9 Application of treatment and disposal methods to health-care waste categories

Suitable treatment and disposal methods for the different categories of health-care waste are summarized in Table 9.1 and discussed in more detail in this chapter.

9.1 Infectious waste and sharps

Within the limitations mentioned in the relevant sections, almost all the treatment methods outlined in Chapter 8 are suitable for infectious waste and sharps, except "inertization." The treatment option should be chosen according to the national and local situation.

Destroying infectious microorganisms—by heat, by chemical means, or by microwave irradiation—is relatively easy. Highly infectious waste, such as cultures and stocks of infectious agents from laboratory work, should be sterilized by wet thermal treatment (e.g. autoclaving) at the earliest stage possible. For other infectious health-care waste, disinfection is adequate.

Sharps should undergo incineration whenever possible, and can be incinerated together with other infectious waste. Encapsulation is also suitable for sharps. After incineration or other disinfection, the residues may be landfilled.

In exceptional emergency situations, such as outbreaks of communicable diseases, burning of infectious health-care waste in open trenches may also be envisaged if it is not possible to use any of the treatment options described in Chapter 8 (see also Chapter 16).

Unless there is an adequate wastewater treatment plant, blood should be disinfected before discharge to a sewer; it may also be incinerated.

9.2 Pharmaceutical waste

Sound management of pharmaceutical products facilitates waste minimization (see section 6.1) and is of prime importance to better waste management in general. Disposal of small amounts of chemical or pharmaceutical waste is easy and relatively cheap; large amounts require the use of special treatment facilities.

9.2.1 Disposal of small quantities of pharmaceutical waste

The disposal options for small quantities of pharmaceutical waste include those outlined in the following paragraphs.

Table 9.1 *Overview of disposal and treatment methods suitable for different categories of health-care waste*

Technology or method	Infectious waste	Anatomical waste	Sharps	Pharmaceutical waste	Cytotoxic waste	Chemical waste	Radioactive waste
Rotary kiln	Yes	Yes	Yes	Yes	Yes	Yes	Low-level infectious waste
Pyrolytic incinerator	Yes	Yes	Yes	Small quantities	No	Small quantities	Low-level infectious waste
Single-chamber incinerator	Yes	Yes	Yes	No	No	No	Low-level infectious waste
Drum or brick incinerator	Yes	Yes	Yes	No	No	No	No
Chemical disinfection	Yes	No	Yes	No	No	No	No
Wet thermal treatment	Yes	No	Yes	No	No	No	No
Microwave irradiation	Yes	No	Yes	No	No	No	No
Encapsulation	No	No	Yes	Yes	Small quantities	Small quantities	No
Safe burial on hospital premises	Yes	Yes	Yes	Small quantities	No	Small quantities	No
Sanitary landfill	Yes	No	No	Small quantities	No	No	No
Discharge to sewer	No	No	No	Small quantities	No	No	Low-level liquid waste
Inertization	No	No	No	Yes	Yes	No	No
Other methods				Return expired drugs to supplier	Return expired drugs to supplier	Return unused chemicals to supplier	Decay by storage

- *Landfill disposal*
  Small quantities of pharmaceutical waste produced on a daily basis may be landfilled provided that they are dispersed in large quantities of general waste. Cytotoxic and narcotic drugs, however, should *never* be landfilled, even in small quantities.

- *Encapsulation*
  Small quantities of pharmaceutical waste may be encapsulated, together with sharps if appropriate.

- *Safe burial on hospital premises*
  Safe burial of small quantities of pharmaceutical waste prevents scavenging and may be an appropriate disposal method for establishments applying **minimal programmes**.

- *Discharge to a sewer*
  Moderate quantities of relatively mild liquid or semi-liquid pharmaceuticals, such as solutions containing vitamins, cough syrups, intravenous solutions, eye drops, etc. (but *not* antibiotics or cytotoxic drugs), may be diluted in a large flow of water and discharged into municipal sewers. It is not acceptable, however, to discharge even small quanti-

ties of pharmaceutical waste into slow-moving or stagnant water bodies.

- *Incineration*
  Small quantities of pharmaceutical waste may be incinerated together with infectious or general waste, provided that they do not form more than 1% of the total waste (in order to limit potentially toxic emissions to the air).

