Medical Waste Management Guidance Manual for SADC and COMESA Countries

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Medical Waste Management Guidance Manual for SADC and COMESA Countries

DISCLAIMER

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ABBREVIATIONS AND ACRONYMS

AIDS	acquired immunodeficiency syndrome
AEB	accidental exposure to blood
AOX	absorbable organic iodinated compounds
ASME	The American Society of Mechanical Engineers
BAT	best available techniques
BEP	best environmental practice
BOD	Biochemical Oxygen Demand
BREF	BAT Reference Documents
CFU	colony forming unit
ClO2	chlorine dioxide
EMS	environmental management system
EPP	environmentally preferable purchasing
ERICards	Emergency response intervention cards
GEF	Global Environment Facility
HCl	hydrochloric acid
HDPE	high-density polyethylene
HEPA	high-efficiency particulate air
HF	hydrofluoric acid
HIV	human immunodeficiency virus
IARC	International Agency for Research on Cancer
ISO	International Organization for Standardization
kBq	Kilobecquerel
kg	kilogram
LDPE	low-density polyethylene
m	meter
MBq	Megabecquerel
mg	miligram
MSDS	material safety data sheet
NaOCl	sodium hypochlorite
ng	nanogram
NGO	nongovernmental organization
O3	Ozone
PC	polycarbonate
PCDD	polychlorinated dibenzodioxins
PCDF	polychlorinated dibenzofurans
PET	polyethylene terephthalate (also known as PETE)
pH	Potential of hydrogen
POPs	persistent organic pollutants
PP	polypropylene
PPE	personal protective equipment
PVC	polyvinyl chloride
SARS	severe acute respiratory syndrome
UN	United Nations

UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Programme
UNIDO	United Nations Industrial Development Organisation
UV	ultraviolet
WHO	World Health Organization
µl	microliter
µm	micromiter

1. INTRODUCTION

Health care is the protection, maintenance or improvement of health through the diagnosis, treatment, and prevention of disease, illness, injury, and other physical and mental impairments in human beings. Health activities also generate waste, 20 percent of which entail risks either of infection, of trauma or of chemical or radiation exposure, particularly when they are not properly managed.

Although the risks associated with infectious medical waste and their management are known and published in manuals and literature, there is still large incidences of infections from medical waste particularly in developing countries. Lack of awareness about the health hazards related to health-care waste, inadequate training in proper waste management, absence of waste management and disposal systems, insufficient financial and human resources and the low priority given to the topic are the most common problems connected with health-care waste. Many countries either do not have appropriate regulations, or do not enforce them. The staff is often unequipped for coping with this task.

Poor waste management can jeopardize health care staff, employees who handle medical waste, patients and their families, and the neighbouring population. Other potential infectious risks may include the spread of drug-resistant microorganisms from health facilities into the environment.

However the risks associated with hazardous medical waste can be reduced through appropriate measures. This manual is intended as a practical and pragmatic tool for the routine management of dangerous hospital wastes. It is modified from a more robust medical waste management manual published by WHO safe Management of Waste from Health Care Activities 2nd Edition (2014).

The manual is intended for people directly involved in the creation and handling of health-care wastes: medical staff, health-care facility directors, ancillary health workers, infection-control officers and waste workers. Others include all people and organizations that have interest in the safe management of health-care wastes: regulators, policy- makers, development organizations, voluntary groups, environmental bodies, environmental health practitioners, advisers, researchers and students.

2.0 DEFINITION AND CHARACTERIZATION OF "MEDICAL WASTE"

2.1. GENERAL DEFINITIONS AND CLASSIFICATION

Health-care waste includes all waste generated within health-care facilities, research centres and laboratories related to medical procedures. It also includes the same types of waste originating from minor and scattered sources, including waste produced in the course of health care undertaken in the home (e.g. home dialysis, self-administration of insulin, recuperative care).

Between 75% and 90% of the waste produced from a health care facility is domestic waste, which is "non-hazardous" or "general health-care waste". It comes mostly from the administrative, kitchen and housekeeping functions and may also include packaging waste and waste generated during maintenance of health-care buildings. The remaining 10–25% of health-care waste is regarded as "hazardous" and may pose a variety of environmental and health risks. Table 2.1 provides classification of the medical wastes. However, if segregation of these non-hazardous wastes is not done properly as is the case in most health care facilities in developing world, even this component of no-hazardous waste become hazardous waste.

Table 2.1: Classification of hazardous medical waste

SN	Waste category	Descriptions and examples
Hazardous health-care waste		
1.	Sharps waste	Used or unused sharps (e.g. hypodermic, intravenous or other needles; auto-disable syringes; syringes with attached needles; infusion sets; scalpels; pipettes; knives; blades; broken glass)
2.	Infectious waste	Waste suspected to contain pathogens and that poses a risk of disease transmission (see section 2.1.2) (e.g. waste contaminated with blood and other body fluids; laboratory cultures and microbiological stocks; waste including excreta and other materials that have been in contact with patients infected with highly infectious diseases in isolation wards)
3.	Pathological waste	Human tissues, organs or fluids; body parts; foetuses; unused blood products
4.	Pharmaceutical waste, cytotoxic waste	Pharmaceuticals that are expired or no longer needed; items contaminated by or containing pharmaceuticals Cytotoxic waste containing substances with genotoxic properties (e.g. waste containing cytostatic drugs – often used in cancer therapy; genotoxic chemicals)
5.	Chemical waste	Waste containing chemical substances (e.g. laboratory reagents; film developer; disinfectants that are expired or no longer needed; solvents; waste with high content of heavy metals, e.g. batteries; broken thermometers and blood-pressure gauges)
6.	Radioactive waste	Waste containing radioactive substances (e.g. unused liquids from radiotherapy or laboratory research; contaminated glassware, packages or absorbent paper; urine and excreta from patients treated or tested with unsealed radionuclides; sealed sources)
Non-hazardous or general health-care waste		
7.		Waste that does not pose any particular biological, chemical, radioactive or

SN	Waste category	Descriptions and examples
		physical hazard

The various categories of waste are set out in detail in the data sheets in Annex 1 (sheets 1 to 11). Cytotoxic and radio- active wastes are dealt with briefly in that annex.

2.2 QUANTIICATION OF MEDICAL WASTE

The quantity of waste produced in a hospital depends on the level of national income and the type of facility concerned. Major sources of medical waste are shown in Table 2.2.

Table 2.2: Examples of health-care waste from different sources Major sources (hospitals and medical centres)

	Sharps	Infectious and pathological waste	Chemical, pharmaceutical and cytotoxic waste	Non-hazardous or general waste
Medical ward	Hypodermic needles, intravenous set needles, broken vials and ampoules	Dressings, bandages, gauze and cotton contaminated with blood or body fluids; gloves and masks contaminated with blood or body fluids	Broken thermometers and blood-pressure gauges, spilt medicines, spent disinfectants	Packaging, food scraps, paper, flowers, empty saline bottles, non-bloody diapers, non-bloody intravenous tubing and bags
Operating Theatre	Needles, intravenous sets, scalpels, blades, saws	Blood and other body fluids; suction canisters; gowns, gloves, masks, gauze and other waste contaminated with blood and body fluids; tissues, organs, foetuses, body parts	Spent disinfectants Waste anaesthetic gases	Packaging; uncontaminated gowns, gloves, masks, hats and shoe covers
Laboratory	Needles, broken glass, Petri dishes, slides and cover slips, broken pipettes	Blood and body fluids, microbiological cultures and stocks, tissue, infected animal carcasses, tubes and containers contaminated with blood or body fluids	Fixatives; formalin; xylene, toluene, methanol, methylene chloride and other solvents; broken lab thermometers	Packaging, paper, plastic containers
Pharmacy store			Expired drugs, spilt drugs	Packaging, paper, empty containers
Radiology			Silver, fixing and developing solutions; acetic acid; glutaraldehyde	Packaging, paper
Chemotherapy	Needles and syringes		Bulk chemotherapeutic waste; vials, gloves and other material contaminated with cytotoxic agents; contaminated excreta and urine	Packaging, paper
Vaccination Campaigns	Needles and syringes		Bulk vaccine waste, vials, gloves	Packaging
Environmental Services	Broken glass		Disinfectants (glutaraldehyde, phenols, etc.), cleaners, spilt mercury, pesticides	Packaging, flowers, newspapers, magazines, cardboard, plastic and glass containers, yard and plant waste

	Sharps	Infectious and pathological waste	Chemical, pharmaceutical and cytotoxic waste	Non-hazardous or general waste
Engineering			Cleaning solvents, oils, lubricants, thinners, asbestos, broken mercury devices, batteries	Packaging, construction or demolition waste, wood, metal
Food services				Food scraps; plastic, metal and glass containers; packaging

Minor	Sharps	Infectious and pathological waste	Chemical, pharmaceutical and cytotoxic waste	Non-hazardous or general waste
Physicians' Offices	Needles and syringes, broken ampoules and vials	Cotton, gauze, dressings, gloves, masks and other materials contaminated with blood or other body fluids	Broken thermometers and blood-pressure gauges, expired drugs, spent disinfectants	Packaging, office paper, newspapers, magazines, uncontaminated gloves and masks
Dental offices	Needles and syringes, broken ampoules	Cotton, gauze, gloves, masks and other materials contaminated with blood and other body fluids	Dental amalgam, spent Disinfectants	Packaging, office paper, newspapers, magazines, uncontaminated gloves and masks
Home health Care	Lancets and insulin injection needles	Bandages and other material contaminated with blood or other body fluids	Broken thermometers	Domestic waste

3.0 MEDICAL WASTE RISKS AND IMPACT ON HEALTH AND THE ENVIRONMENT

3.1. PERSONS POTENTIALLY EXPOSED

All persons who are in contact with hazardous medical waste are potentially exposed to the various risks it entails: persons inside the facility generating medical waste, those who handle it, and persons outside the facility who may be in contact with hazardous wastes or their by-products, if there is no or inadequate sound medical waste management. The following groups of persons are potentially exposed:

a) medical doctors, nurses, health-care auxiliaries and hospital maintenance personnel
b) patients in health-care facilities or receiving home care
c) visitors to health-care facilities
d) workers in support services, such as cleaners, people who work in laundries, porters
e) workers transporting waste to a treatment or disposal facility
f) workers in waste-management facilities (such as landfills or treatment plants), as well as informal recyclers (scavengers).

3.2. RISKS ASSOCIATED WITH HAZARDOUS MEDICAL WASTE

The health risks associated with hazardous medical waste can be divided into six categories:

a) risk of trauma (waste category 1);
b) risk of infection (waste categories 1 and 2);
c) chemical risk (waste categories 3 and 4);
d) risk of fire or explosion (waste categories 3 and 4);
e) risk of radioactivity (waste category 5; and
f) risk of environmental pollution and contamination.

3.2.1. Risks of Trauma and Infection

Health-care wastes are a source of potentially dangerous micro-organisms that can infect hospital patients, personnel and the general public. There are many different exposure routes: through injury (cut, prick), through contact with the skin or mucous membranes, through inhalation or through ingestion.

Table 3.1: Examples of infections that can be caused by hazardous medical waste

Type of infection	Examples of causative organisms	Transmission vehicles
Gastroenteric infections	Enterobacteria, e.g. *Salmonella*, *Shigella* spp., *Vibrio cholerae*, *Clostridium difficile*, helminths	Faeces and/or vomit
Respiratory infections	*Mycobacterium tuberculosis*, measles virus, *Streptococcus pneumoniae*, severe acute respiratory syndrome (SARS)	Inhaled secretions, saliva

Type of infection	Examples of causative organisms	Transmission vehicles
Ocular infection	Herpesvirus	Eye secretions
Genital infections	*Neisseria gonorrhoeae*, herpesvirus	Genital secretions
Skin infections	*Streptococcus* spp.	Pus
Anthrax	*Bacillus anthracis*	Skin secretions
Meningitis	*Neisseria meningitidis*	Cerebrospinal fluid
Acquired immunodeficiency syndrome (AIDS)	Human immunodeficiency virus (HIV)	Blood, sexual secretions, body fluids
Haemorrhagic fevers	Junin, Lassa, Ebola and Marburg viruses	All bloody products and secretions
Septicaemia	*Staphylococcus* spp.	Blood
Bacteraemia	Coagulase-negative *Staphylococcus* spp. (including methicillian-resistant *S. aureus*), *Enterobacter*, *Enterococcus*, *Klebsiella* and *Streptococcus* spp.	Nasal secretion, skin contact
Candidaemia	*Candida albicans*	Blood
Viral hepatitis A	Hepatitis A virus	Faeces
Viral hepatitis B and C	Hepatitis B and C viruses	Blood and body fluids
Avian influenza	H5N1 virus	Blood, faeces

Some accidental exposure to blood (AEB) or to other body fluids are examples of accidental exposure to hazardous medical waste. Nursing staff are at high risk of viral infections such as AIDS and hepatitis B and C, through contaminated needles. Sharps and pathogenic cultures are regarded as the most hazardous medical waste.

Some wastes, such as anatomical wastes, do not necessarily entail a health risk or risk for the environment but must be treated as special wastes for ethical or cultural reasons. A further potential risk is that of the propagation of micro- organisms outside health-care facilities which are present in those facilities and which can sometimes be resistant.

3.2.2. Survival of Micro-Organisms in the Environment

Survival on micro-organisms depend on environmental conditions (temperature, humidity, solar radiation, availability of organic substrate, presence of disinfectants, etc.). Pathogenic micro-organisms have a limited capacity of survival in the environment. Bacteria are less resistant than viruses. Very little is known as yet about the survival of prions and the agents of degenerative neurological dis-eases (such as Creutzfeldt-Jakob's disease, Kuru, and so on), which seem to be more resistant than viruses.

Table 3.2 gives a summary of what is known about the survival of various pathogens.

Table 3.2: Examples of the survival time of certain pathogens[1]

Type of pathogen	Survival time
Hepatitis B virus	Several weeks on a surface in dry air 1 week on a surface at 25°C Several weeks in dried blood 10 hours at 60°C Survives 70% ethanol.
Infectious dose of hepatitis B and C viruses	1 week in a drop of blood in a hypodermic needle
Hepatitis C	7 days in blood at 4°C.
HIV	3 – 7 days in ambient air Inactivated at 56°C 15 minutes in 70% ethanol 21 days in 2 µl of blood at ambient temperature Drying the virus reduces its concentration by 90-99% within the next few hours.
The concentration of micro-organisms in medical waste, with the exception of laboratory cultures of pathogens and the excreta of infected patients, is generally no higher than in household refuse. However, medical waste contain a wider variety of On the other hand, the survival time of the micro-organisms present in medical waste is short (probably because the wastes contain disinfectants micro-organisms	

The role played by carriers such as rats and insects must also be taken into account in the evaluation of micro-organism survival time in the environment. They are passive carriers of pathogens, and measures must be taken to control their proliferation.

3.2.3. Biological Risks Associated with Exposure to Solid Household Refuse

Various studies conducted in high-income countries have shown the following results: Compared to the general population, in the case of persons employed in the processing of household waste

a) the risk of infection is 6 times higher;
b) the risk of contracting an allergic pulmonary disease is 2.6 times higher;
c) the risk of contracting chronic bronchitis is 2.5 times higher; and
d) the risk of contracting hepatitis is 1.2 times higher.

Pulmonary diseases and bronchitis are caused by exposure to the bio-aerosols contained in the air at the sites where the refuse is dumped, stored or processed.[2]

[1] WHO 2010, Public Health Agency of Canada 2001, Thomson *et al.* 2003.

[2] These bio-aerosols contain gram-positive and gram-negative bacteria, aerobic Actinomycetes and sewage fungi.

3.2.4. Chemical Risks

Many chemical and pharmaceutical products used in health-care facilities entail a health risk due to their properties (toxic, carcinogenic, mutagenic, reprotoxic, irritant, corrosive, sensitizing, explosive, flammable, etc.). There are various exposure routes for contact with these substances: inhalation of gas, vapour or droplets, dermal (i.e. contact with the skin or mucous membranes), or ingestion. Some substances (such as chlorine and acids) are incompatible and can generate toxic gases when mixed.

The identification of potential hazards caused by certain substances or chemical preparations can be easily done through labelling: symbols, warning statements or hazard statements. More detailed information is set out in the material safety data sheet (MSDS).

Some examples of the international hazard symbols are shown in Fig. 3.1. Cleaning products and, in particular, disinfectants are examples of dangerous chemicals which are used in large quantities in hospitals. Most are irritant or even corrosive, and some disinfectants (such as formaldehyde) can be sensitizing and toxic.

	Corrosive (C) These substances attack and destroy living tissues, including the eyes and skin.
	Highly flammable (F) These substances easily catch fire (flash point: 21–55 °C). Never store flammable substances together with explosive ones
	Toxic (T) These substances can cause death. They may have their effects when swallowed or breathed in, or when absorbed through the skin
	Harmful (Xn) These substances are similar to toxic substances but are less dangerous

	Explosive (E) An explosive is a compound or mixture susceptible to a rapid chemical reaction, decomposition or combustion, with the rapid generation of heat and gases with a combined volume much larger than the original substance
	Irritant (I) These substances can cause reddening or blistering of skin

Figure 3.1: Example of the labelling of chemicals according to the new (international) system (GHS)

Mercury is a heavy metal in liquid form at room temperature and pressure. It is very dense (1 litre of mercury weighs 13.5 kg). It evaporates readily and can remain for up to a year in the atmosphere. It accumulates in sediments, where it is converted into methylmercury, a more toxic organic derivative. Mercury is found mainly in thermometers, manometers, dental alloys, certain types of battery, electronic components and fluorescent or compact fluorescent light tubes. Health-care facilities are one of the main sources of mercury in the atmosphere due to the incineration of medical waste. These facilities are also responsible for the mercurial pollution of surface water.

Mercury is highly toxic. There is no threshold under which it does not produce any undesirable effect. Mercury can cause fatal poisoning when inhaled.[3] It is also harmful in the event of transcutaneous absorption and has dangerous effects on pregnancy.

Silver is a toxic element that is found in hospitals (photographic developers). It is bactericidal. Bacteria which develop resistance to silver are also thought to be resistant to antibiotics.[4]

The trading and use of expired medicines, particularly in developing countries, entail a public health risk. This manual does not cover the risk associated with cytotoxic drugs (see information outlined in Annex 1 – data sheet no. 6).

Disinfectants, such as chlorine and quaternary ammonium, are used in large quantities in health-care facilities, and are corrosive. It should also be noted that reactive chemicals such as these may form highly toxic secondary compounds. Where chlorine is used in an unventilated

[3] The disease caused by exposure to mercury is called mercurialism.
[4] Anon 2007, Chopra 2007, Senjen & Illuminato 2009.

place, chlorine gas is generated as a by-product of its reaction with organic compounds. Consequently, good working practices should be used to avoid creating situations where the concentration in air may exceed safety limits.

3.3. RISKS ASSOCIATED WITH THE INAPPROPRIATE PROCESSING AND DUMPING OF HAZARDOUS MEDICAL WASTE

3.3.1. Incineration Risks

In some cases, particularly when wastes are incinerated at low temperature (less than 800°C) or when plastics containing polyvinyl chloride (PVC) are incinerated, hydrochloric acid (which causes acid rain), dioxins, furans and various other toxic air-borne pollutants are formed. They are found in emissions but also in residual and other air-borne ash and in the effluent gases released through incinerator chimneys. Exposure to dioxins, furans and other coplanar polychlorinated biphenyls can have effects that are harmful to public health.[5]

These substances are persistent and they accumulate in the food chain. The bulk of human exposure to dioxins, furans and coplanar polychlorinated biphenyls takes place through food intake. Even in high-temperature incinerators (over 800°C) there are cooler pockets at the beginning or the end of the incineration process where dioxins and furans can form. The problem of dioxin and furan formation can be minimised if incineration takes place only at temperatures above 800°C and if the formation of combustion gas is prevented at temperatures of 200 - 400°C.

Incineration of metals or of materials with a high metal content (especially lead, mercury and cadmium) can result in metals being released into the environment. Lead, cadmium are known to be very toxic and thus need to be controlled.

3.3.2. Risks Related to Random Disposal or Uncontrolled Dumping

Burial and random dumping on uncontrolled sites can have a direct impact on the environment in terms of soil and water pollution.

3.3.3. Risks Related to the Discharge of Raw Sewage from Medical Facility

Poor management of wastewater and sewage sludge can result in the contamination of water and soil with pathogens or toxic chemicals. Pouring chemical and pharmaceutical

[5] Long-term exposure to low doses of dioxins and furans can result in immune system disorders in humans as well as abnormal development of the nervous system, endocrine disruption and reproductive damage. Short-term exposure to high doses can cause skin lesions and impaired

wastes down the drain can impair the functioning of biological sewage treatment plants or septic tanks. These can end up polluting the ecosystem and water sources. Antibiotics and their metabolites are excreted in the urine and faeces of patients under treatment and end up in sewage. Hospital sewage contains 2 to 10 times more antibiotic-resistant bacteria than domestic wastewater, a phenomenon which contributes to the emergence and propagation of pathogens such as MRSA (methicillin-resistant Staphylococcus aureus).

4. LEGISLATIVE, REGULATORY AND POLICY ASPECTS OF HEALTH-CARE WASTE

4.1. IMPORTANCE OF A NATIONAL POLICY

A national policy on medical waste management is an important step in creating a successful and sustainable health-care waste-management system, which all health-care facilities can work towards. A policy is a blueprint that drives decision making at a political level and should mobilize government effort and resources to create the conditions to make changes in health-care facilities. A national policy should identify the needs and problems in the country, as well as taking into account the relevant international agreements and conventions adopted nationally that govern public health, sustainable development, the environment and safe management of hazardous waste.

Once a national policy has been prepared, supporting regulations governing health-care waste management should be developed. To be most effective, regulations should describe what is expected from health-care staff and explain the methods for their enforcement. In addition, there are useful internationally available guidance documents produced that may be used to supplement the national policy. These include the World Health Organization (WHO), United Nations Environment Programme – Secretariat of the Basel Convention, and several nongovernmental organizations (NGOs) (e.g. WHO, 2005b).

4.2 GUIDING PRINCIPLES

Five principles are widely recognised as underlying the effective and controlled management of wastes. These principles have been used by many countries when developing their policies, legislation and guidance:

a) **The "polluter pays"** principle implies that all producers of waste are legally and financially responsible for the safe and environmentally sound disposal of the waste they produce.
b) **The "precautionary"** principle is a persuasive principle governing health and safety protection. It was defined and adopted under the Rio Declaration on Environment and Development (UNEP, 1972) as Principle 15: "Where there are threats of serious or irreversible damage to the environment, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation".
c) **The "duty of care"** principle stipulates that any person handling or managing hazardous substances or wastes or related equipment is ethically responsible for using the utmost care in that task. This principle is best achieved when all parties involved in the production, storage, transport, treatment and final disposal of hazardous wastes (including health-care waste) are appropriately registered or licensed to produce, receive and handle named categories of waste.

d) **The "proximity"** principle recommends that treatment and disposal of hazardous waste take place at the closest possible location to its source to minimize the risks involved in its transport.

e) **The "prior informed consent principle"** as embodied in various international treaties is designed to protect public health and the environment from hazardous waste. It requires that affected communities and other stakeholders be apprised of the hazards and risks, and that their consent be obtained. In the context of health- care waste, the principle could apply to the transport of waste and the siting and operation of waste-treatment and disposal facilities.

4.3. INTERNATIONAL AGREEMENTS

There are several international agreements which lay down fundamental principles concerning public health, environmental protection and the safe management of hazardous wastes. These principles and conventions are set out below and must be taken into account in the planning of hazardous medical waste management.

4.3.1 The Basel Convention

The Basel Convention on the Control of Trans-Boundary Movements of Hazardous Wastes and their Disposal (the Basel Convention) aims to protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes. It regulates the transboundary movements of hazardous and other wastes by applying the "prior informed consent" principle. Each party is required to introduce appropriate national or domestic legislation to prevent and punish illegal traffic in hazardous and other wastes. In addition, the convention obliges its parties to ensure that hazardous and other wastes are managed and disposed of in an environmentally sound manner. Strong controls have to be applied from the moment of the generation of a hazardous waste to its storage, transport, treatment, reuse, recycling, recovery and final disposal.

The Basel Convention specifically refers to:

- Y1 – Clinical wastes from medical care in hospitals, medical centres and clinics
- Y3 – Waste pharmaceuticals, drugs and medicines.

The convention also has a category of hazardous characteristics defined as "H 6.2 - Infectious substances - substances or wastes containing viable microorganisms or their toxins which are known or suspected to cause disease in animals or humans."

The Basel Convention Secretariat has produced *Technical guidelines on the environmentally sound management of biomedical and health care wastes (Y1; Y3)* (UNEP, 2003). These guidelines should be used in the preparation of sound management of medical waste at country level.

4.3.2 The Bamako Convention

The Bamako Convention on the Import into Africa and the Control of Trans-Boundary Movement and Management of Hazardous Wastes within Africa (the Bamako Convention) is a treaty of African nations prohibiting the import of any hazardous (including radioactive) waste. The Bamako Convention uses a format and language similar to that of the Basel Convention, but is much stronger in prohibiting all imports of hazardous waste.

4.3.3. The Stockholm Convention

The Stockholm Convention on Persistent Organic Pollutants (POPs) (the Stockholm Convention) is a global treaty to protect human health and the environment from persistent organic pollutants (POPs). POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms and are toxic to humans and wildlife. POPs circulate globally and can cause damage wherever they travel.

Under Article 5 and Annex C, governments that are party to the convention are required to reduce or eliminate releases from unintentional production of POPs - in particular, polychlorinated dibenzo-p-dioxins and dibenzofurans. These chemicals are formed and released to the environment by medical waste incinerators and other combustion processes. Governments must require the use of best available techniques and promote best environmental practices for new incinerators within four years after the convention comes into force for the country.

The *Guidelines on best available techniques and provisional guidance on best environmental practices* (UNEP, 2006) were released in 2006. Section V.A.II deals with health-care waste.

4.3.4. The Environment and Sustainable Development Conferences

The concept of the environment and the pattern of action[2] at national and international level to safeguard it evolved in the years leading up to the United Nations Stockholm Conference 1972. Then, in the mid-1980s, the concept of sustainable development was defined by the World Commission on Environment and Development (Brundtland Commission). In simple terms, it is defined as follows: Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

4.3.5 United Nations Committee of Experts on the Transport of Dangerous Goods

The United Nations Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods has developed recommendations for governments and international organizations responsible for the transport of dangerous goods, or its regulation. The

development of recommendations was triggered by new technical progress, the advent of new substances and materials, the exigencies of modern transport systems, and, above all, an increasing requirement to ensure the safety of people, property and the environment. The recommendations do not apply to the bulk transport of dangerous goods in seagoing or inland navigation bulk carriers or tank vessels, which are subject to other international or national regulations.

The recommendations concerning the transport of dangerous goods are presented as an annex to the *United Nations Recommendations on the transport of dangerous goods – model regulations* (United Nations Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods, 2009). The model regulations present a basic scheme of provisions that will allow uniform development of national and international regulations governing the various modes of transport. It is expected that governments, when revising or developing regulations will conform to the principles of these model regulations, thus contributing to worldwide harmonization.

The model regulations cover principles of classifying and defining classes; listing the principal dangerous goods; general packing requirements; testing procedures, marking, labelling or placarding; and transport documents.

4.4 AVAILABLE GUIDANCE

4.4.1. World Health Organization Guidance

The WHO policy paper, *Safe health-care waste management* (WHO, 2004), recommends that countries conduct assessments before choosing health-care management methods. WHO suggests that government organizations adopt the strategies outlined below:

a) Short-term strategies:
   i) Production of all syringe components using the same plastic to facilitate recycling.
   ii) Selection of polyvinyl chloride–free medical devices.
   iii) Identification and development of recycling options wherever possible (e.g. for plastic, glass).
   iv) Research into, and promotion of, new technology or alternative to small-scale incineration.
   v) Until developing countries have access to health-care waste-management options that are safer for the environment and health, incineration may be an acceptable response when used appropriately. Key elements of appropriate operation of incinerators include effective waste reduction and waste segregation, placing incinerators away from populated areas, satisfactory engineered design, construction following appropriate dimensional plans, proper operation, periodic maintenance, and staff training and management.

b) Medium-term strategies:

i) Further efforts to reduce the number of unnecessary injections, to reduce the amount of hazardous health- care waste that needs to be treated.
ii) Research into the health effects of chronic exposure to low levels of dioxin and furan.
iii) Risk assessment to compare the health risks associated with (a) incineration, and (b) exposure to health-care waste.

c) Long-term strategies
   i) Effective, scaled-up promotion of non-incineration technologies for the final disposal of health-care waste to prevent the disease burden from (a) unsafe health-care waste management, and (b) exposure to dioxins and furans.\
   ii) Support to countries in developing a national guidance manual for sound management of health-care waste.
   iii) Support to countries in developing and implementing a national plan, policies and legislation on health-care waste.
   iv) Promotion of the principles of environmentally sound management of health-care waste as set out in the Basel Convention.
   v) Support to allocate human and financial resources to safely manage health-care waste in countries.

WHO also recommends the *Core principles for achieving safe and sustainable management of health-care waste* (WHO, 2007). These principles require that everyone associated with financing and supporting health-care activities should provide for the costs of managing health-care waste. In particular:

d) Governments should
   i) allocate a budget to cover the costs of establishment and maintenance of sound health-care waste management systems;
   ii) request donors, partners and other sources of external financing to include an adequate contribution towards the management of waste associated with their interventions;
   iii) implement and monitor sound health-care waste management systems, support capacity building, and ensure worker and community health.

e) Donors and partners should
   ☞ include a provision in their health programme assistance to cover the costs of sound health-care waste- management systems.

f) NGOs should
   ☞ include the promotion of sound health-care waste management in their advocacy;
   ☞ undertake programmes and activities that contribute to sound health-care waste management.

g) The private sector should

- ☞ take responsibility for the sound management of health-care waste associated with the products and services it provides, including the design of products and packaging.

h) All concerned institutions and organizations should
   - ☞ promote sound health-care waste management;
   - ☞ develop innovative solutions to reduce the volume and toxicity of the waste they produce and that is associated with their products;
   - ☞ ensure that global health strategies and programmes take into account health-care waste management.

4.5. NATIONAL LEGISLATION

A national policy document should form the basis for developing the law and should be complemented by technical guidelines developed for implementation of the law. This legal "package" should specify regulations on the treatment of different waste categories; segregation, collection, storage, handling, disposal and transport of waste; and responsibilities and training requirements. The national policy should take into account the resources and facilities available in the country concerned and any cultural aspects of waste handling.

A national law on health-care waste management may stand alone, or constitute part of more comprehensive legislation, such as:

- a law on managing all forms of hazardous wastes, where the application to health-care waste is stated explicitly;
- a law on hospital hygiene and infection control, where a specific section should be devoted to health-care waste.

A national law should include the following elements:

a) a clear definition of hazardous health-care waste and its various categories;
b) a precise indication of the legal obligations of the health-care waste producer regarding safe handling and disposal;
c) specifications for record keeping and reporting;
d) establishment of permit or licensing procedures for systems of treatment and waste handling;
e) specifications for an inspection system and regular audit procedures to ensure enforcement of the law and for penalties to be imposed for contravention;
f) designation of courts responsible for handling disputes arising from enforcement of, or non-compliance with, the law.

4.6. TECHNICAL GUIDELINES

Technical guidelines are developed to assist managers and staff. They should contain sufficient detail to ensure that safe practices and appropriate standards can be achieved. They should outline the legal framework to be met for the safe management of health-care waste and how the guidance

improves hospital hygiene, and occupational health and safety. Technical guidelines can address a broad of range of relevant topics:

a) responsibilities of public health authorities
b) safe practices for waste minimization
c) separation, handling, storage and transport of health-care waste
d) treatment and disposal methods for each category of health-care waste and for wastewater
e) limits of emission of atmospheric pollutants and measures for protection of water resources.

4.7. MINIMUM APPROACH TO DEVELOPING HEALTH-CARE WASTE-MANAGEMENT POLICY

Where there is no national policy, legislation or guidelines, this should not prevent a hospital or health-care facility from commencing a modest programme of health-care waste management. A short document could be prepared that states the problems, sets out simple actions, identifies the stakeholders, and mobilizes them to carry out the actions. Initially, this is all that may be necessary.

4.8. DESIRABLE IMPROVEMENTS TO THE MINIMUM APPROACH

A number of desirable improvements should be considered when setting policy and legislation. These are to:

a) set a national budget to ensure that the regulations are fully complied with, and require that individual establishments do the same;
b) continually improve the mandatory standards of health-care waste management;
c) create an organized system of enforcement of the legislation;
d) create a national system of training and assessment of technical competence in the management of health-care waste;
e) create a system of awareness raising, training and regular assessment of sustainable development in the management of all wastes produced in health-care facilities.

5. HEALTH-CARE WASTE-MANAGEMENT PLANNING

5.1. THE NEED FOR PLANNING

A good health care waste management plan is a good basis to explain what needs to be done and to coordinate the roles of the many people involved. Planning defines the strategy for the implementation of improved waste management and the allocation of roles, responsibilities and resources. A plan describes the actions to be implemented by authorities, health-care personnel and waste workers. At the national level, a plan defines its intentions to make improvements, and the resources required across the country for successful implementation.

Planning for health-care waste management at national, regional or local levels should take into consideration the World Health Organization (WHO) core principles for achieving safe and sustainable management of health- care waste (WHO, 2007a). The core principles provide guidance on a clear delineation of responsibilities and funding that takes place chiefly at the planning stage. Planning should cover the six objectives listed below (WHO, Basel Convention & UNEP, 2005):

a) develop the legal and regulatory framework for health-care waste management
b) rationalize the waste-management practices within health-care facilities
c) develop specific financial investment and operational resources dedicated to waste management
d) launch capacity building and training measures
e) set up a monitoring plan
f) reduce the pollution associated with waste management.

The plan should be updated regularly to take care of the changes in policies and technologies.

5.2. NATIONAL PLANS

5.2.1. Purpose of a National Health-Care Waste-Management Plan

A national management plan should be based on an assessment of the health-care waste-management options available and then reach consensus on the related actions to be implemented across the country. A national survey of existing health-care practices and technologies in use should precede a planning exercise. It provides the data to allow realistic plans to be produced that inform government decision-making on the development of new treatment facilities, the regulations and guidance required, and the level of funds necessary to implement a national plan.

5.2.2. Action Plan for Developing a National Programme

The action plan may follow WHO's eight steps (see Figure 5.1).

Step 1 Establish policy commitment and responsibility for health-care waste management

Before an action plan is developed and implemented, there needs to be political commitment to prepare a national policy on health-care waste management. Thereafter, responsibility to prepare the plan is delegated to an appropriate government authority. The ministry of health or the ministry of environment usually serves as the principal authority and should be required to work closely with others, such as ministries, health organizations, private-sector service providers, nongovernmental organizations (NGOs) and professional bodies. It should be recognized that, at the outset, any policy commitment by a government to improve health-care waste management will have cost implications, and this should be reflected in the preparation of cost estimates on the financing necessary to fulfil the national plan.

Step 2 Conduct a national survey of health-care waste management practices

A survey is essential for planning an effective waste- management programme. Data should be collected not only from managers and officials but also from front-line workers. A survey should include both impartial site observations and interviews with health-care managers and medical and support staff (e.g. cleaners, waste handlers) at different levels. A standard data-gathering questionnaire should be prepared to capture data consistently and used at all (or a representative sample) health-care facilities.

A useful assessment should include the following:

a) An inventory of existing health facilities – this can be used as a database on the distribution of health-care facilities, the medical services provided, the numbers of patients treated and the standards of service achieved.

b) An analysis of existing legislation – this is crucial for the planning process, because it defines the amount and type of legal obligations mandated and highlights any deficiencies in legal and regulatory requirements expected of public bodies, the private sector and individuals for the safe handling of health-care waste. It is also a point of reference to determine existing responsibilities for waste management and public safety.

c) An estimate of health-care waste production nationwide – a waste-generation survey provides essential data on the quantities and types of waste produced and a comparison of the rates of generation between health-care facilities and regions. Typical approaches to comparisons between medical areas and health-care waste facilities are to express the waste quantities against the number of hospital beds, bed occupancy rate, or number of outpatients treated per day or per month.

d) A description of health-care waste-management practices – often, central government does not have clear information on the waste practices in use. This information can be gathered by observing staff in hospitals and clinics. Collecting these data is essential so that realistic decisions can be made on where to prioritize interventions according to the magnitude of the risks posed by present methods. The kind of qualitative information that can be collected includes

- ☞ skills and knowledge of personnel involved in the management of health-care waste;
- ☞ current health-care waste-disposal practices, including level of health protection achieved from existing segregation, collection, transportation, storage and disposal methods.

e) An analysis of the availability of training for staff in central authorities and at individual health-care facilities.

f) An analysis of the institutional and monitoring capacities – this is used to show if, or how, the safe disposal of waste is monitored and quality checked.

Other assessment tools also exist, and are useful for costing and assessing progress when implementing a new plan:

g) *Health care waste management rapid assessment tool* (WHO, 2004; currently being updated).[6] The tool can be used to assess management, training, regulatory, technical and financial issues, which helps to pinpoint critical issues that need to be addressed within the framework of a national action plan.

h) *Health care waste management assessment tool* (WHO, 2000). This WHO electronic tool provides a quick snapshot of country progress in health-care waste and focuses on injection waste as a major, high-risk component of the health-care waste stream.

i) *Health care waste management – Expanded costing analysis tools* (WHO, 2007b). The expanded costing analysis helps the user estimate costs related to health-care waste management at the health-care facility, central treatment facility or cluster, and national levels (see Chapter 10 for more details).[7]

The WHO health-care waste-management website provides further information.[8]

Step 3 Develop national guidelines

Technical guidelines are meant to assist the stakeholders in the implementation of a national programme of improvement for health-care waste management. The guideline brings together the policy and the national survey to identify practical guidance that needs to be prepared.

