RADIATION PROTECTION

Recommendations of the International Commission on Radiological Protection

ICRP PUBLICATION 5

Report of Committee V

on the

Handling and Disposal of Radioactive Materials in Hospitals and Medical Research Establishments

(1964)

PUBLISHED FOR
The International Commission on Radiological Protection
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PREFACE

This report was begun under the Chairmanship of the late Dr. A. J. Cipriani, and was completed by the 1959–1962 Committee under the Chairmanship of Dr. C. P. Straub.

For the initial draft this Committee is indebted to Drs. A. J. Cipriani, A. Key and E. A. Watkinson, members of the 1953–1956 Committee. Members of the Committees who assisted in the preparation of the report submitted to the Commission included the following:

1953–1956

A. J. Cipriani, *Chairman*	(Canada)
H. P. Jammet	(France)
A. Key	(Great Britain)
W. G. Marley	(Great Britain)
E. E. Pochin	(Great Britain)
E. H. Quimby	(U.S.A.)
C. P. Straub	(U.S.A.)
E. A. Watkinson	(Canada)
F. W. Western	(U.S.A.)

1956–1959

C. P. Straub, *Chairman*	(U.S.A.)
H. P. Jammet	(France)
W. G. Marley	(Great Britain)
C. A. Mawson	(Canada)
A. Perussia	(Italy)
E. E. Pochin	(Great Britain)
E. H. Quimby	(U.S.A.)
F. D. Sowby	(Canada)
F. Western	(U.S.A.)
G. G. Robeck *Technical Secretary*	(U.S.A.)

1959–1962

C. P. Straub, *Chairman*	(U.S.A.)
L. R. Donaldson	(U.S.A.)
H. J. Dunster	(Great Britain)
H. P. Jammet	(France)
A. W. Kenny	(Great Britain)
C. A. Mawson	(Canada)
A. Perussia	(Italy)
E. H. Quimby, (*Resigned* 1961)	(U.S.A.)
F. D. Sowby	(Canada)
E. G. Struxness	(U.S.A.)
F. Western	(U.S.A.)

The final revision has been undertaken by Mr. W. Binks (Great Britain). This publication also contains a reprint of the Commission's general recommendations, as amended to 1962.

REPORT OF COMMITTEE V

ON THE

HANDLING AND DISPOSAL OF RADIOACTIVE MATERIALS IN HOSPITALS AND MEDICAL RESEARCH ESTABLISHMENTS

INTRODUCTION

(1) Since it is the Commission's wish to maintain fully its traditional contact with medical radiology and to fulfil its responsibilities to the medical profession, it is appropriate that the Commission should give general guidance on the precautions to be taken in the handling and disposal of radioactive materials by hospitals and medical research establishments.

(2) By utilizing the practices outlined in this report, it should in general be possible to maintain radiation doses below the maximum permissible levels recommended by the Commission. The national regulatory authorities should, however, draw up the necessary standards and control procedures.

(3) The Commission's Recommendations* refer to the following three categories† of exposed individuals:

First category: individuals who are occupationally exposed to radiation.

Second category: adults who work in the vicinity of controlled areas or who enter controlled areas occasionally in the course of their duties but who are not themselves employed on work involving exposure to radiation.

Third category: individual members of the population at large (including persons living in the neighbourhood of controlled areas).

In addition, the Commission gives separate recommendations about the exposure of the population as a whole.

(4) The present report is concerned with the following aspects of handling and disposing of radioactive materials as they relate to hospitals and small laboratories:

(*a*) the facilities to be provided in isotope laboratories and clinics and in wards and operating theatres;

(*b*) the procedures to be adopted in handling, storing and transporting radioactive materials;

(*c*) the procedures to be adopted in the safe disposal of radioactive waste products and contaminated materials.

(5) In the use of radioactive materials, two types of problems arise for which effective control must be provided. First, there is the health hazard to the worker from external sources and internally deposited radioactive materials, and to the people outside controlled areas‡ due to the transport and release of radioactive materials. Second, there is the contamination hazard which may adversely affect the results of the scientific work in progress and the future use of the building.

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* See paragraph 36 of the Commission's recommendations at the end of this report.

† It should be noted that exposures within the first two categories defined here correspond to the two classes of exposure used in the International Labour Office's Radiation Protection Convention, namely, (1) workers directly engaged in radiation work and (2) workers not directly engaged in radiation work.

‡ See paragraphs 70d, 71 and 72 of Part 4 of the Commission's recommendations at the end of this report.

(6) In the past, radiation protection has been concerned mainly with protection of the worker and maintenance of a safe working environment. Thus, the emphasis has been on the individual as a worker, and the agencies having a responsibility in occupational health and a safe working environment were able to exercise the necessary degree of control over the industrial application and use of radioactive materials. With an expanding programme, the probability of exposing larger segments of the population to radioactive materials increases. The responsibilities for control in this area will vary, according to whether the materials are in transit or whether they are discharged into the atmosphere, ground sewerage system, or water course. Since, in most countries, different sections of governmental administration are responsible for these provisions, co-ordination is necessary to ensure that the total radiation dose to individuals and to the population does not exceed prescribed limits.

