needlessly be brought from inactive areas to active ones. Contaminated equipment, etc., should not be released from the controlled area for repair, until the level of activity has been reduced to the safe limits set up by the "radiological health and safety officer".

3.1.6. The use of new techniques should first be approved by the responsible person and be tried out with inactive materials or with material of low activity, before being put into operation.
Planning should allow adequate time for the operations required.

Precautions to be taken for handling unsealed sources depend on the degree of radiotoxicity and on the quantity of the substance being used. Contamination hazards such as risks from external contamination, skin penetration, ingestion or inhalation should be considered in addition to the usual radiation hazards of sealed sources. It is recommended that the "radiological health and safety officer" issue working instructions taking into account working conditions and acceptable risks.

A radioisotope can be classified in one of the four following categories of radiotoxicity per unit activity.

1. very high radiotoxicity
2. high radiotoxicity
3. moderate radiotoxicity
4. slight radiotoxicity.

Hazards arising out of the handling of unsealed sources depend on factors such as the types of compounds in which these isotopes appear, the specific activity, the volatility, the complexity of the procedures involved, and of the relative doses of radiation to the critical organs and tissues, if an accident should occur giving rise to skin penetration, inhalation or ingestion. Taking these factors into account, the broad classification is given in Tables I and II.

The following table gives the list of the main isotopes in each of the above mentioned categories:

**TABLE I**

**CLASSIFICATION OF ISOTOPES ACCORDING TO RELATIVE RADIOTOXICITY PER UNIT ACTIVITY**

(The isotopes in each class are listed in order of increasing atomic number)

**Class 1**

(very high toxicity)

### Class 2
(high toxicity)


### Class 3
(moderate toxicity)


### Class 4
(slight toxicity)

H-3, °Be-7, C-14, F-18, °Cr-51, Ge-71, °Tl-201.

3.1.11. The various types of laboratories or working places required are indicated in the following table:

<table>
<thead>
<tr>
<th>Radio toxicity of significant isotopes</th>
<th>Minimum quantity</th>
<th>Type of laboratory or working place required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0.1 µc</td>
<td>Type C Good Chemical Laboratory</td>
</tr>
<tr>
<td></td>
<td>10 µc or less</td>
<td>Type B Radioisotope Laboratory</td>
</tr>
<tr>
<td>High</td>
<td>1.0 µc</td>
<td>Type A High Level Laboratory</td>
</tr>
<tr>
<td>Moderate</td>
<td>10 µc</td>
<td>10 µc — 10 mc</td>
</tr>
<tr>
<td></td>
<td>1 mc or less</td>
<td>100 µc — 100 mc</td>
</tr>
<tr>
<td>Slight</td>
<td>100 µc</td>
<td>100 µc or more</td>
</tr>
<tr>
<td></td>
<td>10 mc or less</td>
<td>100 µc or more</td>
</tr>
</tbody>
</table>

° Gamma-emitters.
3.1.12. Modifying factors should be applied to the quantities indicated in the last 3 columns of Table II, according to the complexity of the procedures to be followed. The following factors are suggested but due regard should be paid to the circumstances affecting individual cases.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Modifying factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage (stock solutions)</td>
<td>$x \times 100$</td>
</tr>
<tr>
<td>Very simple wet operations</td>
<td>$x \times 10$</td>
</tr>
<tr>
<td>Normal chemical operations</td>
<td>$x \times 1$</td>
</tr>
<tr>
<td>Complex wet operations with risk of spills</td>
<td>$x \times 0.1$</td>
</tr>
<tr>
<td>Simple dry operations</td>
<td>$x \times 0.01$</td>
</tr>
<tr>
<td>Dry and dusty operations</td>
<td>$x \times 0.01$</td>
</tr>
</tbody>
</table>

3.1.13. As in the case of sealed sources, unsealed sources should be handled with equipment providing protection against external radiation.

3.1.14. Manipulations should be carried out over a suitable drip tray, or with some form of double container which will minimize the importance of breakages or spills. It is also useful to cover the working surfaces with absorbent material to soak up minor spills. The absorbent material should be changed when unsuitable for further work and considered as radioactive waste.

3.1.15. Shielding should be provided as near the container of radioactive substance as possible.

3.1.16. Handling-tools and equipment used should be placed in nonporous trays and pans with absorbent disposable paper, which should be changed frequently. Pipettes, stirring rods and similar equipment should never be placed directly on the bench or table.

3.1.17. After use, all vessels and tools should be set apart for special attention when cleaning.

3.2. **CHOICE OF RADIOACTIVE MATERIAL AND SUITABLE PROCESSES**

3.2.1. When a choice between several isotopes of varying toxicities is possible one of relatively low toxicity should be used.
3.2.2. Materials of low specific activity should be used if possible.

3.2.3. The working methods should be studied and procedures adopted to avoid as much as possible the dispersal of radioactive material, in particular through the formation of aerosols, gases, vapours or dusts.

3.2.4. Wet operations should be used in preference to dry ones.

3.2.5. Frequent transfers should be avoided.

3.2.6. The quantity of radioactive substances necessary for a specific purpose should always be chosen as small as possible.

3.3. CHOICE AND DESIGN OF WORK PLACES

3.3.1. General considerations:

3.3.1.1. Special consideration should be given to the choice of fire-proof construction for the buildings. As a rule the choice of location of premises should be such that there is small risk of landside or flood.

3.3.1.2. The reservation of special working places for the handling of radioisotopes is recommended. This rule may be considered as optional for work with quantities corresponding to column C of Table II; but it should be compulsory for work with quantities corresponding to column B and A of Table II.

3.3.1.3. As far as possible, the active areas should be planned and utilized in such a manner as to separate widely the different levels of activity.

3.3.1.4. The radioisotopes working areas should be marked.

3.3.2. Floors, walls, working surfaces

3.3.2.1. The floors, walls and working surfaces should be such as to be easily kept clean.

3.3.2.2. For type C working places a linoleum covered floor and working surfaces covered with non-absorbent material and with disposable covers is an example of what would be considered satisfactory. The working surfaces must be able to support the weight of the necessary shieldings against the gamma radiations.
3.3.2.3. For type B working places the walls and the ceilings should be covered with a washable, hard, non-porous paint; the floor with such materials as linoleum, rubber tiles or vinyl. The junction of floors and walls should be rounded off in order to facilitate the cleaning. Corners, cracks and rough surfaces should be avoided. When working with gamma emitters the floor and the working surfaces should be able to support the weight of the shielding.

3.3.2.4. Type A working places should be specially designed by an expert. In general type A laboratories will use glove boxes or other completely enclosed systems.

3.3.2.5. Walls and floors should be free from unnecessary obstacles and all unnecessary objects should be removed from the working surface.

3.3.3. Sinks
Sinks should be provided in the working area of type B or C laboratories. In general the usual type of sink, with a smooth white glaze finish, without blemishes, will suffice. It is desirable to have the sinks connected directly to the main pipe; connexions to open channels should be avoided, and also any unnecessary devices which might accumulate slime. Taps should be designed for operation by foot, knee, or elbow, rather than by hand. A suitable waste disposal system as discussed in 8.3.2. should be provided.

3.3.4. Furniture
The furniture should be reduced to a minimum and easily washable. Dust collecting items such as drawers, shelves and hanging lamps should be as few as possible.

3.3.5. Lighting
The working premises should be adequately lighted.

3.3.6. Ventilation
3.3.6.1. Provision for adequate ventilation should be included in the original design of the premises.

3.3.6.2. Routes of entry and exit for the ventilating air should be clearly defined under all conditions of use, including open and closed positions of doors and windows and various
operating arrangements of the fume hoods. In small laboratories it may be possible to provide the needed flow of air simply by the exhaust systems of the fume hoods, but in such a case special attention must be given to inflow of fresh air into the laboratory under all conditions by such means as providing adequate louvres in the doors of rooms.

3.3.6.3. Consideration should be given to any need to treat or filter incoming air. In cold climates the problem of heating the intake air for a large group of fume hoods should not be overlooked as this may be a major problem.

3.3.6.4. Siting of inlet and exhaust vents should be such as to prevent any recirculation of exhausted air. The need to filter air exhausted from work places and fume hoods will depend on the nature of the work, the position of the exhaust vent relative to surroundings and potential nuisance value of particulates settling in the surrounding neighbourhood.

3.3.6.5. Fume hoods should produce a regular air flow without any eddies. The speed of the air flow should be such that there can be no escape of air into the working place from the fume hood under typical operating conditions including opening of windows and doors, suction of other fume hoods. This can be checked by smoke tests. It is recommended that the fan be placed on the exhaust side of any filter in the system. The gas, water and electrical appliances should be operated from the outside of the fume hood. The inside of the hood and the exhaust ducts should be as easy to clean as possible.

3.4. PROTECTIVE CLOTHING

3.4.1. Protective clothing appropriate to the radioactive contamination risks should be worn by every person in the controlled area, even if only very small quantities of radioactive materials are manipulated.

3.4.2. In type C working place the personnel should wear simple protective clothing such as ordinary laboratory coats or surgical coats. In type A or B working places protective clothing or devices should be provided according to the
nature of the work. When working with experimental animals, clothing proof against teeth or claws may be desirable and protection of the face against blood or body fluid splashings should be provided.

3.4.3. In type A and B working places the protective clothing should be clearly identified, for example by a different colour. It should not, in any case, be worn outside the controlled area.

3.4.4. The working clothes and town clothes should be kept in separate cubicles or changing rooms. When changing from one to the other, one should be careful to avoid cross contamination risks.

3.4.5. Rubber gloves should be worn when working with unsealed radioactive substances. Rubber gloves are provided to protect against contamination of the skin and are of no value for protection from penetrating radiation.

3.4.6. Care should be taken not to needlessly contaminate objects by handling them with protective gloves, in particular light switches, taps, door knobs, etc. The gloves should be either taken off or a piece of non-contaminated material (paper), which should be disposed of afterwards with the contaminated residue, should be interposed.

3.4.7. Contaminated gloves should be washed before taking them off.

3.4.8. A method of putting on and removing rubber gloves without contaminating the inside of the gloves should be used. This procedure is such that the inside of the glove is not touched by the outside, nor is any part of the outside allowed to come in contact with the bare skin. It is desirable to use gloves for which the inside and outside are distinguishable.

3.5. PERSONAL PROTECTIVE MEASURES

3.5.1. No unsealed radioactive sources should be manipulated with the unprotected hand.

3.5.2. No solution should be pipetted by mouth in any isotope laboratory.
3.5.3. It is recommended that special precautions be taken to avoid punctures or cuts, specially when manipulating the more dangerous radioisotopes.

3.5.4. Anyone who has an open skin wound below the wrist (protected by a bandage or not) should not work with radioactive isotopes without medical approval.

3.5.5. The use of containers, glassware, etc., with cutting edges should be avoided.

3.5.6. Care should be taken with contaminated animals to avoid bites or scratches.

3.5.7. Glass blowing by mouth should be avoided in places where unsealed radioactive substances are utilized. Glass blowing, welding, brazing, soldering, etc., should never be permitted on equipment contaminated with radioactive materials unless it is done in specially ventilated facilities, and unless special techniques are used to prevent the inhalation of radioactive dust and fumes.