[6] See http://www.healthcarewaste.org/en/documents.html?id=115&suivant=20
[7] See http://www.healthcarewaste.org/en/documents.html?id=218&suivant=19
[8] See http://www.who.int/water_sanitation_health/en

Action steps		**Action elements**
8 – Review the implemented national programme	←	Develop a review system Improve the programme Develop an information system
7 – Develop and implement a national training programme	←	6 months Develop "train the trainers"
6 – Establish legislation and standards		**Programme**
5 – Develop common treatment policies	←	Modify health curricula Obtain professional assistance Consider international principles Consider best available technologies[b] Include technical, environ- mental and hygienic standards for the complete logistic chain (segregation, transport, storage) Include monitoring and documentation
4 – Formulate a strategy on health-care waste management	←	**System** Use hospital input Develop regional or cooperative treatment facilities Establish onsite treatment facilities Establish alternative treatment facilities Present a national strategy Present law and national policies
3 – Develop national guidelines	←	
2 – Conduct a national survey of health-care waste management	←	
1 – Ensure policy commitment and designate responsibilities	←	Use hospital input Use as the basis of incorporating hospital input into policy development 6 months Design and test the survey Distribute nationally Use to develop guidelines 3 months Designate authority Interact with ministries Start implementation of action plan

a Time (months) to complete action
b Best available technologies (BAT) are the international standards
Source: Adapted from WHO (1997)

Figure 5.1: Action plan for national programme of sound health-care waste management

Step 4 Formulate a national strategy on health-care waste management

The national strategy should:

a) set goals and the means of monitoring infection control and environmental protection;
b) provide an optimal selection of technologies for packaging, transportation, treatment and disposal;
c) identify appropriate options for centralized and local waste-disposal systems;
d) reflect distribution of responsibility in the sector among central, regional and local authorities;
e) propose guidance for training programmes at health-care facilities at municipal, regional and country levels;
f) provide guidance for setting up a monitoring and documentation system on health-care waste management;
g) draw up an action plan for implementing improved waste practices;
h) provide a costed investment plan describing the capital, annual operation and maintenance finance estimated to be needed to implement the national strategy.

Step 5 Develop a policy on regional and cooperative methods of health-care waste treatment

A government may consider identifying the resources needed to build up a national network of disposal facilities for health-care waste, accessible by hospitals and other health-care facilities. There are four basic options for managing health-care waste treatment that may be considered:

a) Option 1: an onsite treatment facility in each health-care establishment;
b) Option 2: regional or cooperative health-care waste-treatment facilities, supplemented by individual facilities for outlying hospitals;
c) Option 3: treatment of health-care waste in existing industrial or municipal treatment facilities (e.g. municipal facilities), where these exist;
d) Option 4: partial treatment undertaken onsite, and remaining waste treated offsite.

Each option has advantages and disadvantages, and the suitability of each option should be considered in a national plan. A national or regional plan should account for local circumstances, such as the number, location, size and type of health-care establishments, quality of the road network, and financial and technical resources available in each area.

Step 6 Establish legislation: regulations and standards for health-care waste management

A national plan and related guidelines are should be supported by legislation to regulate their application. Waste-management laws are usually based on widely accepted principles contained in various international agreements to which a country is a signatory (see Chapter 4).

Step 7 Carry out a national training programme

For the managers and other personnel to be able to implement the plan appropriate training in sound health care waste management is essential. In addition, training programmes are necessary for achieving national health expectations, and for complying with regulations. Developing a health-care waste-management training programme could begin with short training for staff and officials, longer courses for staff and officials, longer courses to train future trainers and refresher courses for experienced staff.

Institutions at national, regional or local levels could assist in preparing "training the trainers" activities and identify competent institutions or centres for the training programme. Details on training programmes are provided in Chapter 12.

Step 8 Review the national health-care waste-management programme after implementation

A national programme for health-care waste management should be viewed as a continuous process with periodic monitoring and reassessment by a responsible national government agency, such as a public health, sanitation or environmental agency. In addition, the recommendations on treatment methods should be regularly updated to keep pace with new developments. The review should base assessment on reports from hospitals and clinics on their success in implementing waste-management plans. It should review annual reports submitted by the heads of the facilities and make random visits to carry out audits of the waste-management systems. Any deficiencies in the waste-management system should be pointed out to the hospital or clinic director in writing, together with recommendations for remedial measures. Where practicable, a time limit for implementing remedial measures should be specified and the head of the establishment should be informed of the date of a follow-up visit.

Offsite waste-treatment facilities, operators of treatment facilities, road-haulage contractors and landfill operators should also be audited. Periodic reviews of waste-management operators by both a national government agency and the health-care facilities that use them should be expected. These latter two bodies should also be expected to press for improvements in the protection of occupational and public health from waste operations.

5.3. WASTE-MANAGEMENT PLAN FOR A HEALTH-CARE FACILITY

5.3.1. Assignment of Responsibilities

Health- care waste management should be viewed as part of infection control, and a local waste-management plan could be developed by infection-control staff where they are present. In the larger health-care facilities where large quantities of waste are generated e.g. in regional or referral hospitals, a separate waste-management group or committee may be formed instead.

A typical waste-management committee in a large hospital may contain the following members:

a) head of hospital (as chairperson)
b) heads of hospital departments
c) infection-control officer
d) chief pharmacist
e) radiation officer
f) matron (or senior nursing officer)
g) hospital manager
h) hospital engineer
i) financial controller
j) waste-management officer (if one is designated).

In larger establishments, the structure may include a specialist hospital hygienist, in addition to, or instead of, the infection-control officer, to address persistent difficulties relating to hospital hygiene, such as persistent methicillin- resistant *Staphylococcus aureus* or *Clostridium difficile* contamination.
In health-care facilities in lower income areas, the suggested approach is to have a smaller infection-control committee with one person responsible for health-care waste management.

The head of hospital should formally appoint the members of the waste-management team in writing, informing each of their duties and responsibilities (outlined in the following sections). The head should appoint a waste-management officer who will have overall responsibility for developing the health-care waste-management plan, and for the day-to-day operation and monitoring of the waste-disposal system. Depending on availability of relevant staff, this post may be assigned to the hospital engineer, hospital manager, or any other appropriate staff member at the discretion of the head of hospital.

In an institution that is not directly involved in patient care, such as a medical research institution, the head of the establishment should use their discretion to appoint members of the waste-management team from among the relevant staff.

5.3.2. Management Structure, Liaison Arrangements and Duties

A typical hospital waste-management structure is shown in Figure 5.2, with line-management responsibilities and liaison paths between key personnel involved in handling health-care waste. This structure may be adjusted to the particular needs of each hospital. Key personnel in large hospitals can share duties (as described in the following paragraphs), while one person can fulfil two or more sets of responsibilities in smaller health-care facilities.

Head of hospital

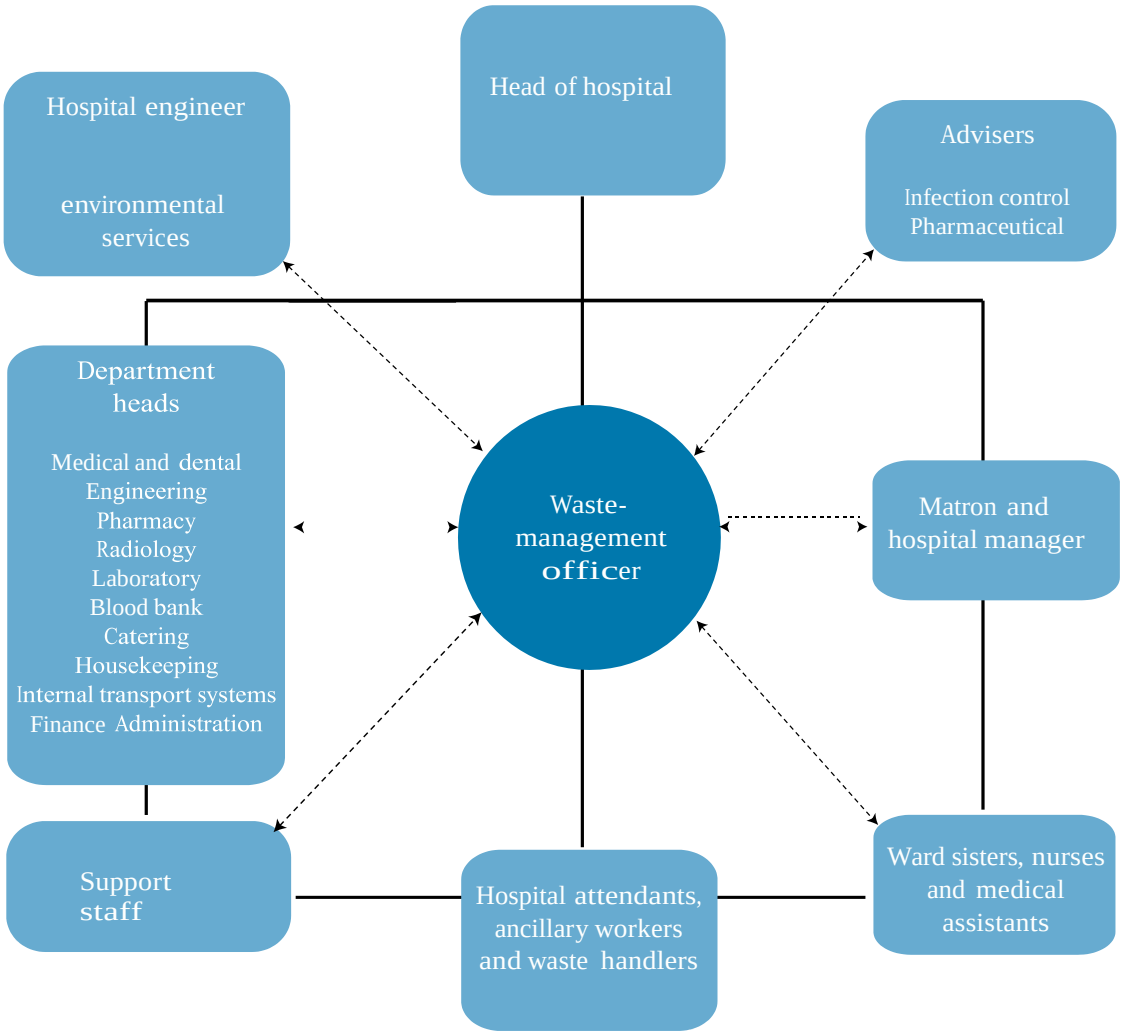
The head of hospital is responsible for the following tasks:

a) Form a waste-management team to develop a written waste-management plan for the hospital. The team should consist of representatives from clinical and non-clinical areas of the organization, in addition to those who are involved in the removal and management of waste. The plan should clearly define the duties and responsibilities of all members of staff, both clinical and non-clinical, in respect to handling health-care waste and to establishing lines of accountability.
b) Oversee and approve a waste-management plan.
c) Designate a waste-management officer to supervise and implement the waste-management plan. The head of hospital retains overall responsibility for ensuring that health-care and other wastes are disposed of according to national guidelines.
d) Keep the waste-management plan updated by setting regular (e.g. annual) review dates.
e) Allocate financial and personnel resources to ensure efficient operation of the plan. For example, sufficient staff should be assigned to the waste-management officer to ensure efficient operation of the waste-management plan.

f) Ensure that monitoring procedures are incorporated in the plan. The efficiency and effectiveness of the treatment and disposal system should be monitored so that the system can be updated and improved when necessary. Any changes should eventually be incorporated into a revised management plan.

g) Appoint a successor in the event of personnel leaving key positions in the waste-management team (or temporarily assign responsibility to another staff member until a successor can be appointed).

h) Ensure adequate training for staff members, and designate the staff responsible for coordinating and implementing training courses.



Note: Liaison paths are represented by dotted lines. Line-management paths are represented by solid lines. Source: Adapted from WHO WPR (1994)

Figure 5.2: Hospital waste-management structure

Waste-management officer

The waste-management officer is responsible for the day-to-day operation and monitoring of the waste-management system and is usually established as a separate post at larger hospitals. It is

therefore important that the waste-management officer has direct access to all members of the hospital staff (see Figure 5.1). The role should be held by a senior member of staff and should be responsible to the head of hospital. The waste-management officer should liaise with the infection-control officer, the chief pharmacist and the radiation officer so that they become familiar with the correct procedures for handling and disposing of pathological, pharmaceutical, chemical and radioactive wastes.

To manage waste collection, storage and disposal, the waste-management officer should:

a) control internal collection of waste containers and their transport to the central waste-storage facility of the hospital on a daily basis;

b) liaise with the supplies department to ensure that an appropriate range of bags and containers for health-care waste, protective clothing and collection trolleys is available at all times;

c) ensure that hospital attendants and ancillary staff immediately replace used bags and containers with the correct new bags or containers;

d) directly supervise hospital attendants, ancillary workers and waste handlers assigned to collect and transport health-care waste;

e) ensure the correct use of the central storage facility for health-care waste, which should be kept locked but should always be accessible to authorized hospital staff;

f) prevent all unsupervised dumping of waste on the hospital grounds;

g) coordinate and monitor all waste-disposal operations;

h) monitor methods of transportation of wastes both onsite and offsite, and ensure that wastes collected from the hospital are transported by an appropriate vehicle to the designated treatment and disposal site;

i) ensure that waste is not stored for longer than specified in the guidelines and that the transport organization (which may be the local authority or a private contractor) collects the waste with the required frequency.

j) To organize staff training and information, the waste-management officer should be responsible for the following actions:

   i) Liaise with the matron (or senior nursing officer) and the hospital manager to ensure that the nursing staff and medical assistants are aware of their own responsibilities for the segregation and storage of waste, as well as for the correct closing and sealing of bags and containers. The waste-management officer also defines the duties of hospital attendants and ancillary staff on the handling and transport of sealed waste bags and containers.

   ii) Liaise with department heads to ensure that all doctors and clinical staff are aware of their own responsibilities regarding waste segregation, and storage and closing and sealing of waste bags, to minimize infection risks, as well as the responsibilities of hospital attendants and ancillary staff regarding the handling and transport of sealed bags and containers.

   iii) Ensure that waste handlers are properly trained in waste collection and treatment, as well as safe and sufficient disposal methods, including how to operate and

maintain machines and technology. Refresher courses should be provided on a routine basis.

iv) Ensure compliance with occupational health measures, including current practices for post-exposure prophylaxis, as well as the provision and use of personal protective equipment for health workers and waste handlers.

To prepare for incident management and control, the waste-management officer should:

a) ensure that written and pictorial emergency and contingency procedures are available, that they are in place at all times, and that personnel are aware of the action to be taken in the event of an emergency;

b) investigate and review any reported incidents concerning the handling of health-care waste (in liaison with the infection-control department).

In addition, the waste-management officer should continuously monitor certain parameters, which are listed in Box 5.1.

Department heads

Department heads are responsible for the segregation, storage and disposal of waste generated in their departments. They should:

a) ensure that all doctors, nurses, and clinical and non-clinical professional staff in their departments are aware of the segregation, sealing and storage procedures, and that all personnel comply with the highest standards;

b) liaise regularly with the waste-management officer to monitor working practices for failures or mistakes;

c) ensure that key staff members in their departments are trained in waste segregation and disposal procedures;

d) encourage medical and nursing staff to be vigilant so as to ensure that hospital attendants and ancillary staff follow correct procedures at all times.

Box 5.1: Parameters to be monitored by the waste-management officer

Waste generated each month, by waste category:

- ☞ in each department
- ☞ treatment and disposal methods.

Waste handled safely and in accordance to the safety operation procedures:

- ➢ occupational safety (e.g. personal protective equipment)
- ➢ use of proper and clean equipment and marking equipment
- ➢ proper segregation at source
- ➢ internal safe transport and storage
- ➢ internal safe treatment methods
- ➢ safe disposal methods if on premises of the health-care facility. Financial aspects of health-care waste management:
  - ✓ direct costs of supplies and materials used for collection, transport, storage, treatment, disposal, decontamination and cleaning
  - ✓ training costs (labour and material)
  - ✓ costs of operation and maintenance of onsite treatment facilities
  - ✓ costs for contractor services. Public health aspects:
    - o Incidents resulting in injury, "near misses" or failures in the handling, segregation, storage, transport or disposal system should be reported to the infection-control officer and the waste-management officer. This information should be used to decide the preventive measures to avoid recurrences.

Matron and hospital manager

The matron (or senior nursing officer) and the hospital manager are responsible for training nursing staff, medical assistants, hospital attendants and ancillary staff in the correct procedures for segregation, sealing, storage, transport and disposal of waste. They should:

- liaise with the waste-management officer and the advisers (infection-control officer, chief pharmacist and radiation officer) to maintain high standards of infection control;
- participate in staff induction and refresher training in the handling and treatment and disposal of health-care waste;
- liaise with department heads to ensure coordination of training activities, and decide what to do about waste- management issues specific to particular departments.

Infection-control officer

The infection-control officer should liaise with the waste-management officer on a continual basis, and provide advice about the control of infection, and the standards of the waste treatment and disposal system. The infection- control officer's duties that relate to health-care waste include:

- identifying training requirements according to staff grade and occupation
- organizing and supervising staff training courses on the infection risks from poor waste management
- liaising with the department heads, the matron and the hospital manager to coordinate training.

The infection-control officer may also have overall responsibility for chemical disinfection, the safe management of chemical stores, and minimizing chemical waste creation.

Chief Pharmacist (if (s)he exists)

The chief pharmacist is responsible for the safe management of pharmaceutical stores and for minimizing pharmaceutical waste. Duties include:

a) liaising with department heads, the waste-management officer, the matron and the hospital manager, and giving advice, in accordance with the national policy and guidelines, on the appropriate procedures for pharmaceutical waste treatment and disposal;
b) coordinating continual monitoring of procedures for the treatment and disposal of pharmaceutical waste;
c) ensuring that personnel involved in pharmaceutical waste handling, treatment and disposal receive adequate training;
d) remaining up to date with the proper treatment and safe disposal of expired, damaged and unusable pharmaceuticals, pharmaceutical packaging and equipment.

The chief pharmacist also has the special responsibility of ensuring that genotoxic products are used safely, and that genotoxic waste is managed safely.

Radiation officer (if (s)he exists)

The duties and responsibilities of the radiation officer are the same as those of the pharmaceutical officer but relate to radioactive waste. There may also be additional regulations regarding the storage and safeguarding of radioactive wastes. These regulations need to be followed strictly for the safety of those handling the wastes.

Supply officer

The supply officer should liaise with the waste-management officer to ensure a continuous supply of the items required for waste management (plastic bags and containers of the right quality, spare parts for onsite health-care waste-treatment equipment). These items should be ordered in good time to ensure that they are always available, but accumulation of excessive stores supplies should be avoided. The supply officer should also investigate the possibility of purchasing environmentally friendly products (e.g. polyvinyl chloride–free plastic items).

Hospital engineer (if (s)he exists)

The hospital engineer is responsible for installing and maintaining waste-storage facilities and handling equipment that comply with the specifications of the national guidelines. The engineer is also accountable for the adequate operation and maintenance of any onsite waste-treatment equipment, and is responsible for the staff involved in waste treatment, ensuring that:

- staff receive training in the principles of waste disposal and are aware of their responsibilities under the hospital waste-management plan;
- staff operating onsite waste-treatment facilities are trained in their operation and maintenance.

5.3.3. Assessment of Waste Generation

To develop a waste-management plan, the waste-management team should assess all waste generated in the hospital. The waste-management officer should be responsible for coordinating such a survey and for analysing the results. The waste should be categorized according to the classification system specified in the national guidelines (or as described in this handbook, if no such guidelines are available). The survey should determine the average daily quantity of waste in each category generated by each hospital department.

The waste-management team should take special care to test the robustness of the waste-management plan during periods of "peak" waste production – the occasional generation of extraordinary quantities of wastes. For example, the waste-management plan should be able to plan for the impact of epidemics and other emergencies that affect the quantities of waste generated. Table 5.1 shows a sample sheet for the daily assessment of waste, by waste category, for each waste-collection point. The survey system for the waste-production survey could form the basis for routine waste-generation record keeping in each medical area.

Table 5.1: Sample sheet for assessing waste generation

Name of the health-care facility: ..... Week: .....

Waste-collection point: department/ location	Waste category[a] (specify)	Quantity of waste generated per day (weight and volume)													
		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
		kg	litre	kg	litre	kg	litre	kg	litre	kg	litre	kg	litre	kg	litre

[a]Infectious waste, pathological waste, sharps, pharmaceutical waste, cytotoxic waste, waste with high heavy metal content, radioactive waste

Source: adapted from Christen (1996)

5.3.4. Development of a Hospital Waste-management Plan

During development of the waste-management plan, every member of the waste-management committee should review existing waste-management arrangements in their area of responsibility. Existing practices should then be evaluated in the light of the national guidelines and recommendations made to the waste-management officer on how the guidelines can be implemented in each area. On the basis of the waste-generation survey and these recommendations, the waste-management officer should prepare a draft discussion document for the waste- management committee. This discussion document should include details of changes to the present waste- management system (as outlined in Box 5.2) and should contain sections addressing the following issues:

a) present situation (waste-management practices, personnel and equipment involved);
b) quantities of waste generated;
c) possibilities for waste minimization, reuse and recycling; waste segregation; onsite handling, transport and storage practices;
d) identification and evaluation of waste-treatment and disposal options (onsite and offsite);
e) identification and evaluation of the options for record keeping and documentation, training and monitoring;
f) estimation of costs relating to waste management, including capital, operational and maintenance costs;
g) strategy for implementing the plan.

A draft discussion document should be prepared in consultation with all members of the waste-management committee and their staff. Officials from the local municipality and perhaps the national government agency responsible for the disposal of health-care wastes should be invited to assist in the planning process.

Subsequently, a waste-management plan would be based on an expanded version of the discussion document and should be presented to the waste-management committee for approval. When full agreement has been reached, the document should be designated as the hospital waste-management plan.

The waste-management plan should include diagrams that outline the line-management structure and the liaison paths between managers and staff, and a list of names and telephone numbers of responsible personnel to be notified in the event of an emergency. The waste-management plan should also include a clear set of actions for implementing the plan across the health-care facility.

Box 5.2: Details to include in the waste-management plan

Location and organization of collection and storage facilities

1. Drawings of the establishment showing designated bag or disposal container for every ward and department in the hospital; disposal container shall be appropriately designated for health-care waste or other waste.
2. Drawings showing the central storage site for health-care waste and the separate site for other waste. Details of the type of containers, security equipment, and arrangements for washing and disinfecting waste-collection trolleys (or other transport devices) should be specified. The document should also address eventual needs for refrigerated storage facilities.
3. Drawings showing the paths of waste-collection trolleys through the hospital, with clearly marked individual collection routes.
4. A collection timetable for each trolley route, the type of waste to be collected, and the number of wards and departments to be visited on one round. The central storage point in the facility for that particular waste should be identified.

Design specifications

1. Drawings showing the type of bag holder to be used in the wards and departments.
2. Drawings showing the type of trolley or wheeled container to be used for bag collection.
3. Drawings of sharps containers, with their specification.

Required material and human resources

1. An estimate of the number and cost of bag holders and collection trolleys.
2. An estimate of the number of sharps containers and health-care waste drum containers required annually, categorized into different sizes, if appropriate.
3. An estimate of the number and cost of colour-coded bags or bins to be used annually.
4. An estimate of the number of personnel required for waste collection.

Responsibilities

1. Definitions of responsibilities, duties and codes of practice for each of the different categories of personnel of the hospital who, through their daily work, will generate waste and be involved in the segregation, storage and handling of the waste.
2. A definition of the responsibilities of hospital attendants and ancillary staff in collecting and handling wastes, for each ward and department; where special practices are required (e.g. for radioactive waste or hazardous chemical waste), the stage at which attendants or ancillary staff become involved in waste handling shall be clearly defined.

Procedures and practices

1. Simple diagram (flowchart) showing procedure for waste segregation.
2. The procedures for segregation, storage and handling of wastes requiring special arrangements, such as autoclaving.
3. Outline of monitoring procedures for waste categories and their destination.
4. Contingency plans, containing instructions on storage or evacuation of health-care waste in case of breakdown of the treatment unit or during closure for planned maintenance.
5. Emergency procedures

Training

Description of the training courses and programmes to be set up and the personnel who should participate in each. For further information, refer to *Basic steps in the preparation of health-care waste management plans for health care establishments* (WHO CEHA, 2002), which is available for purchase through the website (http://www.emro.who.int/ceha).

5.3.5. Implementation of the Waste-management Plan

Implementation involves the following steps:

a) Interim measures, to be introduced as a precursor to complete implementation of the new waste-management system, should be developed by the waste-management officer, in collaboration with the waste-management committee, and be appended to the plan. A bar chart should also be added, showing dates of implementation of each part of the new system.

b) Provision for future expansion – of the hospital or of waste-storage facilities – should be made.

c) The head of hospital appoints personnel to the posts with responsibility for waste management. Notices of these appointments should be widely circulated, and updates should be issued when changes occur.

d) The infection-control officer should organize and supervise training programmes for all staff, in collaboration with the waste-management officer and other members of the waste-management committee. Initial training sessions should be attended by key staff members, including medical staff, who should be urged to be vigilant in monitoring the performance of waste-disposal duties by non-medical staff. The infection-control officer should choose the speakers for training sessions and determine the content and type of training given to each category of personnel.

As soon as the actions in steps 1–4 have been completed and the necessary equipment for waste management is available, the operations described in the waste-management plan can be put into practice.

The waste-management committee should review the waste-management plan annually and initiate changes necessary to upgrade the system. Interim revisions may also be made as and when necessary. These revisions should be documented at the time and added as an appendix to the waste-management plan; they should be incorporated into the full plan when it is reviewed. The waste-management committee should also update policies and practices as new national guidance becomes available. Failures in waste handling, segregation, storage, transport or disposal systems, or waste management incidents that result in injury should be reported as soon as possible to the infection-control officer and the waste-management officer.

The head of hospital should prepare an annual report to the national government agency responsible for the disposal of health-care wastes, providing data on waste generation and disposal, personnel and equipment requirements, and costs.

An initial approach to planning

The approach and recommendations in a waste-management plan should be implemented incrementally, through gradual improvements. It is important for public authorities and managers

of health-care facilities to be fully aware of the infection-control reasons for having proper waste-management procedures.

Introducing waste segregation is the first step in implementing a waste-management plan. Too often, health-care facilities treat hazardous health-care waste in the same manner as general waste. Improving the separation and safe storage of used sharps is a good starting point. Specific methods for disposing of hazardous health-care wastes can then be introduced, followed by measures to encourage waste minimization and the safe reuse of materials, wherever possible.

5.4. MINIMUM APPROACH TO PLANNING

Managing health-care waste safely requires clear objectives and planning at national and local levels. Health-care waste management should involve national partners and stakeholders, and be based on priorities identified by all partners and stakeholders.

5.5. DESIRABLE IMPROVEMENTS TO THE MINIMUM APPROACH

Improvements to the initial, minimum approach to planning health-care waste management should be as follows:

a) Health-care waste generation is understood in more detail for each department in a health-care facility.

b) Health-care waste management is defined as a concern and a priority at national and local levels.

c) Resources can be mobilized within a country to begin and sustain improvements to health-care waste management.

d) Waste-management committees have been formally set up in each health-care facility as part of the serious management of infection control.

6 HEALTH-CARE WASTE MINIMIZATION, REUSE AND RECYCLING

6.1. THE WASTE-MANAGEMENT HIERARCHY

Protecting public health through the management of wastes can be achieved by using the 'waste hierarchy', which is based on the concept of the "3Rs", namely *reduce*, *reuse* and *recycle* as shown in Figure 6.1. 'Desirability' is defined in terms of the overall benefit of each method from their particular impacts on the environment, protection of public health, financial affordability and social acceptability.

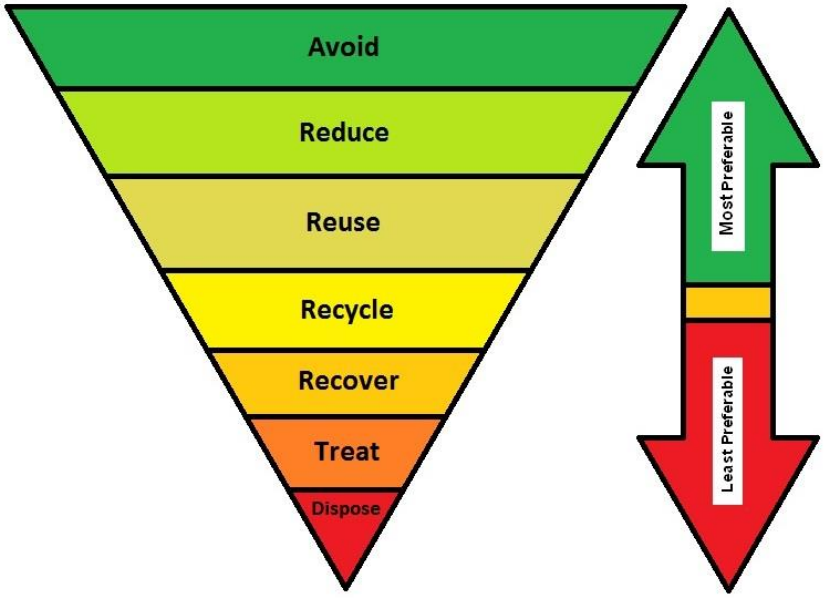


Figure 6.1: The waste-management hierarchy

Best practice waste management will aim to avoid or recover as much of the waste as possible in or around a health-care facility, rather than disposing of it by burning or burial. This is sometimes described as tackling waste "at source" rather than adopting "end-of-pipe" solutions.

The most preferable approach, if locally achievable, is to avoid producing waste as far as possible and thus minimize the quantity entering the waste stream. Where practicable, recovering waste items for secondary use is the next most preferable method. Waste that cannot be recovered must then be dealt with by the least preferable options, such as treatment or land disposal, to reduce its health and environmental impacts.

6.2. WASTE MINIMIZATION

The preferred management solution is quite simply not to produce the waste, by avoiding wasteful ways of working. To achieve lasting waste reduction (or minimization), the focus should be on working with medical staff to change clinical practices to ones that use less materials. Although waste minimization is most commonly applied at the point of its generation, health-care managers can also take measures to reduce the production of waste through adapting their purchasing and stock control strategies. Examples of policies and practices found to minimize quantities of waste are summarized in Box 6.1

Box 6.1 Examples of practices that encourage waste minimization

Source reduction

- Purchasing reductions: selecting supplies that are less wasteful where smaller quantities can be used, or that produce a less hazardous waste product.
- Use of physical rather than chemical cleaning methods (e.g. steam disinfection instead of chemical disinfection).
- Prevention of wastage of products (e.g. in nursing and cleaning activities).

Management and control measures at hospital level

- Centralized purchasing of hazardous chemicals.
- Monitoring of chemical use within the health centre from delivery to disposal as hazardous wastes.

Stock management of chemical and pharmaceutical products

- More frequent ordering of relatively small quantities rather than large amounts at one time, to reduce the quantities used (applicable in particular to unstable products).
- Use of the oldest batch of a product first.
- Use of all the contents of each container.
- Checking of the expiry date of all products at the time of delivery, and refusal to accept short-dated items from a supplier.

Waste minimization usually benefits the waste producer: costs for both the purchase of goods and for waste treatment and disposal are reduced, and the liabilities associated with the disposal of hazardous waste are also lower.

All employees have a role to play in this process and should be trained in waste minimization. This is particularly important for the staff of departments that generate large quantities of hazardous health-care waste.

Suppliers of chemicals and pharmaceuticals can also become responsible partners in waste-minimization programmes. The health centre can encourage this by ordering only from suppliers who provide rapid delivery of small orders, who accept the return of unopened stock, and who offer offsite waste-management facilities for hazardous wastes.

6.3. ENVIRONMENTALLY PREFERABLE PURCHASING

Environmentally preferable purchasing (EPP) refers to the purchase of the least damaging products and services, in terms of environmental impact. At its simplest, EPP may lead to the purchase of recycled paper, through to more sophisticated measures such as the selection of medical equipment based on an assessment of the environmental impact of the equipment from manufacture to final disposal – known as "life-cycle thinking".

The application of EPP can help health-care centres to reduce their overall impact on the environment, provide healthier conditions for patients and staff by switching to less hazardous materials (e.g. solvents, cleaning fluids), and lower the costs related subsequently to waste disposal. A widely cited example is the purchase of mercury versus a mercury-free thermometer. When mercury thermometers break, there are costs associated with cleaning up a hazardous material and then preventing mercury from entering the environment at the final disposal stage (CDHS, 2000; Karliner, 2010; Practice Greenhealth, 2012).

Managing stores carefully will prevent the accumulation of large quantities of outdated chemicals or pharmaceuticals and limit the waste to the packaging (boxes, bottles) plus residues of the products remaining in the containers. These small amounts of chemical or pharmaceutical waste can be disposed of easily and relatively cheaply, whereas disposing of larger amounts requires costly and specialized treatment, which underlines the importance of waste minimization.

Life-cycle management considers benefits, costs and risks over the full life cycle of a product or service – including waste management. Life-cycle management applies approaches to product design and development that minimize environmental impacts of products throughout all life stages of a product, starting with the extraction of resources for raw material inputs, and continuing through processing and manufacturing of all feed stocks and final products, distribution, use and, ultimately, disposal. Life-cycle analysis is a tool used for life-cycle management, to quantify the life-cycle impacts of a product (Kaiser, Eagan & Shaner, 2001).[9]

6.4. GREEN PROCUREMENT

Reducing the toxicity of waste is also beneficial, by reducing the problems associated with its treatment or disposal (Kaiser, Eagan & Shaner, 2001). For example, purchasing plastics that may be easily recycled, or order goods supplied without excessive packaging.

[9] Information on the use of life-cycle analysis for health-care waste packaging is presented at Life Cycle Thinking and Assessment for Waste Management (http://lct.jrc.ec.europa.eu/pdf-directory/Making-Sust-Consumption.pdf).

Globally, the most easily recyclable plastics are polyethylene, polypropylene and polyethylene terephthalate (PET). Conversely, polyvinyl chloride (PVC) is the most difficult, partly because its products come in a variety of forms containing different additives. Packaging of mixed materials, such as paper or card covered in plastic or aluminum foil, is rarely recyclable.

PVC is also of concern because of the toxicity of some of its additives and should be avoided wherever possible. Similarly, polycarbonate is made from bisphenol A, which is an endocrine disruptor. Latex or nitrile gloves are the most common replacements for PVC gloves. Latex or silicone tubing can replace PVC tubing, polyethylene IV bags can replace PVC bags, and ethylene vinyl acetate bags can replace PVC bags for saline and blood. Ethylene oxide is used to sterilize medical devices, but it is carcinogenic and so should be avoided where alternatives exist.

6.4.1. Recycling Symbols for Plastics

An international classification system to identify different types of plastic is available. Common types in health- care settings are:

a) low-density polyethylene – LDPE, 4
b) high-density polyethylene – HDPE, 2
c) polypropylene – PP, 5
d) polyethylene terephthalate – PET or PETE, 1
e) polycarbonate – PC, which has no designated number but may be labelled 7 (a miscellaneous category for low-volume plastics

Where items are not labelled, procurement staff should contact the manufacturer for further information or change to a product that is clearly labelled as being made from a material known to be recyclable.

6.5. SAFE REUSE

The reuse of materials in a health-care facility has provoked much debate, with particular concern over the reuse of single-use (medical) devices. In general, the use of non-disposable items for medical procedures should be encouraged where their reuse after cleaning can be demonstrated to minimize infection transmission to acceptably low probabilities. When considering reuse, it is important to make a distinction between different types of products:

a) non-medical supplies, disposable items (which should be avoided)
b) medical devices that pose no cross-infection risk (e.g. blood-pressure meters)
c) medical devices specifically designed for reuse (e.g. surgical instruments)
d) Single-use devices must not be reused because they cannot be cleaned thoroughly and pose an unacceptable risk of cross-infection. Where there is an option, purchasing a

reusable device of similar quality for a medical or non- medical use is preferable to purchasing a single-use device.

e) Syringes and hypodermic needles should not be reused because of the significant chance of spreading disease. Proper steps should be taken to make sure that they are disposed of safely. Where syringes are in short supply, nurses may replace the needle, but the chance of infection remains. A syringe that has been rinsed but not sterilized can still have a 1.8% chance of passing on human immunodeficiency virus if used for intravenous injection and 0.8% for intramuscular injection (Reid & Juma, 2009). Research is limited and the risk is probably underestimated. Anecdotal reports of syringes being repackaged are common, and a survey in Dhaka, Bangladesh (Hassan et al., 2008), confirms that some hospital cleaners salvaged sharps and other materials for reuse. An outbreak of hepatitis in Gujarat, India, in 2009, involving at least 240 cases and 60 deaths, was traced back to the illegal trade in medical waste, as well as direct reuse of single-use items (Solberg, 2009).
f) Reuse may involve a combination or all of the following steps: cleaning, decontamination, reconditioning, disinfection and sterilization. Common sterilization methods are listed in Box 6.2.
g) Plastic syringes and catheters should not be reused. However, they may be recycled after sterilization.
h) There are also certain devices (e.g. patient self-administered intermittent urinary catheters, face masks for oxygen administration) that are intended for limited reuse by the individual and only require washing with mild detergents.
i) Long-term radionuclides conditioned as pins, needles or seeds and used for radiotherapy may be reused after sterilization.
j) Special measures must be applied in the case of potential or proven contamination with the causative agents of transmissible spongiform encephalopathies (also known as prion diseases). These measures, which are capable of reducing or eliminating infectivity, are described in detail in the World Health Organization (WHO) *Report of a consultation on public health issues related to animal and human encephalopathies* (WHO, 1992)

The effectiveness of thermal sterilization may be checked – for example, by the *Bacillus stearothermophilus* test and for chemical sterilization by the *Bacillus subtilis* test (see Chapter 8).

Certain types of containers may be reused, provided they are carefully washed and disinfected. Containers for pressurized gas should be sent to specialized centres to be refilled. Containers that once held detergent or other liquids may be reused as containers for sharps waste (if purpose-made containers are not affordable), provided they are puncture-proof and clearly marked on all sides for used sharps.

Box 6.2: Examples of sterilization methods for reusable items

Thermal sterilization

Dry sterilization:

- Exposure to 160 °C for 120 minutes or 170 °C for 60 minutes in a "Poupinel" oven. Wet sterilization:
- Exposure to saturated steam at 121 °C for 30 minutes in an autoclave.

Chemical sterilization

Hydrogen peroxide:

- A 7.5% solution can produce high-level disinfection in 30 minutes at 20 °C. Alternatively, equipment exists that can generate a hydrogen peroxide plasma from a 58% hydrogen peroxide solution. The equipment has a 45-minute process time. Hydrogen peroxide can also be used in combination with peracetic acid.