9.2.2 Disposal of large quantities of pharmaceutical waste

Large quantities of solid pharmaceutical waste may have to be dealt with if a pharmacy closes down, for example, or after emergencies (see also *Guidelines for safe disposal of unwanted pharmaceuticals in emergencies and difficult circumstances*[1]). The treatment methods outlined in the following paragraphs are suitable.

- *Incineration*
  Incineration is the best way to dispose of pharmaceutical waste. The wastes should be mixed with their cardboard packaging, and possibly with other combustible material and infectious waste, to ensure optimal combustion conditions. Low-temperature incineration (<800 °C), however, provides only limited treatment for this type of waste; it is not recommended unless it is followed by combustion in a second chamber, operating at temperatures about 1000 °C, to burn off potentially toxic exhaust gases that may be produced. Ideally, large amounts of pharmaceuticals should be treated in incinerators designed for industrial waste (including rotary kilns), which can operate at high temperatures (>1200 °C). Cement kilns are also particularly suited to the treatment of pharmaceuticals; in many countries, cement producers accept pharmaceutical waste as an alternative fuel, thus reducing fuel costs. As a "rule of thumb", however, it is suggested that no more than 5% of the fuel fed into the furnace at any time is pharmaceutical material.

- *Encapsulation*
  Solid, liquid, and semi-liquid waste can be encapsulated in metal drums (see section 8.5).

Landfilling of large quantities of pharmaceuticals is *not* recommended unless the waste is encapsulated and disposed of in sanitary landfill sites, where the risk of groundwater contamination is minimized. Large amounts of pharmaceutical waste should not be disposed of with general hospital waste, nor should they be diluted and discharged into sewers (except for certain very mild solutions, such as vitamin preparations).

Intravenous fluids and glass ampoules are special cases. Intravenous fluids (salts, amino acids, lipids, glucose, etc.), which are relatively harmless, can be disposed of to a landfill or discharged into a sewer. Ampoules should be crushed on a hard, impermeable surface; workers should wear protective clothing, eye protection, gloves, etc. The glass should then be

[1] *Disposal of unwanted pharmaceuticals in emergencies and difficult circumstances.* Geneva, World Health Organization (unpublished document, in preparation; will be available on request from Department of Essential Drugs and other Medicines, World Health Organization, 1211 Geneva 27, Switzerland).

swept up, collected, and disposed of with sharps. Ampoules should not be incinerated as they may explode, damaging the incinerator or injuring workers.

9.3 Cytotoxic waste

Cytotoxic waste is highly hazardous and should never be landfilled or discharged into the sewerage system. Disposal options include the following:

- *Return to original supplier*
  Safely packaged but outdated drugs and drugs that are no longer needed should be returned to the supplier. This is currently the preferred option for countries that lack the facilities for incineration. Drugs that have been unpacked should be repackaged in a manner as similar as possible to the original packaging and marked "outdated" or "not for use".

- *Incineration at high temperatures*
  Full destruction of all cytotoxic substances may require temperatures up to 1200 °C; Table 9.2 gives the minimum temperatures necessary to destroy common cytotoxic products. Incineration at lower temperatures may result in the release of hazardous cytotoxic vapours into the atmosphere.

  Modern double-chamber pyrolytic incinerators are suitable, provided that a temperature of 1200 °C with a minimum gas residence time of 2 seconds or 1000 °C with a minimum gas residence time of 5 seconds can be achieved in the second chamber. The incinerator should be

Table 9.2 *Minimum temperatures for destruction of cytotoxic drugs, for conventional residence times, according to different authors*

Compound	Temperature	Compound	Temperature
Aclarubicin	1000 °C[a]	Etoposide	1000 °C[b], 700 °C[a]
Amsacrine	>260 °C[a], 260 °C[b]	5-Fluorouracil	1200 °C[c], 1000 °C[b], 700 °C[a]
Bleomycin	1000 °C[a]	Idarubicin	700 °C[a]
Carboplatin	1000 °C[a]	Ifosfamide	1000 °C[a]
Carmustine	1000 °C[a,b]	Melphalan	500 °C[a]
Chlormethine (mustine)	800 °C[a]	Methotrexate	1000 °C[a,b]
Cisplatin	250 °C[b], 800 °C[a]	Mithramycin	1000 °C[c], 300 °C[b]
Cyclophosphamide	900 °C[a]	Mitomycin	1000 °C[a]
Cytarabine	1000 °C[a]	Mitoxantrone	800 °C[a]
Dacarbazine	500 °C[a]	Plicamycin	1000 °C[a]
Dactinomycin	1000 °C[a]	Thiotepa	800 °C[a,b]
Daunorubicin	800 °C[b,c], 700 °C[a]	Vincristine	1000 °C[a,b]
Doxorubicin	>700 °C[c], 700 °C[a]	Vindesine	1000 °C[a,b]
Epirubicin	700 °C[b,c]		