3.5.8. Only self-adhesive labels should be used in controlled areas. Labels requiring to be wetted should be avoided.

3.5.9. The following should not be introduced or used in working places containing unsealed sources:
   — Food or beverages (where necessary, drinking fountains should be provided in the vicinity).
   — Smoking items or snuff tobacco.
   — Handbags, lipsticks and other cosmetics, or items used to apply them.
   — Handkerchiefs, other than those mentioned below.
   — Utensils for eating or drinking.

3.5.10. Disposable paper towels and paper handkerchiefs or the equivalent should be provided for the workers. Special containers should be placed in the working places, in which these towels and handkerchiefs should be thrown after use. These should be treated as radioactive residue.

3.5.11. Hands should be washed thoroughly before leaving the controlled area (special attention should be given to the nails, in between fingers and outer edges of the hands).

3.5.12. Showers should be taken when recommended by the
"radiological health and safety officer". Monitoring of hands, shoes and street clothing, if worn at work, may also be necessary before leaving the controlled areas.

3.6. CONTROL OF AIR CONTAMINATION

3.6.1. Radioactive contamination of the air of the working places should be reduced as much as possible. All operations likely to produce radioactive contamination of the air through the production of aerosols (in particular the heating of radioactive solutions) smoke or vapours, should be done in an air-tight enclosure kept below atmospheric pressure (glove box) or in a fume hood.

3.6.2. The aim should be to improve collective protection, and so avoid resort to individual protection like respirators, compressed air masks, frog suits, etc. Conditions which require extended use of respirators should be discouraged.

3.6.3. When the contamination level cannot be maintained below the levels set out by the "radiological health and safety officer", individual protection against contamination must be furnished to the people using the working places.

3.6.4. Respirators should be of a form approved by a recognized testing laboratory for the class of service required, and the practical safe limits of use should be known and respected.

3.6.5. Respirators should be capable of standing up to the conditions of use and should be checked and tested periodically.

3.6.6. Respirators should be individually fitted and tested for tightness of fit by attempting to breathe with the inlet closed off.

3.6.7. Users of respirators must accustom themselves to the discipline necessary in their use, otherwise more harm than good is likely to be done by introducing contamination under the facepiece.

3.6.8. In difficult cases when the use of respirators would not give adequate safety (for instance with radioactive gases), air line hoods may provide the only reliable form of protection. In such cases attention should be given to the purity of the air and its proper supply.
3.7. **SPECIAL USES OF UNSEALED SOURCES**

3.7.1. **Installations for the pumping of radon or thoron**

3.7.1.1. The installation should be in special rooms or preferably in a separate building. The solution of radium or other source material should be in a safe with proper shielding in a separate room. This should be connected through tubing with the pumping apparatus in an adjoining room.

3.7.1.2. The filling of the glass capillaries or gold seeds with radon should be performed before appreciable quantities of decay products have been formed.

3.7.1.3. All rooms where the work with radon is performed should be efficiently ventilated.

3.7.2. **Luminising involving application of radium or similar dangerous isotopes to surfaces**

The following recommendations include extracts from the International Labour Organisation relevant provisions on ionizing radiations. They should prove helpful in any similar type of work with the more hazardous isotopes.

3.7.2.1. Luminising, whether by hand or by machine, should be done only within workplaces of a standard not lower than type B.

3.7.2.2. The provisions relating to wall and floor coverings, covering of working surfaces, ventilating systems, prohibition of eating, drinking, smoking, snufftaking and use of cosmetics, storage of sources and treatment of radioactive residues should, however, be those appropriate to type A workplaces or a high standard of type B.

3.7.2.3. Glove boxes or similar arrangements should be used whenever practicable for the application of luminous compound.

3.7.2.4. Where the equipment referred to in the preceding paragraph cannot be used, additional protective clothing including washable aprons and bibs of rubber or other waterproof materials should be provided and used.

3.7.2.5. Such additional protective clothing should be cleaned daily by a wet method.
3.7.2.6. Operations with dry luminous compound, such as filling glass capillary tubes or weighing out, should only be performed within glove boxes or similar arrangements.

3.7.2.7. Luminised work awaiting drying, or completed, should not be allowed to accumulate on or near luminisers' work benches, but should be removed at frequent intervals to a place of storage affording adequate protection (see storage of sources).

3.7.2.8. Every store or receptacle used for drying luminous compound should be:
— not less than 3 meters from any working place;
— enclosed as far as practicable; and
— effectively ventilated to the open air so that gases or vapours from the stove or receptacle do not contaminate the atmosphere of an occupied area.

3.7.2.9. Instruments for the application of luminous compound should on no account be put in the mouth or in contact with the skin.

3.7.2.10. The use of brushes for the application of luminous compound should be discouraged.

3.7.2.11. Suitable receptacles for luminous compound should be provided for the use of persons handling such compound, and should be constructed as to:
— limit exposure to beta and gamma radiation;
— prevent contamination of the hand.

3.7.2.12. A survey by means of ultra-violet light or by a suitable radiation monitor, should be carried out at least once a month in every workroom in which persons are employed on processes involving the use of luminous compound, for the purpose of detecting areas of radioactive contamination.

3.7.2.13. Any such area should be cleaned forthwith by a wet method.

3.7.2.14. Luminising machines should be so constructed as to afford adequate protection.

3.7.2.15. No person should otherwise than by a wet method or within a glove box:
— remove waste material containing luminous compound from applicators or other tools;
— remove luminous compound from the surface of any other article or from glass tubing; or
— clean contaminated luminising machine parts.

3.7.2.16. Waste material arising from luminising should be disposed of in accordance with the recommendations for radioactive waste disposal.

3.7.3. Medical uses of unsealed sources

In the medical use of unsealed radioactive sources additional difficulties arise through the fact that the radiation protection measures must be observed together with the usual clinical regulations for laboratories, operating theatres, and patients’ wards. Furthermore, protection against radiation, not only of the personnel but also of other patients, must be assured. On the other hand, the medical work is usually limited to a small number of radioisotopes and for each single treatment activities of 100 mc are seldom exceeded. The purely medical problems in the diagnostic and therapeutic use of isotopes are not in the scope of this manual. Unsealed sources should not be used unless any requirements set out by competent authorities for rooms, personnel and instruments are met.

3.7.3.1. For radioisotopes used only for diagnostic and tracer studies, laboratories of type C are sufficient.

3.7.3.2. For the therapeutic use of isotopes, the following should be provided:
1. laboratories of type B to prepare the isotopes for medical treatment.
2. additional rooms for the treatment itself.
3. wards for the patients who have been treated with isotopes.

For special cases table II in 3.1.11. may be consulted whereby the modifying factors for “Complex wet operations with risks of spills” (3.1.12.) should be applied.

3.7.3.3. It is recommended that these rooms are close together and, if possible, isolated from the other sections of the hospital, and considered as “Controlled area”.

3.7.3.4. A patient treated with radioactive isotopes is to be considered as a source of radiation and of contamination from which the personnel as well as the other patients may need to be protected.
3.7.3.5. Special attention should be given to the proper instruction and protection of patients' attendants, since their duties involve particular risks of contamination and irradiation. Unnecessary loitering of attendants near the patients' beds should be avoided.

3.7.3.6. The recommendations of section 3.1. with respect to general operations with unsealed sources should be followed. Special techniques with the medical instruments, e.g. syringes, may be necessary.

3.7.3.7. The quantity of radioactive material on hand within the treatment room should, as far as possible, be limited to that required for actual administration, since this will make it possible to relax many of the safety requirements.

3.7.3.8. Contaminated instruments, vessels, linen, etc., should be decontaminated according to rules of section 7.2.

3.7.3.9. Excreta of internally treated patients should be considered as radioactive waste.

3.7.3.10. The movements of the patient undergoing treatment should be restricted according to the potential hazard he may represent.

3.7.4. Radioactive isotopes in animal experiments

3.7.4.1. The general provisions of preceding sections for work with unsealed sources should be followed.

3.7.4.2. However, the unwarranted spread of contamination by animals or from animal excreta requires special consideration in the design of cages and rooms.

3.7.4.3. Excreta, body constituents from biopsies and autopsies and animal cadavres should be considered as radioactive wastes. Possible hazards of spread of contamination through decomposition process should be prevented, e.g. by deepfreezing, use of disinfectants, sealed plastic containers, etc.

3.7.4.4. Special provisions for collection of excreta and decontamination of cages should be made.

3.7.4.5. The radioactive animals or their cages should be marked with labels indicating the nature and amount of radioactive isotopes used and the time of administration.

3.7.4.6. No uncontrolled exchange of animals, instruments, cages, etc., between active and inactive laboratories should be allowed.
3.7.4.7. Precautions should be taken to prevent the possibility of contaminated wounds produced by handling the animals and the contamination from radioactive aerosols or splashings produced by animals’ movements, coughing, etc.

3.7.4.8. For work with radioactive animals, the modifying factor to be applied in table II should normally be taken as 0.1.

3.7.4.9. Presence of vermin as potential vectors of contamination should be considered.
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4. STORAGE OF SOURCES

4.1. PLACE OF STORAGE

When not in use, radioactive sources should be kept in a place of storage assigned for this purpose only.

4.1.1. The place of storage should be adequately shielded.

4.1.2. Only authorized personnel should be allowed to introduce or remove sources from the place of storage which should be secure against tampering.

4.1.3. The place of storage should be in a room provided with a suitable means of exit that can be operated from the inside.

4.1.4. The place of storage should be chosen so as to minimize risk from fire.

4.1.5. The places where sources are stored should be inspected regularly and checked for possible contamination.

4.2. CONDITIONS OF STORAGE

4.2.1. All radioactive sources should be clearly labelled, giving information on the activity and nature. It may be found desirable to include the name of the person who is responsible for the source. In the event that a number of sources are normally in use in a fume-hood or other working area as, for example in analytical work, the marking might be of a general nature to apply to the whole working area. Any source involving hazards greater than those listed in the general warning should be specially marked.

4.2.2. The containers for beta-emitting isotopes should have adequate thickness to reduce the primary radiation to a safe level. Considerable bremsstrahlung may arise from high intensity sources and additional shielding should be provided if necessary.

4.2.3. Gamma-emitting sources should be stored in such a way as to limit the radiation exposure from other sources when any one source is being handled.

4.2.4. When either sealed or unsealed sources are liable to release a radioactive gas, their place of storage should be
4.2.5. Special equipment should be provided for storing unsealed sources of radioactive substances to prevent not only external irradiation hazards, but also radioactive contamination hazards.

4.2.6. In type C working places the sources may be stored in special cupboards providing adequate protection.

4.2.7. In type B working places it is better to use a special secure receptacle which provides adequate protection and could be ventilated if necessary.

4.3. STORAGE OPERATIONS

4.3.1. Records should be kept of all stored radioactive sources.

4.3.2. The records should give clear information on type of source, activity and time of removal and return as well as the name of the person responsible for the source during its absence from the store.

4.3.3. Periodic inventories should be performed.

4.3.4. The removal of sources from the store and the time for which they are removed should be checked to provide adequate control.