Peracetic acid:

- Can produce sterilization in 12 minutes at 50–55 °C, with instruments ready to use in 30 minutes. Peracetic acid can also be used in combination with hydrogen peroxide.

OPA (ortho-phthaldehyde):

- High-level disinfection in 12 minutes at 20 °C.

Hypochlorous acid/hypochlorite:

- 400–450 ppm active free chlorine, contact conditions established by simulated use testing with endoscopes. NOTE: ethylene oxide and glutaraldehyde are widely used but are being replaced in an increasing number of health-care facilities because of their health effects. Ethylene oxide is a human carcinogen, and glutaraldehyde can cause asthma and skin irritation.

6.6. RECYCLING AND RECOVERY

Recycling is desirable than reusing a waste item, because it frequently requires substantial energy input and transport to offsite recycling centres. The recovery of waste may be used to define energy recovery whereby waste is converted to fuel for generating electricity or for direct heating. The heat generated by onsite incinerators may be an attractive and cost-effective option for heating hospitals, public buildings and residential districts. Alternatively, "waste recovery" used to convert waste items into new products, and composting of organic waste matter to produce compost or soil conditioner for use in agriculture or similar purposes. Recycling is attractive health-care facilities, as it can reduce costs considerably, either through reduced disposal costs or through payments made by a recycling company for the recovered materials. However, some of the hazardous infectious portion of the waste will contain recyclable materials (e.g. paper, cardboard, packaging, as such they should be disinfected to eliminate possible pathogens. Safe handling guidelines should be followed.

Composting hospital food waste is may also be applied particularly in countries where the use of landfill is becoming more restrictive due to legislation, taxation, service charges or land shortages. However, there are legitimate concerns about compost attracting rodents and other pests; however, these problems can be minimized with careful management.

In determining the economic viability of recycling and recovery, it is important to take account of the costs of alternative disposal methods, as well as the value of reclaimed materials, and not just the cost of the recycling and recovery process.

6.7. ENVIRONMENTAL MANAGEMENT SYSTEMS

An environmental management system (EMS) is a a system and database which integrates procedures and processes for training of personnel, monitoring, summarizing, and reporting of specialized environmental performance information to internal and external stakeholders of a firm. Hospitals and health centres of any size should derive a benefit from introducing and implementing an EMS. These benefits include cost reductions through reduced energy consumption, reduced quantities of waste, increased recycling, minimized negative impacts on the environment from waste handling and treatment, and an improved public image.

An EMS framework encompasses the environmental aspects of waste management, including reduction, reuse and recycling. It also has considerable relevance to environmentally preferable purchasing. This is because a health- care facility usually has a choice in the purchase of products or services. An EMS should be an integral part of an organization's approach to good management. It is used to develop and implement its environmental policy and to manage its continuing environmental impacts.

Key elements of an EMS should include the following:

a) process or mechanism for screening project plans and proposals for potential environmental risks; for example, using screening tools, checklists and expert review;
b) development and use of environmental management plans that clearly define which environmental mitigation measures should be taken, by whom, and at which point in the project's implementation;
c) monitoring and reporting activities to verify that relevant environmental management actions are being taken and that they are generating the intended results;
d) evaluation of the overall environmental performance of projects and activities to inform organizational learning and future environmental mitigation actions.

Hospitals, may introduce an EMS with the aim of obtaining ISO 14001 certification as stipulated by the International Standards Organization (ISO). ISO 14001 provides the specific requirements for an EMS and is part of the ISO 14000 series that relates more generally to environmental management.

6.8. MINIMUM APPROACH TO WASTE MINIMIZATION

The waste-minimization hierarchy should feature in the waste-management policy of all health-care facilities, with a broad aim to move current practices upwards in the hierarchy from predominantly disposal to an emphasis on recycling or even prevention.

The first practical steps are to pay more attention to the quantity and type of materials purchased regularly, establish a system to gather waste-management ideas from staff, evaluate these ideas, and put the good ideas into practice. Often, there will be obvious opportunities to reduce the amount and toxicity of materials purchased, and hence the amount and toxicity of waste generated. Targets could be both quantitative (e.g. consumption of paper will be reduced by 10%) or qualitative (e.g. hazardous solvents will be substituted by more environmentally friendly products). Educating staff to use medical materials carefully to avoid generating unnecessary waste is a further simple measure that can be undertaken. Reuse is another option to minimize waste, but it is not without complications and requires a realistic assessment of which reuse practices are considered safe and which to avoid because the risk of infection transmission to patients and staff is unacceptable.

It is sensible for health-care managers to periodically review their purchasing practices and available choices, and to remind their staff to avoid excessive waste production wherever possible.

7 SEGREGATION, STORAGE AND TRANSPORT OF HEALTH-CARE

7.1. GUIDING PRINCIPLES

Health-care facility managers should ensure that waste is kept under control at all times within a health-care facility and disposed of safely either onsite or offsite. Proper segregation, onsite storage and transportation systems are described in this chapter and provide a continuous sequence of safe keeping at each step in the process, from the point of generation of waste to its final treatment or disposal. Each step in the concept of managing the "waste flow" is given below.

The following general principles of waste segregation, storage and transportation relate to the control of waste flow from generation to disposal:

a) health-care waste is generated in a medical area and should be segregated into different fractions, based on their potential hazard and disposal route, by the person who produces each waste item;
b) separate containers should be available in each medical area for each segregated waste fraction;
c) waste containers when filled should be labelled to help managers control waste production;
d) closed local storage inside or near to a medical area may be needed if wastes are not collected frequently;
e) hazardous and non-hazardous wastes should not be mixed during collection, transport or storage;
f) collected waste is often taken to central storage sites before onsite or offsite treatment and disposal;
g) staff should understand the risks and safety procedures for the wastes they are handling.

7.2. SEGREGATION SYSTEMS

The correct segregation of health-care waste is the responsibility of the person who produces each waste item. The health-care facility management is responsible for making sure there is a suitable segregation, transport and storage system, and that all staff adhere to the correct procedures.

Segregation should be carried out by the producer of the waste as close as possible to its place of generation, which means segregation should take place in a medical area, at a bedside, in an operating theatre or laboratory by nurses, physicians and technicians. If classification of a waste item is uncertain, as a precaution it should be placed into a container used for hazardous health-care general waste. However, to provide a minimum level of safety to staff and patients, the hazardous waste portion is commonly separated into two parts: used sharps and potentially infectious items. In the latter, the largest components are typically tubing, bandages, disposable medical items, swabs and tissues. Consequently, the segregation of general, non-hazardous waste, potentially infectious

waste and used sharps into separate containers is often referred to as the "three-bin system". Further types of containers can be used for other categories of wastes, such as chemical and pharmaceutical wastes, or to separate out pathological waste, where it is to be handled and disposed of in different ways from the other portions of the waste flow.

7.2.1. Waste containers, Colour Codes and Labels

Waste-segregation simply means to separate all hazardous waste from the larger quantity of non-hazardous waste.

Ideally, the same system of segregation should be in force throughout a country. The national legislation should prescribes the waste segregation categories to be used and a system of colour coding for waste containers. Where there is no national legislation, a World Health Organization (WHO) scheme is should be used (Table 7.1). Colour coding makes it easier for medical staff and hospital workers to put waste items into the correct container, and to maintain segregation of the wastes during transport, storage, treatment and disposal. Colour coding also provides a visual indication of the potential risk posed by the waste in that container.

Table 7.1: WHO-recommended segregation scheme

Type of waste	Colour of container and markings*	Type of container
Highly infectious waste	Yellow, marked "HIGHLY INFECTIOUS", with biohazard symbol	Strong, leak-proof plastic bag, or container capable of being autoclaved
Other infectious waste, pathological and anatomical waste	Yellow with biohazard symbol	Leak-proof plastic bag or container
Sharps	Yellow, marked "SHARPS", with biohazard symbol	Puncture-proof container
Chemical and pharmaceutical waste	Brown, labelled with appropriate hazard symbol	Plastic bag or rigid container
Radioactive waste**	Labelled with radiation symbol	Lead box
General health-care waste	Black	Plastic bag

*see Figure 7.1 (which lists the biohazard and radiation symbols)

**Not produced in all hospitals

Labelling of waste containers is used to identify the source, record the type and quantities of waste produced in each area, and allow problems with waste segregation to be traced back to a medical area. A simple approach is to attach a label to each filled container with the details of the medical area, date and time of closure of the container, and the name of the person filling out the label. Using an international hazard symbol on each waste container is also recommended. Several symbols are relevant to the different kinds of hazardous waste produced in a health- care facility, and these are reproduced in Figure 7.1.

		
Biohazard symbol	Old radiation symbol	New radiation symbol

Note: The new radiation symbol was adopted by the United Nations in 2007, but the older symbol is still widely recognized and expected to remain in common use for many years.

Figure 7.1: Biohazard, radiation and chemical hazard symbols

Figure 7.2 compares symbols from Annex II of the European Commission's *Directive on dangerous substances 67/548/EEC* (in the left-hand column)[10] with those from the United Nations Economic Commission for Europe's (UNECE's) *Globally harmonized system of classification and labelling of chemicals* (in the right-hand column).[11]

[10] See http://ec.europa.eu/environment/archives/dansub/consolidated_en.htm

[11] See http://live.unece.org/trans/danger/publi/ghs/pictograms.html

	**Corrosive (C)** These substances attack and destroy living tissues, including the eyes and skin	
	**Highly flammable (F)** These substances easily catch fire (flash point: 21–55 °C). Never store flammable substances together with explosive ones	
	**Toxic (T)** These substances can cause death. They may have their effects when swallowed or breathed in, or when absorbed through the skin	
	**Harmful (Xn)** These substances are similar to toxic substances but are less dangerous	
	**Explosive (E)** An explosive is a compound or mixture susceptible to a rapid chemical reaction, decomposition or combustion, with the rapid generation of heat and gases with a combined volume much larger than the original substance	
	**Irritant (I)** These substances can cause reddening or blistering of skin	

Figure 7.2: Comparison of common hazardous waste symbols

	**Extremely flammable (F+)** Liquid substances and preparations that have an extremely low flash point (<21 °C) and therefore catch fire very easily	
	**Very toxic (T+)** Substances and preparations that, in very low quantities, cause death or acute or chronic damage to health when inhaled, swallowed or absorbed via the skin	
	Oxidising (O) These substances provide oxygen, which allows other materials to burn more fiercely.	
	**Dangerous for environment (N)** Substances that, were they to enter into the environment, would present or might present an immediate or delayed danger for one or more components of the environment.	
No direct equivalent; use harmful or irritant symbol as appropriate	**Specific organ toxicity** These substances may cause: • damage to organ or organs after single or repeated exposure • respiratory sensitization • allergy or asthma or breathing difficulties if inhaled	

Figure 7.2: Comparison of common hazardous waste symbols

7.2.2. Beyond Basic Segregation

Non-hazardous waste

Within each major category (e.g. non-hazardous, potentially infectious, used sharps), further segregation may be advantageous. For example, general non-hazardous waste can be broken down into recyclables, biodegradable waste and non-recyclable portions. If these are mixed at the point of generation, it may prevent recyclables from being recovered.

Food wastes can be collected from medical areas and returned directly to the kitchens. Kitchen wastes can be composted or, where regulations allow, sterilized and used for animal feed. Non-hazardous biodegradable wastes (e.g. flowers) may be disposed of with kitchen waste.

Hazardous waste

a) **Highly infectious** waste, such as diagnostic laboratory samples and waste from infectious patients in isolation, should be collected separately and autoclaved at the point of generation. Once disinfected, the waste would leave a medical area in the infectious health-care waste container.

b) **Anatomical waste**, particularly recognizable body parts or foetal material, should be handled according to prevailing religious and cultural preferences (most commonly, authorized burial or cremation). In low-resource areas, placentas and other non-recognizable anatomical waste can be disposed of in a pit where it can biodegrade naturally.

c) **Sharps** waste (needle and syringe combination) should be placed directly into a sharps container. In some places, it is permitted for syringes to have their needles removed or destroyed before placing the syringe in an infectious waste bin. Any removed needles are placed in a puncture-proof container and dealt with accordingly. This approach is not universally accepted as best practice.

d) Policies regarding the use of needle cutters (also known as hub cutters) or needle pullers, and destroyers vary from country to country. A needle puller is a type of pliers that removes the needle from the syringe – a process called defanging. (Luer-lock needles do not require a puller to defang them – they can simply be unscrewed from the syringe.) In some countries, needle cutters or pullers, or destroyers are mandatory for vaccination programmes. Table 7.2 summarises the advantages and disadvantages of needle cutters/destroyers.

Various chemical and pharmaceutical wastes should be segregated and collected separately: subcategories include mercury, batteries, cadmium-containing wastes, photochemicals, stains and laboratory reagents, cytotoxic drugs and other pharmaceuticals. All should be clearly labelled with the type of waste and the name of the major chemicals, with any necessary hazard labels attached to corrosive, flammable, explosive or toxic chemicals. Liquid chemical wastes should never be mixed or disposed of down the drain, but should be stored in strong leak-proof containers. It may be possible to recover silver from photochemicals at a profit, and return of chemicals to suppliers should be practised where possible. Silver is increasingly being used in medical products, but is rarely segregated due to a lack of dedicated disposal or metals recovery facilities. Low-energy light bulbs (compact fluorescents) contain small amounts of mercury. Both these and batteries should be segregated and treated by recycling processes, where suitable facilities exist.

Table 7.2: Advantages and disadvantages of needle cutters/destroyers

Advantages	Disadvantages
Prevents reuse of syringe either inadvertently or illegally	Cost: one will be needed wherever injections are given and will require maintenance. Sharps containers may still be needed for lancets and other sharps waste
Reduces volume of sharps wastes significantly	Some models collect the sharps in containers that need to be capped after filling; potential for spilling of needles and/or needle-stick injuries during container exchange
Potential for recycling syringe barrels after disinfection	Potential splash of blood during operation

Advantages	Disadvantages
Removes inclination of staff to recap used needles	Busy staff may leave syringes to be cut later, increasing chances of needle- stick injuries and infection from discarded syringes
Reduces risk of injury from improperly disposed syringes	Some needle destroyers are electrically operated and so not appropriate where power cuts are common

Mercury use is being reduced in health care and other applications around the world because of its toxicity and pollution potential. Since it is volatile, spilled mercury can be inhaled by staff and patients if it is not cleaned up properly, but a simple spill kit can be cheap and effective. Where mercury thermometers and sphygmomanometers are still in use, medical staff should be supplied with a spill kit and trained in how to use it. Any spill larger than a thermometer should be dealt with in consultation with the local health and safety authority. Brushes and vacuum cleaners should never be used for spilled mercury. Mercury can be cleaned up easily from wood, linoleum, tile and similar smooth surfaces. It cannot be completely removed from carpets, curtains, upholstery or other absorbent materials. The affected portion should be isolated and disposed of in accordance with official guidelines. For more information on spill clean-up, see section 11.3.2.

Unused pharmaceuticals should go back to the pharmacy for return to the manufacturers or dispatched to specialist waste-treatment contractors. Pharmaceuticals should be kept in their original packaging to aid identification and prevent reaction between incompatible chemicals. Spilt and contaminated chemicals and pharmaceuticals should not be returned to the pharmacy but should go directly from the point of production to a waste store. Typically, they are stored and transported within a health-care facility in brown cardboard boxes and must be kept dry.

Where specialist disposal services exist, they should collect and handle radioactive wastes. Otherwise, waste may be stored in secure, radiation-proof repositories (leak-proof, lead-lined and clearly labelled with the name of the radionuclide and date of deposition) where it should be left to decay naturally.

7.2.3. Waste Containers: Specifications and Siting

Many modern waste containers are designed for automated systems that empty their contents into the waste-disposal system and wash and disinfect them mechanically. At the other end of the scale, waste containers may also be made out of reused plastic and metal containers. In all cases, they should be sturdy and leak-proof, and (except for sharps containers) lined with a sturdy plastic bag. The recommended thickness of bags for infectious waste is 70 µm (ISO 7765 2004). Plastics used for either containers or bags should be chlorine-free. Not all plastic bags can withstand temperatures of 121 °C, and some can melt during an autoclave process.

Containers should have well-fitting lids, either removable by hand or preferably operated by a foot pedal. Both the container and the bag should be of the correct colour for the waste they are intended

to receive and labelled clearly. Mixing colours - such as having yellow bags in black bins – should be avoided, because it will increase the potential for confusion and poor segregation.

Since sharps can cause injuries that leave people vulnerable to infection, both contaminated and uncontaminated sharps should be collected in a puncture-proof and impermeable container that is difficult to break open after closure. Performance specifications for these containers are given in WHO (2007).[12]

Sharps containers may be disposable or designed for disinfection and reuse. Disposables are boxes made of plasticized cardboard or plastic (Figure 7.3); reusable designs are plastic or metal. Low-cost options include the reuse of plastic bottles or metal cans. If this is to be done, the original labels should be removed or obscured, and the containers should be clearly re-labelled as "Sharps containers".

The appropriate waste receptacle (bags, bins, sharps boxes) should be available to staff in each medical and other waste-producing area in a health-care facility. This permits staff to segregate and dispose of waste at the point of generation, and reduces the need for staff to carry waste through a medical area. Posters showing the type of waste that should be disposed of in each container should be posted on walls to guide staff and reinforce good habits.

Segregation success can be improved by making sure that the containers are large enough for the quantity of waste generated at that location during the period between collections. Up-to-date waste audit data can be used to assess the volume and type of waste containers necessary, since waste managers also need to spend time with staff in medical areas identifying the type of work that is undertaken. No two areas will be the same.

		
Proper disposal of used syringes into a designated sharps container	A proper cardboard sharps container	Sharps box in a Peruvian hospital

Figure 7.3: Cardboard safety boxes

[12] See http://www.who.int/immunization_standards/vaccine_quality/who_pqs_e10_sb01.pdf.

Medical staff should be encouraged to think of waste disposal as part of a patient's treatment, so all aspects of the care process are completed at the bedside or treatment room. If intervention at the bedside is required, a waste container should be taken to the bed. Sharps bins are also sometimes taken to a patient for drug administration or blood sampling. A mobile trolley with infectious waste and sharps containers may therefore be more versatile and should be used where possible. The alternative is establishing a limited number of locations in a medical area where general waste (black bags) and infectious health-care waste (yellow bags and sharps containers) are placed. The locations should be away from patients; typical sites are the sluice (utility) room, treatment room and nurses' station.

Where containers for segregating hazardous and non-hazardous health-care wastes are in use, they should be located close together, wherever possible. Containers for infectious waste should not be placed in public areas because patients and visitors may use the containers and come into contact with potentially infectious waste items. Static bins should be located as close as possible to sinks and washing facilities, because this is where most staff will deposit gloves and aprons after treating patients. If the general waste container is closest to the sink or under a towel dispenser, it will encourage staff to place towels into the non-infectious receptacle. Containers should be of similar size to overcome the observed tendency for staff to put waste in the largest receptacle.

Unless patients are known or suspected to have readily transmitted infections, the assumption should be that general waste generated in a medical area is of low risk. However, if there is a known communicable infection (e.g. methicillin-resistant *Staphylococcus aureus*, tuberculosis or leprosy), all waste used in and around the patient should be classed as an infection risk and placed in the yellow, potentially infectious waste container. This "blanket" approach to all waste being assumed to be infectious can be avoided where there is a high level of training and communication between the clinical and support staff. Waste from each patient should be treated according to their known infection status.

7.2.4. Setting and Maintaining Segregation Standards

Segregation methods should be clearly set out in the waste-management policy of a health-care facility. It is important that the waste-management policy is supported and enforced by senior staff and managers. Managers and medical supervisors should know the relevant legislation and understand how to implement waste audits, foresee possible problems and take pre-emptive remedial action. Medical staff and waste handlers should understand the reasons for, and operation of, segregation practices, waste auditing, spill management, and accident and injury reporting. Training should be repeated periodically to ensure that all staff are reminded of their responsibilities.

The waste-management committee is responsible for seeing that segregation rules are enforced and waste audits carried out to quantify the amount of waste being produced. Also, segregation posters for medical and waste workers help to raise knowledge about segregation practices and improve the quality of separated waste components.

Waste that has been poorly segregated should never be re-sorted, but instead should be treated as the most hazardous type of waste in the container. Corrective action taken should concentrate on ensuring that waste is segregated properly in the future.

As well as confirming that waste is being segregated properly, waste audit data can be used to indicate the type, size and number of containers needed in each area. It should be used to estimate disposal capacity requirements and the amount of recyclables generated. Both are essential pieces of data for good waste management and cost control. It can also be used to track the entire waste stream through to final disposal. Hospital managers have a duty to prove that all wastes have been disposed of in accordance with the law, and health-care facilities have to obtain proof of treatment from authorized waste-disposal contractors.

Reuse of medical products is common in some countries. Although it is not recommended practice, disposable gloves are often reused in resource-limited facilities, where they may be autoclaved and repacked for non-clinical use. Alternatively, they may be pilfered from the waste stream for illicit reuse. Similarly, used syringes and other medical devices may be washed and repackaged for resale. To prevent this, it may be necessary to ensure that staff mutilate gloves and other used equipment before placing them in the appropriate waste container.

7.3. COLLECTION WITHIN THE HEALTH-CARE FACILITY

Collection times should be fixed and appropriate to the quantity of waste produced in each area of the health- care facility. General waste should not be collected at the same time or in the same trolley as infectious or other hazardous wastes.

Waste bags and sharps containers should be filled to no more than three quarters full. Once this level is reached, they should be sealed ready for collection. Plastic bags should never be stapled but may be tied or sealed with a plastic tag or tie. Replacement bags or containers should be available at each waste-collection location so that full ones can immediately be replaced.

Waste bags and containers should be labelled with the date, type of waste and point of generation to allow them to be tracked through to disposal. Where possible, weight should also be routinely recorded. Anomalies between departments with similar medical services or over time at one location can show up differences in recycling opportunities, or problems such as poor segregation and diversion of waste for unauthorized reuse.

Collection should be daily for most wastes, with collection timed to match the pattern of waste generation during the day. For example, in a medical area where the morning routine begins with the changing of dressings, infectious waste could be collected mid-morning to prevent soiled bandages remaining in the medical area for longer than necessary. Visitors arriving later in the day will bring

with them an increase in general waste, such as newspapers and food wrappings; therefore, the optimum time for general and recyclable waste collection would be after visitors have departed.

In comparison with this general type of medical area, a theatre would generate a high proportion of potentially infectious waste and could have several collections during the day to fit in with the schedule of operations. A child and maternal health clinic might generate primarily sharps waste from injections, which would be collected at the end of each working day.

7.4. INTERIM STORAGE IN MEDICAL DEPARTMENTS

Where possible, hazardous waste generated in medical areas should be stored in utility rooms, which are designated for cleaning equipment, dirty linen and waste. From here, the waste can be kept away from patients before removal, then collected conveniently and transported to a central storage facility. This is known as interim or short-term storage (Figure 7.4).

If utility rooms are not available, waste can be stored at another designated location near to a medical area but away from patients and public access. Another possibility for interim storage is a closed container stationed indoors, within or close to a medical area. A storage container used for infectious waste should be clearly labelled and preferably lockable.

	
Interim waste storage ready for collection	Waste bins in a dirty utility room

Figure 7.4: Examples of interim waste storage places

7.5. ONSITE TRANSPORT OF WASTE

7.5.1. General Requirements

Onsite transport should take place during less busy times whenever possible. Set routes should be used to prevent exposure to staff and patients and to minimize the passage of loaded carts through patient care and other clean areas. Depending on the design of the health-care facility, the internal transport of waste should use separate floors, stairways or elevators as far as possible. Regular

transport routes and collection times should be fixed and reliable. Transport staff should wear adequate personal protective equipment, gloves, strong and closed shoes, overalls and masks.
Hazardous and non-hazardous waste should always be transported separately. In general, there are three different transport systems:

a) Waste transportation trolleys for general waste should be painted black, only be used for non-hazardous waste types and labelled clearly "General waste" or "Non-hazardous waste".
b) Infectious waste can be transported together with used sharps waste. Infectious waste should not be transported together with other hazardous waste, to prevent the possible spread of infectious agents. Trolleys should be coloured in the appropriate colour code for infectious waste (yellow) and should be labelled with an "Infectious waste" sign.
c) Other hazardous waste, such as chemical and pharmaceutical wastes, should be transported separately in boxes to central storage sites.

The use of waste chutes in health-care facilities is not recommended, because they can increase the risk of transmitting airborne infections.

7.5.2. Transport Trolleys

Health-care waste can be bulky and heavy and should be transported using wheeled trolleys or carts that are not used for any other purpose. To avoid injuries and infection transmission, trolleys and carts should:

a) be easy to load and unload
b) have no sharp edges that could damage waste bags or containers during loading and unloading
c) be easy to clean and, if enclosed, fitted with a drainage hole and plug
d) be labelled and dedicated to a particular waste type
e) be easy to push and pull
f) not be too high (to avoid restricting the view of staff transporting waste)
g) be secured with a lock (for hazardous waste)
h) be appropriately sized according to the volumes of waste generated at a health-care facility.

Waste, especially hazardous waste, should never be transported by hand due to the risk of accident or injury from infectious material or incorrectly disposed sharps that may protrude from a container.

Spare trolleys should be available in case of breakdowns and maintenance. The vehicles should be cleaned and disinfected daily. All waste bag seals should be in place and intact at the end of transportation.

Box 7.1: Recommendations for storage facilities for health-care waste

The storage area should:

a) have an impermeable, hard-standing floor with good drainage (away from watercourses); the floor should be easy to clean and disinfect;
b) include the facility to keep general waste separated from infectious and other hazardous waste;
c) have a water supply for cleaning purposes;
d) have easy access for staff in charge of handling the waste;
e) be lockable to prevent access by unauthorized persons;
f) have easy access for waste-collection vehicles;
g) have protection from the sun;
h) be inaccessible to animals, insects and birds;
i) have good lighting and at least passive ventilation;
j) not be situated in the proximity of fresh food stores and food preparation areas;
k) have a supply of cleaning equipment, protective clothing and waste bags or containers located conveniently close to the storage area;
l) have a washing basin with running tap water and soap that is readily available for the staff;
m) be cleaned regularly (at least once per week);
n) have spillage containment equipment;
o) be appropriate to the volumes of waste generated from each health-care facility

7.5.3. Routing

Separate hazardous and non-hazardous routes should be planned and used. In general, a waste route should follow the principle "from clean to dirty". Collection should start from the most hygienically sensitive medical areas (e.g. intensive care, dialysis, theatres) and follow a fixed route around other medical areas and interim storage locations. The frequency of collection should be refined through experience to ensure that there are no overflowing waste containers at any time. Biologically active waste (e.g. infectious waste) must be collected at least daily. A routing plan would be influenced by:

a) waste volume and number of waste bags or containers
b) waste types
c) capacity of the waste storage within medical areas and at interim storage areas
d) capacity of the transportation trolleys
e) transport distances and journey times between the collection points

7.6. CENTRAL STORAGE INSIDE HEALTH-CARE FACILITIES

Central storage areas are places within a health-care facility where different types of waste should be brought for safe retention until it is treated or collected for transport offsite. The general requirements in Box 7.1 are relevant to most types of health-care facilities where sufficient waste is produced and needs to be stored centrally. Some types of waste storage for particular items (e.g. blood, radioactive substances, chemicals) are only likely to be required at large and specialized medical centres.

7.6.1. General Requirements

A storage location for health-care waste should be designated inside the health-care facility. Space for storing wastes should be incorporated into a building design when new construction is undertaken; for an example, see the *Guidelines for design and construction of hospitals and health care facilities* (Facility Guidelines Institute, 2010). These storage areas should be sized according to the quantities of waste generated and the frequency of collection. The areas must be totally enclosed and separate from supply rooms or food preparation areas. Loading docks, space for compactors and balers for cardboard, staging areas for sharps boxes, recycling containers and secure storage (e.g. for batteries) should all be provided.

Storage facilities should be labelled in accordance with the hazard level of the stored waste. Figures 7.5 and 7.6 show typical signs advising the hazard posed by waste. In general, there are four different kinds of waste-storage areas:

a) non-hazardous or general waste
b) hazardous waste
c) infectious and sharps waste
d) chemical and hazardous pharmaceutical waste
e) radioactive waste.

		
No entry for unauthorized persons for all storage areas	Biohazard sign for infectious and sharps waste	Toxic sign for chemical and hazardous pharmaceutical waste

Figure 7.5: Example labels outside the storage facility

Figure 7.6 illustrates the signs that should be displayed inside the storage facilities.

	
No eating or drinking	No smoking

Figure 7.6: The signs that should be displayed inside the storage facilities

7.6.2 Hazardous Waste Storage

Further specifications should be considered for the storage of hazardous waste, in addition to the general requirements.

Infectious waste storage

The storage place must be identified as an infectious waste area by using the biohazard sign. Floors and walls should be sealed or tiled to allow easy disinfection. If present, the storage room should be connected to a special sewage system for infectious hospital wastewater. The compacting of untreated infectious waste or waste with a high content of blood or other body fluids destined for offsite disposal (for which there is a risk of spilling) is not permitted. Sharps can be stored without problems, but other infectious waste should be kept cool or refrigerated at a temperature preferably no higher than 3 °C to 8 °C if stored for more than a week. Unless a refrigerated storage room is available, storage times for infectious waste (e.g. the time gap between generation and treatment) should not exceed the periods shown in Table 7.3):

Table 7.3: Recommended times between generation and treatment

Temperate climate	Warm climate
72 hours in winter	48 hours during the cool season
48 hours in summer	24 hours during the hot season

Pathological waste storage

Pathological waste and the growth of pathogens it may contain are considered as biologically active waste, and gas formation during storage should be expected. To minimize these possibilities, the storage places should have the same conditions as those for infectious and sharps wastes.

In some cultures, body parts are passed to the family for ritual procedures or are buried in designated places. They should be placed in sealed bags to reduce infection risks before release to the public. More information about pathological waste handling can be found in Chapter 8 and in Annex 6. Figure 7.7 shows an example of a label for a pathological waste storage room.

Figure 7.7: Label for a pathological waste storage room

Pharmaceutical waste storage

Pharmaceutical waste should be segregated from other wastes and local regulations followed for final disposal. In general, pharmaceutical wastes can be hazardous or non-hazardous, and liquid or solid in nature, and each should be handled differently. The classification should be carried out by a pharmacist or other expert on pharmaceuticals. The pharmaceutical waste streams that are listed below can be distinguished (WHO, 1999):

a) Pharmaceutical waste with non-hazardous characteristics that can be stored in a non-hazardous storage area
   i) ampoules with non-hazardous content (e.g. vitamins);
   ii) fluids with non-hazardous contents, such as vitamins, salts (sodium chloride), amino salts;
   iii) solids or semi-solids, such as tablets, capsules, granules, powders for injection, mixtures, creams, lotions, gels and suppositories;
   iv) aerosol cans, including propellant-driven sprays and inhalers.

b) Hazardous waste that should be stored in accordance with their chemical characteristics (e.g. genotoxic drugs) or specific requirements for disposal (e.g. controlled drugs or antibiotics)
   i) controlled drugs (should be stored under government supervision);
   ii) disinfectants and antiseptics;
   iii) anti-infective drugs (e.g. antibiotics);
   iv) genotoxic drugs (genotoxic waste);
   v) ampoules with, for example, antibiotics.

Genotoxic waste is highly toxic and should be identified and stored carefully away from other health-care waste in a designated secure location. It can be stored in the same manner as toxic chemical waste, although some cytotoxic waste may also carry a risk of infection.

Chemical waste storage

When planning storage places for hazardous chemical waste, the characteristics of the different chemicals to be stored and disposed of must be considered (inflammable, corrosive, explosive). The storage place should be an enclosed area and separated from other waste storage areas (Figure 7.8). When storing liquid chemicals, the storage should be equipped with a liquid- and chemical-proof sump. If no sump is present, catch-containers to collect leaked liquids should be placed under the storage containers. Spillage kits, protective equipment and first- aid equipment (e.g. eye showers) should be available in the central storage area. The storage area itself should have adequate lighting and good ventilation to prevent the accumulation of toxic fumes.

To ensure the safe storage of chemical wastes, the following separate storage zones should be available to prevent dangerous chemical reactions. The storage zones should be labelled according to their hazard class. If more than one hazard class is defined for a specific waste, use the most hazardous classification:

a) explosive waste
b) corrosive acid waste
c) corrosive alkali waste (bases)
d) toxic waste
e) flammable waste
f) oxidative waste
g) halogenated solvents (containing chlorine, bromine, iodine or fluorine)
h) non-halogenated solvents.

Liquid and solid waste should be stored separately. If possible, the original packaging should be taken for storage too. The packaging used to store and transport chemical wastes offsite should also be labelled. This label should have the following information: hazard symbol(s), waste classification, date, and point of generation (if applicable).

The storage area for explosive or highly flammable materials must be suitably ventilated above and below, with a bonded floor and constructed of materials suitable to withstand explosion or leakage.

	
Advanced storage of chemicals in different safety	Storage of liquid chemical waste in chemical- resistant

compartments	plastic containers
	
Safety cabinet for flammable substances	Inside a safety cabinet for flammable substances

Figure 7.8: Examples of storage places for chemical waste

Radioactive waste

Radioactive waste should be stored in containers that prevent dispersion of radiation, and stored behind lead shielding. Waste that is to be stored during radioactive decay should be labelled with the type of radionuclide, date, period of time before full decay and details of required storage conditions.

The decay storage time for radioactive waste differs from other waste storage, because the main target will be to store the waste until the radioactivity is substantially reduced and the waste can be safely disposed of as normal waste. A minimum storage time of 10 half-life times for radioisotopes in wastes with a half-life of less than 90 days is a common practice. Infectious radioactive waste should be decontaminated before disposal. Sharp objects such as needles, Pasteur pipettes and broken glass should be placed into a sharps container. Liquids associated with solid materials, such as assay tube contents, should be decanted or removed by decay time. All radioactive labelling should be removed on any items to be disposed of. Box 7.2 gives a sample calculation of decay storage time.

Box 7.2: Decay storage of radioactive waste – a sample calculation of decay storage time

Decay storage

Cr-51, Ga-67, I-125, I-131, In-111, P-32, Rb-86, Rd-222, S-35, Tc-99m and so on

Example

I-125

Half-life: 60.2 days (<90 days)

60.2 days × 10 = 602 days of decay storage

Sources: IAEA (2005); FIU (2005)

Radioactive waste with a half-life of more than 90 days must be collected and stored externally in accordance with national regulations. In many countries, this type of waste would be taken to a national disposal site by a government agency or its specialist contractor.

Storage places must be equipped with sufficient shielding material, either in the walls or as movable shielding screens. The storage must be clearly marked with “RADIOACTIVE WASTE”, and the international hazard label should be placed on the door. The storage place should be constructed in a manner that renders it flame-proof and should have such surfaces on floors, benches and walls

that allow proper decontamination. An air-extraction system and radioactive monitoring system should be put in place. The International Atomic Energy Agency provides comprehensive guidance on all aspects of the safety of radioactive waste management in the Safety Standards Series.

7.6.2. Layout Of Waste-Storage Areas

If new health-care waste-management systems are developed and if new infrastructure is planned, a "waste yard" should be built. A waste yard is where all the relevant waste-management activities are brought together. To concentrate certain tasks, it is best to set up multifunctional buildings (waste-storage area), including a fenced storage area for general waste (A), a room for infectious waste (B), a treatment room (C), a fenced area with an ash or sharps pit (D), a container cleaning room (E) and a clean office with lockers and toilets (F).

7.6.3. Documentation of the Operation of Storage Places

Keeping clear records of the wastes stored and their treatment and disposal dates is important to ensure a good control of waste management. Some countries have strict legal requirements to achieve a high level of safety. The following forms of additional documentation are suggested:

a) a written spill contingency plan;
b) a weekly store inspection protocol;
c) protocols for using, repairing and replacing emergency equipment;
d) training system and documentation (names of trained staff, job descriptions, form of training, date of training, date for refresher or revalidation training);
e) hazardous waste storage documentation;
f) collection of relevant material safety data sheets.

8 TREATMENT AND DISPOSAL METHODS

8.1. INTRODUCTION

The purpose of treatment is to reduce the potential hazard posed by health-care waste, while endeavouring to protect the environment.

Treatment should be viewed in the context of the waste-management hierarchy. Measures should first be followed to minimize and reuse waste items where it is safe to do so. Where this is not possible, the unusable waste materials should preferably be treated to reduce their potential health or environmental hazard and volume, with remaining residues sent for land disposal to a suitably constructed site.

8.2. OFFSITE TRANSPORT OF WASTE

Offsite transport is the carriage of health-care waste on the public streets away from a health-care facility. Transporting hazardous health-care waste should comply with national regulations, and with international agreements if wastes are shipped across an international frontier for treatment (Secretariat of the Basel Convention, 1992). Where there are no national regulations, responsible authorities may refer to recommendations on the transport of dangerous goods published by the United Nations. These are available in English, French, (UN, 2009).[13]

8.2.1. Logistic Staff

Drivers of vehicles carrying hazardous health-care waste should have appropriate training about risks and handling of hazardous waste. Training on the following issues should be included:

a) relevant legal regulations
b) waste classifications and risks
c) safe handling of hazardous waste
d) labelling and documentation
e) emergency and spillage procedures.

In addition, drivers should be declared medically fit to drive vehicles.
In case of accident, contact numbers or details of the emergency services and other essential departments should be carried in the driver's cab. For safety reasons, vaccination against tetanus and hepatitis A and B is recommended, and vaccination and training details of staff should be recorded.

[13] See http://www.unece.org/trans/danger/publi/unrec/rev16/16files_e.html

8.2.2. Vehicle Requirements

A fundamental requirement is for the vehicle transporting hazardous waste to be roadworthy and labelled to indicate its load, and its payload to be secured to minimize the risk of accidents and spillages. Any vehicle used to transport health-care waste should fulfil several design criteria:

a) The body of the vehicle should be of a suitable size commensurate with the design of the vehicle.
b) There should be a bulkhead between the driver's cabin and the vehicle body, which is designed to retain the load if the vehicle is involved in a collision.
c) There should be a suitable system for securing the load during transport.
d) Empty plastic bags, suitable protective clothing, cleaning equipment, tools and disinfectant, together with special kits for dealing with liquid spills, should be carried in a separate compartment in the vehicle.
e) The internal finish of the vehicle should allow it to be steam-cleaned and internal angles should be rounded to eliminate sharp edges to permit more thorough cleaning and prevent damage to waste containers.
f) The vehicle should be marked with the name and address of the waste carrier.
g) An international hazard sign should be displayed on the vehicle and containers, as well as an emergency telephone number.
h) The driver should be provided with details of the waste being carried.