(7) In general, the standard of precautions required in the handling of radioactive materials depends on a large number of factors. As far as practicable, these factors have been indicated in the individual recommendations of this report. Some generalization has, however, been inevitable, and the recommendations must be interpreted and applied with judgement. In particular, some relaxations can properly be made when only very small amounts or concentrations of radioactive materials are being used.

(8) Although the recommendations are primarily directed at the control of radiation hazards in institutions, the Commission believes they should be applied, as far as is reasonably practicable, by all medical practitioners and medical research workers.

RESPONSIBILITY FOR RADIATION SAFETY MEASURES

(9) The authority having administrative control of an establishment will normally be responsible for the radiation safety of the operations as they affect its employees and the members of the public.

(10) In order to ensure that its responsibility is effectively met, the controlling authority should appoint one or more radiation protection officers, and also a suitably qualified medical adviser, to exercise medical supervision of the staff concerned. The work of the radiation protection officer(s) should include review of new designs for installations and equipment, review of programmes of work and advice on radiation problems.

(11) In each department in which radioactive materials are used, a radiation safety officer should be appointed from among the full-time employees of the institution concerned, to ensure that the radiation safety rules laid down by the controlling authority are carried out.

(12) The controlling authority shall ensure that all members of the staff concerned are adequately instructed about the radiation hazards they may meet and about the local radiation safety rules, including emergency procedures.

(13) Those working with radioactive materials shall be made aware of their duty to protect themselves and others from radiation hazards arising from their work. They, and their employers, should appreciate the consequences of a careless attitude toward radiation protection provisions. The general practice should be to work as far below the maximum permissible levels as is reasonably practicable. The application of the relevant precautions becomes more important with the larger amounts of radioactive material but should be applied even in dealing with low levels of radioactivity, since good working habits are essential. Bad example and careless working habits may unnecessarily expose associates or contaminate facilities outside the immediate radiation area.

MEDICAL EXAMINATIONS

(14) The functions of the medical adviser are:

(*a*) to carry out pre-employment medical examinations of workers who are directly engaged in radiation work. The purpose of a pre-employment examination is to establish the " normal " health status of an individual at the time of employment, firstly to assess his fitness to perform his duties without danger to himself or to others and secondly to provide a base line against which any subsequent change may be evaluated;

(*b*) to assess continuing fitness and to detect any deterioration in health;

(*c*) to advise on arrangements for first-aid treatment of radiation accident cases; and

(*d*) to make arrangements with appropriate hospitals for remedial treatment of cases following over-exposure.

(15) Medical examinations should be performed at a frequency depending on the conditions of work.

(16) The medical adviser may, at his discretion, require a complete blood count or any other special examination as part of the pre-employment medical examination or of any subsequent medical examination.

(17) When a person has received doses in excess of those permitted, or has an open wound contaminated with radioactive material, the medical adviser should decide whether it is necessary to carry out a medical examination, to arrange for remedial treatment or to recommend to the controlling authority that the person be suspended from employment, and for what period of time, as a worker directly engaged in radiation work.

PERSONNEL MONITORING

External Radiation

(18) Doses received as a result of occupational exposures shall be systematically checked with appropriate instruments to ensure that the maximum permissible doses are not exceeded and to make it possible to keep individual cumulative dose records. It should not be forgotten that, in handling sources, the dose to fingers and hands may be much more significant than the whole-body dose; in such cases, films or ionization chambers should, if practicable, be worn on the fingers or wrists as well as on the body. If these cannot be worn during specific operations, practice runs should be made which permit assessment of the actual exposures to the fingers and hands.

(19) It is the responsibility of the individual concerned to wear the supplied monitoring devices during the whole time that he may be exposed to radiation.

(20) Assessments should be made of the doses likely to be received by workers not directly engaged in radiation work (" second category "—paragraph 3). In the majority of cases, individual monitoring will prove to be unnecessary but occasional check monitoring will be desirable.

Internal Radiation

(21) It is sometimes necessary to make regular evaluations, by appropriate physical or chemical methods, of the amounts of various radionuclides which accumulate within the body of a worker, following intake by inhalation or ingestion or entry through wounds or absorption through the skin. Available information and methods permit meaningful estimates of body burden and of dose from internal radiation for only a small number of radionuclides. Specialist advice should be obtained on the evaluation of body burdens.*

(22) In a limited number of places, specialized equipment is available to estimate the total body burden of gamma-emitting radionuclides or of amounts of negative or positive beta-emitters large enough to produce measurable amounts of Bremsstrahlung or of annihilation radiation. For other materials, estimates are largely dependent upon a knowledge of relationships between body burden and the occurrence of the radionuclide in the blood stream or in excreta. For this purpose, concentrations in urine are most commonly measured, but in some cases examinations of the faeces may be more meaningful.

* The Commission has established a Task Group of Committee 4 to prepare general guidance on this subject.

(23) Sample-collection techniques defined by the examining laboratory should be followed. If the examination is called for as the result of a particular incident, the nature and time of the incident should be recorded insofar as they are known.

Contamination of Skin, Hair and Clothing

(24) In addition to personnel monitoring of external radiation by means of film badges or pocket ionization chambers, the levels of radioactive contamination of the skin, hair and clothing should, where appropriate, be checked regularly so that procedures for dealing with any excess contamination can be put into operation.