4.3.5. Thermally unstable solutions containing radioactive materials in nitric acid or other oxidising solutions containing even traces of organic material and stable solutions with alpha-activity in excess of 5 mc or beta-activity in excess of 50 mc should always be stored in vented vessels.

4.3.6. Bottles and containers should be chosen to open easily.

4.3.7. Solutions having a high alpha-activity in excess of 1 mc/ml should not be stored in thin walled glass bottles, since irradiation might weaken the glass. All glass vessels must be expected to fail without apparent cause.

4.3.8. Bottles containing radioactive liquids should be placed in vessels large enough to hold the entire contents of the bottles in case of breakage.

4.3.9. Special precautions are required when opening vessels containing radioactive liquids liable to catch fire, explode or froth.
5. TRANSPORTATION OF RADIOACTIVE MATERIAL

5.1. TRANSPORTATION WITHIN AN ESTABLISHMENT

5.1.1. The amount of radioactive material moved should be limited to that required.

5.1.2. Transportation should be done in adequately shielded and closed containers. The containers should be constructed to prevent accidental release of the source material in case of upset.

5.1.3. If radioactive material in liquid or gaseous form or in powder, or other dispersible solid form is in a shatterable container it should be transported in an outer non shatterable container. With liquid sources the container should be provided with absorbing material able to retain all the liquid in case of breakage.

5.1.4. Suitable means should be provided for the transfer of the source to and from the transport container.

5.1.5. The transport container should be clearly marked with warning signs.

5.1.6. Containers in transit should bear a transportation tag showing necessary information for safety such as:

- nature of contents
- physical condition
- activity in curies
- dose rate of radiation at the contact of the outer surface of the container
- dose rate of radiation at a specific distance
- kind of packing (when applicable).

In case of unsealed sources, the transportation tag should, in addition, certify that the outsides of the container and carrier are free from contamination.

5.1.7. It is recommended that the transportation tag should be disposed of only when the source is in the charge and under the complete physical control of a person who is aware of the nature of the radioactive material and of the radiation hazards involved.
5.1.8. Emergency procedures should be planned to cover accidents to radioactive material in transit.

5.1.9. Any loss of radioactive materials during transport should at once be reported to the "radiological health and safety officer".

5.1.10. Suitably trained workers should be in charge of all transportation of hazardous quantities of radioactive material inside an establishment.

5.2. TRANSPORTATION OUTSIDE AN ESTABLISHMENT

5.2.1. The route and method of shipment should be ascertained in sufficient detail to permit compliance with the rules and regulations established by all authorities through whose charge the shipment will pass. It should not be assumed in the case of trans-shipment that, because a shipment meets the requirements of the initial carrier, it will meet all requirements.

5.2.2. The recipient should be notified about shipment and receive all significant information in time to make any necessary preparations for receiving the shipment. Such information should at least include the method of shipment and estimated time of arrival. The notification should include any special storage instructions and details of safe opening techniques for special shipping containers.

5.2.3. Unless the rules and regulations referred to in 5.2.1. have different provisions, the following general recommendations should be applied:

5.2.3.1. Packing should be such that the dose rate of radiation outside the package and the foreseeable duration and conditions of handling, transport and storage is unlikely to result in any person receiving radiation in excess of that permitted for non-occupational exposure. The limitation of the number of packages acceptable in one vehicle or storage location should depend upon the same considerations.

5.2.3.2. The outer surface of the package should not be significantly contaminated. Returnable containers should be free from significant external contamination.
5.2.3.3. Packaging should be adequate to prevent any loss of the radioactive material under normal conditions of transport, and any dispersal of radioactive material as a result of accidents that can reasonably be expected with the form of transport used. The packaging should be resistant to shocks, fire, water and in addition the following factors should be considered:

— possible corrosion of container
— effects of changes in outside temperature and barometric pressure
— the degree of self-heating by large sources
— possibility of gas formation and pressure build up
— the possibility of the escape of gases produced and the effects to be expected from any radioactive gases released
— the possibility of increased activity after packing due to build up of daughter products.

5.2.3.4. The shipment should be clearly marked.
The marking should:

(1) indicate the presence of radioactive danger. This marking should remain legible under adverse conditions.

(2) indicate the nature and quantity of radioactive material, the dose rate at the surface of the package and at a specified distance.

(3) indicate that no person should stand by needlessly and that undeveloped photographic films should be kept at as specified safe distance.

(4) be adequate to prevent any loss or misplacement of the shipment if damaged in transit, and provide instructions for safe disposal if delivery cannot be effected.

5.2.3.5. Radioactive material should not be loaded together with dangerous substances such as explosive, inflammable, oxidizing or corrosive substances.

5.2.3.6. The person responsible for transportation should be notified in writing of all particulars listed in 5.2.3.4. and of all other necessary instructions for safe transport, handling or storage of the shipment.
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6. ACCIDENTS

6.1. IDENTIFICATION OF ACCIDENTS

6.1.1. Any unplanned happening which could affect radiation safety is considered an accident from the point of view of this Manual.

6.1.2. The most essential and often the most difficult problem in coping with accidents is the recognition that an accident has occurred.

6.2. PRECAUTIONARY MEASURES

6.2.1. All work should be carried out according to some pre-arranged plan. Any departure from the plan should be followed by a reassessment of the radiation hazards involved.

6.2.2. Appropriate accident instructions should be prepared and posted and the staff should thoroughly understand them.

6.2.3. Accident instructions should avoid any rigid restrictions on conditions of application. A serious situation can develop from a wide variety of causes ranging from a simple spread of radioactive contamination to such natural causes of disaster as fire, flood or earthquakes.

6.2.4. All planning of measures to be taken in case of accidents should give priority to human safety according to need and urgency. Responsibility for protecting the public must take precedence.

6.2.5. The staff should be thoroughly familiar with the position and method of use of the protection and first-aid equipment for emergencies. Practice drills are essential. Equipment should be checked regularly to ensure that it is in good working order.

6.2.6. The public health authorities, fire service and other services or authorities (guards, police ...) should be kept informed of special radiation hazards and of the radiation safety measures to be taken.

6.2.7. No person should undertake dangerous work without someone standing by who can assist in case of trouble.
6.2.8. Emergency facilities and staff should be available when work is being carried out with unsealed sources requiring the use of type A or B working places.

6.2.9. First aid measures in conformity with medical advice should be available.

6.3. ACTIONS COMMON TO ALL ACCIDENTS

6.3.1. The control of measures for dealing with any accident should be the responsibility of one individual. The individual concerned or his alternates should be clearly indicated in the accident instructions and should be available to all concerned.

6.3.2. All accidents should be fully reported. This report may have an important bearing on staff health and legal responsibilities and may assist the "radiological health and safety officer" in making detailed study with a view to avoiding similar accidents in the future.

6.3.3. All accidents should be investigated and appropriate measures should be taken to prevent repetition of the accident.

6.4. ACCIDENTS INVOLVING RADIOACTIVE CONTAMINATION

6.4.1. Radioactive materials may be accidentally released by a spill, by a failure of equipment or by rupture of a sealed source. The actions which may be appropriate to prevent wide-spread contamination and exposure of personnel in such a case, and the order in which such actions should be taken, will depend upon the circumstances involved. For example, in the case of a small spill of liquid it may be desirable to contain and clean up the contamination immediately without severely affecting the routine activities in the room in which the spill occurs. However, the release of a relatively large quantity of a radioactive powder or aerosol in a room will require immediate action to contain the contamination in the room and evacuation of the room by all personnel, followed by elaborate moni-
toring and decontamination procedures. Actions frequently desirable in cases of accidental releases of radioactivity are listed below. Although some effort is made to list these actions in the approximate order in which they are likely to be appropriate, some of these actions will be appropriate only in cases of large releases or under special conditions.

6.4.2 Persons in the vicinity of the spill or release who are liable to either external or internal contamination as a result of the accident should be given appropriate information immediately.

6.4.3 The protection of personnel and the containment of the radioactive material in the room in which the accident occurs should be given primary consideration. If the spill or release is of such a nature that, in the judgment of the person immediately responsible for the work, it is advantageous to take immediate action to contain the material or limit its release, such action may be appropriate.

6.4.4 Persons directly contaminated by a wet spill should immediately remove clothing affected and thoroughly wash the hands and other contaminated areas of the body.

6.4.5 If an inhalation hazard exists, all persons not involved in carrying out planned safety procedures should vacate the contaminated area immediately.

6.4.6 Evacuation or other action should be accomplished with the minimum required movement about the room. Movement should not start until the individual is aware of the situation and has determined the purpose of his movement. Areas of known or suspected contamination should be avoided.

6.4.7 The "radiological health and safety officer" or his representative in the area should be given all available information on the nature and extent of the release.

6.4.8 If evacuation of the room is required, it will generally be desirable to shut off all mechanical ventilation and to close all outside openings. However, there may be local conditions which require consideration. For example, if the release occurs in or near a fume hood, it may be disadvantageous to take any action which would discontinue ventilation by the hood.

6.4.9 If considerable contamination of the air is suspected, inhalation of radioactive material should be minimized by hol-
6.4.10. After all persons are out of the room, it may be desirable to prevent further escape of radioactive material from the room by sealing doors and other closures with adhesive tape.

6.4.11. Persons suspected of inhaling or ingesting considerable quantities of radioactive material should seek or be given immediate attention as discussed in chapter 7.

6.4.12. Except in case of injury or other urgent need, persons who have vacated the contaminated area should not leave the immediate vicinity until they have been monitored and necessary precautions, such as the removal of shoes or outer clothing, taken to limit further spread of radioactivity.

6.4.13. The extent of the area of contamination should be determined and the area roped off, with appropriate warning or guards.

6.4.14. The person in charge of measures for dealing with accidents, or a designated alternate, should arrange for immediate decontamination of personnel as required.

6.4.15. Safe and efficient decontamination of the working area and equipment will generally require careful planning based on an evaluation of all factors involved. In general, the following sequence of procedures will be involved:
(1) locate and contain the contamination,
(2) assess the contamination and plan clean-up operations,
(3) reduce the contamination by appropriate methods, and
(4) assess the residual contamination and repeat the procedure as necessary.

6.4.16. Personnel carrying out decontamination procedures should be provided with appropriate instructions and equipment for their own protection and for the protection of other personnel.
7. DECONTAMINATION

7.1. DECONTAMINATION OF PERSONNEL

The "radiological health and safety officer" should set up instructions and facilities (materials and equipment) for normal decontamination and first aid procedures in conformity with paragraph 1.5.4.2. The staff should be fully acquainted with them.

7.1.1. Measures to be taken in case of internal contamination

7.1.1.1. Radioactive contamination of personnel can be internal through ingestion, inhalation, wounds or skin penetration. If anyone suspects internal contamination in case of an accident during work, it should be immediately reported to the "radiological health and safety officer".

7.1.1.2. Internal contamination is essentially a medical problem, parallel in some ways to the absorption of chemical toxins. Special corrective procedures should therefore be combined with normal medical practice under medical advice and supervision.