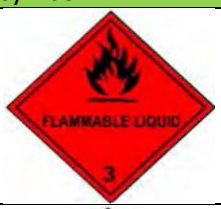
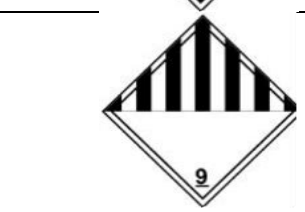
Vehicles or containers used for transporting health-care waste should not be used for transporting any other material. Vehicles should be kept locked at all times, except when loading and unloading, and kept properly maintained. Articulated or demountable trailers (temperature-controlled if required) are particularly suitable, because they can easily be left at the site of waste production. Other systems may be used, such as specially designed large, closed containers or skips. Open-topped skips or containers are unsuitable because they fail to isolate waste from the general public during transportation, and should not be used for health-care waste.

Where the use of a dedicated vehicle cannot be justified, a bulk container that can be lifted onto a vehicle chassis may be considered. The container may be used for storage at the health-care facility and replaced with an empty one when collected. Refrigerated containers could be used if the storage time exceeds the recommended limits described previously, or if transportation times are long. The same safety measures should apply to the collection of hazardous health-care waste from scattered small sources, such as clinics and general practice surgeries.

8.2.3. Labelling of the Transport Vehicle

The transport vehicle should be labelled according to the type of waste that is being transported. The label that is displayed will depend on the United Nations classification of the waste. Relevant examples are shown in Table 8.1.

Table 8.1: Selected United Nations packaging symbols

UN class	Name	Description of symbol	Symbol
3.1	Flammable Liquids	Black symbol: flame Background: red Class "3" in bottom corner	
5.1	Oxidizing Substances	Black symbol: flame over circle Background: yellow Class "5.1" in bottom corner	
6.1	Toxic Substances	Black symbol: skull and crossbones Background: white Class "6" in bottom corner	
6.2	Infectious Substances	Black symbol: three crescents superimposed on a circle Background: white Class "6" in bottom corner	
7A	Radioactive Material Category I – White	Black symbol: trefoil Background: white Class "7" in bottom corner	
7B	Radioactive Material Category II – Yellow	Black symbol trefoil Background: yellow Class "7" in bottom corner	
7C	Radioactive Material Category III – Yellow	Black symbol trefoil Background: yellow Class "7" in bottom corner	
8	Corrosive Substances Category I – White	Black symbol: liquids spilling from two glass vessels and attacking a hand and a metal Background: upper half white, lower half black with white border Class "8" in bottom corner	
9	Miscellaneous Dangerous Substances Category I – White	Black symbol: seven vertical stripes in upper half Background: white, lower half black with white border Class "9" underlined in bottom corner	

A warning plate should:

a) be not less than 250 mm by 250 mm, with a line of the same colour as the symbol running 12.5 mm inside the edge and parallel with it;
b) correspond to the label required for the dangerous goods in question with respect to colour and symbol;
c) display the numbers prescribed for the dangerous goods on the corresponding label, in digits not less than 25 mm high.

8.2.4. Cleaning of Container and Vehicle

Vehicles and transporting containers used for the transportation of waste should be cleaned and disinfected daily after use. Mechanical cleaning, combined with soaps and detergents, which act as solubility promoting agents, can be used. Cleaning and disinfection have to be carried out in a standardized manner or by automated means that will guarantee an adequate level of cleanliness. A standard operating procedure for cleaning should be prepared and explained to cleaning staff. In addition, a schedule for preventive maintenance should be set up for all equipment and vehicles used in the transportation process.

8.2.5. Transport Documentation

Before sending hazardous health-care wastes offsite, transport documentation (commonly called a "consignment note" or "waste tracking note") should be prepared and carried by the driver. A consignment note should be designed to take into account the control system for waste transportation in operation within a country. If a waste regulatory authority is sufficiently well established, it may be possible to pre-notify the agency about a planned offsite transport and disposal of hazardous health-care waste and to obtain the agency's approval. Anyone involved in the production, handling or disposal of health-care waste should recognize that they have a general "duty of care" - that is, an obligation to ensure that waste handling, treatment and disposal and the associated documentation comply with the national regulations.

The consignment note for a vehicle carrying a hazardous health-care waste load should include the following information in case of accidents or official inspection:

a) waste classes
b) waste sources
c) pick-up date
d) destination
e) driver name
f) number of containers or volume
g) receipt of load received from responsible person at pick-up areas.

This information allows quick and effective countermeasures to be taken in the event of an accident or incident. Weight of waste is useful for commercial treatment and disposal operators who bill health-care facilities for their waste services.

On completion of a journey, the transporter should complete a consignment note and return it to the waste producer. A typical consignment note for carriage and disposal of hazardous waste and routing of the copies to a waste producer, waste disposer and regulator is shown in Figure 8.1.
There are four copies of the signed consignment note: one for the generator and one for the transport entity, one for the treatment entity and one for the relevant regulatory authority.

Consignment note in accordance with ADR	Date of collection: (Day, Month, Year)
Consignor (generator) – name	Consignor (generator) –address
Waste carrier – name	Waste carrier –address
Date of receipt: (Day, Month, Year)	
Consignee (treatment site) – name	Consignee (treatment site) and address

Waste description

UN No. and type	Proper	Gross weight

I hereby declare that the contents of the consignment are fully and accurately described above by the proper shipping name and classified packaged, marked and labelled /placarded and are in all respects in proper condition according to applicable international and national governmental regulations. I declare that all of the applicable requirements have been met.

Signature Cosigner	Signature Waste Carrier	Signature
(Generator)	(Transporter)	(Treatment)

Figure 8.1: Example of consignment note for carriage and disposal of infectious waste

To reduce the negative impacts of accidents, contact telephone numbers of the emergency services and environmental and public health regulators should be given to drivers.

Driver documents

Driving trucks with dangerous waste demands special knowledge about risks and handling. For that reason, the driver should have training and preferably also a certificate indicating their confidence to transport hazardous wastes. If there are no national regulations available, the certificate procedures of the *European agreement concerning the international carriage of dangerous goods by road* (the ADR) can be used (UN, 2010). The certificate of approval, "ADR B3 Certificate", is obtainable on an annual basis following satisfactory inspection by an approved testing agency.

Emergency response intervention cards (ERICards or ERICs) kept inside the driver's cab provide guidance on initial actions for fire crews, because they are often the first to arrive at the scene of a hazardous waste transport accident. These cards provide reliable product-specific emergency information that otherwise may not be immediately available. An example ERICard for infectious waste (UN 3291) is given in **Box 8.1.**

Box 8.1: Example of an emergency response intervention card

UN 3291 CLINICAL WASTE, UNSPECIFIED, NOS or (BIO) MEDICAL WASTE, NOS or REGULATED MEDICAL WASTE, NOS

ADR Class 6.2 **Packing group** II

1. Characteristics:

7 Hazardous to skin, eyes and air passages.

8 Biohazard – Infectious to humans and/or animals. Serious risk of contamination of soil and water.

2. Personal protection:

Protection suit.

Gloves, mask and goggles.

Closed shoes.

3. Intervention actions:

3.1 General

Keep upwind. Put on protective equipment before entering danger area.

Minimize number of personnel in risk area.

People and animals who may be contaminated should be kept isolated pending medical/veterinary examination.

3.2 Spillage:

Stop leaks if possible.

Contain spillage by any means available.

Absorb liquid in sand or earth or any other suitable material.

If substance has entered a water course or sewer, inform the responsible authority.

3.3. Fire (involving the substance):

Let breached containers burn. Prevent the fire spreading with water spray

Minimize use of extinguishing media and contain run-o

Remove undamaged containers away from heat radiation.

4. First aid:

8.3. MINIMUM APPROACH TO SEGREGATION, STORAGE AND TRANSPORT

The minimum standard to segregating health-care wastes is the "three-bin system", where separate containers are provided for infectious waste, used sharps and general waste.
The basic features of a minimal level of waste segregation and storage are as follows:

a) Wastes are segregated at their place of production to reduce the health risk from the smaller potentially infectious factions (typically waste items contaminated with body fluids and used sharps).
b) Infectious waste, general waste and used sharps waste are stored in separate colour-coded containers and locations within medical areas, and subsequently at a central storage site at a health-care facility.
c) Central storage area(s) are fenced, lockable and isolated from patients and the public.
d) Maximum storage times before treatment or disposal of infectious waste are not longer than
   - ☞ temperate climate: 72 hours in winter and 48 hours in summer
   - ☞ warm climate: 48 hours during the cooler season and 24 hours during the hot season.
e) Staff receive instruction on three-bin waste segregation and safe handling and storage of health-care wastes.
f) Staff are aware of how to protect themselves from injuries and infection from waste.
g) Waste containers and storage areas are cleaned regularly.

The minimum measures for transporting health-care wastes are as follows:

a) General waste and infectious health-care waste is collected separately and at least once a day.
b) Collection is at regular times and is reliable.
c) Waste containers and onsite transport trolleys are closed with lids to isolate wastes from patients and the public.
d) Where wastes are transported offsite for disposal, the vehicle is able to carry wastes in a closed or covered container, and the driver knows what to do if there is an accident or incident during transportation on public roads.
e) Transport staff are vaccinated at least against hepatitis A and B, polio and tetanus.
f) Waste containers, trolleys and vehicles are maintained and cleaned regularly.

In emergency situations, all waste from patients arriving at a health-care facility could be classified as potentially infectious to minimize the transmission of secondary infection.

8.4. DESIRABLE IMPROVEMENTS TO THE MINIMAL APPROACH

Enhancements of the minimal approach include:

a) developing more detailed arrangements for waste storage and transport in a waste-management plan;
b) exploring opportunities for reducing, reusing and recycling some portions of the health-care wastes produced at the facility;

c) including waste-storage and transport expenses in the annual budgeting;
d) instituting separate chemical and pharmaceutical waste segregation and storage management;
e) developing a separate storage and documentation system for chemical wastes, which could include separate storage zones for:
   - ☞ flammable liquids
   - ☞ bio-toxic compounds
   - ☞ corrosive wastes – acids
   - ☞ caustic wastes – bases
f) chemical waste management included in training activities

There are five basic processes for the treatment of hazardous components in health-care waste, in particular, sharps, infectious and pathological wastes: thermal, chemical, irradiation, biological and mechanical.

8.5. OVERVIEW OF WASTE-TREATMENT TECHNOLOGIES

8.5.1. Thermal Processes

These processes rely on heat (thermal energy) to destroy pathogens in the waste. They represent most treatment facilities in use across the world. This category can be further subdivided into low-heat and high-heat designs. This sub-classification is useful because of the marked differences in the thermochemical reactions and physical changes taking place in the wastes during their treatment in the different types of equipment. These differences produce very different atmospheric emissions characteristics.

Low-heat thermal processes are those that use thermal energy at elevated temperatures high enough to destroy microorganisms but not sufficient to cause combustion or pyrolysis of the waste. Pyrolysis is the thermal degradation of a substance through the application of heat in the absence of oxygen. Pyrolysis is a special case of thermolysis, and is most commonly used for organic materials. It occurs at high temperatures but does not involve reactions with oxygen. In practice, it is difficult to have a completely oxygen-free atmosphere, so some oxidation takes place.

In general, low-heat thermal technologies operate between 100 °C and 180 °C. The low-heat processes take place in either moist or dry-heat environments. Moist (or wet) thermal treatment involves the use of steam to disinfect waste and is commonly performed in an autoclave or steam-based treatment system. Microwave treatment is essentially a moist thermal process, because disinfection occurs through the action of moist heat (hot water and steam) generated by the microwave energy. Dry-heat processes use hot air without the addition of water or steam. In dry-heat systems, the waste is heated by conduction, convection and/or thermal radiation using infrared or resistance heaters.

8.5.2. Chemical Processes

Chemical treatment methods use disinfectants such as dissolved chlorine dioxide, bleach (sodium hypochlorite), peracetic acid, lime solution, ozone gas or dry inorganic chemicals (e.g. calcium oxide powder). Chemical processes often involve shredding, grinding or mixing to increase exposure of the

a) flammable liquids
b) bio-toxic compounds
c) corrosive wastes – acids
d) caustic wastes – bases
e) chemical waste management included in training activities

8.6. SELECTION OF TREATMENT METHODS

The choice of treatment system involves consideration of waste characteristics, technology capabilities and requirements, environmental and safety factors, and costs - many of which depend on local conditions. Factors to consider include:

a) waste characteristics
b) quantity of wastes for treatment and disposal
c) capability of the health-care facility to handle the quantity of waste
d) types of waste for treatment and disposal
e) technology capabilities and requirements
f) local availability of treatment options and technologies
g) capacity of the system
h) treatment efficiency
i) volume and mass reduction
j) installation requirements
k) available space for equipment
l) infrastructure requirements
m) operation and maintenance requirements
n) skills needed for operating the technology
o) environmental and safety factors
p) environmental releases
q) location and surroundings of the treatment site and disposal facility
r) occupational health and safety considerations
s) public acceptability
t) options available for final disposal
u) regulatory requirements
w) cost considerations
x) equipment purchase cost
y) shipping fees and customs duties
z) installation and commissioning costs
aa) annual operating costs, including preventive maintenance and testing

bb) cost of transport and disposal of treated waste
cc) decommissioning costs.

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Another example of a chemical process is a system that uses heated alkali to digest tissues, pathological waste, anatomical parts and animal carcasses in heated stainless-steel tanks.

8.7.3. Irradiation Technologies

Irradiation treatment encompasses designs using irradiation from electron beams, cobalt-60 or ultraviolet sources. These technologies require shielding to prevent elevated occupational exposures to electromagnetic radiation. The pathogen destruction efficacy depends on the dose absorbed by the mass of waste. Electron beams are powerful enough to penetrate waste bags and containers. Germicidal ultraviolet radiation has been used to destroy airborne microorganisms as a supplement to other treatment technologies, but is not able to penetrate closed waste bags.

8.7.4. Biological Processes

These processes are found in natural living organisms but refer specifically to the degradation of organic matter when applied to health-care waste treatment. Some biological treatment systems use enzymes to speed up the destruction of organic waste containing pathogens. Composting and vermiculture (digestion of organic wastes through the action of worms) are biological processes and have been used successfully to decompose hospital kitchen waste, as well as other organic digestible waste (Mathur, Verma & Srivastava, 2006) and placenta waste. The natural decomposition of pathological waste through burial is another example of a biological process. More detailed information can be found in Annex 6.

8.7.5. Mechanical Processes

Mechanical treatment processes include several shredding, grinding, mixing and compaction technologies that reduce waste volume, although they cannot destroy pathogens. In most instances, mechanical processes are not stand-alone health-care waste-treatment processes, but supplement other treatment methods. Mechanical destruction can render a waste unrecognizable and can be used to destroy needles and syringes (depending on the type of shredding). In the case of thermal or chemical treatment processes, mechanical devices such as shredders and mixers can also improve the rate of heat transfer or expose more surface area of waste to waste treatment. Mechanical devices used to prepare wastes before other forms of waste destruction add significantly to the level of management and maintenance required to treat health-care waste safely and efficiently.

Unless shredders, mixers and other mechanical devices are an integral part of a closed treatment system, they should not be used before the incoming health-care waste is disinfected. If they are used, workers are at an increased risk of being exposed to pathogens in aerosols released into the environment by mechanical destruction of untreated waste bags. If mechanical processes are part of a closed system, the technology should be designed in such a way that the air in and from the mechanical process is disinfected before being released to the surroundings.

8.8. SUITABILITY OF TREATMENT METHODS FOR INFECTIOUS WASTE

The largest proportion of hazardous health-care waste generated is potentially infectious. The most established waste-management technologies focus on disinfection. Disinfection can be defined as the reduction or removal of disease-causing microorganisms (pathogens) to minimize the potential for disease transmission.

Sterilization is defined as the destruction of all microbial life. Since the complete destruction of all microorganisms is difficult to establish, sterilization of medical and surgical instruments is generally expressed as a 6 $\log_{10}$ reduction (i.e. a 99.9999% reduction) or greater of a specified microorganism that is highly resistant to the treatment process. A 6 $\log_{10}$ reduction, sometimes also written as "log 6 kill", corresponds to a one millionth (0.000001) survival probability of the microbial population.

The classification system was established to define measures of performance of health-care waste treatment technologies. The levels defined for microbial inactivation are:

a) Level I: inactivation of vegetative bacteria, fungi and lipophilic viruses at a 6 $\log_{10}$ reduction or greater;

b) Level II: inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites and mycobacteria at a 6 $\log_{10}$ reduction or greater;

c) Level III: inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites and mycobacteria at a 6 $\log_{10}$ reduction or greater; and inactivation of *Geobacillus stearothermophilus* spores and *Bacillus atrophaeus* spores at a 4 $\log_{10}$ reduction or greater;

d) Level IV: inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites, mycobacteria and *Geobacillus stearothermophilus* spores at a 6 $\log_{10}$ reduction or greater.

A common microbial inactivation standard for health-care waste treatment based on the STAATT[14] criteria is Level III. Regular testing of the efficacy of disinfection techniques is important. Countries may have different protocols, but general guidelines and procedures are available; for example, STAATT testing procedures, which are kept under constant review.[15]

8.9. STEAM TREATMENT TECHNOLOGIES

8.9.1. Autoclaves

Autoclaves are capable of treating a range of infectious waste, including cultures and stocks, sharps, materials contaminated with blood and limited amounts of fluids, isolation and surgery waste, laboratory waste (excluding chemical waste) and "soft" waste (including gauze, bandages, drapes, gowns and bedding) from patient care. With sufficient time and temperature, it is technically possible

[14] State and Territorial Association on Alternative Treatment. Technologies (***STAATT***

[15] See http://www.epa.gov/osw/nonhaz/industrial/medical/publications.htm

to treat small quantities of human tissue, but ethical, legal, cultural, religious and other considerations may preclude their treatment. Autoclaves are generally not used for large anatomical remains (body parts), because it is difficult to determine beforehand the time and temperature parameters needed to allow full penetration of heat to the centre of the body part.

Autoclaves have been used for more than a century to sterilize medical instruments, and for several years they have been adapted for the treatment of infectious waste. An autoclave consists of a metal vessel designed to withstand high pressures, with a sealed door and an arrangement of pipes and valves through which steam is introduced into, and removed from, the vessel. Some autoclaves are designed with a steam jacket surrounding the vessel; steam is introduced into both the outside jacket and the inside chamber. Heating the outside jacket reduces condensation on the inside chamber wall and allows the use of steam at lower temperatures. An autoclave without a steam jacket, sometimes called a "retort", is commonly found in large-scale applications and is cheaper to construct.

Air is an effective insulator and a principal factor in determining the efficiency of steam treatment. Removal of air from the autoclave is essential to ensure penetration of heat into the waste. Unlike instrument sterilization autoclaves, waste-treatment autoclaves must treat the air that is removed at the start of the process to prevent the release of pathogenic aerosols. This is usually done by treating the air with steam or passing it through a high-efficiency particulate air (HEPA) filter before it is released.
Consequently, autoclaves can be subcategorized according to the method of air removal. The three common types are:

a) gravity-displacement autoclaves
b) pre-vacuum or high-vacuum autoclaves
c) pressure pulse autoclaves.

A gravity-displacement autoclave takes advantage of the fact that steam is lighter than air. Hence, steam is introduced under pressure into the chamber, forcing the air downwards into an outlet port of the chamber.

A more effective but costlier method is the use of a vacuum pump and/or a steam ejector to evacuate air before introducing steam, as is done in pre-vacuum (also called high-vacuum) autoclaves. Pre-vacuum autoclaves need less time for disinfection due to their greater efficiency in removing air and disinfecting waste. Figure 8.2 shows a simple schematic of a pre-vacuum autoclave.

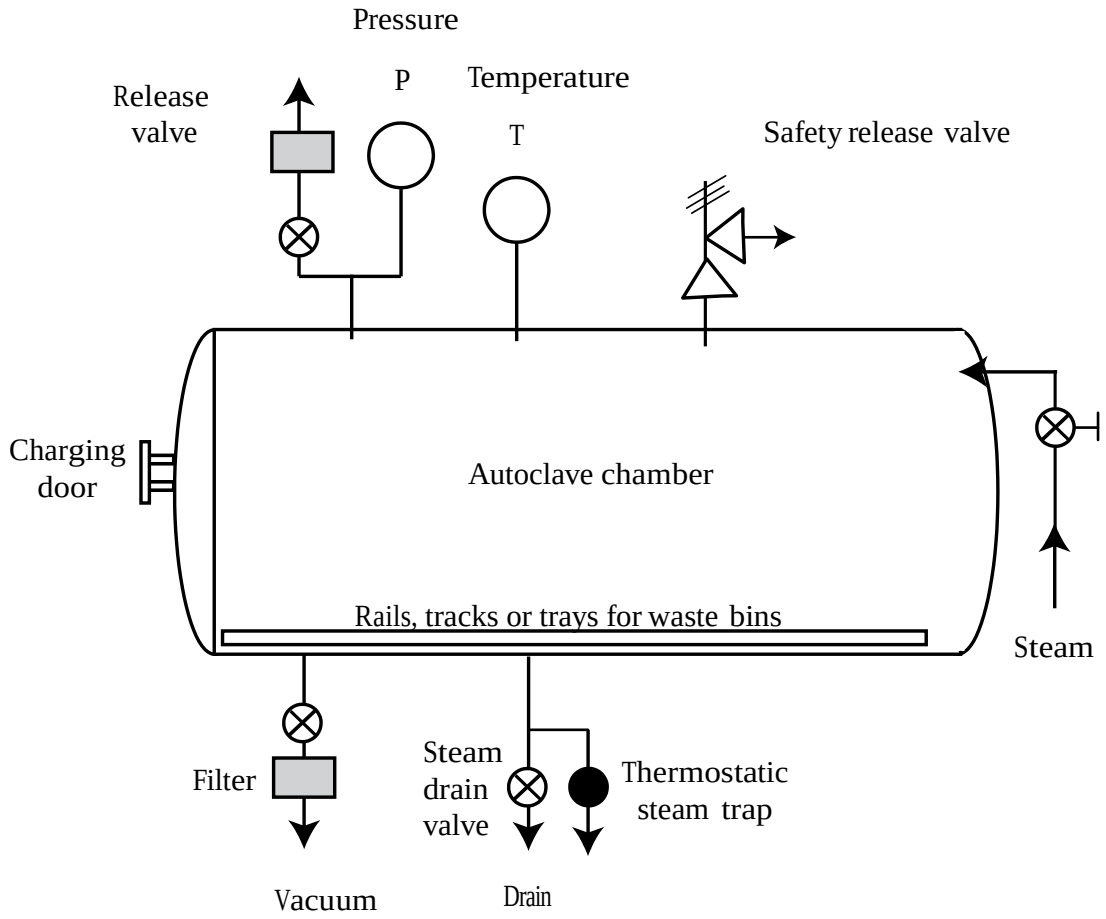


Figure 8.2: Simplified schematic of a pre-vacuum autoclave

Since autoclaves must be able to withstand repeated build-up and release of steam pressures, their construction materials, engineering design, fabrication, accuracy of pressure and temperature sensors, and testing must meet basic requirements to operate safely. Examples of international standards related to pressure vessels are EN 13445, EN 285 and ASME Section VIII (see the list of references and further reading at the end of this chapter). For waste treatment, autoclaves should be rated to operate between 1 and 2 bar gauge pressure (about 15–30 psig, or 1540–2280 mm Hg absolute) or higher.

Waste-treatment autoclaves can range in size from about 20 litres to more than 20 000 litres. Low-heat thermal processes produce significantly less air pollution emissions than high-heat thermal processes. Consequently, there are no specific pollutant emission limits for autoclaves and other steam treatment systems.

A typical operation for an autoclave involves the following:

a) **Waste collection:** Infectious waste bags are placed in a metal cart or bin. The cart or bin should be lined with a plastic liner to prevent waste from sticking to the sides of the container **Pre-**

heating (for autoclaves with steam jackets): Steam is introduced into the outside jacket of the autoclave.

b) **Waste loading:** The metal cart or bin is loaded into the autoclave chamber. With every load, a colour-changing indicator is attached to the outer surface of the waste bag in the middle of the waste load to monitor treatment. The entry (or charging) door is closed, sealing the chamber.
c) **Air evacuation:** Air is removed through gravity displacement, pre-vacuuming or pulse vacuuming.
d) **Steam treatment:** Steam is introduced into the chamber until the required pressure or temperature is reached.

Additional steam is automatically fed into the chamber to maintain the temperature and pressure for a set time period. Pressure pulsing autoclaves vary the pressure according to a set process cycle.

a) **Steam discharge:** Steam is vented from the chamber, usually through a condenser, to reduce the pressure and temperature. In some systems, a post-vacuum cycle is used to remove residual steam and to dry the waste.
b) **Unloading:** Usually, additional time is provided to allow the waste to cool down further, after which the treated waste is removed and the indicator strip is checked. The process is repeated if the colour change on the indicator shows that the treatment cycle was insufficient.
c) **Documentation:** A written log is maintained to record the date, time and operator name; type and approximate amount of waste treated; and post-treatment confirmation results from any automated equipment recording or temperature–pressure monitoring indicator, such as the indicator strip.
d) **Mechanical treatment:** If desired, the treated waste may be fed into a shredder or compactor before disposal in a landfill.

Some options provided by autoclave manufacturers include programmable computer controls, tracks and lifts for carts, recording of treatment parameters, weighing scales, autoclave-compatible carts and cart washers, odour- reducing systems, sensors to detect radioactive or chemical wastes, and shredders. Certain load configurations, such as placing bags in multilevel racks with sufficient spaces between bags to allow more surfaces to be exposed to steam, are more efficient than tightly stacked containers or carts.

Volatile and semivolatile organic compounds, chemotherapeutic waste, mercury, other hazardous chemical waste and radiological waste should not be treated in an autoclave. Large and bulky bedding material, large animal carcasses, sealed heat-resistant containers and other waste loads that impede the transfer of heat should be avoided.

Odours can be a problem around autoclaves if there is insufficient ventilation. If waste streams are not properly segregated to prevent hazardous chemicals from being placed in the treatment chamber, toxic contaminants will be released into the air, as a condensate, or in the treated waste. This happens when waste loads contaminated with laboratory solvents or heavy metals such as mercury are put in the autoclave. Poorly segregated waste may emit low levels of alcohols, phenols, formaldehyde and other organic compounds into the air.

Treated waste from an autoclave retains its physical appearance. If desired, a mechanical process such as a shredder or grinder is used after treatment to make the waste unrecognizable. Shredding reduces the volume of the treated waste by 60–80%, but is prone to breakdowns.

The operation of autoclaves requires the proper combination of temperature/pressure and exposure time to achieve disinfection. In the past, a minimum recommended temperature-exposure time criterion of 121 °C for 30 minutes was suggested. This corresponds to a pressure of 205 kPa or 2.05 bar (15 psig or 30 psia). However, the effective penetration of steam and moist heat depends on many factors, including time, temperature/pressure, process sequence, load size, stacking configuration and packing density, types and integrity of bags or containers used, physical properties of the materials in the waste (such as bulk density, heat capacity and thermal conductivity), the amount of residual air and the moisture content in the waste (Lemieux et al., 2006). If liquids such as blood bags or urine bags are to be sterilized, the sterilization process and time have to be adapted. The Robert Koch Institute recommends treating prions, which cause Creutzfeld–Jacob disease, at 134 °C for 60 minutes because of their exceptional resistance. For these reasons, initial challenge tests should be conducted using waste samples that are representative of actual waste produced in a health-care facility to determine or validate the minimum temperature, pressure and exposure time or pulsing cycle required to achieve the microbial inactivation standard.

After the initial tests, regular validation tests using biological indicators should be performed at periodic intervals (typically, every week, every 40 hours of use, or once a month, depending on usage). As an added check, colour- changing chemical indicators, such as strips that contain thermochromic agents (chemicals that change colour when they reach a given temperature) or integrators (indicators that respond to both time and temperature) can be used with each waste load to document that the required temperature has been achieved. Pre-vacuum and vacuum pressure pulse autoclaves also use Bowie-Dick test packs to detect air leaks and to monitor periodically the air removal system in the autoclave chamber.

8.10. MICROWAVE TREATMENT TECHNOLOGIES

Microwave technology is essentially a steam-based process where treatment occurs through the action of moist heat and steam generated by microwave energy. Water contained in the waste is rapidly heated by microwave energy at a frequency of about 2450 MHz and a wavelength of 12.24 cm. In general, microwave-treatment systems consist of a treatment area or chamber into which microwave energy is directed from a microwave generator (magnetron). Generally, 2 to 6 magnetrons are used with an output of about 1.2 kW each. Some systems are designed as batch processes and others are semicontinuous (Emmanuel, 2001; Emmanuel & Stringer, 2007).

Typical batch systems are designed to handle 30 to 100 litres of waste. Some units require reusable, fully enclosed, microwavable containers. The systems may have multiple programmable cycles

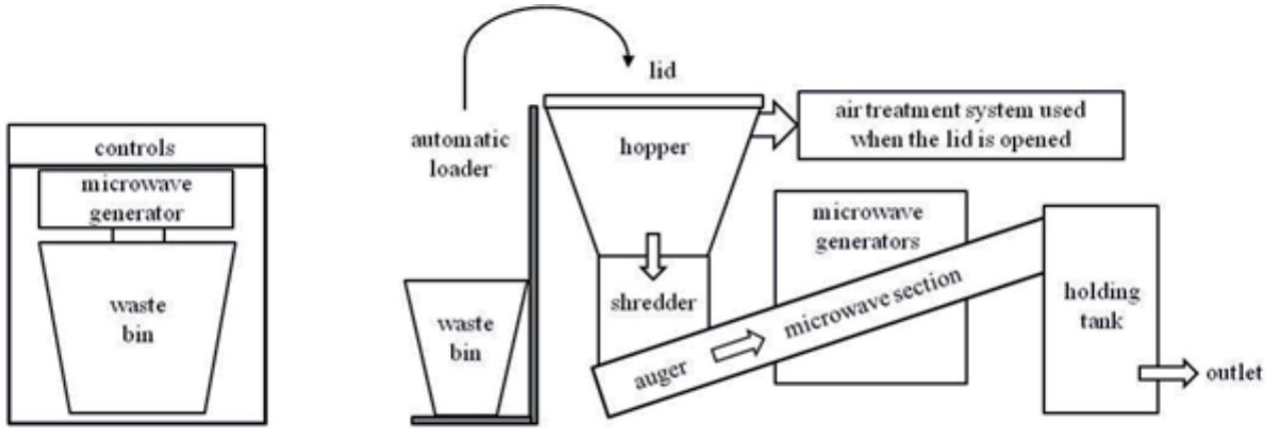
corresponding to different treatment temperatures or levels of disinfection. A cycle may range from 30 minutes to one hour.

A typical semicontinuous microwave system consists of an automatic charging system, hopper, shredder, conveyor screw, steam generator, microwave generators, discharge screw, secondary shredder and controls. The equipment includes hydraulics, HEPA filter and microprocessor-based controls protected in an all-weather steel enclosure. Waste bags are introduced into the hopper, where steam may also be injected. To prevent release of airborne pathogens, air is extracted through a HEPA filter as the waste bags are loaded. After the hopper lid is closed, waste goes through a shredder. The waste particles are conveyed through an auger (conveyor screw), where they are further exposed to steam and heated to 100 °C by four or six microwave generators. Some systems have a holding section to achieve a minimum exposure time. A secondary shredder may be used if treated sharps require finer shredding. A large-scale, semicontinuous microwave unit is capable of treating about 250 kg/hour (3000 tonnes per year).

The types of waste commonly treated in microwave systems are identical to those treated in autoclaves: cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste (excluding chemical waste) and soft waste (e.g. gauze, bandages, gowns and bedding) from patient care. One microwave system has been successfully tested with animal waste and can potentially be used to treat pathological waste such as tissues (Devine et al., 2007). Volatile and semivolatile organic compounds, chemotherapeutic waste, mercury, other hazardous chemical waste and radiological waste should not be treated in a microwave.

A fully enclosed microwave unit can be installed in an open area and, with a HEPA filter to prevent the release of aerosols during the feed process, odour is somewhat reduced, except in the immediate vicinity of the microwave unit.

Figure 8.3 shows a simple schematic of a batch and semicontinuous microwave system.



Source: Jorge Emmanuel

Figure 8.3: Simplified schematic of batch and semi-continuous microwave technologies

8.11. DRY-HEAT TREATMENT TECHNOLOGIES

Circulating hot-air ovens have been used to sterilize glassware and other reusable instruments for many years. This concept of dry-heat treatment has been applied to treatment of infectious health waste more recently. In dry-heat processes, heat is applied without adding steam or water. Instead, the waste is heated by conduction, natural or forced convection, or thermal radiation. In forced convection heating, air heated by resistance heaters or natural gas is circulated around the waste in the chamber. In some technologies, the hot walls of the chamber heat the waste through conduction and natural convection. Other technologies use radiant heating by means of infrared or quartz heaters. As a general observation, dry-heat processes use higher temperatures and longer exposure times than steam-based processes. They are not commonly used in large-scale facilities and usually treat only small volumes. *Bacillus atrophaeus* spores are known to be resistant to dry heat and are commonly used as a microbiological indicator to measure the effectiveness of dry-heat technologies (Emmanuel, 2001; Emmanuel & Stringer, 2007).

8.12. CHEMICAL TREATMENT TECHNOLOGIES

Chemical disinfection, used routinely in health-care facilities to destroy or inactivate microorganisms on medical equipment and on floors and walls, is now being extended to the treatment of health-care waste. This treatment usually results in disinfection rather than sterilization. Chemical disinfection is most suitable for treating liquid waste such as blood, urine, stools or hospital sewage. Solid, even highly hazardous, health-care wastes, including microbiological cultures and sharps, may also be disinfected chemically, with the following limitations:

a) Shredding or milling of waste is usually necessary before disinfection. The shredder is often the weak point in the treatment chain, being susceptible to mechanical failure or breakdown.
b) Powerful disinfectants are required, which can be hazardous and should be used only by well-trained and adequately protected personnel.
c) Disinfection efficiency depends on the operational conditions within treatment equipment.
d) Only the surface of intact solid waste items will be disinfected.

Chemical treatment of solid infectious waste is potentially problematic because of the variability of chemical efficacy based upon load characteristics, and the generation of toxic liquid waste. The speed and efficiency of chemical disinfection will depend on operational conditions, including:

a) the kind of chemical used
b) the amount of chemical used
c) the contact time between disinfectant and waste
d) the extent of contact between disinfectant and waste
e) the organic load of the waste
f) operating temperature, humidity, pH.

Manual systems using chemical disinfection are not regarded as a reliable method for treating waste. Chemical disinfection is usually carried out on hospital premises; however, commercial, self-contained and fully automatic systems have recently been developed for health-care waste treatment

and are being operated away from medical centres at industrial zones. Subsequently, the disinfected waste requires specialized disposal.

8.12.1. Internal Shredding of Waste

Shredding of solid health-care waste before or during disinfection should be done in a closed system to avoid release of pathogens into the air. Rotating-blade shredders are used most commonly and consist of blades attached to two wheels that rotate in opposite directions. The presence of an excessive proportion of sharps in waste may cause accelerated deterioration of the shredder. Internal shredding is essential for the following reasons:

a) to increase the surface area of contact between waste and disinfectant, eliminating voids in the waste load
b) to render any anatomical parts unrecognizable to avoid adverse visual impact on disposal
c) to reduce the volume of waste.

Water is usually added during shredding to prevent excessive wearing of the mechanical parts and facilitate subsequent contact with the disinfectant. Excess water draining from the waste may have to be treated (e.g. by chemical disinfection). Internal shredding of waste before disinfection plus subsequent compacting can reduce the original waste volume by 60–90%, depending on the type of equipment used.

8.12.2. Chemical Disinfectants

The aim of disinfection is to eliminate microorganisms or at least reduce their numbers to an acceptable level. Some disinfectants are effective in killing or inactivating specific types of microorganisms, and others are effective against all types. It is therefore important to know the identity of the target microorganisms to be destroyed. However, selection of disinfectants depends not only on their effectiveness, but also on their availability and hazards related to their handling.

The types of chemicals used for disinfection of health-care waste are mostly chlorine compounds, aldehydes, lime- based powders or solutions, ozone gas, ammonium salts and phenolic compounds. The characteristics of the most commonly used chemical disinfectant for waste applications are outlined in Box 8.2. Formaldehyde and ethylene oxide are no longer recommended for waste treatment due to significant hazards related to their use.

Lime-based chemical treatment systems use dry powder or calcium hydroxide solutions. Some chemical treatment systems use proprietary disinfectants containing glutaraldehyde. Peracetic acid (peroxyacetic acid) has also been used for disinfecting medical instruments. It is a strong irritant but breaks down to form an acetic acid (vinegar) solution.

Users of chemical disinfectants should take into account their stability and shelf life. Some disinfectants are stable for several years and can remain effective for months after opening the container. Other disinfectants degrade quickly.

Powerful disinfectants are often hazardous and toxic, and many are harmful to skin and mucous membranes. Users should therefore be aware of their physiological effects and wear protective clothes, including gloves and protective eye glasses or goggles. Disinfectants are also aggressive to certain building materials and should be handled and stored according to manufacturers' instructions.

8.12.3. Microbial Resistance

Microbial resistance to disinfectants has been investigated, and it is possible to list the major groups of microorganisms from most to least resistant as follows:

a) bacterial spores
b) mycobacteria
c) hydrophilic viruses
d) lipophilic viruses
e) vegetative fungi and fungal spores
f) vegetative bacteria.

Box 8.2: Characteristics of sodium hypochlorite (NaOCl) as a chemical disinfectant

Application

Active against most bacteria, viruses and spores; not effective for disinfection of liquids with high organic content, such as blood or stools; widely used for treatment of wastewater. For waste, operating parameters should be adjusted on the basis of bacteriological tests.

Physical and chemical properties

Available as aqueous solution with 2–12% of active chlorine; at ambient temperature, slowly decomposes into sodium chlorate, sodium chloride and oxygen; solutions of low concentration are more stable; solutions should be protected from light, which accelerates decomposition; reacts with acids to produce hazardous chlorine gas.