[a]Allwood & Wright (1993); [b]Lee (1988); [c]Wilson (1983).

Note: The data included in this table were the most recent data available at the time of preparation of this handbook, but no information has been provided as to the scientific background which led to these proposals. The Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME) (contact address: Centre de Sophia Antipolis, Département Toxicologie et Exotoxicologies, 500 route des Lucioles, 06560 Valbonne, France) is investigating the efficiency of incineration of a number of individual drugs and the genotoxic risk of the outgoing residues.

fitted with gas-cleaning equipment. Incineration is also possible in rotary kilns designed for thermal decomposition of chemical wastes, in foundries, or in cement kilns, which usually have furnaces operating well in excess of 850 °C.

Incineration in most municipal incinerators, in single-chamber incinerators, or by open-air burning is inappropriate for the disposal of cytotoxic waste.

- *Chemical degradation*
  Chemical degradation methods, which convert cytotoxic compounds into non-toxic/non-genotoxic compounds, can be used not only for drug residues but also for cleaning of contaminated urinals, spillages, and protective clothing. The methods are appropriate for developing countries. Drugs for which chemical degradation methods are available are listed in Box 9.1. Most of these methods are relatively simple and safe; they include oxidation by potassium permanganate ($KMnO_4$) or sulfuric acid (H_2SO_4), denitrosation by hydrobromic acid (HBr), or reduction by nickel and aluminium. They are described in detail in Annex 2. The International Agency for Research on Cancer (IARC) may be contacted for further information.[1] The methods are *not* appropriate for the treatment of contaminated body fluids.

It should be noted that neither incineration nor chemical degradation currently provides a *completely* satisfactory solution for the treatment of waste, spillages, or biological fluids contaminated by antineoplastic agents. Until such a solution is available, hospitals should use the utmost care in the use and handling of cytotoxic drugs.

Where neither high-temperature incineration nor chemical degradation methods are available and where exportation of cytotoxic wastes for adequate treatment to a country with the necessary facilities and expertise is not possible, encapsulation or inertization may be considered as a last resort.

Box 9.1 Cytotoxic drugs for which chemical degradation methods exist

Carmustine	Doxorubicin	Semustine
Chlorambucil	Ifosfamide	Spiromustine
Chlormethine	Lomustine	Streptozocin
Chlorozotocin	Melphalan	6-Thioguanine
Cisplatin	6-Mercaptopurine	Uramustine
Cyclophosphamide	Methotrexate	Vincristine sulfate
Daunorubicin	PCNU[a]	Vinblastine sulfate
Dichloromethotrexate	Procarbazine	

[a] 1-(2-Chloroethyl)-3-(2,6-dioxo-3-piperidyl)-1-nitrosourea.

[1] International Agency for Research on Cancer, Unit of Gene–Environment Interactions, 150 Cours Albert-Thomas, 69372 Lyon Cedex 08, France.

9.4 Chemical waste

As for pharmaceutical waste, improving the management of chemical waste starts with waste minimization efforts (see section 6.1).

9.4.1 Disposal of general chemical waste

Non-recyclable, general chemical waste, such as sugars, amino acids, and certain salts (see also section 2.1.7), may be disposed of with municipal waste or discharged into sewers. The discharge into sewers of aqueous chemical wastes that arise in health-care establishments, together with their associated suspended colloidal and dissolved solids, has traditionally been accepted by sewerage authorities in many countries. However, official permission from the appropriate authority may be required and the types and quantities of material that can be discharged may be limited. Generally, conditions for discharge may include restrictions on pollutant concentrations, content of suspended solids, temperature, pH, and, sometimes, rate of discharge. Unauthorized discharge of hazardous chemicals can be dangerous to sewage treatment workers and may adversely affect the functioning of sewage treatment works.