7.1.1.3. Aims of the corrective procedures are:

first: try to eliminate quickly as much as possible of the internally introduced contaminant still remaining in the mouth, gastro-intestinal or respiratory tract and to prevent or reduce its uptake into the bloodstream and tissues;

secondly: try to prevent fixation of the contaminant in the body or to increase its excretion from the body.

7.1.1.4. For the first of these aims it is sometimes necessary that the contaminated person or another non medical person takes immediate action (in the first seconds or minutes) for instance, to promote the mechanical elimination of the contaminant by vomitting or expectoration.

7.1.1.5. In case of contaminated small open wounds, cuts, punctures, etc., the wound should be immediately washed and bleeding encouraged if necessary, and referred to the medical officer.

7.1.1.6. For the second of the aims indicated in 7.1.1.3. any further
procedure of internal decontamination, e.g. more complicated chemical or physico chemical methods, is a matter of medical treatment. It should be undertaken as soon as possible but only under medical supervision.

7.1.2. Measures to be taken in case of external contamination of personnel

7.1.2.1. External contamination on the person can be a hazard in three ways:
— it may cause injury from local exposure of the skin
— it may penetrate the intact skin (especially in the presence of certain organic solvents)
— it may eventually be transferred into the body by ingestion or inhalation.

7.1.2.2. The danger of loose activity being eventually carried into the body is by far the most critical hazard so that decontamination procedures are primarily concerned with loose contamination.

7.1.2.3. As a rule, except for decontamination of hands, or except in cases of emergency as agreed upon by the "radiological health and safety officer", all mild decontaminating procedures described in paragraphs 7.1.2.4. and 7.1.2.5. below should be carried out under supervision of the "radiological health and safety officer". Attempts to remove contamination which resists mild procedures should only be made under medical supervision.

7.1.2.4. The immediate washing of contaminated areas with water and soap is the method of choice for removing loose contamination, subject to certain elementary precautions:
1. Tepid water, not too hot, should be used.
2. Soap should not be abrasive or highly alkaline.
3. The washing can be helped by scrubbing with a soft brush only and in such a way as not to abrade the skin.
4. The skin should be washed for a few minutes at a time, then dried and monitored.

Washing could be repeated if necessary (as indicated by monitoring) providing there is no indication of the skin getting damaged.
7.1.2.5. If this procedure fails, only mild detergent approved by the "radiological health and safety officer" might be used, although repeated applications of detergents to the same area of the skin, hands for instance, might injure the skin and make it penetrable.

7.1.2.6. Use of organic solvents or of acid or alkaline solutions should be avoided.

7.1.2.7. Special attention should be paid to proper decontamination of creases, folds, hair and of such parts of the hands as finger nails, inter-finger space and the outer edges of the hands.

7.1.2.8. Care should be taken to avoid as much as possible the spreading of the contamination to uncontaminated parts of the body and to avoid internal contamination. If there is a risk of such a spread, an attempt should first be made to remove the contamination locally with absorbent material, and, if necessary, with a proper masking of the adjacent non-contaminated areas of the skin. A non-contaminated open wound should be protected.

7.1.2.9. After each decontamination operation, the treated place should be dried with a fresh non-contaminated towel, swab, etc., and monitored. All towels, swabs, etc., used in the decontamination process should be treated as contaminated material.

7.1.2.10. While decontaminating the face, special care should be taken not to contaminate the eyes or lips.

7.1.2.11. Decontamination of the eyes should be undertaken immediately. Not only the radioactive isotope is to be considered, but also the chemical nature of the contaminant and eventual complications due to foreign bodies and mechanical or chemical irritants. Additional irritation of the eyes by decontamination procedures should be avoided. Immediate irrigation of the eyes with a copious amount of water or with appropriate medically approved solutions is recommended. These solutions and a suitable vessel for eye washing should be provided as first aid kit. After this first procedure every case of contamination of the eyes should be submitted to medical control and further treatment.

7.1.2.12. Attempts to remove contamination which resists washing should only be made under medical supervision.
7.2. DECONTAMINATION OF EQUIPMENT

7.2.1. Decontamination of glassware and tools

7.2.1.1. The decision to decontaminate material must take into account the continuing value of the material compared to the cost of decontamination.

7.2.1.2. Where the half life of the contaminating element is short, it may be desirable to store tools and glassware for decay of activity rather than to attempt decontamination.

7.2.1.3. Decontamination of equipment should generally be done as soon as possible after its use. In many cases this will prevent the contamination from getting fixed and from being ultimately more difficult to deal with. It will often be found that surfaces that have been kept moist are easier to clean.

7.2.1.4. The cleaning of contaminated glassware and tools should be done with great care by informed persons in a well ventilated hood set aside in the laboratory for that purpose, or in special decontamination areas.

7.2.1.5. If it is necessary to dismantle any equipment prior to decontamination procedures, careful monitoring should be carried out during the operation.

7.2.1.6. Glassware can be cleaned by any of the normal chemical agents, of which chromic-acid solution is probably the most useful. Other cleaning agents are concentrated nitric acid, ammonium citrate, penta sodium triphosphate and ammonium bifluoride.

7.2.1.7. Metal tools and similar equipment should be washed with a detergent combined with brisk brushing to dislodge trapped contamination. Contamination resisting this treatment may be washed in stronger agents including dilute nitric acid or a 10% solution of sodium citrate or ammonium bifluoride. Other cleaning agents can be chosen based on the material of construction of the equipment and the likely chemical nature of the contaminant. Stainless steel could be treated with sulphuric or, as a last resort, hydrochloric acid.

7.2.1.8. If the decontamination causes any corrosion of the metal, future decontamination will be more difficult to remove and a coat of glossy paint on the decontaminated surface is desirable. Contamination prevention by the use of
strippable coatings or plastic covers is useful. A coat of paint may provide adequate protection from soft emitters which prove resistant to decontamination.

7.2.1.9. The uptake of radioactive substances by glassware may be reduced by a preliminary treatment with the corresponding inactive chemical.

7.2.1.10. In some cases immersion in solutions of the non-radioactive isotope of the contaminant may be tried, although this is a slow procedure.

7.2.1.11. The solutions used for cleaning should not be returned to the stock bottles between uses.

7.2.1.12. Laboratory equipment should be surveyed for residual contamination following decontamination procedures. If the residual contamination indicates that the level of activity remains greater than that specified as permissible, equipment should not be re-used and should be regarded as radioactive waste.

7.2.2. Decontamination of working areas, benches, etc.

7.2.2.1. As soon as possible after contamination of working areas, benches, etc., has occurred or has been detected, decontamination should be carried out by suitably equipped and informed persons.

7.2.2.2. All surfaces should be cleaned by wet methods if possible, as the use of dry methods may create a dust hazard. For porous materials of construction which prove unsuitable for cleaning by wet methods, vacuum cleaning with proper filtration of the rejected air might be attempted; in any case special precautions in using dry techniques are necessary.

7.2.2.3. Cleaning tools should be assigned to the area in which the operations are being performed and not removed or used elsewhere without careful decontamination.

7.2.2.4. Paintwork can be cleaned with soap (or detergent) and water or, in extreme cases, removed with a paint remover. Polished linoleum can be cleaned with soap and water, followed, if necessary, by the removal of the wax polish by means of a solvent.

7.2.2.5. If the contamination is by alpha or soft beta emitters, the radiation may possibly be controlled by painting over. The use of two coats with the undercoat in a contrasting colour
is useful to indicate any wearing away of the protective coat. This method of contamination control should be used with caution with respect to future possible uses of the installation.

7.2.2.6. If after attempted decontamination adequate protection cannot be assured, the contaminated rooms or premises should be abandoned and contaminated removable objects disposed of in accordance with the requirements of the competent authority. Access to these abandoned areas should be forbidden to unauthorized persons and such areas should be identified by an appropriate and recognizable warning sign.

7.2.3. Decontamination of clothing, hospital linen or similar items

7.2.3.1. In any handling of contaminated clothing appropriate precautions should be taken to prevent or control contamination of the worker and of the surrounding areas by the formation of aerosols. The sorting of contaminated garments as indicated in 7.2.3. will often need to be carried out in a fume hood. Care must be taken to prevent airborne contamination from clothing placed in storage.

7.2.3.2. Contaminated clothing and linen should not be released to public laundries without the approval of the “radiological health and safety officer”.

7.2.3.3. With short-life radioactive contamination, storage is recommended until the activity has fallen to safe levels.

7.2.3.4. It will usually be desirable to wash the contaminated clothing in specially provided laundering facilities; the area where decontamination goes on should be monitored. Personnel in charge of these facilities should be provided with protective coats and suitable gloves.

7.2.3.5. Contaminated garments should be segregated into batches of differing degrees of activity to avoid cross contamination.

7.2.3.6. Routine washing of moderately contaminated clothing may be carried out according to schedules recommended for commercial laundry practice. However, it may be advantageous to substitute a standard detergent (chosen on the basis of economy) for the soap because of the tendency of latter to form deposits which may fix the activity in the fabric.
7.2.3.7. Clothing with resistant contamination or high levels of activity is dealt with by longer periods of washing and especially by repeated rinsings.

7.2.3.8. Rubber gloves and other rubber goods and plastics usually decontaminate readily. Such items should first be washed with an ordinary laundry formula. If this does not prove effective, rubber items can be washed in dilute nitric acid or agents chosen in the light of the nature of the contamination. This should be followed by a wash using scouring powder and a thorough rinse in running tap water.

7.2.3.9. If the clothing, linen, etc., cannot be decontaminated to a safe level it should be regarded as radioactive waste.
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8. RADIOACTIVE WASTE CONTROL AND DISPOSAL

8.1. WASTE COLLECTION

8.1.1. In all working places where radioactive wastes may originate, suitable receptacles should be available.

8.1.2. Solid waste should be deposited in refuse bins with foot-operated lids. The bins should be lined with removable paper bags to facilitate removal of the waste without contamination.

8.1.3. Liquid waste should, if no other facilities for liquid waste disposal exist, be collected in bottles kept in pails or trays designed to retain all their contents in the event of a breakage.

8.1.4. All receptacles for radioactive wastes should be clearly identified. In general, it will be desirable to classify radioactive wastes according to methods of disposal or of storage, and to provide separate containers for the various classifications used. Depending upon the needs of the installation, one or more of the following bases for classification of wastes may be desirable: —

- gamma radiation levels (high, low)
- total activity (high, intermediate, low)
- half-life (long, short)
- combustible, non-combustible

For convenient and positive identification, it may be desirable to use both colour coding and wording.

8.1.5. Shielded containers should be used when necessary.

8.1.6. It is generally desirable to maintain an approximate record of quantities of radioactive wastes released to drainage systems, to sewers, or for burial. This may be particularly important in the case of long-lived radioisotopes. For this purpose it is desirable or necessary to maintain a record of estimated quantities of radioactivity deposited in various receptacles, particularly those receiving high levels of activity or long-lived isotopes. Depending upon the system of control used by the installation, it may be
desirable to provide for the receptacle to be marked or tagged with a statement of its contents.

8.1.7. Radioactive wastes should be removed from working places by designated personnel under the supervision of the "radiological health and safety officer".

8.2. WASTE STORAGE

8.2.1. All wastes which cannot be immediately disposed of in conformity with requirements of the competent authority have to be placed in suitable storage.