Records of Personal Radiation Doses

(25) Provision shall be made for maintaining a separate record of all measured doses received by workers directly engaged in radiation work (" first category "—paragraph 3). The retention of these records may be of considerable value in case of possible late effects. In some countries it is the practice to retain the records for 30 years after the last entry.

ENVIRONMENTAL MONITORING*

Monitoring Prior to use of Controlled Area

(26) Before routine operations with radioactive materials commence, the working environment should be surveyed to determine the adequacy of facilities, equipment and safety precautions, and to provide a base line from which to judge the adequacy of radiation controls within the controlled area.

(27) When it is envisaged that the environment outside the controlled area may be significantly altered with respect to radiation hazards, adequate surveys should be made of the level of background radiation and of the radioactivity of air, soil or water. This will aid the identification of the operation responsible for any significant increase of the background radiation or the contamination of the area.

Routine Monitoring

(28) Regular radiation surveys should be made, at a frequency dictated by the operations within the controlled area, to determine the adequacy of safety procedures. Such surveys should include checks of the facilities and equipment (shielding, storage, hoods, respirators, ventilation, etc.) and of the working techniques and, where there is any reasonable probability of a significant radiation hazard existing, of the vicinity of the controlled area. A radiation survey should also be carried out if personnel monitoring tests indicate that the doses received exceed, or are likely to exceed, the maximum permissible levels, and if enquiries have failed to reveal the cause.

(29) If any survey indicates that, under normal operating conditions, personnel may receive doses in excess of those permitted or of those judged necessary for the work, the radiation protection officer should indicate the action to be taken to rectify the situation.

(30) Records should be maintained of the general results of all surveys and the detailed results of surveys following major changes in the radiation pattern.

GENERAL AIMS AND PROCEDURES FOR WORK WITH SEALED SOURCES‡

(31) Sealed sources present potential hazards of external exposure from beta, gamma and sometimes neutron radiation, and of internal exposure resulting from inhalation and ingestion of radio-

* The Commission has established a Task Group of Committee 4 to prepare general guidance on this subject.

‡ Additional details relating to protection from sealed sources will be found in ICRP Publication 3 (Report of Committee III on Protection Against X-Rays up to Energies of 3 MeV and Beta and Gamma-rays from Sealed Sources).

active material that may escape from the source. Precautions should therefore be taken to guard against both external and internal radiation hazards, although only rarely will the internal hazard arise.

(32) Wherever practicable, sealed sources should be labelled and thereby be identifiable as to the nature and activity of the radioactive material contained. Such labelling is not necessary if a source is considered to present no external or internal radiation hazard. For example, sealed sources could normally be regarded as not requiring labelling if they contain not more than 1 μCi of Group 1 radionuclides (see Table 1) or up to 100 μCi of other Groups of radionuclides and have a dose rate not exceeding 10 mrad/h (measured in air) at or near the surface of a container which emits beta or gamma radiation, or have a " dose equivalent" rate not exceeding 10 mrem/h at or near the surface of a container which emits neutrons.

(33) A separate room should be provided for the " make-up " and cleaning of sources and applicators and should be adequately ventilated. It should be occupied only when such work is in progress.

(34) The number and position of removable sealed sources in or on patients receiving treatment should be regularly checked and dressings from such patients should not be disposed of until all the sources used have been accounted for. As an additional precaution, dirty dressings and excreta may be monitored.

External Radiation

(35) Whether the source is in use or in storage*, steps should be taken to ensure that over-exposure of people cannot take place in normal circumstances. Sufficient shielding and working distance should be provided for this purpose. Exposure can also be limited by controlling the working time spent in the radiation field. The radiation dose received by the operator often depends critically on the working procedure adopted. The specifications of these procedures should, therefore, form part of the protective measures. Warning signs and barriers may have to be erected to prevent unauthorised entry into significant radiation fields.

(36) Sealed sources should never be picked up with the fingers. They should be manipulated with appropriate handling equipment or implant instruments. Handling equipment should be easy and convenient to use; cumbersome and heavy tools should be avoided since the longer time required to manipulate them may result in needless exposure. The sources themselves should be so designed that they can be quickly and easily cleaned. In certain types of work, particularly in the making up of medical applicators, experienced operators occasionally receive high doses even when practicable shielding and remote handling equipment are used. With properly trained, experienced operators, it is possible in general to keep the dosage below the maximum permissible level. In cases where it becomes necessary to institute a rota system of duties in order to avoid over-exposure of personnel, both the procedure and design should be reviewed.

(37) It should be appreciated that sealed sources containing pure β-ray emitters may emit Bremsstrahlung or characteristic X-rays or annihilation radiation. Any hazard from such radiations should be evaluated and the necessary precautions taken. Since some β-ray emitters are also γ-ray emitters, they should be protected as such (see ICRP Publication 3).

(38) A source intended for use in β-ray therapy requires a thin " window ". When the source is not in use, the window should be adequately shielded to stop all β-rays. When it is necessary to clean the window, care should be taken to prevent its being damaged and to minimize the exposure of personnel.

Internal Radiation

(39) The possibility of ingesting or inhaling radioactive material arises if a sealed source starts to leak. It is important, therefore, that sealed sources should be constructed in such a way that the

* Advice on the storage and transportation of sealed sources is given in sections beginning at paragraphs 98 and 109.

likelihood of leakage is minimized and that they should be used in such a way that rupture of the container is unlikely. For the latter reason, care should be taken to prevent bending, dropping, or over-heating of sources.