Petroleum spirit, calcium carbide, and halogenated organic solvents should *not* be discharged into sewers.

9.4.2 Disposal of small quantities of hazardous chemical waste

Small quantities of hazardous chemical waste, e.g. residues of chemicals inside their packaging, may be dealt with by pyrolytic incineration, encapsulation, or landfilling.

9.4.3 Disposal of large quantities of hazardous chemical waste

There is no way to dispose both safely and cheaply of significant quantities of hazardous chemical waste. The appropriate means of disposal is dictated by the nature of the hazard presented by the waste.

Certain combustible wastes, including many solvents, may be incinerated. However, incineration of large quantities of halogenated solvents (containing chlorine or fluorine for instance) should not be undertaken unless facilities have adequate gas-cleaning equipment. Any waste that cannot be safely and efficiently incinerated should be handled and disposed of by an organization or company specifically authorized to manage hazardous waste. This organization may eliminate the wastes in a rotary kiln, treat them chemically, or store them in a safe disposal facility engineered for hazardous chemicals.

Other possibilities for disposing of hazardous chemicals include return to the original supplier, who should be equipped to deal with them safely. Where such an arrangement is envisaged, appropriate provisions should be included in the original purchase contract for the chemicals. The waste could also be exported to a country with the expertise and facilities to dispose safely of hazardous waste. Shipment for this purpose should comply with international agreements, such as the Basel Convention (see section 4.1). Use of certain products for non-medical purposes may also be considered; for example, use of outdated disinfectants to clean toilets is often acceptable.

The following additional measures are also recommended:

- Hazardous chemical wastes of different composition should be stored separately to avoid unwanted chemical reactions.
- Hazardous chemical waste should not be discharged into sewerage systems.
- Large amounts of chemical waste should not be buried as they may contaminate water sources.
- Large amounts of chemical disinfectants should never be encapsulated as they are corrosive and sometimes flammable.

9.5 Wastes with high heavy-metal content

Wastes containing mercury or cadmium should never be burned or incinerated because of the risk of atmospheric pollution with toxic vapours, and should never be disposed of in municipal landfills as they may pollute the groundwater.

In countries with "cottage" industries specializing in the recovery of heavy metals, mercury- and/or cadmium-containing waste can be sent to these facilities for recovery of the valuable materials. It may also be possible to send back the waste to the suppliers of the original equipment, with a view to reprocessing or final disposal, but this is unusual because suppliers are generally reluctant to accept these wastes. The situation should be checked before dispatch of wastes. Exporting the waste to countries with the expertise and facilities for its adequate treatment should also be considered.

If none of the above options is feasible, the wastes may be disposed of in a safe storage site especially designed for the final disposal of hazardous industrial waste. Establishments that apply **minimal programmes** may also consider encapsulation, followed by disposal in an impermeable landfill (if available).

Where the production of waste with high heavy-metal content is minimal (e.g. in similar quantities to that present in municipal waste) and there are no facilities for recovery of heavy metals within the country, this waste may join the municipal waste stream.

9.6 Pressurized containers

Incineration or burning is not a disposal option for pressurized containers or aerosol cans because of the risk of explosion. The best disposal options are recycling and reuse; most undamaged pressurized containers may be sent back to the gas suppliers for refilling. Appropriate arrangements for the return of containers should be included in the original purchase contracts. Halogenated agents in liquid form, supplied in glass bottles, should be handled as hazardous chemical waste and disposed of as such (see section 9.4).

The following disposal options exist:

- *Undamaged containers*
  The following containers should be returned to the supplier:

— nitrous oxide cartridges or cylinders attached directly to the anaesthesia equipment;
— ethylene oxide cartridges or cylinders, which are usually attached to specially designed sterilizers;
— pressurized cylinders for other gases, such as oxygen, nitrogen, carbon dioxide, compressed air, cyclopropane, hydrogen, petroleum gases (for heating and cooking), and acetylene (for welding).

- *Damaged containers*
  Pressurized containers that have been damaged and are unsuitable for refilling may be crushed after being emptied completely; they can then be disposed of in any landfill. This option may also be selected when the return of empty containers to the gas suppliers is uneconomical. "Cottage" industries specializing in recovery of metals may also accept damaged pressurized containers. In extreme cases, where containers have corroded valves and still have residual pressure, the only safe solution is to assemble them at a safe location (e.g. a military training area) and arrange for qualified specialists to destroy them by controlled explosion.