8.2.2. Storage may be temporary or indefinite. Temporary storage is used to allow for decrease of activity, to permit regulation of the rate of release, to permit monitoring of materials of unknown degree of hazard or to await the availability of suitable transport. Indefinite storage in special places has to be provided for the more hazardous wastes for which no ultimate disposal method is available to the particular user.

8.2.3. Storage condition should meet the safety requirements for storage of sources. (Chapter 4.)

8.2.4. The storage site should not be accessible to unauthorized personnel. (Control of animals should not be overlooked.)

8.2.5. The method of storage should prevent accidental release to the surroundings.

8.2.6. Appropriate records should be kept of the storage.

8.3. DISPOSAL OF WASTES TO THE ENVIRONMENT

8.3.1. General considerations

8.3.1.1. Disposal of radioactive wastes to the environment should be made in accordance with the conditions established by the "radiological health and safety officer" and by the competent authority.

8.3.1.2. The ways in which radioactive materials may affect the environment should be carefully examined for any proposed waste disposal method.
8.3.1.3. The capacity of any route of disposal to safely accept wastes depends on evaluation of a number of factors, many of which depend on the particular local situation. By assuming unfavourable conditions with respect to all factors it is possible to set a permissible level for waste disposal which will be safe under all circumstances. This usually allows a very considerable safety factor. The real capacity of a particular route of waste disposal can only be found by a lengthy study by experts.

8.3.1.4. The small user should first try to work within restrictive limits which are accepted as being safe and which will usually provide a workable solution to the problem of waste disposal. Such a restrictive safe limit is provided by keeping the level of activity at the point of release into the environment below the permissible levels for non-occupationally exposed persons recommended by the International Commission on Radiological Protection for activity in drinking water or in air and indicated in Appendix I*. This rule should be superseded if the competent authority provides any alternative requirements or if local studies by experts provide reasonable justification for other levels.

8.3.2. Disposal to drains and sewers

8.3.2.1. The release of wastes into drains does not usually need to be considered as a direct release into the environment. Hence, a restrictive safe limit will usually be provided if the concentrations of radioactive waste material based on the total available flow of water in the system, averaged over a moderate period (daily or monthly), would not exceed the maximum permissible levels for drinking water recommended by the International Commission on Radiological Protection for individuals occupationally exposed; these are indicated in Appendix I*. This would provide a large safety factor since water from drains and sewers is not generally to be considered as drinking water. However, in situations where the contamination affects the public water supply, the final concentrations in the water supply should be to the levels set for non-occupationally exposed persons. Some present studies suggest that if the

* Subject to provisions of section 1.3.
contamination affects water used for irrigation the final concentrations in the irrigating water should be a factor of at least ten below the levels set for occupational exposure and the possible build up of activity in the irrigated lands and crops should be carefully surveyed.

Finally, prior to release of wastes to public drains, sewers and rivers, the competent authorities should be informed and consulted to ascertain that no other radioactive release is carried out in such a way that the cumulated release may result in a hazardous situation.

8.3.2.2. Radioactive wastes disposed to drains should be readily soluble or dispersible in water. Account should be taken of the possible changes of p. H. due to dilution, or other physico-chemical factors which may lead to precipitation or vaporization of diluted materials.

8.3.2.3. In general, the excreta of persons being treated by radioisotopes do not call for any special consideration. (This, however, does not apply to the unused residues of medical isotope shipments.)

8.3.2.4. Wastes should be flushed down by a copious stream of water.

8.3.2.5. The dilution of carrier-free material by the inactive element in the same chemical form is sometimes helpful.

8.3.2.6. Maintenance work on active drains within an establishment should only be carried out with the knowledge and under the supervision of the "radiological health and safety officer". Special care should be given to the possibility that small sources have been dropped into sinks and retained in traps or catchment basins.

8.3.2.7. The release of waste to sewers should be done in such a manner as not to require protective measures during maintenance work of the sewers outside the establishment, unless other agreement has been reached with the authority in charge of these sewers. The authority in charge of the sewer system outside the establishment should be informed of the release of radioactive wastes in this system; mutual discussion of the technical aspects of the waste disposal problem is desirable to provide protection without unnecessary anxiety.
8.3.3. **Disposal to the atmosphere**

8.3.3.1. Release of radioactive waste in the form of aerosols or gases into the atmosphere should conform with the requirements of the competent authority.

8.3.3.2. Subject to 8.3.3.1, concentrations of radioactive gases or aerosols at the point of release into the environment should not exceed the accepted maximum permissible levels for non-occupationally exposed persons referred to in Appendix I*. If higher levels are required and protection is based on an elevated release point from a stack, such levels can only be set after examination of local conditions by an expert.

8.3.3.3. Even if activity below permissible levels is achieved at the release point for an aerosol, a hazard or nuisance may still arise from fall-out of coarse particles. Therefore, the need for filtration should be assessed.

8.3.3.4. Used filters should be handled as solid wastes.

8.3.4. **Burial of wastes**

8.3.4.1. Burial of wastes in soil sometimes provides a measure of protection not found if the wastes are released directly into the environment. The possibilities of safe burial of waste should always be appraised by an expert.

8.3.4.2. Burial under a suitable depth of soil (about one meter) provides economical protection from the external radiation of the accumulated deposit.

8.3.4.3. A burial site should be under the control of the user with adequate means of excluding the public.

8.3.4.4. A record should be kept of disposals into the ground.

8.3.5. **Incineration of wastes**

8.3.5.1. If solid wastes are incinerated to reduce the bulk to manageable proportions, certain precautions should be taken.

8.3.5.2. The incineration of active wastes should only be carried out in equipment embodying those features of filtration
and scrubbing as may be necessary for the levels of activity to be disposed of.

8.3.5.3. Residual ashes should be prevented from becoming a dust hazard, for example by damping them with water, and should be properly dealt with as ordinary active waste.
APPENDIX I

I. DEFINITIONS. (FOLLOWED BY TABLE OF RBG VALUES P. 94)

MAXIMUM PERMISSIBLE LEVELS FOR EXPOSURE TO EXTERNAL RADIATIONS AND FOR RADIOACTIVE CONTAMINATION OF AIR AND WATER

The following data* are taken from the recommendations of the International Commission for Radiological Protection as of 1954 and October 1958 (1958 amendments were made available as a prepublication draft through the courtesy of the I. C. R. P., so that official publications of the I. C. R. P. should be consulted to confirm any important points).

I. BASIC CONCEPTS

1. The objectives of radiation protection are to prevent or minimize somatic injuries and to minimize the deterioration of the genetic constitution of the population.

Critical organs and tissues

2. The organs and tissues of the body exhibit varying degrees of radiosensitivity, and it is therefore necessary, for purposes of protection, to consider their radiosensitivity as well as the doses they receive. When this is done, some organs and tissues assume a greater importance, according to the circumstances under which they are irradiated. They are then said to be critical.

3. In the case of more or less uniform irradiation of the whole body, the critical tissues are those tissues of the body that are most radiosensitive. In this report these are taken to be the blood-forming organs, the gonads, and the lenses of the eyes.

4. In the case of irradiation more or less limited to portions of the body, the critical tissue is that tissue most likely to be damaged either because of its inherent radiosensitivity or because of a combination of radiosensitivity, localized high dose, and essentialness

* except paragraphs III. 1, III. 2.
that the tissue remain undamaged in order to preserve the well being of the body as a whole.

**Permissible dose**

5. Any departure from the environmental conditions in which man has evolved may entail a risk of possible deleterious effects. It is therefore assumed that long continued exposure to ionizing radiation additional to that due to natural radiation involves some risk. No radiation dose higher than that contributed by the natural background can be regarded as "safe". However, man cannot entirely dispense with the use of ionizing radiations, and therefore the problem in practice is to limit the radiation dose to that which involves a risk that is not unacceptable to the individual and to the population at large. This is called a "permissible dose".

6. The permissible dose for an *individual* is that dose, accumulated over a long period of time or resulting from a single exposure, which, in the light of present knowledge, carries a negligible probability of severe somatic or genetic injuries, and a limitation of any effects that may more frequently occur, to those of minor nature that would not be considered unacceptable by the exposed individual and by competent medical authorities.

7. Any severe somatic injuries (e.g. leukemia) that might result from exposure of individuals to the permissible dose would be limited to an exceedingly small fraction of the exposed group; effects such as shortening of life span, which might be expected to occur more frequently, would be very slight and would likely be hidden by normal biological variations. The permissible doses can, therefore, be expected to produce effects that could be detectable only by statistical methods applied to large groups.

8. The permissible dose for the *whole population* is limited primarily by considerations with respect to genetic effects.

9. Individual doses resulting from medical exposure are excluded from all maximum permissible doses recommended in this report.

10. The recommendations cover the following categories of exposure. In principle both the exposure of *individuals* and averages over the *whole population* has to be considered, but recommendations with regard to individual exposure are given only for the groups (A) and (B).

   **A) Occupational exposure**
B) Exposure of special groups:
   a) Non-radiation workers, who work in the vicinity of controlled areas.
   b) Those who enter controlled areas occasionally in the course of their duties, but are not regarded as radiation workers.
   c) Members of the public living in the neighbourhood of controlled areas.

C) Exposure of the population at large

D) Medical exposure

Occupational exposure

11. Exposure of an individual who normally works in a controlled area constitutes occupational exposure. Maximum permissible doses are set for the individuals in the small portion of the population that can be occupationally exposed (paragraphs 16—21). The contribution from this group to the genetic dose to the population as a whole is discussed in paragraph 35.

Exposure of special groups

12. Persons who only occasionally enter a controlled area and persons who work or reside in the vicinity of a controlled area may be exposed to radiation originating in the controlled area. They constitute groups that may include children and pregnant women as well as individuals subject to other hazards, and may in total constitute a large fraction of the whole population. For this reason the maximum permissible individual dose to these persons, is set lower than for persons occupationally exposed (paragraphs 22—26). The contribution from these groups to the genetic dose to the whole population is discussed in paragraph 35.

Exposure of the population at large

13. Members of the population at large may be exposed to radiation that cannot be related to any specific controlled area; e.g., exposure from environmental contamination and widely distributed radiation sources such as wristwatches, T.V.-sets and various applications of radioactive materials to be expected as a result of future expansion in the atomic energy field. As such exposure is not easily controlled, it will be impossible to ensure that a recommended maximum per-
missible individual dose is not exceeded in any single case. Where large numbers are involved, it will not be possible to examine the habits of every individual. The normal procedure would be to study a sample of the group involved and to set the environmental level so that no individual in the sample receives any excessive exposure. There will always remain the possibility that someone of grossly different habits from those in the observed sample may receive a higher dose than the maximum in the sample.

14. In order to facilitate planning for the anticipated increased uses of nuclear energy and other sources of radiation, it is desirable at this time to recommend a maximum for the genetic dose to the population (paragraph 33); this maximum will determine the highest average gonad exposure. Part of the recommended maximum genetic dose will have to be used for exposure of groups such as (A) and (B) and for medical exposure. The proper apportionment for exposure of the population at large must allow for both internal and external exposure (paragraphs 34 — 35).