Health hazards

Irritant to skin, eyes and respiratory tract; toxic.

Protective measures

Gloves and protective eye glasses should be worn during handling of sodium hypochlorite to protect skin and eyes; in case of eye contact, the eyes should be rinsed abundantly with water.

Corrosiveness

Aqueous solutions are corrosive to metals; usually stored in plastic containers in well-ventilated, dark and leakage-proof rooms; should be stored separately from acids.

Comments

Sodium hypochlorite may be widely used because of relatively mild health hazards. Unused solutions should be reduced with sodium bisulfite or sodium thiosulfate and neutralized with acids before discharge into sewers. Large quantities of concentrated solutions should be treated as hazardous chemical waste.

Sodium hypochlorite is a commonly used disinfectant in health-care facilities and often referred to as "hypochlorite". It is readily available and effective in inactivating bacteria, fungi and viruses, as well as controlling odour. However, the biocidal activity of hypochlorite is diminished by a high organic content in liquid waste, such as blood. It is an irritant of the respiratory tract, skin and eyes, and should be handled carefully. Hypochlorite can react with organic compounds in the wastewater to form toxic by-products. Chlorine dioxide is an alternative to hypochlorite. It is a toxic gas that is readily soluble and stable in water and can be generated onsite at a health-care facility.

A disinfectant known to be effective against a particular group of microorganisms will also be effective against all the groups that are less resistant. Most parasites, such as *Giardia* and *Cryptosporidium* spp., are significantly resistant to disinfection and are usually rated between mycobacteria and viruses. The effectiveness of disinfection is estimated from the survival rates of indicator organisms in standard microbiological tests.

8.12.4. Alkaline Hydrolysis

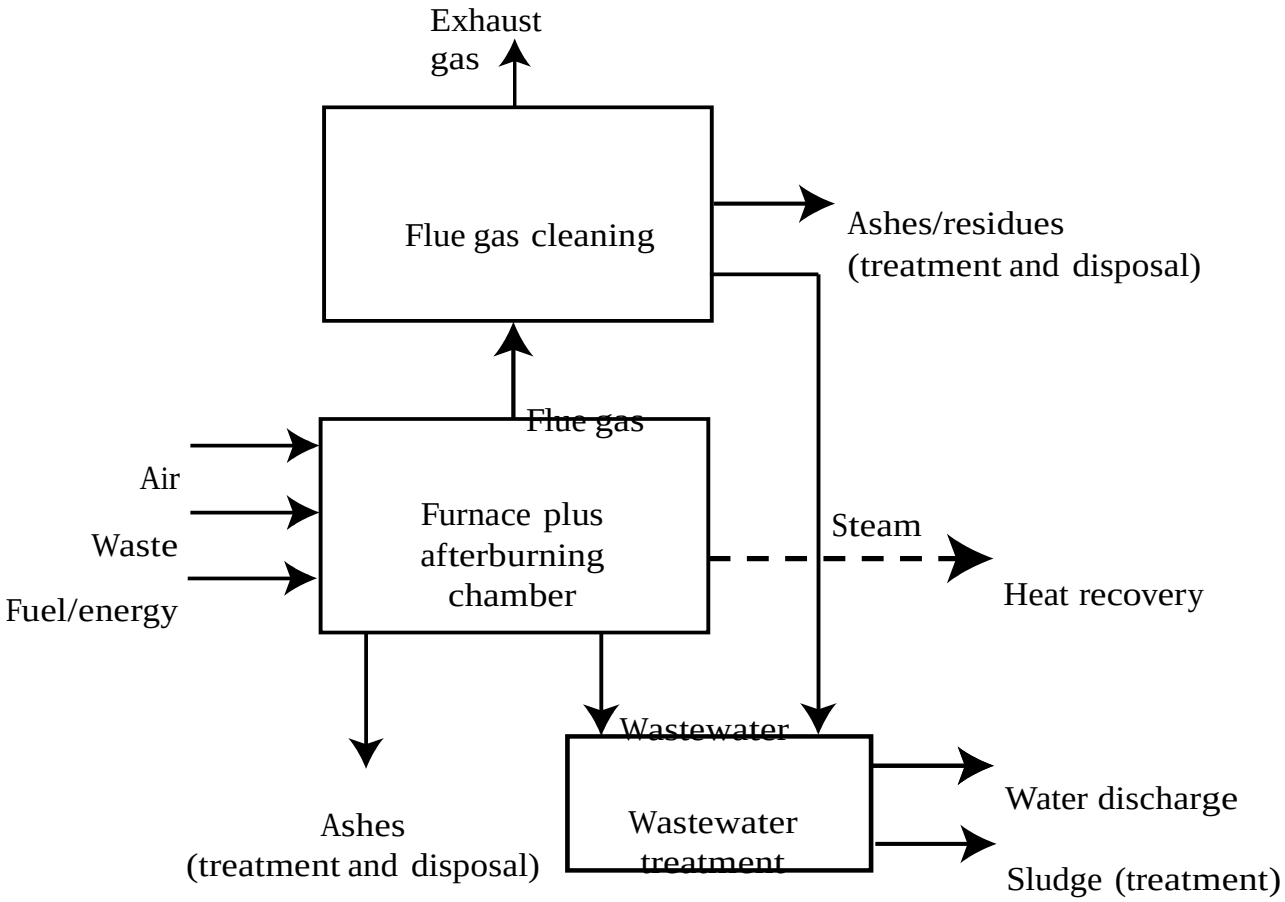
Alkaline hydrolysis or alkaline digestion is a process that converts animal carcasses, human body parts and tissues into a decontaminated aqueous solution. The alkali also destroys fixatives in tissues and various hazardous chemicals, including formaldehyde, glutaraldehyde and chemotherapeutic agents. The technology uses a steam- jacketed, stainless-steel tank and a basket. After the waste is loaded in the basket and into the hermetically sealed tank, alkali (sodium or potassium hydroxide) in amounts proportional to the quantity of tissue in the tank is added, along with water. The contents are heated to between 110 °C and 127 °C or higher, and stirred. Depending on the amount of alkali and temperature used, digestion times range from six to eight hours.

The technology is designed for tissue wastes including anatomical parts, organs, placenta, blood, body fluids, specimens, human cadavers and animal carcasses. The process has been shown to destroy prion waste. The by- products of the alkaline digestion process are biodegradable mineral constituents of bones and teeth (which can be crushed and recovered as sterile bone meal) and an aqueous solution of peptide chains, amino acids, sugars, soaps and salts. An excess of hydroxide could lead to a high pH of the liquid waste. Alkaline hydrolysis units have been designed to treat from 10 kg to 4500 kg per batch. The technology has been approved for the destruction of prion waste when treated for at least six hours (European Commission Scientific Steering Committee, 2003; Thacker, 2004).

8.13. INCINERATION

8.13.1. Combustion

Incineration is a high-temperature, dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a significant reduction of waste volume and weight. High-heat thermal processes take place at temperatures from about 200 °C to more than 1000 °C. They involve the chemical and physical breakdown of organic material through the processes of combustion, pyrolysis or gasification. A disadvantage of these technologies is the release of combustion by-products into the atmosphere and the generation of residual ash. The combustion of health-care waste produces mainly gaseous emissions, including steam, carbon dioxide, nitrogen oxides, a range of volatile substances (e.g. metals, halogenic acids, products of incomplete combustion) and particulate matter, plus solid residues in the form of ashes. Figure 8.4 shows a simple schematic of the incineration process.



Source: Adapted by Jorge Emmanuel from UNEP (2006)

Figure 8.4: Simplified flow scheme of the incineration process

The Stockholm Convention guidance on best available techniques and best environmental practices states: "If medical waste is incinerated in conditions that do not constitute best available techniques or best environmental practices, there is potential for the release of PCDD [polychlorinated dibenzodioxins] and PCDF [polychlorinated dibenzofurans] in relatively high concentrations" (Secretariat of the Stockholm Convention, 2006).

The World Health Organization (WHO) has reviewed small-scale health-care incinerators and reported "significant problems regarding the siting, operation, maintenance and management of [these] incinerators" (Batterman, 2004). As a result of these and other concerns, together with the very high costs for modern incineration to meet best available technique (BAT) standards, the WHO report concluded that "small-scale incineration is viewed as a transitional means of disposal for health care waste" (Batterman, 2004).

8.13.2. Pyrolysis and Gasification

Pyrolysis and gasification processes operate with sub-stoichiometric air levels. The difference between pyrolysis, gasification and incineration is clarified in Table 8.2.

Table 8.2: Typed of thermal treatment processes

	Pyrolysis	Gasification	Incineration
Reaction temperature (°C)	250–700	500–1600	800–1450
Pressure (bar)	1	1–45	1
Atmosphere	Inert/nitrogen	Gasification agent: O_2, H_2O	Air
Stochiometric ratio	0	<1	>1
Products from the process:			
Gas phase	H_2, CO, C_xH_y, H_2O, N_2	H_2, CO, CO_2, CH_4	CO_2, H_2O, O_2
Solid phase	Ash, coke	H_2O, N_2	NO_2
Liquid waste	Pyrolysis oil, water	Slag, ash	Slag, ash

Source: BREF (2006)

8.13.3. Required Waste Characteristics

Incineration of waste is affordable and feasible only if the "heating" (or "calorific") value of the waste reaches at least 2000 kcal/kg (8370 kJ/kg). While the value for hospital wastes containing high levels of plastics can exceed 4000 kcal/kg (16 740 kJ/kg), some health-care waste may contain a high proportion of wet waste and have much lower calorific values. The basic characteristics necessary for incineration include:

a) heating value above 2000 kcal/kg (8370 kJ/kg);
b) calorific values within the regulatory and design requirements (e.g. the desired residence time, system operating temperature and excess air levels);
c) content of combustible matter above 60%;
d) content of non-combustible solids below 5%;
e) content of non-combustible fines below 20%;
f) moisture content below 30%.

Incineration requires no pretreatment, provided the following waste types are not included or are kept to an absolute minimum:

a) pressurized gas containers;
b) large amounts of reactive chemical waste;
c) silver salts and photographic or radiographic wastes;
d) halogenated materials such as polyvinyl chloride (PVC) plastics (waste and packaging of waste should not contain PVC material);
e) waste containing mercury, cadmium and other heavy metals, such as broken thermometers, used batteries and lead-lined wooden panels;
f) sealed ampoules or vials that may implode during the combustion process;
g) radioactive materials;
h) pharmaceuticals thermally stable in conditions below 1200 °C (e.g. 5-fluorouracil).

8.13.4. Energy Recovery

Many modern large incineration facilities can reuse the heat generated from the combustion of waste, so energy recovery seems an attractive proposition. However, there are characteristics that need to be taken into consideration. Most health-care waste incinerators are too small for energy recovery to be effective. Whenever energy recovery is being considered, it requires specialized advice on whether the proposition is technically and financially feasible for the local circumstances.

8.13.5. Types of Incinerators for Health-Care Waste

Incinerators range from extremely sophisticated, high-temperature operating plants to very basic combustion units. All types of incinerators, if operated properly, should eliminate pathogens from waste and reduce waste to a small volume of ash. Incineration equipment should be chosen on the basis of the available resources and the local situation, balancing the public health benefits of pathogen elimination against the technical requirements needed to avoid the health impacts of air or groundwater pollution from the by-products of waste combustion.

Three generic kinds of incineration technology are commonly used for treating health-care waste:

a) dual-chamber starved-air incinerators, which operate in the starved-air mode (below stochiometric conditions) in the primary chamber and are designed to burn infectious health-care waste;
b) multiple chamber incinerators, including in-line incinerators and retort incinerators used for pathological waste, which operate in the excess-air mode (above stochiometric conditions);
c) rotary kilns, normally capable of reaching temperatures that break down genotoxic substances and heat- resistant chemicals.

Starved-air incinerators

Starved-air incineration is a commonly used incineration process for health-care waste. The process is also known as controlled-air incineration, pyrolytic incineration, two-stage incineration or static hearth incineration. The combustion air used for incineration is less than stoichiometric (that is, the amount of oxygen is less than the ideal proportion needed for burning the carbon and hydrogen).

A starved-air incinerator comprises a primary chamber and a post-combustion secondary chamber. In the primary chamber, the waste is thermally decomposed through an oxygen-deficient, medium-temperature combustion process (800 to 900 °C), producing solid ashes and gases. The primary chamber includes a fuel burner, used to start the process. Waste residence time can vary from 1 to 4 hours, depending on the size of the installation. The gases produced in the primary chamber are burned at high temperature (ranging from 1100 to 1600 °C) in the secondary chamber, using an excess of air to minimize smoke, carbon monoxide and odours. If the temperature drops below 1100 °C (the minimum requirement specified in the European Union's *Waste incineration directive 2000/76/EC*), additional energy should be provided by a gas or fuel burner.

Larger pyrolytic incinerators (capacity >20 tonnes/day) are usually designed to function on a continuous basis. They are also capable of automatic operation, including loading of waste, removal of ashes and internal movement of burning waste.

Multiple chamber incinerators

Multiple chamber incinerators were more common in the past and are still used in some countries for pathological waste. There are two major types: in-line incinerators and retort incinerators. In-line incinerators are rectangular in design and have a large primary chamber with a moving grate, a secondary chamber to burn off volatile organic compounds in the flue gas, and additional chambers that force the gas to turn in different directions to remove particulate matter as ash residues.

Retort incinerators have a primary and a secondary chamber arranged in a "U" shape. Flue gas from the primary chamber (hearth) is generally passed under the primary chamber to add heat to the hearth. Both types of incinerators operate in the excess-air mode and use supplementary fuel to reach temperatures of around 800–1000 °C. These designs are not commonly used because of their high volumes of airborne emissions.

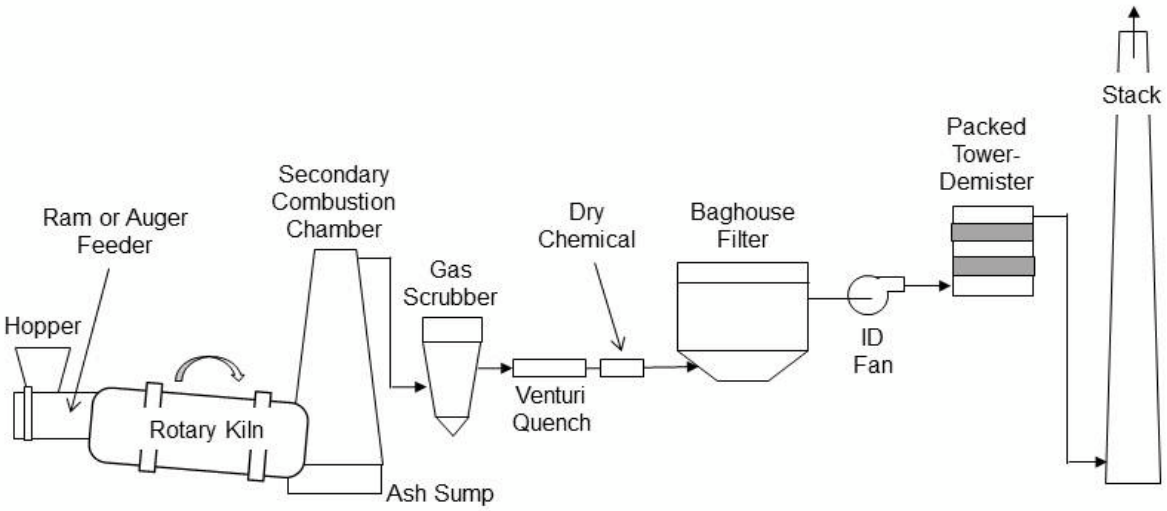
Rotary kilns

A rotary kiln has a rotating oven and a post-combustion chamber (see Figure 8.5). They can be specifically designed to burn chemical wastes and may also be suitable as a large-scale regional health-care waste incinerator if appropriate temperatures and scrubbing (flue gas cleaning) equipment are used. The main characteristics of rotary kilns are:

a) incineration temperatures between 900 and 1200 °C are possible;
b) incinerator capacities up to 10 tonnes per hour are available;
c) additional equipment and operation costs are high, as is energy consumption; the system also requires well- trained personnel.

The axis of a rotary kiln is inclined at a slight angle to the horizontal (3–5% slope). The kiln rotates 2–5 times per minute and is charged with waste at its upper end. Ashes are subsequently discharged at the bottom end. The gases produced in the kiln are heated to high temperatures to burn off gaseous organic compounds in the post- combustion chamber, and typically have a long residence time of two or more seconds.

Rotary kilns may operate continuously and are adaptable to a wide range of loading devices. Those designed to treat toxic wastes should preferably be operated by specialist waste-disposal agencies and located away from health-care facilities in industrial areas.



Source: Jorge Emmanuel

Figure 8.5: Simplified schematic of a rotary kiln incinerator

Small-scale incinerators

Small-scale incinerators are designed to meet an immediate need for public health protection where there is no access to more sophisticated technologies. This involves a compromise between the environmental impacts from controlled combustion and an overriding need to protect public health if the only alternative is indiscriminate dumping. These circumstances exist in many developing situations, and small-scale incineration can be a realistic response to an immediate requirement (Batterman, 2004). As far as possible, a small-scale facility should avoid burning PVC plastics and other chlorinated waste.

If small-scale incinerators are the only option available, the best practices possible should be used, to minimize operational impacts on the environment. Best practices in this context are (Batterman, 2004):

a) effective waste reduction and segregation, ensuring only the smallest quantities of combustible waste types are incinerated;
b) an engineered design with sufficient residence time and temperatures to minimize products of incomplete combustion;
c) siting incinerators away from health-care buildings and residential areas or where food is grown;
d) construction using detailed engineering plans and materials to minimize flaws that may lead to incomplete destruction of waste and premature failures of the incinerator;
e) a clearly described method of operation to achieve the desired combustion conditions and emissions; for example, appropriate start-up and cool-down procedures, achievement and maintenance of a minimum temperature before waste is burned, use of appropriate loading/charging rates (both fuel and waste) to maintain appropriate temperatures, proper disposal of ash and equipment to safeguard workers;
f) periodic maintenance to replace or repair defective components (including inspection, spare parts inventory and daily record keeping);

g) improved training and management, possibly promoted by certification and inspection programmes for operators, the availability of an operating and maintenance manual, visible management oversight, and regular maintenance schedules.

h) In 2004, WHO commissioned a screening-level health risk assessment for exposure to dioxins and furans from small-scale incinerators. The study found that the expected practice with small-scale incinerators resulted in unacceptable cancer risks under medium usage (two hours per week) or higher (Batterman, 2004). The report concluded that small-scale incineration should be viewed as a transitional means of disposal for health-care waste. Single-chamber, drum and brick incinerators do not meet the BAT requirements of the Stockholm Convention guidelines (Secretariat of the Stockholm Convention, 2006).

Co-incineration

- High-temperature incineration of chemical and pharmaceutical waste in industrial cement kilns or steel furnaces is practised in some countries. Significant additional investments can be required to modify the facilities for safe handling and loading of medical wastes, and the machines are rarely equipped with filtration and clean-up equipment suitable for the pollutants generated. The Stockholm Convention guidelines list infectious medical wastes on a negative list of wastes not recommended for co-processing (Secretariat of the Stockholm Convention, 2006).
- In some countries, it is permitted to incinerate health-care waste in a municipal solid waste incineration plant. The heating value of health-care waste can be higher than that of domestic refuse, and the introduction of relatively small quantities of health-care waste should not affect significantly the operation of municipal incinerators. Care must be taken with the handling and loading of the health-care wastes to avoid hazardous situations. Municipal incinerators are usually designed with an operating temperature of >850 °C.

8.13.6. Environmental Control Of Incinerators

General principles

a) Incinerator emissions should comply with national standards and in accordance with the Stockholm Convention BAT and best environmental practices (BEP) guidance in those countries that have signed the convention. If the relevant authorities have not established such regulations, the BAT/BEP guidelines or international standards are examples of those that could be followed (Table 8.3).

Table 8.3: Emission guidelines for health-care waste incinerators

Conditions[a]			Small[b]	Medium[b]	Large[b]	Daily ave.	Half-hour ave.[c]	0.5–8-hour ave.	
Particulate matter or total dust	mg/m^3	20 °C, 101.3 kPa,	66	22	18				223
		7% O_2, dry							
		273 °K,					10, 30		
		101.3 kPa,							
		11% O_2, dry							
Carbon monoxide	ppm(v)	20 °C, 101.3 kPa,	20	1.8	11				127
		7% O_2, dry							
	mg/m^3	273 °K, 101.3					100[d]		
		kPa,							
		11% O_2, dry							
Dioxins/furans	ng TEQ $/m^3$	20 °C, 101.3 kPa,	0.013	0.014	0.035				4.1
		7% O_2, dry							
	ng TEQ $/m^3$	273 °K, 101.3				0.1[e]			
		kPa, 11% O_2, dry							
Gaseous and vaporous organics as total organic carbon	mg/m^3	273 °K, 101.3					10, 20		15
		kPa, 11% O_2, dry							
Hydrogen chloride	ppm(v)	20 °C, 101.3 kPa,	15	7.7	5.1				1106
		7% O_2, dry							
	mg/m^3	273 °K, 101.3					10, 60		
		kPa, 11% O_2, dry							
Hydrogen fluoride	mg/m^3	273 °K, 101.3					2, 4		
		kPa, 11% O_2, dry							
Sulphur dioxide	ppm(v)	20 °C, 101.3 kPa,	1.4	1.4	8.1				54.6
		7% O_2, dry							
	mg/m^3	273 °K, 101.3					50, 200		
		kPa, 11% O_2, dry							
Nitrogen oxides	ppm(v)	20 °C, 101.3 kPa,	67	67	140				
		7% O_2, dry							
	mg/m^3	273 °K, 101.3				200	200, 400		
		kPa, 11% O_2, dry							
Cadmium	mg/m^3	20 °C, 101.3 kPa,	0.017	0.0098	0.00013				0.3
Cadmium and thallium	mg/m^3	273 °K, 101.3 kPa, 11% O_2, dry						total 0.05	
Mercury	mg/m^3	20 °C, 101.3 kPa, 7% O_2, dry	0.014	0.0035	0.0013			0.05	5.4
	mg/m^3	273 °K, 101.3 kPa, 11% O_2, dry						0.05	
Lead	mg/m^3	20 °C, 101.3 kPa, 7% O_2, dry	0.31	0.018	0.00069				3.6
	mg/m^3	273 °K, 101.3 kPa, 11% O_2, dry						0.05	

Conditions[a]			Small[b]	Medium[b]	Large[b]	Daily ave.	Half-hour ave.[c]	0.5–8-hour ave.	
Antimony, arsenic, lead, chromium, cobalt, copper, manganese, nickel, vanadium and their compounds	mg/m^3	273 °K, 101.3 kPa, 11% O_2, dry						total 0.05	

- ✓ AP 42, air pollution emission factor 42; ave., average; EU, European Union; TEQ, toxic equivalent; US EPA, United States Environmental Protection Agency
- ✓ Different standard conditions are defined for EPA and EU limits; corrections have to be made to convert between different standard temperatures and percentage oxygen. EPA defines small incinerators as having a waste burning capacity ≤200 lbs/h, medium capacity as >200–500 lbs/h and large capacity as >500 lbs/h.
- ✓ At least 97% of half-hourly average concentrations must meet the first value and 100% must meet the second value. All half-hourly average concentrations taken in any 24-hour period must meet this value.
- ✓ The sampling period for dioxins/furans must be a minimum of 6 hours and a maximum of 8 hours under the EU directive.
- ✓ AP 42 (EPA, 1996) are emission estimates for incinerators without air pollution equipment and are shown for comparison; adapted from Batterman (2004). Sources: EPA (2011); European Parliament and the Council of the European Union (2000

a) Incinerators require emission controls equipment to meet modern emission standards. Ferraz & Afonso (2003) determined that without emission controls dioxin concentrations in combustion gases 710 times higher than the European Union legal limit (0.1 ng TEQ/m^3), depending on variations in the waste composition.
b) Flue (exhaust) gases from incinerators contain fly ash (particulates), heavy metals, dioxins, furans, thermally resistant organic compounds, and gases such as oxides of nitrogen, sulphur, carbon and hydrogen halides were 93 to
c) The flue gases should be treated, and this should be done in at least two different stages:
    - "de-dusting" to remove most of the fly ash
    - washing with alkaline substances to remove hydrogen halides and sulphur oxides.

Flue gas treatment can be performed by wet, dry or semidry treatment, or a combination of these processes. The temperature of the combustion process has to be very closely controlled to avoid generating furans and dioxins, and the temperature in the flue gases should be cooled down rapidly to prevent dioxins and furans from reforming.

Stockholm Convention

The Stockholm Convention is a legally binding treaty with the goal of protecting human health and the environment from persistent organic pollutants. Under the convention, the countries party to the treaty are required to use the best available techniques for new incinerators. The Stockholm Convention's guidelines for best available techniques and best environmental practices limit the levels of dioxins and furans in air emissions to 0.1 ng I-TEQ/Nm^3 at 11% O_2. Moreover, dioxins in the

wastewater of treatment plants treating effluents from any gas treatment scrubber effluents should be well below 0.1 ng I-TEQ per litre. In addition, the guidelines list primary and secondary measures to achieve the performance levels for removal of dioxins and furans. The primary measures are to:

a) introduce the waste into the combustion chamber only at temperatures of ≥850 °C;
b) install auxiliary burners for start-up and shut-down operations;
c) avoid regular starting and stopping of the incineration process;
d) avoid combustion temperatures below 850 °C and cold regions in the flue gas;
e) control oxygen input depending on the heating value and consistency of feed material;
f) maintain minimum residence time of two seconds above 850 °C in the secondary chamber after the last injection of air or at 1100 °C for wastes containing more than 1% halogenated organic substances (generally the case for health-care waste) and 6% O_2 by volume;
g) maintain high turbulence of exhaust gases and reduction of excess air by injection of secondary air or recirculated flue gas, preheating of the air-streams or regulated air inflow;
h) conduct on-line monitoring for combustion control (temperature, oxygen content, carbon monoxide, dust), and operation and regulation of the incinerator from a central console.

The secondary measures to further reduce dioxins and furans are an appropriate combination of dust-removal equipment and other techniques, such as catalytic oxidation, gas quenching and wet or (semi) dry adsorption systems. Furthermore, fly and bottom ash, as well as wastewater, should be treated appropriately. Carbon monoxide, oxygen in the flue gas, particulate matter, hydrogen chloride, sulphur dioxide, nitrogen oxides, hydrogen fluoride, airflows and temperatures, pressure drops and pH in the flue gas should be routinely monitored according to national laws and manufacturers' guidance.

8.13.7. Dust Removal

The design of flue gas cleaning facilities assumes normal operation of an incinerator, especially temperature and air inputs. Depending on the type of incinerator, it is likely to produce between 25 and 30 kg of dust per tonne of waste (known as fly ash). For example, an incinerator of 20 tonnes/day capacity would need to be equipped with dust removal equipment to handle at least 600 kg/day (30 kg/tonne × 20 tonnes) of dust. The most common types of dust removal equipment used at incinerator plants are:

a) cyclonic scrubbers
b) fabric dust removers (commonly called "baghouse filters")
c) electrostatic precipitators.

Flue gas emerges from the post-combustion chamber at about 800–1000 °C and must be cooled to 200–300 °C before entering the dust-removal equipment. This can be achieved in cooling towers, called quenching towers or baths, where the gas is cooled by water circulating in a closed system. (The water may subsequently be used for preheating waste or for other purposes.) A common method is the use of a boiler in which heat exchange takes place between the hot flue gas

stream and boiler water. The hot flue gas stream is cooled, and boiler water is heated (the energy of this heated water or steam can be used for generating electricity or for other purposes). The flue gas can also be cooled by introducing fresh air, although this method is less efficient.

Removal of acids or alkalis

Three processes – wet, semi-dry and dry – are available for removing acids such as hydrofluoric acid (HF), hydrochloric acid (HCl), and sulfuric acid (H_2SO_4). In the wet process, gases are washed in a spraying tower with soda or lime solution, which also contributes to gas cooling and to the removal of very small particulates. In the semi-dry process (also known as semi-wet process), a lime suspension is injected into the gas column. Salts generated by the neutralization process have to be removed. In the dry process, lime powder is injected into the gas column, and the salts produced during the neutralization have to be removed. The wet process is the most efficient of these three options, but requires complex treatment of the resultant wastewater.

Wastewater from gas washing and quenching of ashes must undergo a chemical neutralization treatment before being discharged into a sewer. This treatment includes neutralization of acids and flocculation, and precipitation of insoluble salts.

Solid residues

Sludges from wastewater treatment and from cooling of fly ash should be considered as hazardous waste. They may either be sent to a waste-disposal facility for hazardous chemicals, or be treated onsite by drying, followed by encapsulation. Solid ashes from health-care waste incineration (known as bottom ash) are often assumed to be less hazardous than fly ash and in the past have been reused in civil engineering works. Recently, growing debate about potential leakage of toxic substances from these ashes and possible pollution of groundwater has led some countries to require these ashes to be disposed of in landfills designed specifically for hazardous substances.

The United Nations Environment Programme tested two hospital waste incinerators that had been built in the mid-1990s and reported that "the bottom ashes [from a hospital waste incinerator] were between 1,410 and 2,300 ng I-TEQ/kg" (UNEP, 2001). The extremely high concentrations in the bottom ashes reflect the inefficient combustion in the furnace and the synthesis of polychlorinated dibenzodioxins or polychlorinated dibenzofurans overnight.

8.14. ENCAPSULATION AND INERTIZATION

Disposal of untreated health-care waste in municipal landfills is not advisable. However, if the health-care facility has no other option, the waste should be contained in some way before disposal. One option is encapsulation, which involves filling containers with waste, adding an immobilizing material, and sealing the containers. The process uses either cubic boxes made of high-density polyethylene or metallic drums, which are three quarters filled with sharps or chemical or pharmaceutical residues. The containers or boxes are then filled up with a medium such as plastic foam, bituminous sand,

cement mortar, or clay material. After the medium has dried, the containers are sealed and placed into landfill sites.

This process, where the encapsulation materials are available, is appropriate for establishments for the disposal of sharps and chemical or pharmaceutical residues. Encapsulation alone is not recommended for non-sharps waste, but may be used in combination with treatment of such waste. The main advantage of the process is its effectiveness in reducing the risk of scavengers gaining access to the hazardous health-care waste.

The process of inertization involves mixing waste with cement and other substances before disposal to minimize the risk of toxic substances contained in the waste migrating into surface water or groundwater. It is especially suitable for pharmaceuticals and for incineration ashes with a high metal content (in this case, the process is also called "stabilization").

For the inertization of pharmaceutical waste, the packaging should be removed, the pharmaceuticals ground, and a mixture of water, lime and cement added. A homogeneous mass is formed, and cubes (e.g. of 1 m^3) or pellets are produced onsite. Subsequently, these can be transported to a suitable storage site. Alternatively, the homogeneous mixture can be transported in liquid state to a landfill and poured onto the surface of previously landfilled municipal waste, then covered with fresh municipal waste.

The following are typical proportions (by weight) for the mixture:

a) 65% pharmaceutical waste
b) 15% lime
c) 15% cement
d) 5% water.

The process is reasonably inexpensive and can be performed using relatively unsophisticated mixing equipment. Other than personnel, the main requirements are a grinder or road roller to crush the pharmaceuticals, a concrete mixer and supplies of cement, lime and water.

8.15. APPLICATIONS OF TREATMENT AND DISPOSAL METHODS TO SPECIFIC WASTE CATEGORIES

Treatment options should be chosen according to the national and local situation. Below are examples from middle- and low-income countries of treatment methods applied to specific components of health-care waste.

8.15.1. Sharps

Improper disposal of sharps waste poses a high risk of disease transmission among health-care workers, waste workers and the general public.

In India, sharps are often collected in cardboard safety boxes and burned in small incinerators. Several non- burn methods have been developed in response to concerns about air pollution and the short lifespan of brick incinerators (WHO, 2005a; PATH, 2007). The methods generally entail the following steps:

a) using onsite mechanical needle cutters or electric needle destroyers
b) shredding the treated plastic parts
c) burying the metal pieces in sharps pits
d) remelting the plastics for recycling.

Alternatively, the sharps waste can be autoclaved, shredded and then encapsulated in cement blocks that later become useful items such as hospital benches.

8.15.2. Anatomical Waste, Pathological Waste, Placenta Waste And Contaminated Animal Carcasses

The treatment of anatomical, pathological, and placenta and foetal remains wastes may be bound by sociocultural, religious and aesthetic norms and practices. Two traditional options have been:

a) interment (burial) in cemeteries or special burial sites
b) burning in crematoria or specially designed incinerators.

In some countries, placenta waste is composted or buried in placenta pits designed to facilitate natural biological decomposition. More information about treatment disposal methods of anatomical waste can be found in Annex 6.

8.15.3. Pharmaceutical Waste

Pharmaceutical waste can be minimized by good inventory control or a “just-in-time” inventory strategy; by purchasing drugs in the dosages routinely administered; by monitoring expiration dates so that existing stock is used before newly arrived supplies (also known as good “stock rotation”); by replacing prepackaged unit dose liquids with patient-specific oral doses; and other good management practices (Practice Greenhealth, 2008).

Before treatment, pharmaceutical waste should be labelled and sorted using proper personal protective equipment. Pharmaceutical waste can be sorted according to dosage form (solids, semi-solids, powders, liquids or aerosols) or by active ingredient, depending on the treatment options available. Special consideration is needed for controlled substances (e.g. narcotics), anti-infective drugs, antineoplastic and cytotoxic drugs, and disinfectants.

Several options exist for small quantities of pharmaceutical waste:

a) return of expired pharmaceuticals to the donor or manufacturer;
b) encapsulation and burial in a sanitary landfill;
c) chemical decomposition in accordance with the manufacturer's recommendations if chemical expertise and materials are available;
d) dilution in large amounts of water and discharge into a sewer for moderate quantities of relatively mild liquid or semi-liquid pharmaceuticals, such as solutions containing vitamins, cough syrups, intravenous solutions and eye drops.

Antibiotics or cytotoxic drugs should not be discharged into municipal sewers or watercourses. For large quantities of pharmaceutical waste, the options available include:

a) encapsulation and burial in a sanitary landfill;
b) incineration in kilns equipped with pollution-control devices designed for industrial waste and that operate at high temperatures;
c) dilution and sewer discharge for relatively harmless liquids such as intravenous fluids (salts, amino acids, glucose).

8.15.4. Cytotoxic Waste

Chemotherapeutic waste, including cytotoxic, antineoplastic and cytostatic waste, should first be minimized by careful segregation, purchasing optimal drug quantities, using proper spill containment and clean-up procedures, and substituting environmentally persistent drugs with degradable drugs, where possible.

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

a) return to the original supplier
b) incineration at high temperatures
c) chemical degradation in accordance with manufacturers' instructions.

Full destruction of all cytotoxic substances may require incineration temperatures up to 1200 °C and a minimum gas residence time of two seconds in the second chamber. The incinerator should be equipped with gas-cleaning equipment. Incineration at lower temperatures may release hazardous cytotoxic vapours into the atmosphere. Incineration in most municipal incinerators, in single-chamber incinerators or by open-air burning, is inappropriate for the disposal of cytotoxic waste.

Chemical degradation methods, which convert cytotoxic compounds into non-toxic/non-genotoxic compounds, can be used for drug residues and for cleaning contaminated urinals, spillages and protective clothing (IARC, 1983; IARC, 1985). These methods are not used widely and require special knowledge. They are not appropriate for treating contaminated body fluids. The International

Agency for Research on Cancer (IARC) Unit of Gene– Environment Interactions can be contacted for further information.[16] Further information can also be found in Annex 3.

It should be noted that neither incineration nor chemical degradation currently provides a completely satisfactory solution for treating waste items, spillages or biological fluids contaminated by antineoplastic agents. Until such a solution is available, hospitals should exercise 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. Alkaline hydrolysis and some of the emerging technologies may have useful applications in the destruction of cytotoxic waste.

8.15.5. Chemical Waste

Chemical safety and hazardous chemical waste management should ideally be the subject of a national strategy with an infrastructure, cradle-to-grave legislation, competent regulatory authority and trained personnel.

Improving the management of chemical waste begins with waste minimization. Minimization options include:

a) substituting highly toxic and environmentally persistent cleaners and solvents with less toxic and environmentally friendly chemicals;
b) using minimum concentrations where possible;
c) ensuring good inventory control (i.e. “just-in-time” purchasing);
d) designing storage areas well;
e) integrating pest management;
f) keeping disinfecting trays covered to prevent loss by evaporation;
g) developing spill prevention and clean-up procedures;
h) recovering solvents using fractional distillation.

Where allowed by local regulations, non-recyclable, general chemical waste, such as sugars, amino acids and certain salts, may be disposed of with municipal waste or discharged into sewers. 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 (volatilizes to produce flammable vapours), calcium carbide

[16] See http://www.iarc.fr

(produces flammable acetylene gas on contact with water) and halogenated organic solvents (many compounds are environmentally persistent or ecologically damaging) should not be discharged into sewers.

It is not possible to dispose both safely and cheaply of large quantities of hazardous chemical waste without using sophisticated treatment methods. The appropriate means of storage and disposal is dictated by the nature of the hazard presented by the waste. The following measures are suggested:

a) Hazardous chemical wastes of different composition should be stored separately to avoid unwanted chemical reactions.
b) Hazardous chemical waste should not be discharged into sewerage systems.
c) Large amounts of chemical waste should not be buried, because they may leak from their containers, overwhelm the natural attenuation process provided by the surrounding waste and soils, and contaminate water sources.
d) Large amounts of chemical disinfectants should not be encapsulated, because they are corrosive to concrete and sometimes produce flammable gases.

An option for disposing of hazardous chemicals is to return them 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. Preferably, these wastes should be treated by a specialist contractor with the expertise and facilities to dispose safely of hazardous waste. Use of certain products for non-medical purposes may also be considered; for example, use of outdated disinfectants to clean toilets is often acceptable.

Photochemicals should be collected separately, because there is a recovery value from silver compounds contained in the solutions. Recovery of silver from photoprocessing wastewater may be possible using cation exchange, electrolytic recovery or filtration. Spent fixing bath and developing bath solutions should be carefully mixed and the neutralized solution stored for a minimum of one day. The mixture should be diluted (1:2) and very slowly poured into a sewer.