- *Aerosol cans*
  Small aerosol cans should be collected and disposed of with general waste in black waste bags, but *only* if this waste is not destined for burning or incineration. They should never be placed in yellow bags, which will go for incineration. Large quantities of disposable aerosol cans may be returned to the supplier or sent to waste recycling plants where possible.

9.7 Radioactive waste

Note: A number of specific terms used in this section are explained in the Glossary (page 183).

The safe management of radioactive waste should ideally be the subject of a proper national strategy with an infrastructure that includes appropriate legislation, competent regulatory and operational organizations, and adequately trained personnel. The national strategy should also determine whether there will be centralized waste management or whether waste will be managed entirely at source (e.g. at the health-care institutions). This decision will be based on the quantity and activity levels of the waste generated and on the outcome of a cost–benefit analysis.

Each hospital or laboratory that uses unsealed radioactive sources for diagnostic, therapeutic, or research purposes should designate a trained Radiation Officer who will be responsible for the safe use of radioactive substances and for record-keeping. Properly calibrated instruments should be available for monitoring dose rates and contamination. A suitable record system that will ensure the traceability of radioactive waste transferred or disposed of locally should be established and kept up to date at all times.

9.7.1 Radioactive waste classification

Note: The classification of radioactive waste and the clearance levels should be established by the regulatory authority. Table 9.3 and

Table 9.3 *Radioactive waste classification*

Class	Description
Cleared material/waste	Materials containing levels of radionuclides at concentrations less than those expressed in Annex 3 (Tables A3.1–A3.3)
Low-level (short-lived)/ decay waste	Low-level radioactive waste containing short-lived radionuclides only (e.g. with half-lives less than 100 days), that will decay to clearance levels within 3 years of being produced
Low- and intermediate-level short-lived waste (LILW-SL)	Waste that will not decay to clearance levels within 3 years, containing β- and γ-emitting radionuclides with half-lives less than 30 years and/or α-emitting radionuclides with an activity less than 400 Bq/g and a total activity of less than 4000 Bq in each waste package
Low- and intermediate-level long-lived waste (LILW-LL)	Radioactive waste that contains radionuclides at concentrations above those for LILW-SL but with heat-generating capacity not exceeding 2 kW/m^3 of waste
High-level waste (HLW)	Radioactive waste that contains radionuclides at concentrations above those for LILW-SL and with heat-generating capacity above 2 kW/m^3 of waste

Annex 3 provide examples of waste classification and clearance levels.

Radioactive waste should be classified in accordance with national legislation and according to the activity levels and half-lives of the radionuclides present, as shown in Table 9.3.

9.7.2 Radioactive waste segregation and characterization

Radioactive waste should be categorized and segregated on the basis of the available options for treatment, conditioning, storage, and disposal. Possible categories are:

- half-life—for instance, short-lived (e.g. half-life <100 days), suitable for decay storage;
- activity and radionuclide content;
- physical and chemical form:
  - — liquid: aqueous and organic
  - — non-homogeneous (e.g. contain sludges or suspended solids)
  - — solid: combustible/non-combustible (if applicable) and compactable/ non-compactable (if applicable)
- sealed/non-sealed sources—for instance, spent sealed sources;
- waste content—for instance, waste containing hazardous (e.g. pathogenic, infectious, toxic) material.

After segregation, each category of waste should be kept separately, i.e. in separate containers. The waste containers should:

- be clearly identified;
- bear a radiation trefoil symbol when in use;
- be robust;
- be compatible with the waste contents;
- be capable of being filled and emptied safely.

The following information should be recorded for each waste container:

- identification number;
- radionuclides;
- activity (if measured or estimated) and date of measurement;
- origin (room, laboratory, individual, etc. if applicable);
- potential/actual hazards (chemical, infectious, etc.);
- surface dose rate and date of measurement;
- quantity (weight or volume);
- responsible person.

Containers for solid wastes should be lined with a durable transparent plastic bag which can be sealed (tied with plastic adhesive tape or heat-sealed).