II. MAXIMUM PERMISSIBLE DOSES

15. It is emphasized that the maximum permissible doses recommended in this section are maximum values; the Commission recommends that all doses be kept as low as practicable, and that any unnecessary exposure be avoided.

EXPOSURE OF INDIVIDUALS

Occupational Exposure

16. In any organ or tissue, the total individual dose due to occupational exposure shall comprise the dose contributed by external sources during working hours and the dose contributed by internal sources taken into the body during working hours. It shall not include any medical exposure or exposure to natural radiation. Exposure of the gonads, the blood-forming organs and the lenses of the eyes

17. The maximum permissible total dose accumulated in the gonads,
the blood-forming organs and the lenses of the eyes at any age over 18 years shall be governed by the relation:

\[ D = 5 (N-18) \]

where

- \( D \) is tissue dose in rems
- \( N \) is age in years.

18. For a person who is occupationally exposed at a constant rate from the age of 18 years, the formula implies a maximum weekly dose of 0.1 rem. It is recommended that this value be used for purposes of planning and design.

**Rate of dose accumulation**

19. To the extent the formula permits, an occupationally exposed person may accumulate the maximum permissible dose at a rate not in excess of 3 rems during any 13 consecutive weeks (i.e., in no 13 consecutive weeks shall the dose exceed 3 rems). If necessary, the 3 rems may be received as a single dose, but as the scientific knowledge of the biological effects of such exposure is scant, single doses of the order of 3 rems should be avoided as far as practicable.

**Application to special cases**

20. a) *Previous exposure history unknown.* When the previous occupational exposure history of an individual is not definitely known, it shall be assumed that he has already received the full quota permitted by the formula.

b) *Persons exposed in accordance with the former maximum permissible weekly dose.* Persons who were exposed in accordance with the former maximum permissible weekly dose of 0.3 rem and who have accumulated a dose higher than that permitted by the formula, shall be assumed to have accumulated only that dose that is permitted by the formula.

c) *Persons starting work at an age of less than 18 years.* When a person is occupationally exposed at an age of less than 18 years, the dose shall not exceed 5 rems in any one year under age 18, and the dose accumulated to age 30 shall not exceed 60 rems.

d) *Accidental high exposures.* An accidental high exposure that occurs only once in a lifetime and contributes no more than 25 rems shall be added to the dose accumulated up to the
time of the accident. If the sum then exceeds the maximum value permitted by the formula, the excess need not be included in future calculations of his accumulated dose. Accidental exposure to doses higher than 25 rems must be regarded as being potentially serious, and shall be referred to competent medical authorities for appropriate remedial action and recommendations on subsequent occupational exposure.

e) Planned emergency exposure. Emergency work involving high exposure shall be planned on the basis that the individual will not receive doses higher than one half of the accidental dose of 25 rems stipulated above, subject to the same qualifications. Women of reproductive age shall not be subjected to planned emergency exposure.

**Exposure of single organs other than the gonads, the blood-forming organs and the lenses of the eyes**

21. For exposure that is essentially restricted to portions or single organs of the body, with the exception of the gonads, the blood-forming organs and the lenses of the eyes, a higher dose than the one derived from the formula $D = 5(N-18)$ is permitted. The following recommendations are made:

a) A maximum dose of 8 rems per 13 weeks for the skin\(^*\). The dose in the skin accumulated over any 13 consecutive weeks, shall not exceed 8 rems. This recommendation now applies to all exposure of the skin, except the skin of the hands and forearms, feet and ankles. As the 8 rems are derived from an average of 0.6 rem per week, the annual dose for a 50-week year is limited to 30 rems.

b) A maximum dose of 20 rems for 13 weeks for the hands and forearms, feet and ankles. This recommendation applies to all tissues of the above mentioned extremities. As the 20 rems are derived from an average of 1.5 rems per week, the annual dose for a 50-week year is limited to 75 rems.

c) A maximum dose of 4 rems per 13 weeks for limited exposure of internal organs other than the thyroid, the gonads and the blood-forming organs. In the case of internal organs, limited exposure originates almost exclu-

\(^*\) This also applies to the thyroid, see Committee II report.
ively from radioisotopes within the body. As most planning of release of radioactive isotopes to the air and water supplies in controlled areas is made under conditions where occupational groups rather than single individuals are exposed, a formula corresponding to the one given in paragraph 17 cannot in general be applied to internal exposure. An average of 0.3 rem per week in the organ of interest is expected to be maintained under equilibrium conditions if the concentration in air or water of the relevant isotope is kept at levels given in the tables in the report of Committee II. Variations of the dose rate will occur in practice, and are permissible, provided that the dose accumulated over any 13 consecutive weeks does not exceed 4 rems. As this maximum is derived from a weekly average of 0.3 rem, the annual dose for a 50-week year is limited to 15 rems.

d) **Whole body exposure from uptake of several radioisotopes.** When the radioactive isotopes in a mixture are taken up by several organs, the combined exposure constitutes essentially whole body exposure. Accordingly, the levels of exposure will be those applicable for the gonads, the blood-forming organs and the lenses of the eyes.

**EXPOSURE OF SPECIAL GROUPS**

22. The total maximum permissible individual dose shall consist of the sum of the doses contributed by both external and internal sources. It shall not include any medical exposure or exposure to natural radiation.

*Total annual dose to the gonads, the blood-forming organs and the lenses of the eyes*

23. For any individual in the groups B (a) and B (b) (see paragraph 10), the total annual dose, including contributions from external and internal sources, to the gonads, the blood-forming organs and the lenses of the eyes, due to operation within the controlled area shall not exceed 1.5 rems, nor shall the contribution from a mixture of isotopes whose combined exposure constitutes essentially whole body exposure make the total annual dose exceed 1.5 rems. There is an exception in the case of the skin and the thyroid where an annual maximum of 3 rems is allowed.
24. The group B (c) differs from the groups B (a) and B (b) in that it contains children for whom it is considered that a lower figure, namely 0.5 rem per year, should apply. Accordingly, the presence of children in the group B (c) will require the use of a value of 0.5 rem per year for this group for purposes of planning and design.

Internal exposure of single organs

25. The individual maximum permissible dose will not be exceeded from internal exposure of any single organ, if the release of radioactive material is planned on the basis of 1/10 of the maximum permissible concentration (MPC) in air or water as given for continuous exposure in the tables in the report of Committee II.

26. Whole body exposure from uptake of several radioisotopes. When the radioactive isotopes in a mixture are taken up by several organs, the combined exposure constitutes essentially whole body exposure. Therefore, in most cases a reduction of the maximum permissible concentrations based on the exposure of single organs (see Committee II report) becomes necessary. The reduction should take into account the number and importance of the organs in question and the contribution to the whole body exposure made by radioactive material in the circulating blood and in organs other than those in which it is assumed to concentrate. In this case the total body is the critical organ and the MPC values for the individual radioisotopes are reduced so that the MPC for the mixture corresponds to an average annual dose of 0.5 rem to the total body. For a number of mixtures of radioisotopes this is equivalent to a reduction in the MPC value by a factor of 1/3 or less in addition to the factor 1/10 recommended in paragraph 25.

EXPOSURE OF POPULATIONS

General

27. Proper planning for nuclear power programmes and other peaceful uses of atomic energy on a large scale requires a limitation of the exposure of whole populations, partly by limiting the individual doses and partly by limiting the number of persons exposed.

28. This limitation necessarily involves a compromise between deleterious effects and social benefits. Consideration of genetic effects plays a major role in its evaluation. The problem has been discussed extensively in recent years and suggestions have been made by different national bodies. The Commission is aware of the
fact that a proper balance between risks and benefits cannot yet be made since it requires a more quantitative appraisal of the probable biological damage and the probable benefits than is presently possible. Furthermore, it must be realized that the factors influencing the balancing of risks and benefits will vary from country to country and that the final decision rests with each country.

29. Because of the urgent need for guidance in this regard, the Commission in the following sections suggests an interim ceiling for the exposure of the whole population. The proposed level is essentially in accordance with suggestions by other scientific groups that have studied the problem and tried to evaluate the possible biological effects. It is felt that this level provides reasonable latitude for the expansion of atomic energy programmes in the foreseeable future. It should be emphasized that the limit is not intended to represent the proper balance between possible harm and probable benefit, for reasons already mentioned.

30. On the assumption that the genetic effects are linearly related to the gonad dose and provided that no threshold dose exists, it is possible to define a population dose average that is relevant to the assessment of genetic injury to the whole population (paragraphs 31 — 32). In the case of somatic effects no such dose can easily be defined although the annual per capita dose to certain tissues or to the whole body may be relevant on the assumption of a non-threshold, linear dose-effect relation.

**Genetic Dose**

**Assessment of genetic dose**

31. The genetic dose to a population is the dose which, if it were received by each person during the reproductive period, would result in the same genetic burden to the whole population as do the actual doses received by the individuals. A permissible genetic dose is that dose, which, if it were received by each person during the reproductive period, would result in an acceptable burden to the whole population.

32. The genetic dose to a population can be assessed as the annual genetically significant dose multiplied by the mean age of childbearing, which for the purpose of these recommendations is taken to be 30 years. The annual genetically significant dose to a population is the average of the individual gonad doses, each
weighted for the expected number of children conceived subsequent to the exposure.

**Maximum permissible genetic dose**

33. It is suggested that the genetic dose (see paragraph 32) to the whole population from all sources additional to the natural background, should not exceed 5 rems plus the lowest practicable contribution from medical exposure. The background is excluded from the suggested value because it varies considerably from country to country. The contribution from medical exposure is considered separately for the same reason and also because the subject is being studied for the purpose of limiting such exposure to the minimum value consistent with medical requirements.

**Apportionment of genetic dose**

34. The suggested maximum generic dose of 5 rems in addition to the dose from medical procedures and natural background must not be used up by one single type of exposure. The proper apportionment of the total will depend upon circumstances which may vary from country to country, and the decision should, therefore, be made by national authorities.

35. In the case of internal exposure, the individual maximum permissible dose will not be exceeded for any single organ, if the concentration of the relevant isotope in air or water supplies is kept at \( \frac{1}{10} \) of maximum permissible concentration for continuous exposure as given in the tables in the report of Committee II. However, the use of the factor \( \frac{1}{10} \) does not guarantee that the apportionment of the genetic dose to the whole population is not exceeded. This apportionment shall also include external exposure. If the average concentrations in public air and water supplies are lower by a factor of \( \frac{1}{100} \) than the occupational concentrations, this would imply a genetic dose of 1.5 rems. If, further, a 25 per cent allowance is made for the contribution of external radiation, the total would be 2.0 rems.

The Commission does not wish to make any firm recommendations as to the apportionment of genetic dose of 5 rems but for guidance, gives the following apportionment as an illustration.