(40) Even when the above precautions have been taken, every sealed source should be tested for leakage or surface contamination both initially and periodically and a record kept of the results of such tests*. With simple equipment, amounts of free activity of 0.01 to 0.1 μCi are readily detectable.

(41) A leaking source should be placed in an airtight container but heat sealing—as in a glass tube or by soldering a metal container—should be avoided if there is a risk of aggravating the damage by over-heating the source. Arrangements should then be made with the manufacturer or some qualified laboratory to receive the source for repair. The package should be so prepared that no contamination will result during transportation. For emergency procedures following a spill or leakage or a loss of a sealed source, see paragraphs 70 to 72, and 108.

Sterilization of Small Sealed Sources

(42) When small sealed sources are sterilized (e.g. radium needles), care should be taken to minimize the radiation exposure of staff, and to avoid damage to, or loss of, the sources. Examples of methods of carrying out such sterilization are given in Appendix B.

GENERAL AIMS AND PROCEDURES FOR WORK WITH UNSEALED RADIOACTIVE MATERIALS

(43) The design and facilities of laboratories, isotope clinics, wards and operating theatres, the design of all medical and experimental equipment, and the general working procedures should be aimed at:

(*a*) minimizing the exposure of staff;

(*b*) limiting the doses to patients to the minimum levels consistent with medical requirements;

(*c*) protecting visitors and other patients when in proximity to patients undergoing treatment with sealed or unsealed radionuclides; and

(*d*) controlling the spread of radioactive material into the working environment.

(44) In dealing with unsealed radioactive materials, special attention should be paid to internal radiation hazards. This section gives detailed guidance on controlling such hazards. The extent of the precautions to be taken will depend upon a number of factors such as the nature of the operations, the total activity, the specific activity, the radiotoxicity, the chemical toxicity and other chemical and physical properties of the radionuclides or radioactive compounds. However, even when the internal radiation hazards are small, there may still be external radiation risks in handling radioactive materials, in which case measures similar to those recommended for sealed sources will apply.

Classification of Radionuclides

(45) The information given in Table 1 of ICRP Publication 2†, regarding maximum permissible concentrations of various radionuclides in air, serves as a basis for a classification of radionuclides

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* In Appendix A guidance is given on methods of testing sealed sources for leakage or surface contamination and on the levels of free activity below which a source may be regarded as free from leakage or surface contamination.

† Report of Committee II on " Permissible Dose for Internal Radiation " (1959).

according to relative radiotoxicity. Such a classification, based on one drawn up by the International Atomic Energy Agency*, is given in Table 1 below†.

TABLE 1. CLASSIFICATION OF ISOTOPES ACCORDING TO RELATIVE RADIOTOXICITY PER UNIT ACTIVITY

Group 1‡

Pb-210	Po-210	Ra-223	Ra-226	Ra-228	Ac-227	Th-227	Th-228	Th-230
Pa-231	U-230	U-232	U-233	U-234	Np-237	Pu-238	Pu-239	Pu-240
Pu-241	Pu-242	Am-241	Am-243	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246
Cf-249	Cf-250	Cf-252						

Group 2‡

Na-22	Cl-36	Ca-45	Sc-46	Mn-54	Co-56	Co-60	Sr-89	Sr-90
Y-91	Zr-95	Ru-106	Ag-110m	Cd-115m	In-114m	Sb-124	Sb-125	Te-127m
Te-129m	I-124	I-126	I-131	I-133	Cs-134	Cs-137	Ba-140	Ce-144
Eu-152 (13 y)		Eu-154	Tb-160	Tm-170	Hf-181	Ta-182	Ir-192	Tl-204
Bi-207	Bi-210	At-211	Pb-212	Ra-224	Ac-228	Pa-230	Th-234	U-236
Bk-249								

Group 3‡

Be-7	C-14	F-18	Na-24	Cl-38	Si-31	P-32	S-35	A-41
K-42	K-43	Ca-47	Sc-47	Sc-48	V-48	Cr-51	Mn-52	Mn-56
Fe-52	Fe-55	Fe-59	Co-57	Co-58	Ni-63	Ni-65	Cu-64	Zn-65
Zn-69m	Ga-72	As-73	As-74	As-76	As-77	Se-75	Br-82	Kr-85m
Kr-87	Rb-86	Sr-85	Sr-91	Y-90	Y-92	Y-93	Zr-97	Nb-93m
Nb-95	Mo-99	Tc-96	Tc-97m	Tc-97	Tc-99	Ru-97	Ru-103	Ru-105
Rh-105	Pd-103	Pd-109	Ag-105	Ag-111	Cd-109	Cd-115	In-115m	Sn-113
Sn-125	Sb-122	Te-125m	Te-127	Te-129	Te-131m	Te-132	I-130	I-132
I-134	I-135	Xe-135	Cs-131	Cs-136	Ba-131	La-140	Ce-141	Ce-143
Pr-142	Pr-143	Nd-147	Nd-149	Pm-147	Pm-149	Sm-151	Sm-153	Eu-152
Eu-155	Gd-153	Gd-159	Dy-165	Dy-166	Ho-166	Er-169	Er-171	(9.2 hr)
Tm-171,	Yb-175	Lu-177	W-181	W-185	W-187	Re-183	Re-186	Re-188
Os-185	Os-191	Os-193	Ir-190	Ir-194	Pt-191	Pt-193	Pt-197	Au-196
Au-198	Au-199	Hg-197	Hg-197m	Hg-203	Tl-200	Tl-201	Tl-202	Pb-203
Bi-206	Bi-212	Rn-220	Rn-222	Th-231	Pa-233	Np-239		