Liquid waste should be collected in suitable containers according to its chemical and radiological characteristics, volume, and handling and storage requirements.

Spent sealed sources should be kept under shielding.

Containers should be checked for radioactive contamination; loose contaminating material should be removed before containers are reused.

Characterization of radioactive waste in terms of activity, radionuclide content, physical and chemical form, and associated hazards can be achieved by a combination of quality assurance (records of radionuclide inventory, activity decay, composition of materials used, etc.) and direct measurement techniques. Waste of unknown origin and composition will require detailed analysis. This may be complex and expensive.

9.7.3 Management options for radioactive health-care waste

A range of options may need to be considered for dealing with radioactive waste generated by health-care activities, depending on the amount and characteristics of the waste.

The waste may be suitable for release from regulatory control immediately or after a period of decay storage, which may vary from some days to a few years. Such waste may be released in quantities or at activity levels established by the regulatory authority. The recycling or reuse of radioactive materials is also possible if the regulatory authority has approved such an option.

If release is not a feasible option, return of the waste to the producer/supplier of the original material should be considered. This is of particular importance for large sealed sources and sources containing long-lived radionuclides.

For waste that can neither be released from regulatory control nor returned to the producer/supplier, an acceptable destination will need to be identified. This could be either a disposal facility or a facility for long-term storage pending future disposal. In both cases, prior treatment or conditioning of waste may be needed.

Decisions on waste management have significant financial implications that have to be addressed, since the waste generator is responsible for the waste. In developing its strategy, the national government may choose to undertake essential waste treatment, conditioning, storage,

and/or disposal if it is in the public interest to do so. In such cases, the function of the regulatory authority should be clearly separate and independent from that of the operating organizations.

Exemption and clearance
Some radioactive wastes can be exempted, or released, from regulatory control, because they represent a negligible radiological hazard. The radioactivity of materials released to the environment should be below the clearance levels established by the regulatory authority (examples are given in Tables A3.1–A3.3 of Annex 3). The discharge or release of the radioactive material should be monitored and recorded with sufficient detail and accuracy to demonstrate its compliance with the regulations.

Radioactive waste containing short-lived radionuclides should be stored for decay to the clearance levels.

Exemption of radioactive health-care waste from regulatory control is unlikely to mean that it is also exempt from regulatory control of other hazards.

Recycling and reuse
Recycling and reuse of radioactive materials should be considered as an alternative to disposal, if circumstances permit. Possibilities include:

- reuse of sealed sources;
- decontamination and reuse of equipment and protective clothing;
- reuse of dilute waste streams (for rinsing and washing of waste tanks that contained liquid waste with higher radioactivity content).

The reuse and/or recycling of radioactive materials should be subject to approval by the regulatory authority. Special attention should be given both to the implications of producing secondary waste streams, and to the need to ensure that sealed sources are in a serviceable condition and suitable for the intended application.

Spent sealed sources should not be recycled by the health-care institutions.

Return to supplier
If at all possible, spent sealed sources should be returned to suppliers. This is particularly important for sources with high activity and those containing long-lived radionuclides.

The high-activity radionuclides, usually of long half-life, used for therapeutic purposes are conditioned as sealed sources, in the form of pills, seeds, ribbons, capsules, tubes, or needles. Brachytherapy sources are recovered after use, washed, disinfected, and stored under lead shielding until needed for other patients. These items may become waste if their conditioning is damaged, the activity has decayed, or they are no longer required. Spent sources for teletherapy also become waste. In countries that lack a nuclear industry equipped to dispose of spent sealed sources, hospitals should return these items to their original containers or otherwise package them appropriately (see Chapter 7) and send them back to the supplier for reprocessing, recycling, or safe disposal. Where a nuclear industry with appropriate capabilities exists, hospitals may send non-

recyclable spent sealed sources to an authorized facility or to the national agency designated for radioactive waste disposal.

Any health-care institution proposing to import a sealed source containing radioactive material that will have an activity greater than 100 MBq 10 years after receipt is recommended to:

- require the supplier to accept the source back after expiry of its useful lifetime, within 1 year of such return being requested, on condition that the user undertakes to return the source to the supplier not later than 15 years after receiving it;
- submit to the regulatory authority a copy of relevant parts of the contract (if the source is purchased) or acceptance document (if the source is donated) and obtain the written agreement of the authority before purchasing or accepting the source.