(A) Occupational exposure: 1.0 rem
(B) Exposure of special groups: 0.5 rem
(C) Exposure of the population at large: 2.0 rem
Reserve: 1.5 rem
Assuming that the ratio of the total population to the reproductive population is the same in all groups, the largest fraction ($\xi$) of the whole population that can be exposed to an average annual dose $D_1$ is given by the equation:

$$\xi \cdot 30 \cdot D_1 = D_{30}$$

where $D_{30}$ is the apportionment of the genetic dose to the $i^{th}$ exposure group, and the average annual dose within the group can be expressed as a fraction of the maximum permissible individual annual dose; i.e.

$$D_1 = F \cdot D_i$$

**Occupational exposure.** Assigning 1.0 rem to occupational exposure would mean that 0.7 per cent of the whole population could accumulate the maximum permissible occupational gonad dose of 60 rems by age 30. It is very unlikely that such a figure will be approached in the foreseeable future. At the present time, the number of persons occupationally exposed in technologically developed countries is about 0.1 to 0.2 per cent of the population, and most of these persons receive doses which are considerably less than the maximum permissible doses.

**Exposure of special groups.** Since the contribution from the special groups is largely due to group B (c), an apportionment of 0.5 rem for the special groups would imply that about 3 per cent could be exposed to the maximum permissible individual annual gonad doses for these groups. The allowable size of these groups increases inversely with the average dose within the groups; thus if this dose were only 10 per cent of the maximum individual doses, the groups could amount to 30 per cent of the whole population, very much larger than is likely to occur.

**Exposure of the population at large.** The apportionment of 2.0 rems (with a long-term reserve of 1.5 rems for possible eventualities) for the genetic exposure of the population at large is intended for planning purposes in the development of nuclear energy programmes (with the associated waste disposal problems and more extensive uses of radiation sources).

**Somatic Dose**

36. No specific recommendations are made as to the maximum permissible "somatically" relevant dose to the population. However, it is expected that the limitation of the individual doses recommended in paragraphs 16 — 27 will keep the average external dose in any tissue at such levels that the number of injuries that could possibly occur in a population would be very small.
37. Although no population dose can be defined for specific organs or even for the whole body with regard to somatic effects, it is expected that 1/100 of the maximum permissible concentrations for continuous occupational exposure applied to any radioisotope or mixture of radioisotopes would be a safe value to use for planning purposes until better information is obtained. In the case where organs other than the gonads are the critical organs, the equivalent procedure is to apply a factor of 1/30 to the MPC values for continuous occupational exposure based upon the dose rate of 0.3 rem/week in a single organ, and a reduction by a factor of 1/3 to allow for the fact that a mixture of radioisotopes will result in the exposure of several organs or the whole body.

III. PERMISSIBLE CONCENTRATIONS OF RADIOACTIVE ISOTOPES IN AIR AND WATER

III.1. In the recommendations of 1954 the maximum permissible weekly dose for occupational exposure was established as 0.3 rem and the maximum permissible concentrations listed in the table below are calculated, in principle, on the assumption that under continuous exposure to such concentrations this value of dose would not be surpassed in the whole body or in any critical organ.

III.2. In the recommendations of 1958 this table was preserved as a basis for calculations. However, in accordance with the newly recommended maximum permissible doses for different organs and for different categories of exposure, the current maximum permissible concentrations in different circumstances must be calculated according to the statements in paragraphs 21 c and 21 d, 23, 25, 26, 35 and 37.

III.3. Extracts from Table C. VIII of I.C.R.P. 1954 recommendations. The following table is taken from the 1954 recommendations of Sub-Committee II of the I.C.R.P. which stated: “The purpose of this report is to list recommended values of maximum body burden and maximum concentration in air and water of the various radioisotopes that are considered permissible for occupational exposure. Appropriate values depend upon the physical condition of the individual exposed, the physical and chemical properties of the radioactive
material and the method of body intake — ingestion, inhalation, through wounds or direct absorption through the skin. Therefore, in order to limit the scope of this international report on internal dose, only general maximum permissible concentration values for soluble or insoluble compounds are considered; the only methods of body intake referred to in the tables are ingestion and inhalation; and all calculations are referred to the so-called 'standard man' in whom all characteristics are assumed to be those representative of the average man.”

Furthermore it is stated:

“The values in Table C VIII are based on continuous exposure. Since many of the occupational exposures would last only a fraction of the week (i.e. 8 hours/day, during which time it is assumed the body intake of air and water is half the daily requirement, 5 days/week and 50 weeks/year), the maximum permissible concentration values in Table C VIII could be multiplied by a factor of 3 for the usual occupational exposure (i.e. $2 \times \frac{7}{8} \times \frac{52}{50} = 3$).”
### III.4. MAXIMUM PERMISSIBLE CONCENTRATIONS IN AIR AND WATER FOR CONTINUOUS EXPOSURE

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<thead>
<tr>
<th>Radioisotope</th>
<th>Critical organ</th>
<th>Maximum permissible concentration</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>In Water (μc/cc.)</td>
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<tr>
<td>H³</td>
<td>Total body</td>
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<tr>
<td>Be⁷</td>
<td>Bone</td>
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</tr>
<tr>
<td>C¹⁴</td>
<td>Fat</td>
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<td>Sc⁴⁶</td>
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<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Critical organ</th>
<th>Maximum permissible concentration</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>In Water (µc/cc.)</strong></td>
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<tr>
<td>Co⁶⁰</td>
<td>Liver</td>
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</tr>
<tr>
<td>Ni⁵⁹</td>
<td>Liver</td>
<td>$4 \times 10^{-3}$</td>
</tr>
<tr>
<td>Cu⁶⁴</td>
<td>Liver</td>
<td>$5 \times 10^{-3}$</td>
</tr>
<tr>
<td>Zn⁶⁵</td>
<td>Bone</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Ga⁷²</td>
<td>Bone</td>
<td>$5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Ge⁷¹</td>
<td>Kidneys</td>
<td>$2 \times 10^{-2}$</td>
</tr>
<tr>
<td>As⁷⁶</td>
<td>Kidneys</td>
<td>$2 \times 10^{-4}$</td>
</tr>
<tr>
<td>Rb⁸⁶</td>
<td>Muscle</td>
<td>$3 \times 10^{-3}$</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Critical organ</th>
<th>Maximum permissible concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In Water (µc/cc.)</td>
</tr>
<tr>
<td>Sr$^{89}$</td>
<td>Bone</td>
<td>$7 \times 10^{-5}$</td>
</tr>
<tr>
<td>Sr$^{90}$ + Y$^{90}$</td>
<td>Bone</td>
<td>$8 \times 10^{-7}$</td>
</tr>
<tr>
<td>Y$^{91}$</td>
<td>Bone</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>Zr$^{95}$ + Nb$^{95}$</td>
<td>Bone</td>
<td>$6 \times 10^{-4}$</td>
</tr>
<tr>
<td>Nb$^{95}$</td>
<td>Bone</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Mo$^{99}$</td>
<td>Bone</td>
<td>$3 \times 10^{-3}$</td>
</tr>
<tr>
<td>Tc$^{99}$</td>
<td>Kidneys</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Ru$^{106}$ + Rh$^{106}$</td>
<td>Kidneys</td>
<td>$10^{-4}$</td>
</tr>
<tr>
<td>Rh$^{105}$</td>
<td>Kidneys</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Pd$^{103}$ + Rh$^{103}$</td>
<td>Kidneys</td>
<td>$5 \times 10^{-3}$</td>
</tr>
<tr>
<td>Ag$^{105}$</td>
<td>Liver</td>
<td>$4 \times 10^{-4}$</td>
</tr>
<tr>
<td>Ag$^{111}$</td>
<td>Liver</td>
<td>$5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Cd$^{109}$ + Ag$^{109}$</td>
<td>Liver</td>
<td>$7 \times 10^{-2}$</td>
</tr>
<tr>
<td>Sn$^{113}$</td>
<td>Bone</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Te$^{127}$</td>
<td>Kidneys</td>
<td>$7 \times 10^{-4}$</td>
</tr>
<tr>
<td>Radioisotope</td>
<td>Critical organ</td>
<td>Maximum permissible concentration</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In Water</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>($\mu$c/cc.)</td>
</tr>
<tr>
<td>Te$^{129}$</td>
<td>Kidneys</td>
<td>$2 \times 10^{-4}$</td>
</tr>
<tr>
<td>I$^{131}$</td>
<td>Thyroid</td>
<td>$6 \times 10^{-5}$</td>
</tr>
<tr>
<td>Xe$^{133}$</td>
<td>Total body</td>
<td>$4 \times 10^{-3}$</td>
</tr>
<tr>
<td>Xe$^{135}$</td>
<td>Total body</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Cs$^{137}$ + Ba$^{137}$</td>
<td>Muscle</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Ba$^{140}$ + La$^{140}$</td>
<td>Bone</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>La$^{140}$</td>
<td>Bone</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>Ce$^{144}$ + Pr$^{144}$</td>
<td>Bone</td>
<td>$10^{-4}$</td>
</tr>
<tr>
<td>Pr$^{143}$</td>
<td>Bone</td>
<td>$5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Pm$^{147}$</td>
<td>Bone</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Sm$^{151}$</td>
<td>Bone</td>
<td>$8 \times 10^{-3}$</td>
</tr>
<tr>
<td>Eu$^{154}$</td>
<td>Bone</td>
<td>$4 \times 10^{-4}$</td>
</tr>
<tr>
<td>Ho$^{166}$</td>
<td>Bone</td>
<td>$5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Tm$^{170}$</td>
<td>Bone</td>
<td>$5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Lu$^{177}$</td>
<td>Bone</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Radioisotope</td>
<td>Critical organ</td>
<td>Maximum permissible concentration</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In Water (µc/cc.)</td>
</tr>
<tr>
<td>Ta$^{152}$</td>
<td>Liver</td>
<td>$5 \times 10^{-4}$</td>
</tr>
<tr>
<td>W$^{181}$</td>
<td>Bone</td>
<td>$7 \times 10^{-4}$</td>
</tr>
<tr>
<td>Re$^{188}$</td>
<td>Thyroid Skin</td>
<td>$2 \times 10^{-5}$</td>
</tr>
<tr>
<td>Ir$^{192}$</td>
<td>Kidneys Spleen</td>
<td>$3 \times 10^{-3}$</td>
</tr>
<tr>
<td>Ir$^{192}$</td>
<td>Kidneys Spleen</td>
<td>$5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Pt$^{191}$</td>
<td>Kidneys</td>
<td>$7 \times 10^{-4}$</td>
</tr>
<tr>
<td>Pt$^{193}$</td>
<td>Kidneys</td>
<td>$9 \times 10^{-4}$</td>
</tr>
<tr>
<td>Au$^{196}$</td>
<td>Liver Kidneys</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Au$^{198}$</td>
<td>Liver Kidneys</td>
<td>$6 \times 10^{-4}$</td>
</tr>
<tr>
<td>Au$^{199}$</td>
<td>Liver Kidneys</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Tl$^{200}$</td>
<td>Muscle</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Tl$^{201}$</td>
<td>Muscle</td>
<td>$9 \times 10^{-3}$</td>
</tr>
<tr>
<td>Tl$^{202}$</td>
<td>Muscle</td>
<td>$5 \times 10^{-3}$</td>
</tr>
<tr>
<td>Tl$^{204}$</td>
<td>Muscle</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Pb$^{205}$</td>
<td>Bone</td>
<td>$2 \times 10^{-3}$</td>
</tr>
<tr>
<td>Radioisotope</td>
<td>Critical organ</td>
<td>Maximum permissible concentration</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In Water (µc/cc.)</td>
</tr>
<tr>
<td>Pb$^{210}$ + dr.</td>
<td>Bone</td>
<td>$2 \times 10^{-6}$</td>
</tr>
<tr>
<td>Po$^{210}$</td>
<td>(sol.) Spleen (insol.) Lungs</td>
<td>$3 \times 10^{-6}$</td>
</tr>
<tr>
<td>At$^{211}$</td>
<td>Thyroid</td>
<td>$3 \times 10^{-6}$</td>
</tr>
<tr>
<td>Rn$^{220}$ + dr.</td>
<td>Lungs</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>Rn$^{222}$ + dr.</td>
<td>Lungs</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>Ra$^{226}$ + 55% dr.</td>
<td>Bone</td>
<td>$4 \times 10^{-8}$</td>
</tr>
<tr>
<td>Ac$^{227}$ + dr.</td>
<td>Bone</td>
<td>$3 \times 10^{-6}$</td>
</tr>
<tr>
<td>Th− natural</td>
<td>Bone (insol.) Lungs</td>
<td>$5 \times 10^{-7}$</td>
</tr>
<tr>
<td>Th$^{234}$ + Pa$^{234}$</td>
<td>Bone</td>
<td>$2 \times 10^{-4}$</td>
</tr>
<tr>
<td>U− natural</td>
<td>(sol.) Kidneys (insol.) Lungs</td>
<td>$2 \times 10^{-8}$</td>
</tr>
<tr>
<td>U$^{233}$</td>
<td>(sol.) Bone (insol.) Lungs</td>
<td>$3 \times 10^{-6}$</td>
</tr>
<tr>
<td>Pu$^{239}$</td>
<td>(sol.) Bone (insol.) Lungs</td>
<td>$3 \times 10^{-6}$</td>
</tr>
<tr>
<td>Am$^{241}$</td>
<td>Bone</td>
<td>$3 \times 10^{-6}$</td>
</tr>
<tr>
<td>Cm$^{242}$</td>
<td>Bone</td>
<td>$2 \times 10^{-6}$</td>
</tr>
<tr>
<td>Any fission mixture (beta, gamma)</td>
<td></td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>Any mixture of alpha emitters</td>
<td></td>
<td>$10^{-7}$</td>
</tr>
</tbody>
</table>
NOTA: 1) *Unidentified radioisotopes*