8.15.6. Waste containing heavy metals

Some health-care wastes contain heavy metals, such as high concentrations of cadmium from dry-cell batteries, and mercury from thermometers, sphygmomanometers, cantor tubes, dilators, mercury switches and some button-shaped batteries.

A WHO policy paper on mercury in health care outlines a strategy that includes developing safe mercury clean-up, handling and storage procedures; reducing unnecessary use of mercury equipment; replacing mercury-containing products with mercury-free alternatives; and supporting a replacement of the use of mercury-containing devices in the long term (WHO, 2005b). Wastes containing mercury or cadmium should not be burned or incinerated. Cadmium and mercury volatilize at relatively low temperatures and can cause atmospheric pollution.

In some countries, mercury- or cadmium-containing wastes can be sent to facilities that specialize in the recovery of heavy metals. 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. Exporting the waste to countries with the expertise and facilities for its adequate treatment should also be considered, but only within the rules laid down by the Basel Convention. If none of the above options are feasible, the wastes would have to go to a disposal or storage site designed for hazardous industrial waste.

The Secretariat of the Basel Convention has been developing technical guidelines on the environmentally sound management of mercury waste (UNEP, 2012). The guidelines include mercury waste prevention and minimisation, handling, interim storage, transportation, treatment, recovery, long-term storage and disposal. The United Nations Development Programme has developed detailed guidance on the clean-up, transport and interim storage of mercury waste from health-care facilities (UNDP, 2010).

8.15.7. Radioactive Waste

The treatment and disposal of radioactive waste is generally under the jurisdiction of a nuclear regulatory agency, which defines clearance levels and waste classifications according to activity levels and half-lives of the radionuclides present. A radioactive waste-management plan should include a programme of waste minimization. The primary methods of waste minimization are source reduction, extended storage for decay of radioactivity, and substitution with a non-radioactive alternative. Source reduction strategies include limiting the quantity of radioactivity purchased, and laboratory procedures that reduce the volume of waste generated. Substitution means replacing long-lived radionuclides with shorter half-life radionuclides or non-radioactive substitutes, where possible.

Unsealed sources – short-lived radionuclides

Three disposal methods are possible for low-level radioactive waste:

a) “decay in storage”, which is the safe storage of waste until its radiation levels are indistinguishable from background radiation; a general rule is to store the waste for at least 10 times the half-life of the longest lived radionuclide in the waste (more information can be found in Chapter 7);
b) return to supplier;
c) long-term storage at an authorized radioactive waste disposal site.

Containers used for storing 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. Facilities should segregate radioactive waste according to the length of time needed for storage: short-term storage (half-lives less than 60 days)

and long-term storage (half-lives more than 60 days). Decayed but infectious waste should be disinfected before subsequent treatment and disposal.

A health-care facility should ensure that radionuclides are not released to the environment unless:

a) the radioactivity released is confirmed to be below the clearance levels; or
b) the radioactivity of liquid or gaseous effluents is within limits authorized by a regulatory authority.

Sealed sources and long-lived radionuclides

Sealed sources, long-lived radionucleotides and spent sources (e.g. from X-ray equipment) should be returned to the producer or supplier of their original form. Health-care facilities planning to import a sealed source with a radioactivity greater than 100 MBq should require the supplier to accept the source back after expiration of its useful lifetime and within a year after a notification is made. If this is not possible, the waste must be stored in an approved long-term storage facility in keeping with international guidelines. Whether the waste is returned or stored in a long-term facility, the waste should first be "conditioned" to make it suitable for handling, transportation and storage. Conditioning may involve immobilization in concrete, securing the waste in suitable containers and providing additional packaging.

A summary of further practices for radioactive health-care wastes

Disposable syringes containing radioactive residues should be emptied in a location designated for the disposal of radioactive liquid waste. Syringes 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 when the drain or sewer is opened up, and appropriate precautions should be taken to avoid unacceptable radiation exposures.

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 sewerage 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 government 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 regulators informed of the circumstances that gave rise to the incident. It is important to learn from such incidents and for working methods to be changed to avoid it happening again.

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 accumulation of radioactive contamination. 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, also called holding tanks, or special treatment systems for patients undergoing radiotherapy.

8.16. LAND DISPOSAL

In all waste systems, the removal of the remaining health-care waste materials after minimization or treatment will require access to land for final disposal. In less developed areas, where a municipality or health-care facility lacks the means to treat wastes before disposal, the direct use of a landfill is likely to be required for much of the material produced. The alternative is often an accumulation of health-care waste at medical facilities where it is openly burnt or spread indiscriminately around the facility's grounds. This constitutes a far higher risk of transmission of infection than controlled disposal in a land disposal site, even if the land disposal site is not designed to the precise standards used in higher income places.

There are two distinct types of waste disposal to land:

- **Uncontrolled dumping** is characterized by the scattered, uncontrolled deposit of wastes at a site. It is a practice that almost always leads to acute pollution problems, fires, higher risks of disease transmission and open access to scavengers and animals. **Health-care waste should not be deposited on or around uncontrolled dumps.** The risk to people and animals coming into contact with infectious pathogens or hazardous materials is obvious, with the further risk of subsequent disease transmission through direct contact, wounds, inhalation or ingestion, as well as indirectly through the food chain or a pathogenic host species.
- **Controlled landfilling** represents various types of disposal to land characterized by better operating practices and design improvements to reduce health and environmental impacts. The first step to improvement is "controlled dumping", where small improvements can restrict environmental consequences and physical access to waste. This is followed by "engineered landfill" where increasing standards of engineering are used to improve geological isolation of wastes from the environment and to allow wastes to be covered daily. Disposing of certain types of health-care waste (infectious and small quantities of pharmaceutical wastes) in engineered landfills is possible within the constraints of local regulations. A well-engineered landfill is designed to minimize contamination of soil, surface

water and groundwater; limit atmospheric releases and odours; block access to waste by pests and vectors; and prevent contact with the public. Where skills and resources are available, still higher standards of site preparation are possible to achieve a "sanitary landfill", with trained staff and specialized equipment present onsite to manage operations.

8.16.1. Municipal And Other External Disposal Sites

Without treatment

If a municipality or health-care facility lacks the means to treat wastes before disposal, the use of a landfill is a realistic option to protect public health. A starting point can be to use a site operated in a controlled manner that may already exist for municipal waste. In some countries, there may also be suitable sites provided by private operators. Where a municipal waste landfill is available, it is possible to deposit health-care waste safety in two ways:

- In a shallow hollow excavated in mature municipal waste (preferably over three months old) immediately in front of the base of the working face where waste is being tipped. When a load of health-care waste has been deposited, it would be covered during the same day by the advancing tipping face of fresh municipal waste (preferably creating a layer of municipal waste around 2 m thick). Scavenging in this part of the site must be prevented. The same method is often used for hazardous solid industrial wastes, where the specific intent is to prevent animals and scavengers from re-excavating the waste materials once they have been deposited.
- In a deeper (1–2 m) pit excavated in a covered area of mature municipal waste (i.e. waste at least three months old). The pit is then backfilled with the mature municipal waste removed previously, and an intermediate soil cover (approximately 30 cm) or topsoil cover (up to 1 m). Scavenging in this part of the site must be prevented.

After treatment

In more developed situations where health-care waste is treated, the residual material is typically disposed of in landfill sites. Upgrading from open dumping directly to more sophisticated sanitary landfills may be technically and financially difficult for many municipalities. However, this is no reason for municipal authorities to abandon the move towards more controlled and safer land-disposal techniques. Some of the essential design elements are outlined in Box 8.3.

Box 8.3: Essential elements for the design and operation of sanitary landfills

a) Controlled access to the site; designation and supervision of working areas for waste delivery.
b) Presence of personnel capable of effective control of daily operations.
c) Division of the site into manageable phases of operation, each appropriately prepared before landfilling starts in each phase.
d) Adequate sealing of the base and sides of the site to minimize the movement of wastewater (leachate) off the site.
e) Adequate mechanisms for leachate collection and, where necessary, treatment systems to reduce the pollution potential before discharge offsite.
f) Organized deposit of wastes in small working areas, which allow waste to be spread, compacted and covered daily.
g) Surface waste drainage trenches around site boundaries.
h) Placement of final cover to minimize rainwater infiltration when each phase of the landfill is completed.

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es of health-care waste, such as anatomical waste, will still have an offensive visual impact after treatment and preferably should not be landfilled. Disposing of such waste in landfill may also be culturally or religiously unacceptable in many countries. Such wastes should be placed in approved burial grounds or cremated. If this is not possible, these wastes could be placed in containers or rendered unrecognizable before disposal. In some countries, cemetery design must also meet minimum official standards.

Ash from incineration is conventionally considered to be hazardous by virtue of its likely heavy metal content and the dioxins and furans it may contain. Ash should preferably be disposed of in sites designed for hazardous wastes; for example, placed in designated cells at engineered landfills, encapsulated and placed in specialized monofill sites, or disposed of in an ash pit in the ground.

Before health-care wastes are sent for disposal, it is prudent for the management of a health-care facility to inspect the landfill site to ensure there is sensible control of waste deposition.

Safe burial on hospital premises

Minimal approaches to health-care waste management need to be used in remote health-care facilities and underdeveloped areas. In addition, minimal practices may also be necessary in temporary refugee encampments and areas experiencing exceptional hardship. Consequently, the safe burial of waste on hospital premises may be the only viable option available at that time. Even in these difficult circumstances, the hospital management can establish the following basic principles:

a) Access to the disposal site should be restricted to authorized personnel only.
b) The burial site should be lined with a material of low permeability, such as clay, dung and river silt, if available, to prevent pollution of shallow groundwater and nearby wells.
c) New water wells should not be dug near the disposal pit.
d) Only infectious health-care waste should be buried (if general hospital waste were also buried on the premises, available space would be quickly filled).
e) Larger quantities (<1 kg) of chemical wastes should not be buried at one time; however, burying small quantities occasionally is less likely to create adverse pollution.
f) The burial site should be managed as a landfill, with each layer of waste covered by a layer of soil to prevent odours and contact with the decomposing waste, and to deter rodents and insects.

Once the pit is constructed, the safe burial of waste in minimal circumstances depends critically on staff following sensible operational practices. This must be insisted upon, and the local health-care manager must realize their responsibility for making an organized waste-disposal system work properly.

Safe onsite burial is practicable only for relatively limited periods (i.e. 1–2 years), and for relatively small quantities of waste (i.e. 5–10 tonnes in total). Where these conditions are exceeded, a longer term solution, probably involving disposal at a land-disposal site away from the health-care facility, should be found.

8.17. MINIMUM APPROACH TO TREATMENT AND DISPOSAL

Hazardous health-care waste should be treated to reduce the potential for harm. At a minimum, this entails segregation and other practices to minimize the amount of waste that needs to be treated; a treatment process that achieves at least the minimum required disinfection level; and safe disposal. Treatment can be done on the premises or at a centralized treatment facility. When treating onsite, the technology should be carefully selected based on waste characteristics, technology capacity and requirements, environment and safety factors, and cost. In low-income settings, for example, this may mean modifying an existing autoclave or using a commonly available disinfectant such as hypochlorite. Other health-care facilities may be able to invest in small steam treatment units or use existing incinerators with air-pollution control equipment. Anatomical waste can be buried in cemeteries or approved burial sites. Except for sharps waste, treated waste can be disposed of with regular municipal solid waste.

In extreme circumstances where no treatment is possible, hazardous health-care waste from small health-care facilities could be buried within the premises of the facility where public access can be restricted. A safe burial pit design should be used. Larger health-care facilities should make arrangements with a local landfill to provide a special cell or pit, daily soil cover, and restricted access. Encapsulation, inertization and land disposal could be used for some pharmaceutical and chemical wastes, as well as sharps waste. A well- designed sharps pit is another minimum option for sharps waste.

8.18. DESIRABLE IMPROVEMENTS TO THE MINIMUM APPROACH

Improving segregation and waste minimization are important initial steps towards improving existing waste- treatment systems. For health-care facilities that already use autoclaves, microwave units or other steam- based technologies, the addition of a shredder, grinder and/or compactor, especially for sharps waste, is an option. Scheduling regular validation tests, documenting test results and improving ventilation are important improvements. The health-care facility should also adopt good preventive maintenance procedures.

Health-care facilities that use chemical treatment systems should take extra precautions to ensure the safety and health of their workers. It may be possible to find less hazardous but equally effective chemical disinfectants. Minimizing the environmental impact of air, liquid and solid releases of the chemical residues or by-products is also important. The facility should conduct periodic validation tests and adjust the treatment parameters using the minimum effective chemical concentrations. As with all technologies, periodic maintenance is essential.

Health-care facilities that use incineration may be able to further minimize air emissions by adding air-pollution control devices or upgrading the existing flue gas cleaning system. The health-care

facility should also adopt the primary measures outlined in the BAT/BEP guidelines of the Stockholm Convention (see section 4.3.3 of this document). Another issue that is often neglected is proper handling and disposal of toxic incinerator ash. Incinerator stack tests can be expensive but are a necessary tool for improving the combustion process and for ensuring compliance with emission limits. Health-care facilities should also consider installing continuous emission monitoring systems. Periodic maintenance is a must for any incinerator. If the incinerator is reaching its end of life, priority consideration should be given to alternative technologies with lower pollutant releases.

With regard to land disposal, the health-care facility could work with other stakeholders and the local municipal authorities to upgrade the existing landfill or construct a sanitary landfill, if necessary, for the safe disposal of waste in the area.

9 COLLECTION AND DISPOSAL OF WASTEWATER

9.1. CHARACTERISTICS OF HEALTH-CARE WASTEWATER

Health-care wastewater is any water that has been adversely affected in quality during the provision of health- care services. It is mainly liquid waste, containing some solids produced by humans (staff and patients) or during health-care-related processes, including cooking, cleaning and laundry. Health-care wastewater can be divided into the following three categories:

a) **Blackwater** (sewage) is heavily polluted wastewater that contains high concentrations of faecal matter and urine.
b) **Greywater** (sullage) contains more dilute residues from washing, bathing, laboratory processes, laundry and technical processes such as cooling water or the rinsing of X-ray films.
c) **Stormwater** is technically not a wastewater itself, but represents the rainfall collected on hospital roofs, grounds, yards and paved surfaces. This may be lost to drains and watercourses and as groundwater recharge, or used for irrigating hospital grounds, toilet flushing and other general washing purposes.

9.2. HAZARDS OF WASTEWATER FROM HEALTH-CARE FACILITIES

A large part of the wastewater from health-care facilities is of a similar quality to domestic wastewater and poses the same risks. Just as domestic wastewater is considered to be potentially infectious, wastewater from health-care facilities must also be considered in a similar manner and precautions taken.

A proportion of the generated wastewater from health-care facilities will pose a higher risk than domestic wastewater. Depending on the service level and tasks of the health-care facility, the wastewater might contain chemicals, pharmaceuticals and contagious biological agents, and might even contain radioisotopes. Sewers of health-care facilities are often not watertight, and a significant part of the wastewater in many places may leak into the groundwater. Often, hospitals are not connected to efficient, working sewage-treatment plants, and sometimes municipal sewerage networks may not even exist. In many developing countries, the major part of health-care wastewater is discharged in surface watercourses or percolates into underlying groundwater aquifers with no or only partial treatment.

9.2.1. Wastewater-Related Diseases

Improper management, collection, treatment and disposal of wastewater and sludge will result in the pollution of local water sources with pathogens. This can cause numerous waterborne and vector-borne diseases (e.g. malaria and filariasis) by providing breeding places for the vectors, and favours the spread of parasites (e.g. roundworms or *Ascaris lumbricoides*). By disposing of untreated wastewater in the environment, nutrients are biologically degraded in groundwater, lakes and rivers by using oxygen present in fresh water (eutrophication). If the oxygen demand of the wastewater is too high,

hypoxia (oxygen depletion) of a watercourse will result in significant environmental degradation. Additionally, the nutrients can increase algal production and algal blooms that will favour potentially hazardous bacteria (e.g. *Cyanobacteria*) and might result in hazardous toxins forming that can cause illnesses, such as from exposure to cyanotoxins. Nitrate in the groundwater from untreated wastewater can result in methaemoglobinaemia, particularly in babies. Wastewater discharged in an uncontrolled manner into the environment can lead to several waterborne diseases that are a threat to human life, especially in developing countries. A selection of these diseases found widely in the world is presented in the following sections.

a) **Campylobacteriosis** is an infection of the gastrointestinal tract (severe form of diarrhoea). The cause is a bacterium, usually *Campylobacter jejuni* or *Campylobacter coli*. People are exposed to the bacteria after consuming food or water contaminated with human wastes.
b) **Cholera** is an acute infection of the intestine caused by the bacterium *Vibrio cholerae*. People become infected after eating food or drinking water that has been contaminated by the faeces of infected individuals.
c) **Hepatitis A and hepatitis E** lead to infection and inflammation of the liver. Both infections are transmitted via the faecal–oral route, often through contaminated water due to inadequate sanitation systems. Both hepatitis A and E are found worldwide.
d) **Schistosomiasis** is a water-based disease that is considered the second most important parasitic infection after malaria in terms of public health and economic impact. Infections are transmitted when faeces or urine of infected humans are disposed of into water systems. Parasite eggs can infect aquatic snails in which the parasite transforms and divides into second-generation larvae. These are released into fresh water ready to infect humans.
e) **Typhoid fever** is a bacterial infection of the intestinal tract and bloodstream caused by the bacteria *Salmonella typhi* and *Salmonella paratyphi*. People become infected by drinking water that has been contaminated by sewage containing the bacteria. The annual incidence of typhoid is estimated to be about 16 million cases worldwide (Crump, Luby & Mintz, 2004).

9.2.2. Hazards from Liquid Chemicals In Wastewater

A major part of liquid chemical waste is disposed of via the sink. The most important chemicals in hospital wastewater are anaesthetics, disinfectants, chemicals from laboratory activities, developer and fixer solutions from photographic film processing, and iodinated X-ray contrast media.

X-ray contrast media contain absorbable organic iodinated compounds (AOX). As AOX are biologically inert and stable, they are excreted almost completely within a day after administration and enter into the wastewater. Little is known about their fate and long-term effects; therefore, the risk associated with their spread in the environment must not be underestimated.
Photochemical wastes (fixer and developer solution from X-ray diagnostics) form a major part of generated chemical waste. Fixer baths contain large amounts of silver. Developing solution can contain formaldehyde, which is a known human carcinogen.[17]

[17] See http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf for more information

Glutaraldehyde solutions are widely used in hospitals to disinfect reusable fibre-optic endoscopes. Formaldehyde- based disinfectants (formalin) are used for dialysers, and disinfection of dialysis equipment and the associated reverse osmosis units, as well as in pathology. As well as exhibiting human toxicity, both chemicals can cause severe water pollution and operational problems within a wastewater treatment plant if discharged to the sewer.

Dental amalgam is an alloy of mercury with other metals and might be set free into wastewater during dental activities if not separated. Mercury is a neurotoxin. It is environmentally persistent and bioaccumulates in the food chain. Mercury might also reach the wastewater by the disposal of laboratory chemicals in sinks or through the drains of maintenance departments if mercury-containing equipment, such as sphygmomanometers, is in use.

9.2.3. Hazards from Pharmaceuticals in Wastewater

Antibiotics are used extensively for treatment in hospitals. These antibiotics and their metabolites are excreted with urine and faeces and end up in the wastewater stream, a problem recently recognized worldwide. Hospital wastewaters are a source of bacteria with acquired resistance against antibiotics with a level of at least a factor of 2 to 10 times higher than in domestic wastewater. Gene transfer is optimal at high cell densities and under high antibiotic concentrations. Under heterogeneous environmental conditions, this gene transfer can still occur at significant levels and will contribute to the emergence and spread of resistant pathogens, such as methicillin- resistant Staphylococcus aureus if the wastewater is not properly treated. Also, in some places, isolates of vancomycin-resistant enterococci have been detected in samples of sewage obtained downstream from hospitals, such as in the Porto area in Portugal (Novais et al., 2005).

Other pharmaceuticals that have been found in wastewater include lipid regulators, analgesics, antidepressants, antiepileptics, antineoplastics, antipyretics, antiphlogistics, antirheumatics, ß-blockers, broncholytics, ß2-sympathomimetics, estrogens, secretolytics and vasodilators. Most of them pass through wastewater treatment plants and have been found in drinking-water in high-income, as well as low-income, countries. Ecosystems to which pharmaceutical contaminated wastewaters are discharged can also be adversely affected.

9.2.4. Hazards from Radioactive Substances

Radioactive waste results from the use of tracers and other radioactive diagnostic and treatment procedures. High-level radioactive waste should be segregated and collected by authorized companies. Waste fluids containing low-level radioactive contents are typically discharged into sewers from, for example, oncology departments. This should not pose a risk to health if the fluids have been stored

for a sufficient period of time to permit radioactive decay according to national requirements or the recommendations made in Chapter 9.

9.2.5. Quantity of Wastewater

The quantity of wastewater produced in a health-care facility depends on the amount of water used and is best measured by water consumption. The water consumption depends heavily on factors such as the kind of health- care services provided, number of beds, accessibility to water, climatic situation, level of care and local water-use practices.

In high-income countries, wastewater generation in secondary- and tertiary-level hospitals is mainly measured on an inpatient ratio (litre of generated wastewater per patient treatment day). Typical generation rates are (Anonymous, 2001):

a) small–medium-sized hospitals: 300–500 l per inpatient per day
b) large health-care settings: 400–700 l per inpatient per day
c) university hospitals: 500–>900 l per inpatient per day.

In primary health-care clinics, the rate of waste generation is often measured as the sum of the number of inpatients and outpatients. Minimum water quantities required in the health-care setting are (WHO, 2008):

a) 40–60 l per inpatient; plus
b) 5 l per outpatient; and
c) 100 l per surgical procedure.

While a lack of maintenance in the water supply can contribute heavily to high wastewater generation rates, water- saving programmes can efficiently minimize the amount of wastewater produced.

9.2.6. Quality of Wastewater by Hospital Department

Wastewater from health-care facilities contains organic particles (faeces, hairs, food, vomit, paper, and fibres), soluble organic material (urea, proteins, pharmaceuticals) and inorganic particles (sand, grit, metal particles), soluble inorganic material (ammonia, cyanide, hydrogen sulphide, thiosulfates) and other substances. The composition depends on the source of origin.

a) **General medical areas** generate wastewater comparable to domestic wastewater. The urine of patients from some wards (oncology, infectious disease) will probably contain higher amounts of antibiotics, cytotoxics, their metabolites and X-ray contrast media. Additionally, higher concentrations of disinfectants can be found.
b) **Kitchens** at hospitals often generate a polluting wastewater stream containing food leftovers, waste from food processing and high concentrations of disinfectants and detergents. Starch, grease, oil and an overall high organic content have the potential to create problems during wastewater management.

c) **Laundries** are places where the highest quantity of greywater is produced. Often, the wastewater is hot, has a high pH (alkaline) and may contain high rates of phosphate and AOX if chlorine-based disinfectants are used. Shower blocks also create large volumes of greywater containing dilute concentrations of detergents.
d) **Theatres and intensive-care units** generate wastewater with high contents of disinfectants (glutaraldehyde), detergents and pharmaceuticals. Additionally, the organic content can be high due to the disposal of body fluids and rinsing liquids (such as those from suction containers).
e) **Laboratories** are a possible source for chemicals in the wastewater stream. Of special relevance are halogenated and organic solvents, colorants from histology and haematology (Gram staining), cyanides (haematology) and formaldehyde and xylene (pathology). Laboratories may also contribute to the presence of blood in wastewater from the emptying of samples into the sinks.
f) **Radiology** departments are the main generator of photochemical (developing and fixing) solutions in wastewater and potentially contaminated rinsing water. In some countries, this source of wastewater contamination is declining due to the increasing use of digital X-ray technology.
g) **Haemodialysis** requires the disinfection of the dialysers and sometimes the used filters. Accordingly, the concentration of disinfectant in the wastewater can be high.
h) **Dental departments** can contaminate wastewater with mercury (amalgam) from the filling of dental cavities if no amalgam separators are installed in the sink waste pipe system.
i) **Central sterile supply departments** are one of the main consumers of disinfection solutions, including aldehyde- based disinfectants. Hot water from the sterilizers and detergents from the CD-machine (cleaning and disinfectant) might also increase pollution load in the wastewater.

9.3. COLLECTION AND PRETREATMENT OF LIQUID HEALTH-CARE WASTE

Segregation, minimization and safe storage of hazardous materials are just as important for liquid wastes as they are for solid wastes.

Typically, a system of sewer pipes linked to form a sewerage system will collect wastewater from around a health- care facility and carry it below ground to a central location for treatment or disposal. This treatment plant may be located at a health-care facility or some distance away, where it will also provide treatment for the wider community or municipality. This is known as a "central system". Where a main sewerage system has not been constructed, wastewater may be collected from medical areas by pipe system and passed into cesspits or septic tanks. This is a "decentralized" collection arrangement, where the wastewater is removed periodically from the pits by a tanker fitted with a sludge pump and taken for treatment and disposal. A decentralized collection and treatment system is not the preferred approach for health-care facilities.

9.3.1. Sewerage Systems for Health-Care Facilities

The preferred set-up is to construct separate sewerage systems for wastewater and storm water (referred to as sanitary sewers and storm sewers). Combined sewerage systems (which transport liquid waste discharges and storm water together to a common treatment facility) are no longer recommended. The separate collection of grey and black water is normally not recommended, because it can cause hydraulic problems (blockages) due to low flow volumes in the collection of the black water. Storm water or rainwater can be collected separately and used for gardens or other purposes that do not need highly processed water, such as toilet flushing, washing vehicles or cleaning outdoor paved areas.

A sufficient number of access holes should be installed in a sewerage system to allow maintenance. The distance between access holes should be <50 m to permit easy access to all subsurface parts of the system. All sewage pipes and access holes should be watertight.

9.3.2. Pre-treatment of Hazardous Liquids

The basic principle of effective wastewater management is a strict limit on the discharge of hazardous liquids to sewers. Chemical waste, especially photochemicals, aldehydes (formaldehyde and glutaraldehyde), colorants and pharmaceuticals, should not be discharged into wastewater but should be collected separately and treated as a chemical health-care waste. Pre-treatment is recommended for wastewater streams from departments such as medical laboratories. This pre-treatment could include acid–base neutralization, filtering to remove sediments, or autoclaving samples from highly infectious patients. Non-hazardous chemicals such as syrups, vitamins or eye drops can be discharged to the sewer without pre-treatment.

A grease trap can be installed to remove grease, oil and other floating materials from kitchen wastewater. The trap and collected grease should be removed every 2–4 weeks.

Collected body fluids, small quantities of blood and rinsing liquids from theatres and intensive care can be discharged in the sewer without pre-treatment. Precautions against blood spatter should always be taken (e.g. earing personal protective equipment [PPE] and following standardized handling procedures), and care should be taken to avoid blood coagulation that could block pipes. Larger quantities of blood may be discharged if a risk assessment shows that the likely organic loading in the wastewater does not require pre-treatment. Otherwise, blood should be first disinfected, preferably by a thermal method, or disposed of as pathological waste. Blood can also be disposed of directly to a septic tank system (see section 9.7.2) if safety measures are followed.

Note that 5% sodium hypochlorite (NaOCl – bleach) is not effective for disinfecting liquids with a high organic content such as blood and stools. Sodium hypochlorite should never be mixed with detergents or used for disinfecting ammonia-containing liquids, because it might form toxic gases. Lime milk (calcium oxide) can be used to destroy microorganisms in liquid wastes with high organic

content requiring disinfection (e.g. stool or vomit during a cholera outbreak). In these cases, faeces and vomit should be mixed with the lime milk in a ratio of 1:2, with a minimum contact time of six hours. Urine can be mixed 1:1, with a minimum contact time of two hours (Robert Koch Institute, 2003).

Wastewater from the dental department should be pre-treated by installing an amalgam separator in sinks, particularly those next to patient treatment chairs. Mercury waste must be safely stored. Where there is no existing national system for storing mercury, health-care facilities can follow general guidelines for safe storage (e.g. UNDP, 2010).

Radioactive wastewater from radiotherapy (e.g. urine of patients undergoing thyroid treatment) should be collected separately and stored in a secured place until the levels of radioactivity have decreased to background concentrations. After the required storage time, the wastewater can be disposed of into a sewer.

9.4. DISCHARGE INTO MUNICIPAL SEWAGE SYSTEMS

Discharging wastewater generated from a health-care facility into the municipal sewage system, after adequate pre-treatment (see section 9.3.2), is a preferred method if the municipal sewage-treatment plant fulfils the local regulatory requirements.

In countries operating only basic sewerage systems or experiencing epidemics of enteric disease, or with endemic intestinal helminthiasis, the onsite treatment or at least pre-treatment of the wastewater before discharge into the municipal sewerage system should be considered.
Typically, the minimum requirements for discharging into a municipal sewerage system are:

a) the municipal sewers should be connected to efficient sewage-treatment plants with primary, secondary and tertiary treatment;
b) a central treatment plant ensures at least a 95% removal of bacteria;
c) the sludge resulting from sewage treatment should be subjected to further treatment, such as anaerobic digestion, leaving no more than one helminth egg per litre in the digested sludge;
d) the waste-management system of the health-care facility maintains high standards, ensuring only low quantities of toxic chemicals, pharmaceuticals, radionuclides, cytotoxic drugs and antibiotics in the discharged sewage.

If these requirements cannot be met, the wastewater should be managed and treated as described in sections 9.5 and 9.7.

9.5. ONSITE WASTEWATER TREATMENT

Larger health-care facilities, particularly those that are not connected to any municipal treatment plant, should operate their own wastewater-treatment equipment. This could include physical, chemical and biological processes to remove contaminants from the raw sewage. The objective is to produce a treated effluent that is suitable for reuse or discharge back into the environment, usually surface watercourses.

Typically, wastewater treatment involves three stages. The first stage is the removal of solids that are separated by sedimentation (primary treatment). Second, dissolved biological matter is progressively converted into a solid mass using indigenous waterborne bacteria. Some inorganic components will be eliminated by sorption to sludge particles, which are then separated from the liquid phase of the wastewater by sedimentation (secondary treatment). During the third stage (at the end of the treatment process), after the solid and liquid materials are separated, the treated water may be further treated to remove suspended solids, phosphates or other chemical contaminants, or may be disinfected (tertiary treatment).

9.5.1. Wastewater-Treatment Systems

The most efficient onsite treatment plants for health-care wastewater should include primary, secondary and tertiary treatment.

Primary treatment

The purpose of this first stage is to prevent the damage or clogging of wastewater treatment equipment and to produce a generally homogeneous liquid capable of being treated subsequently biologically or mechanically. A raked screen is used to remove large objects, after which the velocity of incoming wastewater is reduced to allow the settlement of sand, grit and stones. Floating material, such as grease and plastics, is skimmed off, and primary sedimentation tanks are installed to allow faecal solids to settle.

Secondary treatment

The task of secondary treatment is to remove dissolved carbon and nitrogen components by microbial digestion. Bacteria and protozoa consume biodegradable soluble organic material (e.g. sugars, fats, organic short-chain carbon molecules) and bind much of the less soluble fractions into floc particles. These microorganisms require oxygen and a substrate on which to live. These two essentials are provided in a variety of designs, which broadly fall into different systems: fixed-film or suspended growth.

In fixed-film systems, such as trickling filter, rotating biological contactors, fluidized bed reactors or biological aerated filter, the biomass grows on media and the sewage passes over its surface. Oxygen is either supplied to the biota by spraying or trickling the wastewater over the filter materials, or the system is mechanically aerated.

In suspended growth systems, the biota is living on the sludge (called activated sludge). The activated sludge is mixed with the sewage and aerated in a tank or basin. This then passes to a clarifier, where the activated sludge can settle. Some of the sludge will be returned to the aeration tank; some will be disposed of or will undergo further treatment, depending on the local situation and regulations.

Fixed-film systems are more able to cope with drastic changes in the amount of biological material, and can better adjust to specific wastewater characteristics. Fixed-film systems can provide higher removal rates for organic material and suspended solids, and are normally used for health-care wastewater treatment.

The removal of nitrogen is by biological oxidation from ammonia to nitrate. This is achieved by nitrification involving nitrifying bacteria such as *Nitrospira* sp. and Nitrosomonus sp. This is followed by reduction from nitrate to nitrogen gas (denitrification), which is released to the atmosphere. Denitrification requires anoxic conditions and might be carried out during the tertiary treatment in a sand filter or a reed bed. Nitrification and denitrification require carefully controlled conditions to encourage the appropriate microbiological communities to form.

Tertiary treatment

Tertiary treatment, also called "effluent polishing", is the final step in a wastewater-treatment process before the effluent is discharged to the receiving environment. More than one tertiary treatment process can be used. If disinfection of the effluents as the final treatment step is required, then another step to remove suspended organic matter must be carried out before the disinfection.

Sand filtration, platooning or planted horizontal gravel filters can be used to remove suspended organic matter. Constructed wetlands and engineered reed bed systems are another effective option.

Disinfection of wastewater from health-care establishments is often required, particularly if the wastewater is discharged into any waterbody used for recreational activities or used as a source of drinking-water (including aquifers). Disinfection of the wastewater is particularly important if it is discharged into coastal waters close to shellfish habitats, especially if the dietary habits of local people include eating raw shellfish.

9.5.2. Disinfection of Wastewater

Chlorine-based disinfectants are traditionally used to disinfect health-care wastewater (tertiary treatment). The effectiveness of disinfection depends heavily on the quality of the water being treated (e.g. turbidity, pH), the type of disinfectant being used and the disinfectant dosage (concentration and time). Short contact times, low doses, high organic contents and high flows all reduce effective disinfection.

Chlorine disinfection will be effective only if the wastewater contains <10 mg/l of suspended organic matter, and turbid water will be treated less successfully, because solid matter can shield organisms. Chlorination of residual organic material may generate chlorinated organic compounds that may be carcinogenic and harmful to the environment. Therefore, disinfection by chlorine is only recommended if it can be ensured that the organic matter is below 10 mg/l.

Common methods and agents for disinfection include NaOCl (a commonly used disinfectant in health- care facilities) and chlorine dioxide (ClO_2). Chlorine dioxide can be considered as more efficient than NaOCl. Ultraviolet (UV) light is replacing chlorine due to the concerns about the impacts of chlorine; however, UV lamps need frequent maintenance and replacement, as well as a highly treated effluent. Ozone (O_3) is another option that can oxidize most organic material it comes in contact with, but requires highly skilled operators, and investment costs are comparatively high. However, ozone has advantages: it is a more effective disinfectant than chlorine, its action is less susceptible to changes in pH, and it can destroy specific chemical contaminants (such as some pharmaceuticals) in the wastewater.

9.5.3. Disposal of Sludge

Onsite treatment of hospital sewage will produce a sludge that contains high concentrations of helminths and other pathogens, and should be treated before disposal. The most common treatment options include anaerobic digestion, aerobic digestion and composting.

Anaerobic thermophilic or mesophilic digestion is a complex bacterial process that is carried out in the absence of oxygen and is mainly used for large-scale plants. Composting or sludge de-watering and mineralization beds are most commonly used for onsite treatment in hospitals. For composting, sludge is mixed with a carbon source such as sawdust, straw or wood chips. In the presence of oxygen, bacteria digest the sludge and the carbon source, and create heat that will pasteurize the sludge. In de- watering and mineralization beds, sludge is applied on a horizontal system – flow reed bed. One part of the water is absorbed by the reeds, which then transpire moisture into the air; the other part is returned to the wastewater- treatment plant through a drainage layer in the bottom of the reed bed. The de-watered sludge is incorporated into the microbiologically active top layers of the root zone of the reeds, where it is mineralized and turned into soil.

Figure 9.1 shows a simple schematic of a horizontal reed bed system.

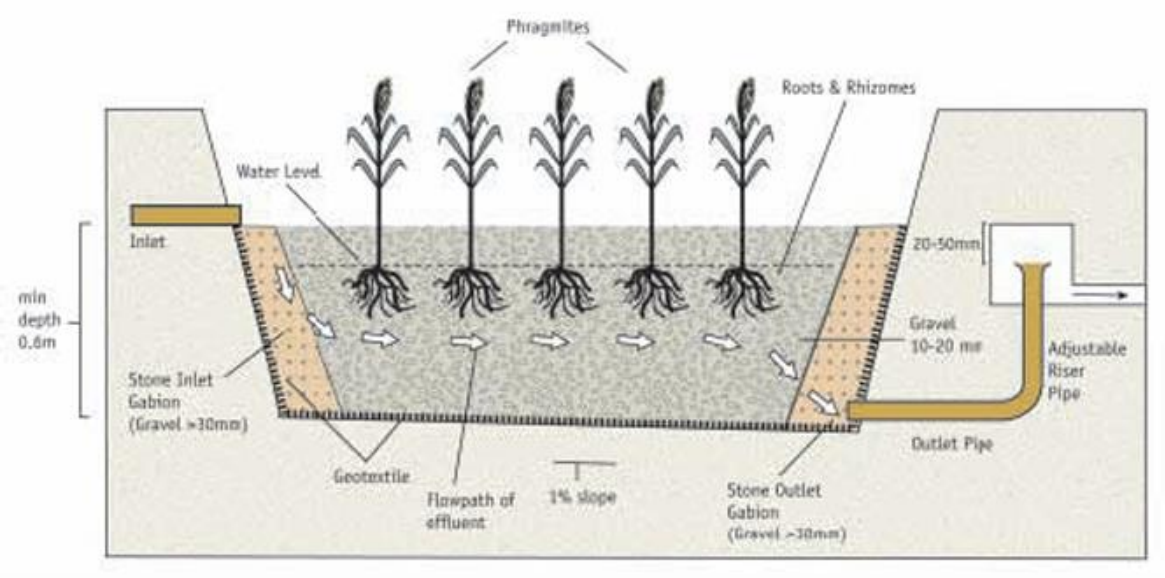

Figure 9.1: Horizontal reed bed system

9.5.4. Reuse of Wastewater and Sludge

Wastewater-treatment plants of health-care facilities often face operational problems, due to concerns about chemicals and pharmaceuticals in wastewater and the potential hygiene risks. The reuse of wastewater and sludge from hospitals with standard wastewater-treatment plants is generally not recommended and should only be done if knowledgeable staff and appropriate testing facilities are available.

While the reuse of treated sludge was common in the past, this practice has been criticized in recent times due to often high heavy metal concentrations and potential public health impacts. If sludge is reused for agricultural purposes, it should be tested to confirm that it does not contain more than one helminth egg per gram of total solids, and contains no more than 1000 faecal coliforms per gram of total solids (WHO, 2006). The sludge should be applied to fields in trenches and then immediately covered with soil.