Group 4‡

H-3	O-15	A-37	Co-58m	Ni-59	Zn-69	Ge-71	Kr-85	Sr-85m
Rb-87	Y-91m	Zr-93	Nb-97	Tc-96m	Tc-99m	Rh-103m	In-113m	I-129
Xe-131m	Xe-133	Cs-134m	Cs-135	Sm-147	Re-187	Os-191m	Pt-193m	Pt-197m
Th-232	Th-Nat	U-235	U-238	U-Nat.				

* International Atomic Energy Agency (Vienna). Technical Reports Series No. 15—A Basic Toxicity Classification of Radionuclides (1963).

† An alternative classification has been suggested by K. Z. Morgan, W. S. Snyder and M. R. Ford, *Health Physics*, **10** (3), 151, 1964.

‡ The International Atomic Energy Agency refers to Groups 1 to 4 as " High Toxicity ", " Medium-Toxicity—Upper Sub-Group A ", " Medium Toxicity—Lower Sub-Group B " and " Low Toxicity " respectively.

Classification of Laboratories

(46) For convenience in discussion, laboratories designed for handling low levels of radioactivity are described as Type 1, for intermediate levels as Type 2, and for high levels as Type 3. The amount of any given radionuclide that can be handled at one time will vary according to the type of laboratory available, and the type of laboratory suitable for any given amount of material will vary with its toxicity. Table 2 gives a classification of types of laboratories required for various amounts of radionuclides in the groups defined in Table 1. It is unlikely that, at present, there will be the need for a Type 3 laboratory for clinical work in hospitals.

Table 2. Classification of Laboratories for Handling Radionuclides

Group of Radionuclide	Type of laboratory required for levels of activity specified below		
	Type 1	Type 2	Type 3
1	< 10 μCi	10 μCi to 1 mCi	> 1 mCi
2	< 1 mCi	1 mCi to 100 mCi	> 100 mCi
3	< 100 mCi	100 mCi to 10 Ci	> 10 Ci
4	< 10 Ci	10 Ci to 1000 Ci	> 1000 Ci

Modifying factors (see text)	Factors
Simple storage	× 100
Very simple wet operations (e.g. preparation of aliquots of stock solutions)	× 10
Normal chemical operations (e.g. analysis, simple chemical preparations)	× 1
Complex wet operations (e.g. multiple operations, or operations with complex glass apparatus)	× 0.1*
Simple dry operations (e.g. manipulation of powders) and work with volatile radioactive compounds	× 0.1*
Dry and dusty operations (e.g. grinding)	× 0.01*

(47) It is apparent that no exact definition of these requirements is given in Table 2. To attempt to do so would give a misleading impression of precision, because many factors must be considered that do not appear in the table. Experienced people can work safely with equipment which might be dangerous in the hands of beginners, and no weight has been given to difficulties of manipulation caused by the shielding and remote handling required by γ-emitters.

(48) Numerical values can be assigned to certain additional factors, and this is done by applying the " modifying factors " given beneath Table 2. If, for example, normal chemical operations are to be carried out with up to 10 mCi of a Group 2 radionuclide, a Type 2 laboratory would be required. However, 100 mCi (i.e. 10 mCi × modifying factor 10) of such material could be used

* These factors could be increased by one or more orders of magnitude if the operations are carried out in closed boxes.

if only aliquots were to be prepared, but if the work were to consist of grinding Group 2 material, only 100 μCi (i.e. 10 mCi $\times$ modifying factor 0.01) could be handled in this laboratory unless a closed box is used.

(49) The nature of Table 2 is such that the actual selection of amounts of radionuclides to be handled is a matter for judgement. If a quantity of radioactive material, after applying any modifying factors, falls within a factor of 2 or 3 of a dividing line between classes of laboratory, then guidance should be given by the radiation protection officer, bearing in mind factors such as experience of staff, availability of emergency services, and other things which cannot be expressed numerically.

Facilities for Work with Unsealed Radioactive Materials

(50) One of the cardinal principles in the use of radioactive materials is that the facilities should be separated from other facilities insofar as is practicable, much in the same way that bacteriological laboratories dealing with pathogenic organisms, or laboratories handling toxic agents, are separated from other laboratories. (For further details regarding the lay-out and facilities for a Type 2 laboratory, see Appendix C.)

(51) Floors should have smooth, continuous and non-absorbent surfaces and should be made of materials that can be cleaned easily and possess a surface that can be removed easily.

(52) Walls and ceilings should be finished with a non-porous washable surface, such as a good hard-gloss paint.

(53) Special attention should be given during the planning stage to such aspects as the mode of heating (e.g. enclosed wall heaters or under-floor heaters rather than small wall radiators which are difficult to decontaminate), the ventilation, and the design of drains. It should be appreciated that the use of closed boxes fitted with gloves or remote-controlled manipulators will lead to a reduction in capital and running costs of heating and ventilation of laboratories where therapeutic quantities of radionuclides are to be dealt with.