The last two values listed in Table C. VIII are for "any fission mixture (β, γ)" and "any mixture of α emitters". These values are convenient to use when the identity of the radioactive contaminant has not been established. They are safe for use for short periods of time — a few months — regardless of the radioactive contaminant. If the gross β, γ and α counts of air and water samples do not exceed these values, their use may obviate the necessity for expensive and time-consuming radiochemical analyses. These values are safe for indefinite use with exceptions as follows: (1) the safety factor of 10 mentioned previously should be considered when the values are applied to large populations, and (2) a few radioisotopes have lower values, namely:

(a) $10^{-7}$ μc/c.c. of water is safe for any mixture of β, γ emitters, and all α emitters except $^{236}$Ra.
(b) $10^{-9}$ μc/c.c. of air is safe for any mixture of β, γ emitters except $^{90}$Sr.
(c) $5 \times 10^{-12}$ μc/c.c. of air is safe for any mixture of α, emitters except $^{239}$Pu and $^{227}$Ac.

2) *Toxicity*

A radioelement becomes a problem of chemical toxicity rather than one of radiation hazard when the maximum permissible values based on chemical toxicity are smaller than the maximum permissible values based on the radiation hazard. In all cases in Table C. VIII, with possible exception of uranium — see reference (e) — the specific activities are so high that the radiation hazard is of primary concern.

*Note (c)* The original values were based on chemical toxicity. The present values are based on radiation exposure and are considered to be safe from the standpoint of chemical toxicity.
IV. DEFINITIONS

(as given in 1954 I.C.R.P. recommendations)

Absorbed dose: of any ionizing radiation: amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It shall be expressed in rads. (See Recommendations of I.C.R.U., Copenhagen, 1953.)

Curie: A unit of radioactivity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is $3.700 \times 10^{10}$. Denoted by "c".
Microcurie (\(\mu\)c): 1/1,000,000 curie.
Millicurie (mc): 1/1000 curie.

Rad: Unit of absorbed dose. It is 100 ergs per gramme.
(See "Absorbed dose".)
Millirad (mrad): 1/1000 rad.


Röntgen (r): Unit of dose of X and \(\gamma\) rays, but not other ionizing radiation. Defined as below:
"The röntgen shall be the quantity of X- or \(\gamma\)-radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign." (It becomes increasingly difficult to measure the dose in röntgens as the quantum energy of X- or \(\gamma\)-radiation approaches very high values. The unit may, however, be used for most practical purposes for quantum energies up to 3 MeV. See I.C.R.U. Recommendations.)

Rem: The rem is the absorbed dose of any ionizing radiation which has the same biological effectiveness as one rad of X-radiation with average specific ionization of 100 ion pairs per micron of water, in terms of its air equivalent, in the same region.
A dose in rems is equal to the dose in rads multiplied by the appropriate R.B.E.
The following values of R.B.E. for all the critical organs according to the value of the average specific ionizations occurring in the critical organ in which it is highest, are recommended for the determination of permissible tissue doses in rads from external sources by the relation:

\[
\frac{\text{Permissible dose in rems}}{\text{R.B.E.}} = \text{Permissible dose in rads}
\]

The specific ionization is expressed in ion pairs per micron of water in terms of its air equivalent.

R.B.E. is expressed in terms of the pertinent biological effectiveness of ordinary X rays taken as one (average specific ionization of 100 ion pairs per micron of water, or linear energy transfer of 3.5 keV per micron of water).

1. X rays, electrons and positrons of any specific ionization

   \[\text{R.B.E.} = 1\]

2. Heavy ionizing particles

<table>
<thead>
<tr>
<th>Average specific ionization (ion pairs per micron of water)</th>
<th>R.B.E.</th>
<th>Average linear energy transfer to water (keV per micron)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 or less</td>
<td>1</td>
<td>3.5 or less</td>
</tr>
<tr>
<td>100 to 200</td>
<td>1 to 2</td>
<td>3.5 to 7.0</td>
</tr>
<tr>
<td>200 to 650</td>
<td>2 to 5</td>
<td>7.0 to 23</td>
</tr>
<tr>
<td>650 to 1500</td>
<td>5 to 10</td>
<td>23 to 53</td>
</tr>
<tr>
<td>1500 to 5000</td>
<td>10 to 20</td>
<td>53 to 175</td>
</tr>
</tbody>
</table>

For practical purposes, an R.B.E. of 10 is applicable to fast neutrons and protons up to 10 MeV and an R.B.E. of 20 to heavy recoil nuclei for whole-body irradiation and the most sensitive critical organs. (See report of Sub-Committees IV and V.)

*Extension to all ionizing radiations:*

For exposure to any ionizing radiation, the respective permissible weekly doses (or total doses in a period of time, as the case may be) for the different tissues and organs of the body expressed in rems shall be numerically equal to the appropriate permissible X-ray doses expressed in rads.
### APPENDIX II

**MAXIMUM PERMISSIBLE LEVELS FOR SURFACE CONTAMINATION**

The following data are given as examples of various maximum permissible levels for surface contamination used in different countries.

I


<table>
<thead>
<tr>
<th>Radiotoxicity of isotopes</th>
<th>Equipment and working places</th>
<th>Clothing</th>
<th>Skin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in “inactive” areas</td>
<td>in “active” areas</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>(10^{-5}) (\mu c/cm^2)</td>
<td>(10^{-4}) (\mu c/cm^2)</td>
<td>(10^{-5}) (\mu c/cm^2)</td>
</tr>
<tr>
<td>(\beta)-emitters:</td>
<td>(10^{-4}) (\mu c/cm^2)</td>
<td>(10^{-3}) (\mu c/cm^2)</td>
<td>(10^{-4}) (\mu c/cm^2)</td>
</tr>
<tr>
<td>High</td>
<td>(10^{-4}) (\mu c/cm^2)</td>
<td>(10^{-3}) (\mu c/cm^2)</td>
<td>(10^{-4}) (\mu c/cm^2)</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* The classification of radiotoxicities of isotopes is similar to that given in this manual.

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### IV


<table>
<thead>
<tr>
<th>Radiotoxicity of isotopes</th>
<th>Skin, clothing, bedding, laboratory tools, glassware</th>
<th>Surfaces of laboratory walls, floors, work benches, hoods, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high \ High</td>
<td>Radiation level close to background:</td>
<td>Radiation level close to background:</td>
</tr>
<tr>
<td></td>
<td>0.1 m. rep/hr \ in ( \beta ) or ( \gamma ) ( \times 100 ) cpm* \ radiation</td>
<td>0.1 m. rep/hr \ in ( \beta ) or ( \gamma ) ( \times 100 ) cpm* \ radiation</td>
</tr>
<tr>
<td>Moderate \ Low</td>
<td>1 m. rep/hr \ in ( \beta ) or ( \gamma ) ( \times 1000 ) cpm* \ radiation</td>
<td>1 m. rep/hr \ in ( \beta ) or ( \gamma ) ( \times 1000 ) cpm** \ radiation</td>
</tr>
</tbody>
</table>

**Note:**

1. The classification of radiotoxicity of isotopes is similar to that given in Paragraph II.
2. * As measured on contact with a thin-window Geiger-Müller counter having a flat plate area of 2 square inches.
3. ** It is indicated however that: “In order to keep the general background in the working area low enough for satisfactory instrument operation, it is advisable to decontaminate large areas to a level of 0.1 m. rep/hr.”

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<table>
<thead>
<tr>
<th></th>
<th>Number of particles emitted in 1 minute per 150 cm²</th>
<th>( \alpha )-contamination</th>
<th>( \beta )-contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>before decontamination</td>
<td>after* decontamination</td>
<td>before decontamination</td>
</tr>
<tr>
<td>Hands</td>
<td>75</td>
<td>Background</td>
<td>5000</td>
</tr>
<tr>
<td>Special underwear &amp; towels</td>
<td>75</td>
<td>Background</td>
<td>5000</td>
</tr>
<tr>
<td>Cotton overalls</td>
<td>500</td>
<td>100</td>
<td>25000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Number of particles emitted in 1 minute per 150 cm²</th>
<th>( \alpha )-contamination</th>
<th>( \beta )-contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>before decontamination</td>
<td>after* decontamination</td>
<td>before decontamination</td>
</tr>
<tr>
<td>Film plastic clothing</td>
<td>500</td>
<td>200</td>
<td>25000</td>
</tr>
<tr>
<td>Gloves' surface</td>
<td>500</td>
<td>100</td>
<td>25000</td>
</tr>
<tr>
<td>Special shoes' surface</td>
<td>500</td>
<td>200</td>
<td>25000</td>
</tr>
<tr>
<td>Working surfaces and equipment</td>
<td>500</td>
<td>200</td>
<td>25000</td>
</tr>
</tbody>
</table>

* Contaminated objects should not be put back to use before contamination levels have been lowered down to these limits.
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