Storage

Storage facilities may be required for untreated, treated, and conditioned radioactive health-care waste; special care is needed for the storage of unconditioned waste in order to limit the risk of dispersion. Storage facilities should be designed to provide physical security, retrievability, and radiological protection. Radioactive waste must be stored in such a way that human health and the environment are protected; it must not be stored in the vicinity of corrosive, explosive, or readily flammable materials.

Where activity limits for immediate or simple discharge/disposal methods cannot be met, health-care establishments should segregate radioactive waste and store it for the time required for the activity to decay to clearance levels. Since the half-life of most radioactive materials used in hospitals is of the order of hours or days, storage for at least 10 half-life periods can be followed by disposal to the ordinary waste system (with appropriate monitoring). Decayed, non-infectious radioactive waste should be placed in transparent bags to facilitate visual inspection (if the wastes are to be landfilled). Decayed but infectious radioactive waste requires disinfection before disposal and is therefore collected in yellow plastic bags.

All radioactive waste that is to be stored during decay should be kept in suitable containers that prevent dispersion of their content. A plastic bag in an easy-to-handle can or drum should be used. Containers used for the storage of radioactive waste should be clearly identified (marked with the words “RADIOACTIVE WASTE” and the radiation symbol), and labelled to show the activity of the radionuclide on a particular date, period of storage required, origin of the waste, surface dose rate on a particular date, quantity, and responsible person. The containers should be stored in a specially designated area in storage rooms—lead-shielded if necessary—designed for radioactive substances or waste. The storage record should be clearly endorsed to indicate the items that are “radioactive waste”.

Facilities or areas for radioactive waste must be clearly demarcated, with controlled access, and should have the characteristics listed in Box 9.2. Areas for untreated (raw) waste should be separate from those for conditioned waste.

Box 9.2 Characteristics of storage facilities/areas for radioactive health-care waste

- Sufficient capacity to accommodate all waste generated before discharge, treatment, or transportation.
- Simple construction, with non-flammable walls and floors that may be easily decontaminated.
- Impermeable floor covering, with a containment edge and slight slope to a central collection area.
- Adequate ventilation.
- Air sampling and radiation alarms (as required by the regulatory authority).
- Fire detection/control equipment (as required by the regulatory authority).
- Fire-resistant, lockable doors.
- Compartments to allow separation of different kinds of waste (e.g. to facilitate the safe storage of materials presenting particular hazards—volatile, pathogenic, infectious and putrescible, chemically reactive).
- Demarcation as radiologically controlled areas.
- A log-book, listing the number of containers, entry date, waste types, activity, etc., which should be kept outside, but near, the storage room or area.
- Protection from the environment (weather), including extremes of temperature.
- Protection against unauthorized entry and against the intrusion of animals, insects, etc.
- Movable radiation shielding (placed as appropriate to protect workers from radiation).

Treatment and conditioning

Radioactive health-care waste should be treated and conditioned in accordance with the national radioactive waste management strategy and, in particular, to meet any waste acceptance criteria laid down by the regulatory authority. Treatment and conditioning should be undertaken, when necessary, to improve the characteristics of waste before interim storage and/or disposal.

Treatment includes operations intended to improve safety or economy by changing the characteristics of the radioactive waste. The basic objectives are:

- Volume reduction:
  — for solid waste: shredding, low-force compaction, and controlled incineration;
  — for liquid waste: evaporation under controlled conditions.

- Removal of radionuclides:
  — for solid waste: decontamination;
  — for liquid waste: ion exchange.
- Change of composition:
  — for liquid waste: precipitation/filtration.

It is important to be aware that treatment processes may result in the production of secondary radioactive waste streams (contaminated filters, spent resins, sludges, ash), which also need to be appropriately managed.

Conditioning involves those operations that convert radioactive waste into a form that is more suitable for handling, transportation, storage, and disposal. The operations may include immobilization of radioactive waste in concrete, placing the waste in suitable containers, and providing additional packaging. In many instances, treatment and conditioning take place in close physical conjunction with one another.

Discharge/disposal

Although management may involve the concentration and containment of radioactive waste, it may also involve the discharge of effluents (for example, of liquid and gaseous waste) into the environment. This may be done only within the limits authorized by the regulatory authority, and should take into account subsequent dispersion. For all practical purposes this is an irreversible action and is considered suitable only for limited amounts of certain radioactive wastes.