The use of treated health-care wastewater should only be carried out if resources to meet environmental and safety standards can be assured and the relevant national or WHO guidelines on wastewaters can be followed. For unrestricted agricultural irrigation, there should be no more than one helminth egg per litre, and the number of *Escherichia coli* should be <1000 per 100 ml (WHO, 2006).

9.5.5. Offsite Treatment and Disposal in Specialized Facilities

Some categories of liquid hazardous health-care wastes, such as chemicals and cytotoxic wastes, should be treated and disposed of at offsite specialized treatment plants for hazardous waste in accordance with national standards or international conventions, such as the Basel and Stockholm conventions. Countries should plan hazardous waste- management systems that take into consideration the collection, transportation, treatment and disposal of some categories of hazardous liquid health-care wastes.

9.6. OPERATION AND MONITORING OF SEWERAGE SYSTEMS

Problems in the management of wastewater in health-care facilities are mainly due to insufficient operation and maintenance. In most hospitals, the disposal of liquid hazardous waste via the sink is still practised daily. Leakages and blockages are likely to increase where sewers are insufficiently maintained. Commonly, the first indication of a problem is large wastewater losses between the entry points (sinks, toilets, drains) and an onsite treatment plant or tank or discharge point into a municipal sewerage system.

9.6.1. Operation and Maintenance of Wastewater Systems

Typical problems in the operation of wastewater systems include:

a) lack of awareness among senior staff at health-care facilities on wastewater problems;
b) insufficient or non-functioning pre-treatment and primary treatment systems, or no hazardous wastewater- management system;
c) little or no programme of preventive maintenance;
d) non-availability of basic tools to carry out maintenance;
e) use of systems that are too complex to be operated by unskilled workers, or operational costs that are unbudgeted or too high to be affordable.

To ensure that wastewater-management responsibilities are taken seriously, a trained wastewater officer should be appointed. The starting point for developing a successful wastewater system is a wastewater audit, which would identify the expected wastewater streams from each medical and service area of the health-care facility, and provide data for pre-treatment, collection and treatment arrangements for wastewater to be developed. A maintenance plan to cover both corrective and preventive maintenance should also be prepared. If an onsite treatment plant exists, it must be included in the operations and maintenance plans, and a budget allocated to sustain operations.

9.6.2. Monitoring of Wastewater Systems

The monitoring of the wastewater system includes two aspects: monitoring the sewerage system and monitoring effluent quality.

An often underestimated aspect in wastewater management is the loss of wastewater during collection and transport. Losses of 10–30% of the wastewater due to broken sewer pipes, non-watertight access holes and leakages at pipe connections are common. Installing a flow meter at the discharge point of the health-care facility is recommended for accurate monitoring. Maintenance and leakage problems can often be identified through regular (daily or weekly) comparison of water consumption and discharged wastewater quantities.

The most common parameters for monitoring the effluent quality are:

a) temperature;
b) pH;
c) BOD5 (a test to estimate the amount of oxygen consumed by biochemical oxidation of waste contaminants in a five-day period at 20 °C); chemical oxygen demand;
d) nitrate;
e) total phosphorus;
f) total suspended solids;
g) presence and concentration of *Escherichia coli*.

If an onsite treatment plant is operated, the inflow of wastewater and the outflowing treated effluent should be tested regularly to monitor how efficiently the treatment plant reduces the concentration of contaminants.

9.7. MINIMUM APPROACH TO WASTEWATER MANAGEMENT

9.7.1. Sanitation System

In many health-care facilities in developing countries, patients have no access to sewer-based sanitation facilities. In these places, human sanitation is often by pit latrines or something similar, and at worst by open defecation in the grounds of the health-care facility or nearby. Excreta collected from patients is usually disposed of via the same routes, creating a risk of infection to other people. This underlines the prime importance of providing access to adequate sanitation in every health-care facility. Sufficient toilets should be available; the recommended minimum is one toilet per 20 users for inpatient medical areas, and at least four toilets per outpatient location (one each for male and female staff, one for female patients, one for male patients) (WHO, 2008). Ideally, the toilets should be connected to a sewerage system. Where there are no sewerage systems, technically sound onsite sanitation should be provided. Guidance on this is available in a number of publications (e.g. Franceys, Pickford & Reed, 1992; Mara, 1996). These cover both simple techniques, such as the basic pit latrine, ventilated pit latrine and pour-flush latrine, and more advanced options, such as a septic tank with soakaway or an aqua-privy. Waterless systems and composting toilets are also now available.[18]

[18] See, for example, http://en.wikipedia.org/wiki/Composting_toilet

In temporary field hospitals during outbreaks of communicable diseases, other options such as chemical toilets may also be considered (Dunsmore, 1986). In addition, convenient washing facilities (with warm water and soap) should be available for patients, staff and visitors, to improve personal hand hygiene and so help limit the spread of infectious diseases within the health-care facility.

9.7.2. Minimal Liquid Hazardous Waste-Management System

The lower the standards of the wastewater treatment, the more important are the specific arrangements that are put in place for managing hazardous liquid waste. The following actions should be only carried out if no other way of hazardous waste disposal is available or during an emergency situation. The use of appropriate PPE is of utmost importance in all situations:

a) Body fluids and the contents of suction systems from non-infectious patients from an operating theatre should be discharged via the drain by staff wearing PPE and with all possible further precautions to avoid fluid splashing.
b) Stool, vomit and mucus from highly infectious patients (e.g. cholera patients) should be collected separately and thermally treated before disposal (e.g. by an autoclave reserved for waste treatment). Lime milk (calcium oxide) can be used during emergencies and if no appropriate autoclave or other disinfectant is available.
c) Blood can be emptied into a septic or sewerage system if safety measures are followed (e.g. PPE and precautions against spatter). Other options for expired blood bags include disposal at a controlled land-disposal site, or treatment in a high-temperature incinerator (1100 °C) or in an autoclave that has a special liquid treatment programme cycle. If no other disposal option is available, expired blood bags may be isolated from patients and staff by placing unopened into a protected pit excavated within the grounds of the health-care facility or at another secure location.
d) Solid health-care waste, especially solid hazardous waste (pharmaceuticals, chemicals), should not be mixed into wastewater.
e) Liquid laboratory hazardous waste (colorants, formalin) should be collected separately. Adsorbent (e.g. sawdust) should be used for easier handling. The solid mass should be rendered immobile or encapsulated.
f) Chlorine-based disinfectant should be diluted to reach a concentration of <0.5% active chlorine, and should be disposed of directly in a soakaway pit. Chlorine-based disinfectant should not be disposed of in a septic tank, because it will harm the biodegradation process.
g) Liquid pharmaceuticals in vials (but not cytotoxic materials) can be crushed in a closed bucket, mixed with sawdust, and the solid mass incinerated or encapsulated.
h) Glutaraldehyde should be stored after use and can be neutralized using glycine. Subsequently, it can be slowly disposed of via a soakaway pit.

Note that sludge and sewage from health-care facilities generated by a basic wastewater-management system should never be used for agricultural or aquaculture purposes. Effluents from the basic treatment should not be discharged into water bodies that are used nearby to irrigate fruit or vegetable crops or to produce drinking-water or for recreational purposes.

9.7.3. Basic Wastewater-Treatment Systems

Figure 9.2 shows a schematic of a basic hospital wastewater-treatment system. This system consists of a primary and secondary treatment stage, which is considered as the minimum treatment for primary- and secondary-level rural hospital.

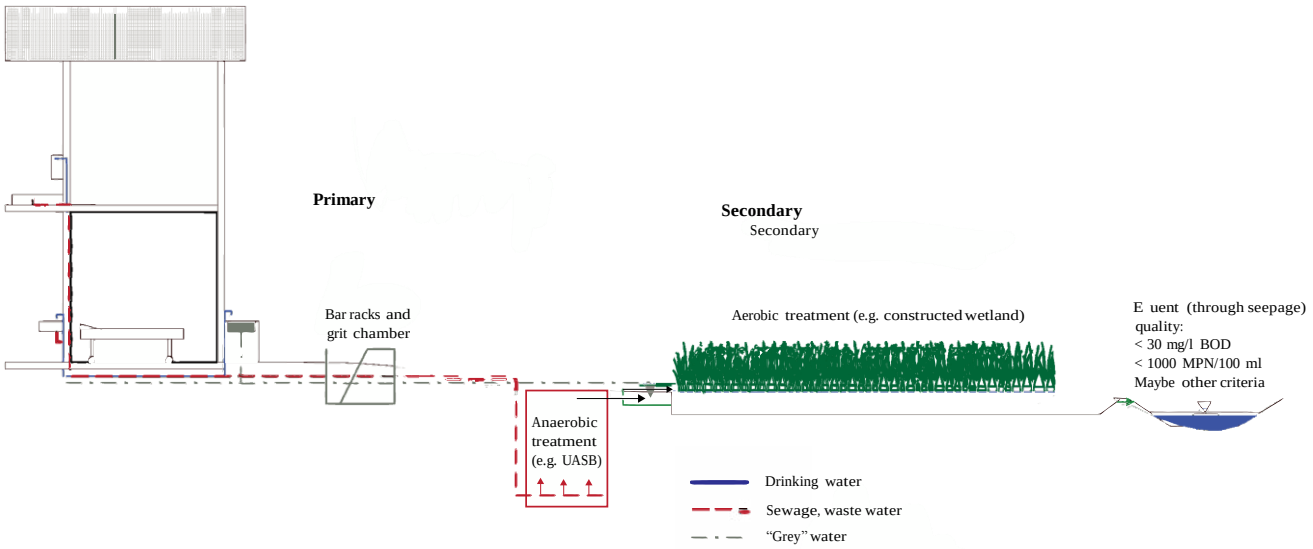

Figure 9.2: Basic hospital wastewater-treatment system with two treatment stages

Decentralized septic tank system

The minimum treatment method for wastewater is the septic tank, a watertight receptacle for the separation of solid and liquid components of wastewater and for the digestion of organic matter in an anaerobic environment. A septic tank also takes on the functions of storing solids and allowing clarified liquid to outflow for further treatment or discharge.

A septic tank normally consists of two or more chambers and can be divided into the following zones:

a) horizontal: inflow, settlement and clarifying zone
b) vertical: scum, detention and sludge zone.

The capacity of the septic tank should be equivalent to a total of two days' wastewater flow. If a two-chamber system is used, the first chamber should be two thirds of the total capacity. Access holes, inspection ports and ventilation should be installed in every chamber.

The wastewater enters the septic tank via a ventilated pipe. The heavier solid matter (sludge) falls to the bottom; fats and other lighter matter (scum) float to the surface. The effective settling and

floating of solids is directly dependent upon the retention time within the tank, which should be not less than 24 hours. Anaerobic bacteria partly break down this solid matter.

Note that excessive build-up of sludge and scum reduces the capacity of the detention zone, resulting in discharge of suspended solids to the effluent disposal system. Solid matter (sludge, scum) from septic tanks must be removed when the chambers are half filled with sludge. If the level of solid matter cannot be controlled, it should ideally be removed once every two years.

Centralized, basic system

Centralized onsite treatment is recommended for health-care facilities to minimize maintenance, allow more advanced treatment, and improve the monitoring of the wastewater system. Basic centralized systems consist of primary treatment (sand catchment and screen to remove large particles) and an anaerobic secondary treatment system. Typical secondary treatment systems include:

a) baffled flow reactors
b) anaerobic filters
c) Imhoff tank
d) upflow anaerobic sludge blanket reactor the harvesting of methane biogas if facilities are available. The effluents can be further treated. If this is not possible, a controlled discharge to soakaway pits or leachfields should be carried out.

Most of the systems allow for:

Soakaway pits and leachfields

A soakaway pit should have one or more tanks, with the total volume equal to the wastewater-treatment plant. Effluents from the treatment plant are collected and allowed to infiltrate into the ground. The pit may be filled with stones, broken bricks or similar material or may be lined with open-jointed masonry. The top 0.5 m of the pit should be lined solidly, to provide firm support for a reinforced concrete cover. Planting trees adjacent to or over a soakaway can improve liquid removal through transpiration and increased soil permeability.

When larger amounts of wastewater need to be infiltrated (e.g. district hospitals), a leachfield is often a better solution. Leachfields consist of gravel-filled underground trenches, called leachlines, which allow the liquid effluent from the wastewater treatment to permeate into the ground. Open jointed (stoneware) or perforated (polyvinyl chloride) pipes carry the liquid effluent into the leachfield. The leach trenches are usually 0.3–0.5 m wide and 0.6–1.0 m deep (from the top of the pipes). The trenches are laid with a 0.2–0.3% gradient of gravel (20–50 mm diameter), covered by a 0.3–0.5 m layer of soil.

Soakaway pits and leachfields present a threat of contamination to nearby wells. Both should be kept as far as practicable from shallow water wells and, where possible, they should be installed downstream of water abstraction sources. The distance between the bottom of the infiltration

system and the groundwater table should be at least 1.5 m (more in coarse sands, gravels and fissured geological formations), and the system should be at least 30 m from any groundwater source (Harvey, 2002).

Lagooning system

In a region or an individual health-care facility that cannot afford sophisticated sewage-treatment plants, and where infiltration of the wastewater is not possible, a lagooning system is a basic solution for treating wastewater, if enough land is available. Lagooning systems are divided in facultative lagoons (oxygen is supplied primarily by algae) and aerated lagoons (oxygen is supplied by mechanical surface aeration). Mechanical aeration requires comparatively high operational costs (electricity); therefore, facultative lagoons are preferred.

Facultative means the presence of an anaerobic bottom region below an aerobic top layer. Facultative lagoons consist of a shallow basin in which settlable solids carried by the wastewater fall to the bottom and form a sludge layer that decomposes anaerobically. In the water column, the biodegradable organic materials held in suspension are degraded aerobically. Biodegradable organic carbon is converted by bacteria to biomass and carbon dioxide, and the latter is used photosynthetically by algae to form algal biomass and oxygen. The oxygen required for aerobic decomposition is supplied by bacteria.

Facultative lagoons can have the disadvantages of potentially generating pungent odours, variable effluent quality and a need for a large land surface area. Reed bed systems perform a similar function to lagoons and are regarded as a preferable option if resources exist to establish them.

9.8. DESIRABLE IMPROVEMENTS TO THE MINIMUM APPROACH

Enhancements to the minimum, initial approach include the following:

a) Enforce liquid hazardous waste management; segregate and pre-treat hazardous waste.
b) Set up a maintenance system for the sewers and the septic tanks, provide maintenance equipment and clean septic tanks regularly.
c) Set up a budget line to cover wastewater-treatment costs.
d) Install grease traps for the kitchen wastewater and clean regularly.
e) Replace any broken or non-watertight septic tanks and install sewer pipes with watertight joints.

Connect any decentral treatment facilities to a central wastewater-treatment system

a) Ensure that chemical disinfection is only used when the suspended organic matter in wastewater is >10 mg/l.
b) Enhancements for intermediate approaches include the following:
c) Upgrade lagoon systems to engineered reed bed systems.
d) Regularly inspect the sewerage system and repair whenever necessary.

e) Introduce tertiary treatment systems such as sand filtration or a subsurface horizontal gravel filter overplanted with vegetation to increase transpiration.
f) Disinfect the wastewater by UV or change to chlorine dioxide or ozone (a combination of UV and ozone is most effective). Neutralize wastewater from laboratories before discharge into the sewerage system.
g) Set up an "antibiotic committee" to minimize the usage of antibiotics within the health-care facility

10 HEALTH AND SAFETY PRACTICES FOR HEALTH- CARE PERSONNEL AND WASTE WORKERS

10.1. GUIDING PRINCIPLES

The purpose of this chapter is to explain the hazards and infection risks they may encounter, and the prevention and control of exposure to them. Health-care waste-management policies or plans should include arrangement for the continuous monitoring of workers' health and safety. This is to ensure that correct handling, treatment, storage and disposal procedures are being followed. Sensible occupational health and safety measures include the following:

a) develop a standardized set of management rules and operating procedures for health-care waste;
b) inform and train waste workers so that they perform their duties properly and safely;
c) involve waste workers in the identification of hazards and recommendations for prevention and control;
d) provide equipment and clothing for personal protection;
e) establish an occupational health programme that includes information, training and medical measures when necessary, such as immunization, post-exposure prophylactic treatment and regular medical surveillance.

Standardized and written health-care waste-management procedures, when respected by personnel and monitored by the hospital management, can dramatically reduce the risk of accidents. Hospital staff should be taught and kept informed about the health-care waste-management system and procedures that are in place.

Workers at risk from infection and injury include health-care providers, hospital cleaners, maintenance workers, operators of waste-treatment equipment, and all personnel involved in waste handling and disposal within and outside health-care facilities.

Training in health and safety is intended to ensure that workers know of and understand the potential risks associated with health-care waste, and the rules and procedures they are required to respect for its safe management. They should be informed on the importance of consistent use of personal protective equipment (PPE) and should be aware of where to obtain post-exposure follow-up in case of a needle-stick injury or other blood exposure.

Health-care personnel should be trained for emergency response if injured by a waste item, and the necessary equipment should be readily available at all times. Written procedures for the different types of emergencies should be drawn up. For dangerous spills of hazardous chemicals or highly infectious materials, the clean-up operation should be carried out by designated personnel specially trained for the purpose.

To limit the risks, the hospital management must set up management rules and operating procedures for health-care waste and establish standardized emergency procedures. It is the responsibility of everybody involved in handling waste to know the emergency procedures and to act accordingly. One

person should be designated as responsible for the handling of emergencies, including coordination of actions, reporting to managers and regulators, and liaising with emergency services. A deputy should be appointed to act in case of absence.

10.2. OCCUPATIONAL HEALTH RISKS

Health-care waste handlers are at greatest risk from infectious hazards, especially sharps that are not disposed of into puncture-resistant containers. The risk of acquiring a secondary infection following needle-stick injury from a contaminated sharp depends on the amount of the contamination and nature of the infection from the source patient. The risk of infection with hepatitis B is more than 10 times greater than for hepatitis C, and up to 100 times greater than for human immunodeficiency virus (HIV).

Actual cases of non-sharps waste being demonstrated to cause an infection in health-care staff and waste workers are rarely documented. However, it is known that waste handlers were infected by tuberculosis (TB) at a medical waste-processing facility in Morton, Washington, in the United States of America, as a result of exposure to health- care waste. The National Institute for Occupational Safety and Health evaluated the response to an outbreak of TB among the employees of the waste-processing facility. In October 1998, the *Health hazard evaluation report* identified several factors present in the facility that could have contributed to employee exposures to pathogens potentially present in the waste (Weber, Boudreau & Mortimer, 1998).

10.2.1. Health hazards

Other hazards to health-care waste workers include chemical exposures such as chemotherapeutic drugs, disinfectants and sterilants; physical hazards such as ionizing radiation; and ergonomic hazards such as manual lifting and transporting of heavy waste loads (Table 10.1).

Table 10.1: Hazards to health-care waste workers

Hazards	Health effects	Control measures
Sharps injuries and resulting exposure to bloodborne pathogens	Infections with hepatitis B or C, HIV, malaria or other bloodborne infections (Prüss-Ustün, Rapiti & Hutin, 2005)	Immunization against hepatitis B virus (WHO, 2009a). Appropriate disposal of sharps at site of use into a puncture-resistant container without recapping (Hutin et al., 2003; WHO, 2010) Use of engineered needles that automatically retract, blunt resheath, or disable the sharp (CDC, 1997; Lamontagne et al., 2007)
Other biological hazards	SARS (WHO, 2007a, 2009b) Tuberculosis Influenza	Exhaust ventilation (natural or mechanical (WHO, 2009c, 2009d) Standard precautions (WHO, 2007b) Respiratory protection with N95, FFP3 respirators for high-risk cough-inducing procedures (Jefferson et al., 2008; WHO, 2009c) Autoclaving laboratory waste in the laboratory before disposal (Weber, Boudreau & Mortimer, 1998)
Chemicals Chlorine disinfectants (sodium hypochlorite)	Skin and respiratory sensitization (International Programme on Chemical Safety, 1999; Zock et al., 2007) Eye and skin irritation, weakness,	Substitute soap and water for cleaning chemicals Avoid soaking of sharps in chlorine when they will receive autoclaving or incineration before disposal Dilute chemicals appropriately according to

Hazards	Health effects	Control measures
	exhaustion, drowsiness, dizziness, numbness and nausea	manufacturer for less toxic exposure (Zock, Vizcaya & Le Moual, 2010)
High-level disinfectant glutaraldehyde	Irritation of the eyes, nose and throat Skin sensitization Occupational asthma where the symptoms in affected individuals include chest tightness and difficulty in breathing (Mirabelli et al., 2007)	Substitute steam sterilization except for pressure sensitive Instruments (Harrison, 2000; Pechter et al., 2005) Ensure appropriate dilution and use in closed, ventilated system
Substitute steam sterilization except for pressuresensitive Instruments (Harrison, 2000; Pechter et al., 2005) Ensure appropriate dilution and use in closed, ventilated system	Eye and skin irritation, difficulty breathing, nausea, vomiting, and neurological problems such as headache and dizziness Reproductive hazard, linked to nerve and genetic damage, spontaneous abortion and muscle weakness Carcinogen (IARC, 1999)	Substitute steam sterilization for ethylene oxide except for pressure-sensitive instruments (EPA, 2002) Use only in a closed and ventilated system
Sterilants: ethylene oxide (International Programme in Chemical Safety, 2003)	Eye and skin irritation, difficulty breathing, nausea, vomiting, and neurological problems such as headache and dizziness Reproductive hazard, linked to nerve and genetic damage, spontaneous abortion and muscle weakness Carcinogen (IARC, 1999)	Substitute steam sterilization for ethylene oxide except for pressure-sensitive instruments (EPA, 2002) Use only in a closed and ventilated system
Heavy lifting Handling heavy loads over long periods	Back injuries and musculoskeletal disorders (Schneider & Irastorza, 2010) Degenerative diseases of the lumbar spine	Reduce mass of objects or number of loads carried er day (Nelson, 2003) Use waste carts with wheels, automated waste transfer from cart to truck and treatment Use lifts and pulleys to assist in transferring loads
Ionizing radiation	Irreversible damage of cells, anaemia, leukaemia, lung cancer from inhalation (Niu, Deboodt & Zeeb, 2010)	Safe waste management, in full compliance with all relevant regulations, must be considered and planned for at the early stages of any projects involving radioactive materials It should be established from the outset that the waste can be properly handled, treated and ultimately disposed of See International Atomic Energy Agency for national regulatory standards and safety guidance (IAEA, 1995)

10.2.2. Cytotoxic safety

The senior pharmacist at a health-care facility should be made responsible for ensuring the safe use of cytotoxic drugs. Large oncological hospitals may appoint a full-time genotoxic safety officer, who should also supervise the safe management of cytotoxic waste. The following measures are important to minimize exposure:

a) written procedures that specify safe working methods for each process;

b) data sheets, based on the suppliers' specifications, to provide information on potential hazards and their minimization;
c) established procedure for emergency response in case of spillage or other occupational accident;
d) appropriate education and training for all personnel involved in the handling of cytotoxic drugs.

These measures are unlikely to be needed in rural or smaller district hospitals that do not typically use genotoxic products, either cytotoxic or radioactive. In countries where the safe use of cytotoxic and radioactive materials is difficult to ensure, it may be advisable to limit the use of those substances to a small number of specialized (e.g. oncological) hospitals that are better able to implement appropriate safety measures. In hospitals that do use cytotoxic products, specific guidelines on their safe handling should be established for the protection of personnel. These guidelines should include rules on the following waste-handling procedures:

a) separate collection of waste in leak-proof bags or containers and labelling for identification;
b) return of outdated drugs to suppliers;
c) safe separate storage of genotoxic waste away from other health-care waste;
d) arrangements for the disposal of contaminated material, the decontamination of reusable equipment and the clean-up of spillages;
e) arrangements for the treatment of infectious waste contaminated with cytotoxic products, including excreta from patients, disposable linen and absorbent material for incontinent patients.

More information on the treatment and disposal of cytotoxic waste is given in section 8.11.4. Specific procedures to follow in case of spillage and decontamination of mutagenic and carcinogenic products are presented in Annex 5. Minimal protective measures for all waste workers who handle cytotoxic waste should include protective clothing, gloves (chemical barrier), goggles and face masks.

Hospital staff should ensure that the families of patients undergoing chemotherapy at home are aware of the risks and know how they can be minimized or avoided.

10.3. EXPOSURE PREVENTION AND CONTROL

All health-care workers are at risk of exposure to blood at work and should be immunized against the hepatitis B virus before commencing employment.

A proper and safe segregation system for hazardous waste is the key to occupational safety and environmental sound handling. Implementing a proper segregation system must be accompanied by safe and standardized handling procedures.

10.3.1. Hierarchy of controls (applied to bloodborne pathogens)

Methods to control occupational hazards have traditionally been discussed in terms of hierarchy and presented in order of priority for their effectiveness in preventing exposure to the hazard or

preventing injury resulting from exposure to the hazard. Box 10.1 shows how to apply the hierarchy of controls framework to bloodborne pathogen hazards.

Box 10.1: Controls framework

Elimination of hazard – complete removal of a hazard from the work area. Elimination is the method preferred in controlling hazards and should be selected whenever possible.

Examples include removing sharps and needles and eliminating all unnecessary injections. Jet injectors may substitute for syringes and needles. All unnecessary sharps, such as towel clips, should also be eliminated, and needleless systems should be used.

Engineering controls – controls that isolate or remove a hazard from a workplace.

Examples include sharps disposal containers (also known as safety boxes) and needles that retract, sheathe or blunt immediately after use (also known as safer needle devices or sharps with engineered injury-prevention features).

Administrative controls – policies to limit exposure to a hazard (e.g. universal precautions).

Examples include allocation of resources demonstrating a commitment to staff safety, an infection-control committee, an exposure control plan, replacement of all unsafe devices and consistent training on the use of safe devices.

Work practice controls – controls that reduce exposure to occupational hazards through the behaviour of workers. Examples include no needle recapping, placing sharps containers at eye level and at arm's reach, emptying sharps containers before they are full, and arranging for the safe handling and disposal of sharps devices before beginning a procedure.

Personal protective equipment (PPE) – barriers and filters between the worker and the hazard. Examples include eye goggles, gloves, masks and gowns.

See also http://www.who.int/hiv/pub/prev_care/ilowhoguidelines.pdf

Source: ILO & WHO (2005)

10.3.2. Dealing With Spillages

Spillages require clean-up of the area contaminated by the spilt waste. For spillages of highly infectious material, it is important to determine the type of infectious agent, because immediate evacuation of the area may be necessary in some cases. In general, the most hazardous spillages occur in laboratories rather than in medical care departments.

Procedures for dealing with spillages should specify safe handling operations and appropriate protective clothing. Appropriate equipment for collecting the waste and new containers should be available, as should means for disinfection.

In case of skin and eye contact with hazardous substances, there should be immediate decontamination. An exposed person should be removed from the area of the incident for decontamination, generally with copious amounts of water. Special attention should be paid to the eyes and any open wounds. In case of eye contact with corrosive chemicals, the eyes should be irrigated continuously with clean water for 10–30 minutes; the entire face should be washed in a basin, with the eyes being continuously opened and closed.

10.3.3. Reporting accidents and incidents

All waste-management staff should be trained in emergency response and made aware of the correct procedure for prompt reporting. Accidents or incidents, including near misses, spillages, damaged containers, inappropriate segregation and any incidents involving sharps, should be reported to the waste-management officer (if waste is involved) or to another designated person. The report should include details of:

a) the nature of the accident or incident
b) the place and time of the accident or incident
c) the staff who were directly involved
d) any other relevant circumstances.

The cause of the accident or incident should be investigated by the waste-management officer (in case of waste) or other responsible officer, who should also take action to prevent recurrence. The records of the investigation and subsequent remedial measures should be kept.

10.3.4. Protective Equipment

The most effective PPE in reducing risk of injury are gloves to protect from exposure to blood, other potentially infectious materials and chemicals; particulate masks (respirators) to protect from respiratory infections hazards and particulates from burning waste; and boots for waste handlers to protect from sharps injuries to the foot. Availability and access to soap and water, and alcohol hand rub, for hand hygiene are also important to maintain cleanliness and inhibit the transfer of infection via dirty hands.

The type of protective clothing used will depend to an extent upon the risk associated with the health-care waste, but the following should to be made available to all personnel who collect or handle waste:

a) obligatory
   - ✓ disposable gloves (medical staff) or heavy-duty gloves (waste workers)
   - ✓ industrial aprons
   - ✓ overalls (coveralls)
   - ✓ leg protectors and/or industrial boots
b) depending on type of operation
   - ✓ eye protectors (safety goggles)
   - ✓ face masks (if there is a risk of splash into eyes)
   - ✓ helmets, with or without visors.

Industrial boots and heavy-duty gloves are particularly important for waste workers. The thick soles of the boots offer protection in the storage area, as a precaution from spilt sharps, and where floors are slippery. If segregation is inadequate, needles or other sharps items may have been placed in plastic bags; such items may also pierce thin- walled or weak plastic containers. If it is likely that health-care waste bags will come into contact with workers' legs during handling, leg protectors may also need to be worn.

10.3.5. Occupational post-exposure prophylaxis

Post-exposure prophylaxis (PEP) is short-term antiretroviral treatment (for HIV) or immunization (for hepatitis B) to reduce the likelihood of infection after potential exposure, either occupationally or through sexual intercourse. Within the health sector, PEP should be provided as part of a comprehensive universal precautions package that reduces staff exposure to infectious hazards at work.

PEP for HIV comprises a set of services to prevent development of the infection in the exposed person. These include first-aid care; counselling and risk assessment; HIV blood testing; and, depending on the risk assessment, the provision of short-term (28 days) antiretroviral drugs, with follow-up and support. Most incidents linked to occupational exposure to bloodborne pathogens occur in health-care facilities.

The World Health Organization (WHO) and the International Labour Organization have published guidelines on PEP to prevent HIV infection.[19] A summary of PEP recommendations from these guidelines are as follows:

a) WHO recommends that PEP should be provided as part of a package of prevention measures that reduce staff exposure to infectious hazards.
b) PEP should be available to health-care workers and patients.
c) Occupational PEP should also be available to all workers who could be exposed while performing their duties (such as social workers, law enforcement personnel, rescue workers, refuse collectors).
d) Countries should include occupational PEP in national health-care plans.
e) Appropriate training to service providers should ensure the effective management and follow-up of PEP.
f) PEP should be initiated as soon as possible within the first few hours and no later than 72 hours after exposure to potentially infected blood or body fluids.
g) PEP should not be prescribed to a person already known to be infected with HIV.
h) In addition, risk evaluation, and counselling on side effects, and benefits of adherence and psychosocial support is needed.
i) Any occupational exposure to HIV should lead to evaluation and, where relevant, strengthening of safety and working conditions.

10.4. TRAINING

Health-care waste workers should be trained before starting work handling waste, and then on a routine basis (e.g. annually) to update their knowledge of prevention and control measures.

Training should include awareness raising about the potential hazards from waste, the purpose of immunization, safe waste-handling procedures, reporting of exposures and injuries, preventing

[19] http://whqlibdoc.who.int/publications/2007/9789241596374_eng.pdf

infection following an exposure with PEP, and the use of PPE.

10.5. MINIMUM APPROACHES T O HEALTH AND SAFETY PRACTICES

The minimum approach to health and safety practices for health-care personnel and waste workers includes:

a) implementation of standardized management procedures;
b) hepatitis B vaccination (in addition to compulsory vaccinations) for all personnel who are at risk of exposure to blood (these personnel include cleaners and waste handlers);
c) provision of sharps boxes where injections are taking place;
d) implementation of standard precautions, such as no recapping of needles after use;
e) promotion of proper hand hygiene;
f) availability, as a minimum, of gloves to provide personal protection from patients' body fluids;
g) allocation of an additional role (e.g. for an infection-control nurse) to assume responsibility for promoting better worker safety.

11 HOSPITAL HYGIENE AND INFECTION CONTROL

11.1. GUIDING PRINCIPLES

Management of health-care waste is an integral part of hospital hygiene and infection control. Health-care waste can be considered as a reservoir of pathogenic microorganisms, which – if someone is exposed – could give rise to an avoidable infection. If waste is inadequately managed, these microorganisms can be transmitted by direct contact, by inhalation or by a variety of animal vectors (e.g. flies, rodents, roaches), which could come into contact with waste.

This chapter outlines the basic principles of prevention and control of infections that may be acquired in health-care facilities. It does not address other aspects of hospital hygiene and infection control and safety, such as bloodstream and urinary tract infections. It is stressed that other environmental health considerations, such as adequate water supply and sanitation facilities for patients, visitors and health-care staff, are of prime importance in minimizing the transmission of infections.

11.2. CHAIN OF INFECTION

A basic infection-control principle is to know the chain of infection and identify the most effective points to prevent potential disease transmission. Transmission of infectious diseases in a health-care facility requires at least six elements: an infectious agent, a reservoir, a portal of exit, a means of transmission, a portal of entry, and a susceptible host. Numerous actions, some of which are described in this chapter, can be taken to break the links in this chain of events.

11.3. EPIDEMIOLOGY OF NOSOCOMIAL INFECTIONS

Nosocomial infections (also known as hospital-acquired infections, hospital-associated infections and hospital infections) are infections that are not present in the patient at the time of admission to a health-care facility but develop during the course of the patient's stay.

Nosocomial infections occur as a result of medical procedures performed on patients that lead to infections from a patient's own (endogenous) flora or as a result of exposure to items contaminated with infectious agents. Additionally, the risk of acquiring an infection increases for patients with altered or compromised immunity.

Human beings are reservoirs of numerous types of microorgansims. Faeces contain approximately 10^{13} bacteria per gram, and the number of microorganisms on skin varies between 10^{2} and 10^{4} per cm^{2}. Many species of microorganisms live on mucous membranes and are considered normal flora. When the integrity of these barriers is challenged (e.g. microorganisms penetrate the skin or the mucous membrane), this creates an opportunity for an infection to occur.

11.3.1. Transition from exposure to infection

Whether an infection will develop after an exposure to microorganisms depends upon the interaction between the microorganisms and the host. Healthy individuals have a normal general resistance to infection. Patients with underlying disease, newborn babies and the elderly have less resistance and are at greater risk to develop an infection after exposure.

Local resistance to infection also plays an important role: the skin and the mucous membranes act as barriers in contact with the environment. Infection may occur when these barriers are breached. Local resistance may also be overcome by the long-term presence of an irritant, such as a cannula or catheter. The likelihood of infection increases daily when a patient has a catheter attached.

The most important determinants of infection are the nature and number of the infectious agents. Microorganisms range from the completely innocuous to the extremely pathogenic; the former will never cause an infection even in immunocompromised individuals, while the latter will cause an infection in virtually every case of exposure. A classification of conventional, conditional and opportunistic pathogens is given in Box 11.1.

Box 11.1: Classification of pathogenic organisms

Conventional pathogens

Cause disease in healthy individuals in the absence of specific immunity. Examples:

Methicillin-resistant *Staphylococcus aureus*, *Streptococcus pyogenes* (beta strep group A), *Salmonella* spp., *Shigella* spp., vancomycin-resistant *Enterococcus*, *Corynebacterium diphtheriae*, *Mycobacterium tuberculosis*, *Bordetella pertussis*, hepatitis A and B viruses, rubella virus, rotaviruses, human immunodeficiency virus (HIV).

Conditional pathogens

Cause disease, other than trivial local infections, only in persons with reduced resistance to infection (including newborn infants) or when implanted directly into tissue or a normally sterile body area.

Examples:

- Streptococcus agalactiae, Enterococcus spp., Clostridium tetani, Escherichia coli, Klebsiella spp., Serratia marcescens,
- Acinetobacter baumanii, Pseudomonas aeruginosa, Candida spp.

Opportunistic pathogens

Cause generalised disease, but only in patients with profoundly diminished resistance to infection. Examples:

• Atypical mycobacteria, Nocardia asteroides, Pneumocystis carinii. Source: Parker (1978)

When only a few organisms are present, an infection will not necessarily develop. However, when a critical number is exceeded, it is very likely that an infection will become established. For every type of microorganism, the *minimal infective dose* can be determined. This is the lowest number of bacteria, viruses or fungi that cause the first clinical signs of infection in a healthy individual. For most causative agents of nosocomial infections, the minimal infective dose is relatively high. For example, for

Klebsiella and *Serratia* spp. and other Enterobacteriaceae, it is more than 10^5 colony-forming units (CFUs)/gram, but for hepatitis B virus it is less than 10 plaque-forming units (PFUs)/gram.

11.3.2. Sources of Infection

In a health-care facility, the sources of infectious agents may be the personnel, the patients or the inanimate environment.

The hospital environment can be contaminated with pathogens. *Salmonella* or *Shigella* spp., *Escherichia coli* O157:H7 or other pathogens may be present in the food and cause an outbreak, just as they can in a community outside the hospital. Waterborne infections may develop if the water-distribution system breaks down. In more sophisticated facilities, the water-cooling system of air-conditioning equipment may become contaminated with *Legionella pneumophilia*, causing Legionnaires' disease in susceptible patients. Pharmaceuticals may become contaminated during production or preparation; an outbreak of infection by *Pseudomonas aeruginosa*, *Burkholderia cepacia* or *Serratia marcescens* may occur as a consequence. In all these examples, it may be possible to isolate the same causative agent in several patients, which would suggest a common source. All possible measures should be taken to prevent the recurrence of such incidents.

The source of a nosocomial infection may also be a health-care worker who is infected or colonized (a carrier) with an infectious agent. The symptoms of infection will make the potential transmission apparent to the health- care worker and/or to managerial staff, and infected personnel are usually taken off patient care duties. Sometimes a carrier may be symptomless (i.e. is colonized by potentially pathogenic organisms but does not develop any infection). A typical example is methicillin-resistant *Staphylococcus aureus*, which may be carried in the nasal passages of 30–60% of health-care personnel. Faecal carriage of enteropathogens such as *Salmonella* spp. also occurs frequently, but the prevalence varies according to the region. Other conventional pathogens that can be found in symptomless carriers include *Streptococcus pyogenes*, *Corynebacterium diphtheriae*, *Neisseria meningitidis*, hepatitis B virus and cytomegalovirus. Exposure of patients to carriers can give rise to an outbreak of disease. Careful investigation and isolation of the same organisms from a cluster of patients as well as the carrier should reveal the cause of the outbreak.