Working Procedures with Unsealed Radioactive Materials

(54) Good working procedures are so important that techniques must be well thought out and understood before work is undertaken. These procedures should be tried out by practice runs so that when radioactive material is used, operations are performed speedily and confidently with minimum exposure and risk of accident. A balance should be struck between hurried manipulations, which cause accidents, and prolonged operations, which may lead to excessive exposure. Working procedures should be reviewed by the radiation protection officer.

(55) Maintenance work, e.g. on laboratory equipment, ducts, or waste pipes, should be undertaken only after preliminary monitoring. If ducts or pipes are opened up during the work, monitoring of air and surfaces should be undertaken as the work progresses.

(56) Working surfaces in the laboratory should be covered, and manipulations should be carried out over trays made of non-absorbing substances (e.g. stainless steel, enamelled metal, polyethylene) lined with absorbent material (e.g. paper). It should be remembered, however, that the use of flammable materials introduces a fire hazard. In such cases it may be better to omit the lining material.

(57) Work involving spray, dust, fume or gas should be carried out in a hood or closed box. When the work is completed, the worker should clean his contaminated material and, if necessary, arrange for its disposal. Trays and bench surfaces should also be cleaned after work. Suitable waste cans should be provided (see Appendix C). They should be monitored and changed with sufficient frequency to ensure that they do not become a hazard.

(58) Vessels containing radioactive material should be covered when not in use.

(59) The use of mouth-operated pipettes and wash-bottles shall not be permitted in controlled areas. Special techniques are available which avoid glass blowing by mouth and these should be used in controlled areas whenever practicable.

(60) Eating, smoking and the application of cosmetics should not be permitted in controlled areas or clinics where unsealed radioactive materials are being handled or used. Such personal habits as sucking pencils and fingers should be discouraged.

(61) The unbroken skin is an effective barrier against direct entry of many radioactive materials into the blood stream, so precautions should be taken to avoid cuts and puncture wounds. If there are open wounds on exposed parts of the body, no work should be permitted with the more hazardous materials or larger quantities of the less hazardous ones unless the wounds are properly dressed and protected. Cracked or chipped vessels should not be used in controlled areas.

(62) The type of protective clothing required in laboratories depends upon the amount of radioactivity. The handling of even tracer amounts will require laboratory coats over normal attire. When large quantities of radioactivity are handled, coveralls or other clothing that completely cover the body should be worn. The use of such clothing should be restricted to these operations. In such operations the risk of contamination may also require the use of special shoe coverings or the provision of shoes for use only in controlled areas. Rubber gloves should be worn when there is a likelihood of contaminating the hands.

(63) As regards ward procedures, general rules should be issued to nurses in charge of wards. These should indicate any limitations of the time that ward staff and visitors may spend in proximity to patients containing therapeutic quantities of sealed or unsealed radioactive materials. Instruction sheets should also be drawn up, summarizing the techniques to be followed by the staff for particular isotopes. In all cases, the handling of contaminated articles (e.g. bed linen, patients' clothing, towels and china) should be reduced to a minimum.

Contamination Control

(64) An essential feature of contamination control is regular and proper cleaning of controlled areas. Cleaning should be done by someone aware of the need for taking precautions; cleaners without special training are not suitable for this purpose. Guidance on " permissible " levels of surface contamination is given in Appendix D.

(65) Cleaning equipment (mops, brushes, rags, buckets, wax, soap, etc.) should be restricted to controlled areas and not used elsewhere. Such equipment should be monitored periodically and, if necessary, disposed of as radioactive waste. Floors, benches and furniture should be cleaned by a vacuum cleaner equipped with a high-efficiency filter or by a wet or moist method. Dry sweeping should be avoided.

(66) Special attention should be paid to techniques for avoiding the build-up of contamination on gloves used more than once and for avoiding the transfer of contamination from the gloves to parts of the body.

Spills of Radioactive Materials

(67) Spills will occur and it should be the responsibility of the person who causes the spill to notify the proper person to ensure that it is effectively cleaned up. If the amount of radioactive material used is no greater than that needed to carry out the given operation, the seriousness of spills and of exposure to personnel in normal work will be reduced.

(68) Any spill should be dealt with immediately, but appropriate action will vary with circumstances. Local procedures for dealing with spills, therefore, should be drawn up and posted in the laboratories.

Minor Spills

(69) Absorbent paper should be laid immediately over a wet spill. Dry spills should preferably be removed by wet methods, using wet absorbent paper to prevent dispersion, if necessary. Alternatively, a vacuum cleaner equipped with a high-efficiency filter could be used. Any paper used should then be removed to a suitable waste receptacle and the affected area monitored. Decontamination should be carried out until the surface levels are below the appropriate prescribed levels (see Appendix D). Swabbing should always be done inward toward the centre of the spill. If contamination levels cannot be sufficiently reduced, the surface should be stripped or covered. In all of these operations, great care should be taken to avoid spread of the radioactivity and to prevent contamination of clothing, skin and monitoring instruments.

Emergencies (Serious spills or fires)

(70) Local emergency instructions should be drawn up for all controlled areas where the quantities of radioactive material used are such that a serious spill or fire is capable of causing excessive exposure. These instructions must be seen and read by all persons who may be concerned.