The health-care institution should ensure that radionuclides are not released to the environment unless:

- the activity released is confirmed to be below the clearance levels; or
- the activity of the liquid or gaseous effluents discharged is within limits authorized by the regulatory authority.

Any health-care institution wishing to release to the environment solid, liquid, or gaseous radioactive waste with activity above the clearance levels should apply for an authorization. It should also:

- keep all radioactive discharges or releases as far below the authorized limits as is reasonably achievable;
- monitor and record the discharges or releases of radionuclides with sufficient detail and accuracy to demonstrate compliance with the authorized discharge limits;
- report discharges to the regulatory authority at whatever intervals are specified in the authorization; and
- report promptly to the regulatory authority any discharges or releases that exceed the authorized limits.

Whether radioactivity is released within the clearance levels or under authorization, the non-radiological hazards of the release must also be considered and the requirements of any regulations governing those hazards should be met.

Disposal is the final step in the management of radioactive waste. Essentially, it involves the placement of radioactive waste in a disposal facility that provides reasonable assurance of safety; in general there is no intention of retrieval, and no long-term surveillance or maintenance of

the disposal site. The establishment of an engineered disposal facility (repository) is thus a complex and costly undertaking.

When radioactive waste is not suitable for discharge or release to the environment or for clearance within a reasonable time, the health-care institution should submit its proposals for disposal to the regulatory authority. It should then ensure that the criteria set by the regulatory authority for acceptance of the waste at any repository or by any national waste management organization are met.

Additional remarks

- Disposable syringes containing radioactive residues should be emptied in a location designated for the disposal of radioactive liquid waste. They should then be stored in a sharps container to allow decay of any residual activity, before normal procedures for disposal of syringes and needles are followed.
- It is not appropriate to disinfect radioactive solid waste by wet thermal or microwave procedures.
- Solid radioactive waste such as bottles, glassware, and containers should be destroyed before disposal to avoid reuse by the public.
- The drains that serve sinks designated for discharge of radioactive liquids should be identified. If repairs become necessary, radiation levels should be measured as the drain or sewer is opened up, and appropriate precautions should be taken.
- Liquids that are immiscible with water, such as scintillation counting residues, should not be discharged to sewers but treated by an alternative method, e.g. incineration, absorption.
- Higher-level radioactive waste of relatively short half-life (e.g. from iodine-131 therapy) and liquids that are immiscible with water, such as scintillation counting residues and contaminated oil, should be stored for decay in marked containers, under lead shielding, until activities have reached authorized clearance levels. Water-miscible waste may then be discharged to the sewer system and immiscible waste may be disposed of by the methods recommended for large quantities of hazardous chemical waste.
- Radioactive waste resulting from cleaning-up operations after a spillage or other accident should be retained in suitable containers, unless the activity is clearly low enough to permit immediate discharge. If excessive activity enters the sewer accidentally, a large volume of water should be allowed to flow to provide dilution to about 1 kBq per litre. The relevant governmental agency must be informed urgently if radioactive waste in excess of the permitted amounts has been discharged to sewers, the atmosphere, or otherwise into the environment. After the emergency period, the activity of the resulting waste should be assessed and the relevant ministries should be informed of the circumstances that gave rise to the incident.
- It is not usually necessary to collect and confine patients' excreta after diagnostic procedures, although ordinary toilets used by such patients should be checked regularly for radioactive contamination by competent staff (e.g. the Radiation Officer). In the case of therapeutic procedures involving radionuclides, hospital toilets must be checked for radioactive contamination after each use by patients, unless every patient has an individual toilet. Some countries require the use of separate toilets equipped with delay tanks and/or special treatment systems for patients undergoing radiotherapy.

- Radioactive gases, deriving mainly from research and radioimmunoassays, should be discharged directly to the atmosphere for dilution by dispersal (within the authorized limits). In general, all gaseous waste discharges, including exhausts from stores and fume cupboards, should be designed and sited to prevent re-entry into any part of the premises. Radiation and contamination levels near discharge points should be checked periodically by the Radiation Officer. The WHO air quality guideline value for atmospheric radioactivity is 1 Bq/m^3.

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