The source of most hospital epidemics is infected patients; that is, patients infected with pathogenic microorganisms. These microorganisms are often released into the environment in very high numbers, depending on the disease, exceeding the minimal infective dose, and exposing other patients, who subsequently develop hospital-acquired infections. The recent case of severe acute respiratory syndrome and its impact on health-care waste-generation rates (Chiang et al., 2006) is a classic example of hospital-based epidemics relating to a respiratory disease.

11.3.3. Routes of Transmission

In health-care settings, the main modes of transmission from a source to a new host are:

a) contact transmission

- ✓ direct contact (e.g. a surgeon with an infected wound on a finger performs a wound dressing);
- ✓ indirect contact (e.g. secretions transferred from one patient to another via hands in contact with a contaminated waste item);
- ✓ faecal–oral via food

b) bloodborne transmission

- ✓ blood is transferred via sharps or needle stick injuries, transfusion or injection.

c) droplet transmission

- ✓ infectious droplets expelled into the air or onto a surface (e.g. when sneezing, coughing, vomiting); the droplets are too heavy to remain in suspension in the air and typically fall <2 m from the source;
- ✓ direct droplet transmission – droplets reach mucous membranes or are inhaled;
- ✓ droplet-to-contact transmission – droplets contaminate surfaces/hands and are transmitted to another site (e.g. mucous membranes); indirect droplet transmission is often a more efficient transmission route than direct transmission (examples are the common cold, respiratory syncytial virus)

d) airborne transmission

- ✓ small particles carrying microbes are transferred as aerosols via air currents for >2 m from the source (e.g. droplet nuclei or skin scales); direct airborne transmission can be from particles in suspension in air (e.g. *Varicella zoster*) or from deposition on to contaminated wounds (e.g. *Staphylococcus aureus*) (Siegel et al., 2007)

e) vector transmission

- ✓ typical in countries where insects, arthropods and other pests are widespread; these vectors become exposed to a disease organism (such as on the feet of flying insects) through contact with excreta or secretions from an infected patient and transmit the infective organisms directly to other patients.

11.4. PREVENTION OF NOSOCOMIAL INFECTIONS

Two basic principles govern the main control measures to prevent the spread of nosocomial infections in health- care facilities:

a) separate an identified source of infection from other patients and medical areas
b) eliminate all obvious routes of transmission.

The separation of the source has to be interpreted in a broad sense. It includes the isolation of infected patients and implements aseptic conditions by introducing measures intended to act as a barrier between infected or potentially contaminated tissue and the environment, including other

patients and medical staff.

In recent years, increasing attention has been paid to the protection of the personnel against the transmission of bloodborne infections, such as acquired immunodeficiency syndrome (AIDS), and viral hepatitis B and C. Preventive measures are known as "universal". In 1996, the Centers for Disease Control and Prevention published new guidelines (standard precautions) for isolation precautions in hospitals (Garner, 1996). Standard precautions synthesize the major features of body substance isolation and universal precautions to prevent transmission of a variety of organisms. Standard precautions were developed for use in hospitals and may not necessarily be indicated in other settings where universal precautions are used, such as childcare facilities and schools.

11.4.1. Standard Precautions

Standard precautions should be taken with every patient, independent of any known condition (e.g. infected or colonized), to protect health-care workers from exposure to infectious disease. These precautions are designed to prevent cross-transmission before a diagnosis is known. All objects that come in contact with patients should be considered potentially contaminated.

Some areas use the term "routine practices" instead of standard precautions. Standard precaution measurements are outlined in Chapter 11. The routes of transmission intended to be prevented by basic hygienic precautions are:

a) contact
b) bloodborne
c) droplet.

It is impossible to avoid all contact with infected tissue or potentially contaminated body fluids, excreta and secretions. Even when they are not touched with the bare hands, they may come in contact with instruments, containers, linen or similar items.

If an object is disposable, it should be discarded as waste. If it is reusable, transmission of infective agents must be prevented by cleaning, disinfection or sterilization, in accordance with manufacturers' instructions.

11.4.2. Isolation of Infected Patients and Standard Precautions

The first measure in preventing the spread of nosocomial infections is the isolation of infected patients. The term "isolation" covers a broad range of measures. The strictest form of isolation is applied for very infectious diseases (e.g. haemorrhagic fever, diphtheria). Less stringent precautions can be taken in the case of diseases such as tuberculosis, other respiratory infections and infectious diarrhoea.

Maintaining isolation is expensive, labour-intensive and usually inconvenient or uncomfortable for both patients and health-care personnel. Its implementation should be adapted to the severity of the

disease and to the causative agent. Disease-specific precautions should include details of all the measures (e.g. private room, wearing of masks or gowns) to be taken.

11.4.3. Cleaning

Cleaning is one of the most basic measures for maintaining hygiene in the health-care environment. The principal aim of cleaning is to remove visible dirt. It is essentially a mechanical process whereby the dirt is dislodged from a surface, suspended or dissolved in a water film, diluted until it is no longer visible, and rinsed off. Soaps and detergents act as solubility-promoting agents. The microbiological effect of cleaning is also essentially mechanical: bacteria and other microorganisms are suspended in the cleaning fluid and removed from the surface. The efficacy of the cleaning process depends completely on this mechanical action, since neither soap nor detergents possess any antimicrobial activity. Thorough cleaning will remove more than 90% of microorganisms. However, careless and superficial cleaning is much less effective; it is even possible that it has a negative effect, by dispersing the microorganisms over a greater surface and increasing the chance that they may contaminate other objects.

Cleaning should be carried out in a standardized manner and preferably by automated means that will guarantee an adequate level of cleanliness. Diluting and removing the dirt also removes the breeding ground or culture medium for bacteria and fungi. Most non-sporulating bacteria and viruses survive only when they are protected by dirt or a film of organic matter; otherwise, they dry out and die.

11.4.4. Sterilization and Disinfection

The effectiveness of disinfection and sterilization is increased by prior or simultaneous cleaning. Self-evidently, an object should be sterile (i.e. free of microorganisms) after sterilization. However, sterilization is never absolute; by definition, it reduces the number of microorganisms by a factor of more than 10^6 (i.e. more than 99.9999% of microorganisms are killed). Standard reference works, such as pharmacopoeias, often state that no more than one out of a million sterilized items may still bear microorganisms. It is therefore important to minimize the level of contamination of the material to be sterilized. This is done by sterilizing only objects that are first cleaned (free of visible dirt) and applying the principles of good operating practice.

The term "disinfection" is difficult to define, because the activity of a disinfectant process can vary widely. The guidelines for environmental infection control in health-care facilities (CDC, 2003) allow the following distinctions to be made:

a) *high-level disinfection*: can be expected to destroy all microorganisms, with the exception of large numbers of bacterial spores;
b) *intermediate disinfection*: inactivates *Mycobacterium tuberculosis*, vegetative bacteria, most viruses and most fungi; does not necessarily kill bacterial spores;
c) *low-level disinfection*: can kill most bacteria, some viruses and some fungi; cannot be relied on to kill resistant microorganisms such as tubercle bacilli or bacterial spores.
d) There is no ideal disinfectant, and the best compromise should be chosen according to the situation. A disinfectant solution is considered appropriate when the compromise between

the antimicrobial activity and the toxicity of the product is satisfactory for the given application. Another consideration may well be the cost. The more active disinfectants are also the more toxic ones; potentially toxic products can be applied to inanimate objects or surfaces, whereas only the less toxic disinfectants can be considered for disinfection of human tissues. For antisepsis, different disinfectants are used for application to intact skin (e.g. alcoholic solutions) and to mucous membranes or wounds (only aqueous solutions of non-toxic substances). Cost is a less important consideration for an antiseptic than for a disinfectant.

The principal requirements for a good antiseptic are absence of toxicity, rapid action, and adequate activity on natural flora and pathogenic bacteria and other microorganisms after a very short exposure time. Essential requirements for a disinfectant are somewhat different. There must be adequate activity against bacteria, fungi and viruses that may be present in large numbers and protected by dirt or organic matter. In addition, since disinfectants are applied in large quantities, they should be of low ecotoxicity.

In general, use of the chosen disinfectant, at the appropriate concentration and for the appropriate time, should kill pathogenic microorganisms, rendering an object safe for use in a patient, or rendering human tissue free of pathogens to exclude cross-contamination. An overview of the characteristics of the main groups of disinfectants is given in Table 11.1.

11.4.5. Hand Hygiene

The hands of health-care workers are the most frequent transmission route for nosocomial infections. Hand hygiene, both hand washing and hand disinfection, should be seen as the primary preventive measure that is the responsibility of all health-care personnel.

Thorough hand washing with adequate quantities of water and soap removes more than 90% of the transient (i.e. superficial) flora, including all or most contaminants. An antimicrobial soap will further reduce the transient flora, but only if used for several minutes. Hand washing with (non-medicated) soap is essential when hands are dirty and should be routine after every physical contact with a patient.

Killing *all* transient flora within a short time (a few seconds) necessitates hygienic hand disinfection: *only alcohol or alcoholic preparations act sufficiently fast*. Hands should be disinfected with alcohol when an infected tissue or body fluid is touched without gloves. An overview of the main forms of hand hygiene is given in Table 11.2.

Table 11.1: Characteristics of the main disinfectant groups

Agent	Spectrum	Uses	Advantages	Disadvantages
Alcohols (60–90%) including ethanol or isopropanol	Low- to intermediate level disinfectant	Used for some semicritical and noncritical items (e.g. oral and rectal thermometers and stethoscopes) Used to disinfect small surfaces such as rubber stoppers of multidose vials Alcohols with detergent are safe and effective for spot disinfection of countertops, floors and other surfaces	Fast acting No residue No staining Low cost Readily available in all countries	Volatile, flammable, and irritant to mucous membranes Inactivated by organic matter May harden rubber, cause glue to deteriorate, or crack acrylate plastic
Chlorine and chlorine compounds: the most widely used is an aqueous solution of sodium hypochlorite 5.25–6.15% (household bleach) at a concentration of 100–5000 ppm free chlorine	Low- to high-level disinfectant	Used for disinfecting tonometers and for spot disinfection of countertops and floors Can be used for decontaminating blood spills Concentrated hypochlorite or chlorine gas is used to disinfect large and small water-distribution systems such as dental appliances, hydrotherapy tanks, and water-distribution systems in haemodialysis centres	Low cost, fast acting Readily available in most settings Available as liquid, tablets or powders	Corrosive to metals in high concentrations (>500 ppm) Inactivated by organic material Causes discoloration or bleaching of fabrics Releases toxic chlorine gas when mixed with ammonia Irritant to skin and mucous membranes Unstable if left uncovered, exposed to light or diluted; store in an opaque container
Corrosive to metals in high concentrations (>500 ppm) Inactivated by organic material Causes discoloration or bleaching of fabrics Releases toxic chlorine gas when mixed with ammonia Irritant to skin and mucous membranes Unstable if left uncovered, exposed to light or diluted; store in an opaque container	High-level disinfectant/ sterilant	Most widely used as high-level disinfectant for heat-sensitive semicritical items such as endoscopes (for 20 minutes at 20 °C)	Good material compatibility	Allergenic, and its fumes are irritating to skin and respiratory tract Causes severe injury to skin and mucous membranes on direct contact Relatively slow activity against some mycobacterial species Must be monitored for continuing efficacy levels
Peracetic acid 0.2–0.35% and other stabilized organic acids	High-level disinfectant/ sterilant	Used in automated endoscope reprocessors Can be used for cold sterilization of heat-sensitive critical items (e.g. haemodialysers) Also suitable for manual instrument processing (depending on the formulation)	Rapid sterilization cycle time at low temperature (30–45 min. at 50–55 °C) Active in presence of organic matter Environment friendly byproducts (oxygen, water, acetic acid)	Corrosive to some metals Unstable when activated May be irritating to skin, conjunctiva and mucous membranes
Orthophthalaldehyde (OPA)	High-level	High-level disinfectant for endoscopes	Excellent stability over	Expensive

Agent	Spectrum	Uses	Advantages	Disadvantages
0.55%	disinfectant/ sterilant		wide pH range, no need for activation Superior mycobactericidal activity compared with glutaraldehyde Does not require activation	Stains skin and mucous membranes May stain items that are not cleaned thoroughly Eye irritation with contact May cause hypersensitivity reactions in bladder cancer patients following repeated exposure to manually processed urological instruments Slow sporicidal activity Must be monitored for continuing efficacy levels
Hydrogen peroxide 7.5%	High-level disinfectant/ sterilant	Can be used for cold sterilization of heat-sensitive critical items Requires 30 min at 20 °C	No odour Environment friendly byproducts (oxygen, water)	Material compatibility concerns with brass, copper, zinc, nickel/silver plating
Hydrogen peroxide 7.5% and peracetic acid 0.23%	High-level disinfectant/ sterilant	For disinfecting haemodialysers	Fast-acting (high-level disinfection in 15 min) No activation required No odour	Material compatibility concerns with brass, copper, zinc and lead Potential for eye and skin damage
Glucoprotamin	High-level disinfectant	Used for manual reprocessing of endoscopes Requires 15 min at 20 °C	Highly effective against mycobacteria High cleansing performance No odour	Lack of effectiveness against some enteroviruses and spores
Phenolics	Low- to intermediatelevel disinfectant	Have been used for decontaminating environmental surfaces and noncriticalsurfaces Should be avoided	Not inactived by organic matter	Leaves residual film on surfaces Harmful to the environment No activity against viruses Use in nurseries should be avoided due to reports of hyberbilirubinemia in infants
Iodophores (30–50 ppm free iodine)	Low-level disinfectant	Have been used for disinfecting some non-critical items (e.g. hydrotherapy tanks); however, they are used mainly as an antiseptic (2–3 ppm free iodine)	Relatively free of toxicity or irritancy	Inactivated by organic matter Adversely affects silicone tubing May stain some fabrics

Table 11.2: The main forms of hand hygiene

Technique	Main purpose	Influence on hand flora	Agents	Rapidity of action	Residual effect
Social hand washing	Cleansing	Reduces transient flora	Non-medicated soap	Slow	Short
Careful hand washing	Cleansing after patient contact	Partly removes transient flora	Non-medicated soap	Slow	Short
Hygienic hand disinfection	Disinfection after contamination	Kills transient flora	Alcohol	Fast	Short
Surgical hand disinfection	Preoperative disinfection	Kills transient flora and inhibits resident flora	Antibacterial soap, alcoholic solutions	Slow (soap) or fast (alcohol)	Long

The World Health Organization's (WHO's) *WHO guidelines on hand hygiene in health care* (WHO, 2009) include a recipe for alcohol hand rub, for local production (see page 49 of the guidelines). The WHO (2009) guidelines also include the following guidance for hand washing and use of alcohol-based hand rubs:

a) If hands are not visibly soiled, use an alcohol-based hand rub for routine antisepsis (hygienic hand disinfection).
b) Rub until hands are dry.
c) Wash hands before starting work, before entering an operating theatre, before eating, after using a toilet, and in all cases where hands are visibly soiled.
d) Keep nails short and clean.
e) Do not wear artificial fingernails, nail polish or jewellery.
f) Do not wash gloves between uses with different patients.
g) Multiple-use cloth towels of the hanging or roll type are not recommended for health-care institutions.
h) When bar soap is used, soap racks that facilitate drainage and only small bars should be used; liquid detergents in dispensers are preferred.
i) To prevent contamination, do not add soap to a partially empty liquid-soap dispenser. Empty the dispenser completely and clean it thoroughly before refilling.
j) Hand hygiene products should have low skin irritation, particularly in multiple-use areas, such as intensive- care or operating rooms.
k) Ask personnel for their views regarding the tolerance of any products under consideration.
l) For surgical scrub, preferably use an alcohol-based hand rub.
m) When using an alcohol-based surgical hand rub, pre-wash with soap, and dry hands and forearms completely (including removal of debris from underneath the nails using a nail cleaner) once a day before starting surgery and when hands become soiled (e.g. glove perforation) or sweaty. Brushes are not necessary and can be a source of contamination. Hand washing immediately before every rub does not improve its efficacy and should be abandoned. Rub for 1–5 minutes according to the manufacturer's recommendation after application, and rub until hands are dry before donning sterile gloves.

n) Hands must be fully dry before touching the patient or patient's environment/equipment for the alcohol hand rub to be effective. This will also eliminate the extremely rare risk of flammability.
o) Use hand lotions frequently to minimize the possibility of irritant contact dermatitis.

11.5. MEASURES FOR IMPROVING INFECTION CONTROL

Infection control can be improved in three ways:

a) avoiding wasteful practices
b) using good infection-control practices
c) using good cost-effective practices.

11.6. MINIMUM APPROACH TO HYGIENE AND INFECTION CONTROL

Infection control is a team effort. Therefore, at a minimum, a multidisciplinary infection-control committee must be organized, comprising (but not limited to):

a) a senior physician to provide leadership
b) a clinical microbiologist
c) an infection-control nurse
d) an antibiotic specialist
e) a director of environmental services.

The committee should set clear aims that are time specific and measurable, and that target a specific population of patients, location or employees. Aims could include implementing a hand hygiene programme, and implementing an environmental cleaning and disinfection programme.

In summary, the minimum approach to good hospital hygiene and infection control includes:

a) setting modest aims;
b) establishing baseline rates;
c) implementing evidence-based interventions shown to be effective elsewhere;
d) carrying out daily process surveillance (or clinical audit) throughout the project period to monitor compliance with the interventions by staff;
e) measuring rates again at the end of the project period;
f) if desired improvements have not occurred, analysing the reasons (e.g. poor compliance with the interventions), implementing necessary changes and repeating the cycle

12 TRAINING, EDUCATION AND PUBLIC AWARENESS

12.1. IMPORTANCE OF TRAINING AND EDUCATION

Training and capacity building of health-care staff are essential in the efforts to minimize the transmission of secondary infections. Staff training leads to a more informed workforce, which is the foundation for achieving higher standards of infection control. Knowledgeable staff can also help patients and visitors to understand their role in maintaining good hygiene, and to become more responsible for the wastes they produce.

The overall goals of training are to:

a) prevent occupational and public health exposures to the hazards associated with health-care waste;
b) raise awareness of the health, safety and environmental issues relating to health-care waste;
c) ensure that health-care staff are knowledgeable about best practices and technologies for health-care waste management and are able to apply them in their daily work;
d) foster responsibility among all health-care workers for health-care waste management.

Training and continuing education are integral parts of the health-care waste-management system. When health- care personnel are properly sensitized to the importance of waste management, they become advocates for best practices, and help to improve and sustain a good waste-management system. Importantly, training should be institutionalized and become part of the standard functions of the health-care facility. Training is therefore linked to health-care quality improvements, institutional policies and procedures, human resource development including staff performance evaluations, and facility organization to ensure that someone takes responsibility for the training programme. At the national level, minimum requirements for training in health-care waste management could be considered in national policies, as well as in health-care facility accreditation or licensing.

The availability of proper waste equipment, such as sharps containers and personal protective equipment, goes hand-in-hand with training. Nothing can be more frustrating than to train health-care workers in proper segregation methods when the health-care facility has inadequate or improper containers, thereby hindering the staff from putting their knowledge into practice. Hence, budgeting and procurement of equipment are also linked to training. Furthermore, the costs of training should be incorporated into the health-care facility's annual budget.

Training health-care personnel in implementing a waste policy is a central requirement if improvements to waste management are to be successful. However, training is not a goal in

itself (training for the sake of training); rather, it is a means to achieve a goal, such as behaviour change to improve waste-management practices. The training is successful if it leads to observable improvements in performance. For this reason, training is used in conjunction with creating a supportive environment, other forms of communication (e.g. posters, signs), incentives (e.g. awards and recognition to individuals), a means for personnel to provide input on improving practices, monitoring, reflective supervision, and corrective action.

12.2. EDUCATION AND TRAINING OF HEALTH-CARE PERSONNEL

12.2.1. Planning and Implementation

For health-care facilities that do not have a training programme, one of the first steps is to obtain the support of the administration. This may be in the form of a facility-wide policy or approval for a pilot training programme in selected departments.

The development of a training programme can be facilitated by establishing core competencies related to health- care waste management. Core competencies are a set of knowledge, skills and attitudes that are essential for the effective performance of a job function. Core competencies establish a framework for training and education. Some national policies, licensing authorities or standard-setting bodies may already have minimum core competencies defined. The United Nations Development Programme's Global Healthcare Waste Project (Emmanuel, 2009) has examples of core competencies related to health-care waste management.

In health-care facilities that had initial training that was not sustained, an assessment of learning needs and why the programme was stopped could be conducted. Gaps in training should be identified to inform the development of a new programme. An assessment of organizational capacity for training is also important.

At a national or regional level, training programmes could be in the form of training of trainers. The training-of- trainers approach allows rapid capacity building and widespread training outreach because of its cascade effect, in which master trainers impart knowledge and skills to trainees, who then become trainers and who in turn train others. Some training-of-trainers programmes may not be successful, especially if trainers are not trained in both content knowledge and training skills. Certain individual traits are helpful for potential trainers; these include a personality that is outgoing, confident, well organized, open to constructive criticism, self-motivated, articulate and creative. Factors that could lead to failure include the trainer's inexperience or lack of in-depth knowledge, poor modelling by the master trainer, inadequate time to practise training skills among peers, a lack of follow-up by the master trainer, and no system of evaluation and feedback to help

the trainers improve their programmes. If well-designed, planned and implemented, a training-of-trainers programme can be an efficient and effective approach.

The need for training can also be met if more medical, dental and nursing schools include health-care waste management in their courses. Health professional organizations and associations of hospitals can provide a service to their members by offering seminars and training programmes.

The following are recommended steps in the planning and preparation of a training programme. These steps are not in chronological order and are interrelated:

a) Identify and prioritize the employees to be trained.
b) Define the specific learning objectives for each target audience.
c) Explore multiple training delivery options to maximize outreach, considering the work schedules of the participants (e.g. short 30-minute or 1-hour in-service training sessions once a week for several weeks; on-the- job coaching and mentoring; an intensive three-day workshop; self-paced study using printed materials or CDs; web-based or video-conference training; classes in an academic institution).
d) Develop a detailed curriculum specifying the following for each session: topic, expected outcomes, duration, teaching/learning method, teaching/learning aids, participant assignment before the session (if any), facilitator/ learner activities, assessment, and resources (see the example in Box 12.1).
e) Incorporate pre-evaluation and post-evaluation of learners, evaluation of trainers, follow-up activities, and documentation into the training programme.
f) Develop training content or adapt available training materials; tailor training content to specific target audiences.
g) Identify potential trainers and build training skills.
h) Develop a budget and secure funding.
i) Explore incentives for training (e.g. training in collaboration with a health professional society or academic institution that can award certificates, academic credits or professional credentials).
j) Send out announcements and build interest in the training programme among target participants.

12.2.2. Employees to be Trained

All hospital personnel, including senior medical staff and managers, should be able to communicate the benefits of health-care waste management. They should be prepared to undertake training and be convinced of the health, occupational safety, economic, environmental and regulatory advantages. Achieving this outcome should strengthen the participation and collaboration of other personnel in training activities.

Separate training activities can be designed for different categories of health care personnel:

a) hospital managers and administrative staff responsible for implementing regulations on health-care waste management;
b) medical doctors;
c) nurses, nursing assistants and allied professions;
d) cleaners, porters, auxiliary staff and waste handlers.

Since action to improve waste management has to take place throughout a health-care facility (notably managers, medical staff producing the waste, porters and waste handlers), training all these categories of personnel is equally important. Medical doctors can be trained through short senior staff workshops and general staff through longer formal seminars. The training of waste handlers and nurses managing medical areas should be more thorough and focus on practical procedures. Nurses and waste handlers are key personnel to instil a disciplined approach in the day-to-day management of wastes. Experience has shown that their training should be practical and undertaken at their own place of work or somewhere similar. In some countries, this approach can be supplemented with seminars or courses run by public health and training institutions.

12.2.3. Content of Education Programmes

Training should highlight the roles and responsibilities of each member of staff and how they contribute to the broader management policy to achieve good waste practices. Neither a local initiative nor a more extensive national policy for health-care waste can be effective unless the training purpose is explained, the expected benefits to recipients are clear, and the means of delivering training are flexible enough to be tailored to regional and local customs and sensibilities.

Staff education programmes should include:

a) information on, and justification for, all aspects of the health-care waste policy;
b) information on potential infection risks posed by health-care waste;
c) information on the role and responsibilities of each staff member to follow waste-management procedures;
d) technical instructions on the application of waste-management practices relevant to particular types of work by some medical or support staff;
e) information on monitoring, record keeping and maintenance of equipment.

One of the best ways of learning is through practice. Hands-on training by small groups of personnel should be considered, whenever appropriate. Testing the participants at the end of training by means of recalling procedures, measuring their ability to demonstrate techniques, and asking factual questions, often provides an incentive for learning. It also

allows the course organizers to assess the level of knowledge acquired by participants and to adjust the teaching methods used in future training.

Box 12.1: Example of a training set-up

Workshop topic: health-care waste classification and segregation

Expected outcomes – participants will be able to:

a) list the major classifications and characteristics of health-care waste
b) define what comprise sharps waste and its contribution in disease transmission
c) demonstrate basic segregation of health-care waste items
d) demonstrate appropriate containerization of health-care waste. Teaching and learning method:
e) lecture and discussion
f) small-group discussion
g) individual participant activity.

Teaching and learning aids:

a) projector
b) laptop computer
c) PowerPoint presentation
d) board and chalk, or flip chart paper and marker pens
e) matrix of examples of different waste items designed to get the participants to think about the corresponding segregation requirements
f) surrogate waste (uncontaminated waste items made to look like real waste, such as bandages smeared with tomato sauce to look like blood) and different types of colour-coded waste containers.

Participant assignment before the session:

- each participant reads the excerpt from the country's regulations on the health-care waste-classification system and segregation requirements.

Facilitator and learner activities:

a) The trainer presents the country's classification system, characteristics of different types of health-care waste, and segregation requirements for health-care waste.
b) Group activity 1: the trainer shows a matrix listing different types of waste and facilitates a discussion with the class about which containers each type of waste should be placed in.
c) Group activity 2 (small group): the trainer divides the participants into groups of three or four people and gives each group different types of surrogate waste items, including sharps. Each group is then asked to place their waste items in the proper containers.
d) Homework: each participant writes guidelines on classification and segregation specific to their service or department.

Source: adapted from the United Nations Development Programme GEF Global Healthcare Waste Project, *Sample master curriculum for healthcare waste management training*

Trainers should have experience in teaching and coaching young and new staff. To be able to speak with authority, they should be familiar with the hazards and practices of health-care

waste management. They should also have some practical experience in the correct handling of waste.

12.2.4. Follow-up and Refresher Courses

Periodic repetition of courses will provide an opportunity to instruct new employees, and "refresher" courses for existing employees can remind them of practices and inform about changes or new responsibilities. Follow-up training is instructive for trainers, too, indicating how much information has been retained by course participants and for revising the scope of future refresher courses.

12.2.5. Training Responsibility

The waste-management officer, in cooperation with the infection-control officer, is typically given responsibility for all training related to health-care waste. The waste-management officer should ensure that staff at all levels are aware both of waste-management methods in use, and of their own responsibilities and obligations. A record should be kept of all training sessions and the members of staff who completed each course successfully. The content of training programmes should be periodically reviewed with the infection-control officer and, if possible, regulators and waste contractors, and updated where necessary.

Medical staff working in clinics and similar places with smaller sources of health-care waste should also receive training. This could be offered centrally by larger health-care facilities or by regional public health organizations.

12.3. IMPLEMENTATION OF A TRAINING COURSE

12.3.1. The Training Package

A national training package could be developed by the government agency responsible for health care or the environment. Alternatively, a certified programme in health-care waste management could be delivered by public health or training institutions through locally prepared courses or by home study and distance learning, or even by tailoring training materials already available from an international organization, a development agency or another country. The package should be suitable for various types of health-care facilities, including government, private, teaching, general hospitals, polyclinics, health centres, health-care research institutions and clinical laboratories. It could also be useful for more general educational establishments and for organizations that provide services for the health-care waste sector.

A standard, national training package should be liberally illustrated with drawings, diagrams, photographs, posters and slides to demonstrate the concepts of infection control and safe

waste management. These should reflect workplace situations and provide examples of measures that have been (or will be) implemented. Where it is likely that waste handlers and other workers are illiterate, diagrams and photographs should be used to demonstrate procedures.

12.3.2. Selection of Participants

The ideal number of participants on a training course is 20 to 30. Larger groups may make effective discussions and exercises difficult to operate. Courses should be aimed at all categories of personnel. Discussions may be easier and more useful if the group is composed of trainees from various disciplines (e.g. supervisors, medical and nursing staff, laboratory staff, engineers, ancillary staff), or at least contain one or two medical assistants and nurses. It may also be valuable to include senior administration staff and heads of departments in certain training groups to demonstrate their commitment to the waste-management policy and to show the relevance of the policy to all personnel of health-care facilities.

12.4. TRAINING HEALTH-CARE WASTE HANDLERS

The minimum training for health-care waste handlers should include:

a) information on the techniques and risks associated with the handling of health-care waste
b) procedures for dealing with spillages and other accidents
c) instructions on the use of protective clothing.

The training needs will obviously depend on the type of waste operations performed, but may include specific topics such as operation of treatment technologies and waste transportation. Boxes 12.2–12.3 list the points that should be stressed when training waste handlers.

12.4.1. Health-care Personnel

Training should provide an overview of the waste-management policy and its underlying rationale, and information on practices relevant to the targeted group of trainees. Waste segregation is a key element in waste-management training for personnel who provide health care. Box 12.3 lists precautions that should be emphasized.

Box 12.2: Training health-care personnel

a) Great care should be taken if needles have to be removed from syringes.
b) Hazardous and general waste should not be mixed. Segregation is the key to safe health-care waste management.
c) No attempt should be made to correct waste-segregation mistakes by removing items from a bag or container, or by placing one bag into another of a different colour.
d) Nursing and clinical staff should ensure that adequate numbers of bag holders and containers are provided for the collection, and subsequent onsite storage, of health-care waste in the medical areas, clinics, theatres and other areas where waste is generated. These receptacles should be located as close as practicable to the common sources of waste generation in a medical area.

13.4.2 Cleaning staff

Topics to be covered may include the waste-management policy, health hazards, onsite transportation, storage, safety practices and emergency response. Awareness of the need for safety may decrease with time among staff who routinely handle health-care waste, which will, in turn, increase the risk of injury. Periodic short informal reminders and refresher training are suggested. Box 12.3 lists the key points relevant to training for cleaning staff.

Box 12.3: Training cleaning staff

a) Check that waste-storage bags and containers are sealed. No bags should be removed unless properly labelled and securely sealed to prevent spillages.
b) Bags should be picked up by the neck only. They should be put down in such a way that they can again be picked up by the neck for further handling. Manual handling of waste bags should be minimized whenever possible.
c) Waste bins should be cleaned after removing the filled waste bag, and a new bag should be placed into the bin immediately.
d) Waste bags should not touch the body during handling, and collectors should not attempt to carry too many bags at one time. No more than two is a sensible limit.
e) When handling and transporting waste bags or containers is completed, seals should again be checked to ensure they are unbroken.
f) To avoid puncture or other damage, waste bags should not be thrown or dropped.
g) Mismanagement of sharps waste may occasionally puncture the side or bottom of a polypropylene container; the container should therefore be carried by its handle and should not be supported underneath with the free hand.
h) Bags for hazardous health-care waste and for general waste should not be mixed, but should be segregated throughout handling and transport. Hazardous waste should be placed only in specified storage areas.
i) Appropriate cleaning and disinfection procedures should be followed in the event of accidental spillage. Any such incident should be reported immediately to the responsible member of staff.
j) Protective clothing (gloves, apron, sturdy shoes) should be worn during all waste-handling operations.
k) Raw food supplies such as vegetables and fruits should not to be unloaded or stored near waste-storage areas.

12.4.3. Staff who Transport Waste

A health-care facility itself may carry out the transportation of waste or it may contract this operation to an "authorized" waste transporter. In many countries, waste is transported to a central treatment or disposal site. Drivers and waste handlers should be aware of the nature and risks associated with the waste they transport. In particular, transport staff should be trained to be able to carry out all waste-related procedures in accordance with instructions, and without help from others. Box 12.4 summarizes the key points relating to training for staff who transport waste.

Box 12.4: Training waste-transport staff

a) Follow correct procedures for handling, loading and unloading colour-coded waste bags and containers.
b) Be aware of the correct procedures for dealing with spillages or other accidents, and be aware of established, usually written, instructions for these procedures.
c) Use protective clothing and strong footwear at all times.
d) Ensure the availability of dedicated waste-collection vehicles, spare plastic bags, protective clothing, cleaning tools and disinfectants to deal with any spillage that occurs during loading, transport or unloading.
e) Document health-care waste inside a health-care facility and, if carried offsite, be aware of how a consignment note system operates to track waste from its point of generation to its final place of disposal.

Managers at a health-care facility should liaise with the transport contractor to ensure that the waste-collection crew is well trained. Untrained personnel should not be allowed to handle hazardous health-care waste. They would be a danger to others and to themselves.

12.4.4. Treatment Plant Operators

Qualified operators are needed for incinerators, autoclaves and microwave and other treatment facilities. If no qualified operators are available, managers of health-care facilities should arrange to train an adequate number of personnel.

Treatment plant operators should have received technical education to at least secondary school level. Box 12.5 lists the tasks they should be specifically trained in.

Box 12.5: Training treatment plant operators

a) General functioning of the treatment facility, including heat recovery and flue-gas cleaning technologies, where appropriate.
b) Health, safety and environmental implications of treatment operations.
c) Technical procedures for operation of the plant.
d) Recognition of abnormal or unusual conditions.
e) Emergency response, in case of equipment failures and alarms.
f) Maintenance of the plant and record keeping.
g) Surveillance of the quality of ash and emissions, according to the limits laid down in permits, laws or plant specifications (for incinerator operators).

12.5. INTEGRATING TRAINING WITH PUBLIC EDUCATION ON RISKS OF HEALTH-CARE WASTE

Promotion of safe and sensible waste handling and disposal is relevant both to users of health-care facilities and to the wider community as one approach to achieve a better understanding of health public. A training and public awareness programme should contain two aspects. The first is to create awareness and foster responsibility for good hygiene among all workers, patients and visitors at health-care facilities. The public awareness programme can go further and explain how good health-care waste management protects public health. The second aspect is to inform the public in general about the risks from poor hygiene and health-care practices, with particular regard to people living or working in close proximity to health-care facilities, families of patients treated at home, and scavengers working at disposal sites.

Various methods can be used to promote public education on health-care waste. Commonly used approaches include the following:

a) Poster exhibitions can be used to educate about health-care waste issues, such as the risks involved in reusing syringes and hypodermic needles or the infection-control benefits of waste segregation and treatment.

b) Medical staff can explain to new patients and visitors their personal responsibilities to help maintain good hygiene and safe waste management. This may be difficult to achieve with people who have entrenched views, and face-to-face discussion should be supplemented with diagrams, posters and leaflets.

c) Information signs and pictograms can be used in hospitals, at strategic points such as waste-bin locations, giving instructions on waste segregation. Signs should be explicit, using diagrams, illustrations and consistent colour coding to convey the message to a broad audience, including illiterate people and those with a lower educational capacity.

Box 12.6: Issues to address when training treatment plant operators

Waste handling

- Procedures for receiving, handling and storage of health-care waste.
- Loading of waste into the treatment unit.

Operation of the plant temperatures, pressures, concentrations of emissions, speeds, flows and maintenance of correct conditions.

a) Detection of defects or malfunctions (following written procedures) and servicing.
b) Safe removal of residues, ashes and treated material.
c) Operation of the plant equipment, including start-up and shut-down procedures.
d) Operation and testing of control, alarm and instrumentation systems, including corrections when necessary.
e) Optimum operating

Maintenance

• Daily, weekly, monthly, periodic and annual tests, inspection, cleaning, lubrication, replacement and replenishment of consumables (e.g. thermocouples). Special attention should be paid to major components of the installation and reporting the need for repairs when necessary.

Note that, recently, biomedical engineers have been recruited by provincial governments in some countries to oversee and monitor the efficiency of plant operators.

Safety measures and emergency response

a) Use of protective equipment and maintenance of personal hygiene.
b) Fire precautions.
c) Procedures for emergency response, including manual operation of the plant under emergency conditions, dealing with spillages, accidents and other incidents.
d) Contingency plans for alternative operations during breakdown or planned maintenance.

Administrative procedures

a) Licence conditions and regulations governing emissions and ways of working.
b) Record keeping.
c) Reporting of spillages, accidents and other incidents, and suggesting changes.
d) Health risks related to health-care waste.
e) Hazards related to sorting health-care waste, which should not be practised by landfill operators, informal recyclers or the general public.
f) Minimizing the handling of health-care waste by drivers and treatment and disposal site operators.
g) Use of protective equipment and personal hygiene.
h) Safe procedures for landfilling the wastes.
i) Updating procedures for emergency response.

For maximum effectiveness, all information should be displayed or communicated in an attractive manner to hold people's attention and increase the likelihood they will remember the important messages to be conveyed by an information campaign.

In medical areas, general health-care waste bins should be easily accessible for patients and visitors, and signs should explain clearly what they should do with other categories of waste.

Growing awareness of health and environmental hazards has increased across the world, leading to higher public demand for information and guidance on these issues. Demand has intensified in some countries due to a rise in the prevalence of HIV/AIDS, viral hepatitis B and other well-publicized illnesses. Health-care facilities should set an example to society by demonstrating that they are managing their waste in a manner designed to protect health and the environment.

12.6. MINIMUM APPROACH TO TRAINING, EDUCATION AND PUBLIC AWARENESS

With the help of suitably developed information, education and communication material, a half- to one-day training programme can be carried out. Such training programmes can be designed separately for the waste handlers and health-care staff in medical areas and their supervisors. Further details for training treatment plant operators are given in Box 13.6.

12.6.1. Landfill Operators

In many middle- and lower-income countries, “safe burying” will continue to be used for the disposal of health- care waste until there is sufficient capacity for incineration or other treatment method. Training landfill operators is important for limiting the risks associated with buried health-care waste, in relation to both scavenging and the quality of groundwater. Landfill operators should therefore be trained in similar issues outlined for treatment plant operators in Box 12.6 above.

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