(71) The best course of action in an emergency will depend on the nature of the emergency and on local circumstances. However, in all cases the first concern should be the protection of the persons involved, including patients (whether in the operating theatre, treatment cubicle or ward). The second concern should be the limitation of the spread of radioactive contamination. The local emergency instructions might be based on the example given in Appendix E.

(72) Certain basic equipment should be available for use in emergencies. This should include monitoring equipment, coveralls, caps, gloves and overshoes. Suitable respirators may also be required. Large bags made of heavy paper are useful for quick disposal of contaminated material. Several rolls of sticky tape should be available for sealing the disposal bags and, if it should prove necessary, for sealing off a room contaminated by radioactive materials.

DECONTAMINATION OF PERSONNEL

Decontamination of Intact Skin

(73) Persons who have handled radioactive materials should wash their hands thoroughly with soap and water before leaving a controlled area. After washing, the hands should be checked for contamination. If contamination is present after several washings the case should be referred to the medical adviser. Cleaning methods that seriously damage the skin should be avoided. However, it may be necessary to use powerful chemical reagents when ordinary cleaning methods fail. Moderate activity that remains fixed to the skin after the application of the above procedures may be less harmful than employment of harsher decontamination measures.

(74) Great care should be taken during decontamination of the face to avoid further contamination of the lips and eyes. If the eye is being irrigated, it should be ascertained that the adjacent skin is not highly contaminated; measures should be taken first to prevent such contamination from being washed into the eye. The eye should be irrigated outwards to avoid contamination of tear ducts.

Decontamination of Injured Skin

(75) When corrosive or other toxic materials are present in addition to radioactive contaminants, the usual first-aid measures should be applied before attempting to carry out radioactive decontamination.

(76) If the skin is accidentally broken when working with radioactive materials, the wound should be irrigated immediately with tap water, the edges of the gash being spread to assist the flushing action of the water, and to encourage bleeding. All wounds of this nature should be referred

to the medical adviser as soon as first-aid measures have been started, so that steps can be taken to free the wound from contamination.

Radioactivity Deposited in the Body

(77) In the case of an accidental intake of radioactive materials, which it is believed may lead to a significant dose of internal radiation, the medical adviser should be called immediately. Pending arrival of the medical adviser, certain simple first-aid measures may be applied to assist in the elimination of the radioactivity. These include the cleansing of the nasal passages, the expectoration of saliva and, perhaps in some cases, the induction of vomiting.

DECONTAMINATION OF BUILDINGS, EQUIPMENT AND CLOTHING

Buildings

(78) Good operating methods and routine cleaning will normally keep contamination levels in the working areas below prescribed limits (see Appendix D). Special decontamination procedures will, however, be needed after spills and when a laboratory ceases to be used for work with radioactive materials.

(79) Such decontamination should start with conventional cleaning methods, but special precautions may be required. If these conventional methods fail to reduce the contamination to below the prescribed limits, additional measures will be needed.

(80) In general, short lived contamination of a half-life less than a month may be covered, after scrubbing to remove loose contamination. Substantial, long-lived contamination remaining after scrubbing may necessitate the covering or removal of the contaminated surfaces. If the contamination is covered, precautions must be taken against subsequent escape and the area should be marked.

Equipment

(81) Equipment may often be cleaned by washing with detergent followed, if necessary, by the use of complexing agents or ultrasonic methods. Equipment which cannot be decontaminated below prescribed levels, or be retained until the activity has decayed below prescribed levels, and for which further use cannot be found, e.g. in more active areas, should be discarded as radioactive waste.

Clothing

(82) Any article of protective clothing or personal clothing found to be contaminated should be placed in a container provided for the purpose.

(83) Contaminated protective clothing should not be released to public laundries unless the activity is below prescribed levels (Appendix D). For articles contaminated above these levels with short-lived radionuclides, storage is recommended until the activity has fallen below the indicated levels.

(84) In the case of heavily contaminated clothing, precautions should be taken against external radiation and possible inhalation of dispersed radioactivity.

(85) Where special laundering facilities are available as, for example, in a hospital or an atomic energy establishment, such clothing may be laundered. It should not, however, be laundered with uncontaminated articles of clothing or bedding. The procedures should be reviewed by the radiation protection officer and the decontaminated articles should be monitored before re-use. If the contamination cannot be reduced to prescribed levels, the garments should be treated as radioactive waste.

DISPOSAL OF RADIOACTIVE WASTE

(86) The authority having administrative control of an establishment will be responsible for arrangements for the safe disposal of any radioactive waste that may arise. The Commission realizes that the factors influencing the procedures for the disposal of radioactive waste vary from country to country and, therefore, stresses that disposal should be in accordance with the regulations or codes of practice in operation in each country. General guidance for those responsible for drawing up national regulations or codes of practice is given in Appendix F.

(87) It is convenient to recognize three main types of waste, namely, liquid, solid and gaseous. As regards hospitals and medical research establishments, the waste may comprise excreta from patients undergoing diagnosis or therapy with unsealed radionuclides, unwanted solutions of radionuclides, normal low-level liquid waste, normal low-level solid waste (e.g. paper, glass, carcasses of experimental animals), sealed sources, waste from spills and decontamination, and gases.

Disposal of Liquid Wastes

(88) For small quantities of soluble radioactive wastes containing nuclides of short half-lives, the most convenient and, generally, the most practicable procedure is disposal into the sanitary sewerage system. This provides a period of delay for decay before the radioactive materials can reach water or food supplies, and also provides some degree of dispersal or dilution.

(89) Direct discharge into the sanitary sewerage system is particularly satisfactory for the disposal of excreta from patients given radioactive materials in medical diagnosis and therapy.

(90) Valid estimates of quantities of radioactive wastes which may appropriately be released into sewerage systems will depend on local factors. However, under conditions representative of most hospitals and medical research establishments using diagnostic or tracer quantities of radionuclides, discharges which correspond to concentrations (averaged over, say, 1 month) in the range of 10^{-4} to 10^{-5} μCi/ml in the effluent from the establishment will usually be sufficient to allow disposal of the wastes which arise.

(91) For wastes containing radionuclides which cannot appropriately be discharged immediately to the sewerage system because of their long half-lives or high activities, the alternatives are utilization of specialised waste disposal services or storage.

Disposal of Solid Wastes

(92) Solid waste which is only lightly contaminated may be disposed of with ordinary waste. A few microcuries in an ordinary waste bin would not be hazardous. Occasional releases up to 100 μCi of radionuclides other than those in Group 1 would also be non-hazardous.

(93) For larger amounts of radioactivity other disposal methods, including incineration or burial, should be used; indeed, these methods may be preferable even for activities less than 100 μCi.

(94) Incineration can sometimes be an effective method of disposal for radionuclides which form gaseous products when the refuse is burned. Tritium, carbon-14 and iodine-131 are examples. The amount of waste arising from the use of carbon-14 and, at present, of tritium, in hospitals and medical research establishments, is rarely great enough to preclude disposal by incineration or burial. In the case of iodine-131, it is normally possible to dispose of millicurie amounts per day by incineration.

(95) Under suitable conditions, burial of waste to a depth of at least one metre in a municipal dump can be employed as a method of disposal with radionuclides dispersed throughout the waste, and for wastes in a form unattractive for salvage.

(96) The problems presented by small sealed sources are somewhat different. Here the activity is in a concentrated, manageable form. The waste is the original source which has decayed to a

level of activity too low for economical use. It is recommended that sources having activities greater than 10 μCi should not be disposed of with refuse. The sources should be stored until decay permits local disposal by ordinary methods or should be collected in any national disposal areas set aside for this purpose.

Disposal of Airborne Wastes

(97) Airborne wastes will originate mainly from the stores (especially radium stores in hospitals), from the incineration of solid combustible wastes and from laboratory fume hoods and closed boxes. It is important that the points of release to the atmosphere be carefully sited. Consideration should also be given to the necessity of using filters in the exhaust system (see Appendix C).

STORAGE OF RADIOACTIVE MATERIALS

(98) Each hospital or medical research establishment should be provided with one or more main areas where radioactive materials, when not in use, may be stored. Each area should be properly marked with approved warning signs, and pertinent regulations regarding its use should be posted at points of access. Where access to the area might otherwise be available to unauthorized individuals, a lock should be provided to prevent deliberate or inadvertent entry into the storage area or compartment.

(99) The area should be so located as to simplify transport problems but care should be exercised to ensure that radiation backgrounds in adjacent areas are acceptable. To minimize exposure of staff resulting from the transport of sources, stores should, where practicable, be located near working areas; e.g. the radium store and "make-up" room might be near to the radium theatre. There should be a storage area where samples of urine and faeces can be temporarily stored. When such samples are of high-activity it may be necessary to use a shielded container.

(100) Where radioactive gases or vapours may be emitted by stored sources, the store should be adequately ventilated by mechanical means.

(101) Procedures for the introduction and withdrawal of material and the requirements for storage containers and labelling should be prescribed by a responsible person, for example, a radiation protection officer. The store should be used only for the storage of radioactive material. Adequate records should be kept of all stored radioactive materials with a check-in and check-out system for sources that are used frequently. Periodic inventories should be performed and made a matter of record.

(102) Consideration should also be given to (*a*) shielding, (*b*) contamination control and (*c*) flooding, fire and theft, as discussed below.

Shielding

(103) Radioactive materials may emit combinations of alpha, beta and gamma radiation, and neutrons. Shielding is not normally required for alpha radiation. Shielding should be provided for gamma-emitting radionuclides to protect not only those who enter the room, but those in adjacent areas. (Information on shielding against gamma-emitting sources is given in ICRP Publication 3). Sources emitting only beta radiation should be stored in containers which will reduce the radiation to negligible levels. It is often convenient to use transparent materials; 4 to 5 mm of glass or 7 to 8 mm of plastic will usually suffice. With very large sources, additional precautions may be needed against Bremsstrahlung. Paraffin or other hydrogenous materials are convenient for neutron shielding. Radium-beryllium sources of neutrons containing up to 100 mCi of radium do not require shielding beyond that provided for gamma radiation. Above 100 mCi, additional hydrogenous or other neutron-shielding material will usually be needed. (See ICRP Publication 4—Report of Committee IV on Protection Against Electromagnetic Radiation above 3 MeV and Electrons, Neutrons and Protons.)